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

Benjamin C. McLellan[1] [1], Andrew J. Chapman[1] and Kazumasu Aoki[2]

[1]Kyoto University, Graduate School of Energy Science, Yoshida-honmachi, Sakyo-ku, Kyoto, 606-8501, Japan.

[2]University of Toyama, 3190 Gofuku, Toyama-shi, Toyama, 930-8555, Japan.

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

[1] Corresponding author contact details: E-mail: b-mclellan@energy.kyoto-u.ac.jp Phone: +81 75 753 9173

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.

Key words: transitions theory; urbanization; geography; energy; decentralization;

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.

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 (NGO's) and non-profit organizations (NPO's) began to identify preferences for a transition from a large scale centralized energy system to a small scale distributed system [1]. 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 [2, 3].

Following from the recognition of the problem outlined above, this paper utilizes transition theory, as presented by Geels et al. [4, 5] 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 [6]. While we do not address this directly, we recognize the importance of power relationships in enabling or blocking transitions (discussed by others [7]) – particularly in a system that is technically complex and centralized, and has a longstanding political power structure [2]. 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 [8].) 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 [9].

In post-war Japan, rapid reconstruction and industrial modernization was undertaken, with economic growth at a rate of around 10% per annum [10]. From 1945 to 1958, domestic coal resources and hydroelectricity were the emphasis of government policy, which favoured the strengthening of local industry [10]. At the beginning of the 1960's 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 1960's. A reduction of import barriers led to the low cost oil of the 1960's becoming the dominant energy source by 1970, with a 59% share in electricity generation alone [11]. After the second oil price shock in 1979, the government further tightened energy policy to promote greater efficiency and fuel switching [12]. 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 [13]. 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 2-3 years in the 1960`s to 14-15 years in the 1980`s [14]. 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 [15]. 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 [16]. 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, Figure 1 shows the energy consumption trends – as total primary energy and electricity consumption (data from the IEA [17]). In this figure we can see the evidence of two important energy transitions in Japan – firstly, the post-war rapid expansion of energy consumption with oil being the major contributor, and secondly, the transition beginning at the first oil crisis (early 1970`s) from which point nuclear power and natural gas begin a dramatic expansion, with a specific focus on the electricity sector.

The most important aspect of this transition is arguably the move from very high oil dependence prior to the 1970`s oil shocks, to a much more diversified energy mix pre-Fukushima. In the aftermath of the Fukushima accident, the supply lost to the grid due to the shutting-down of all nuclear power plants has been taken up largely by gas and oil, thus increasing costs due to fuel imports, increasing environmental impacts due to greenhouse gas emissions and reverting to a less energy-secure system [18]. Various policies, technologies and behavior changes led to the dramatic shift between 1970 and 1990, but the current crisis has undermined one of the pillars of energy policy in Japan – nuclear power – making the solution more difficult to see clearly. The electricity industry particularly focuses on the concept of "3E`s and S" – energy security, environment, economy, and safety – as the fundamental criteria for the planning of the future energy system. In particular, the importance of energy security leads inevitably to the discussion of renewable energy technology expansion, as Japan is resource-poor in all forms of conventional energy. This, and the importance of decentralized smart grids are seen as key technology elements in the future of Japan`s energy system [19], although the electric power companies, large businesses and the incumbent government are in favor of nuclear power and the maintenance of large scale systems in order to maintain their profitability [20]. The question arises whether a new transition is in play, and whether this will be based on small-scale renewable energy – as indicated by the pinching of the nuclear electricity generation and the rapid expansion in Figure 1 (c) in solar generation – a trend starting well before the 2011 disaster, but certainly strengthened in the aftermath.

2 Using Transition Theory to envision the electricity system reforms

2.1 The features and issues with the current electricity system

In Japan, the current electricity system is a large-scale, centralized system dominated by local monopolies, meaning that general consumers have been unable to freely select their electricity provider. The current 10 providers of electricity control supply and transmission and provide electricity on a fully-distributed cost basis, thus they have been able to on one hand guarantee their profitability, while on the other hand they are subject to the "Electric Utility Industry Law" meaning they are responsible for the provision of a stable supply of electricity. It can be said that for this very reason, the electric utilities have not aggressively pursued more sustainable forms of electricity supply such as renewable energy, and have instead utilized Oil, Natural Gas, Fossil Fuels and Nuclear power which are considered to be appropriate for base load electricity supply and controllable, cost-effective demand-matching. Liberalization of the electricity market was started in the 1990`s, but did not progress further than large-to-medium scale generators entering the market, due in large part to the pressure applied by monopoly generators [2].

The Fukushima accident has again reinforced negative opinion of nuclear power, and it has been very difficult for private electric utility companies to convince local communities of the safety of their operations and to gain their approval for constructing and restarting power plants, making it necessary to rely on the strength of the national government [9]. In addition, prior to the Great East Japan Earthquake, electric utilities and the government policy direction expected to achieve the majority of their CO_2 emissions reduction goals through the construction of new or expanded nuclear facilities. Achievement of the stated goal of creating a path to CO_2 free renewable energy integration into a distributed energy system has not been set about in earnest until now [21], and there is still a state of ambivalence reflecting the economic constraints of renewables.

The inefficiency and vulnerability of the existing centralized large-scale system has been heavily criticized in this country, although decentralized systems are not risk-free [22]. The Great East Japan Earthquake and Fukushima accident exposed these systemic risks as a reality. Due to the severity of the accident at the Fukushima Daiichi plant, all nuclear power facilities were halted, leading to an increased reliance on oil, coal and natural gas-based power plants which are more expensive to operate – and rely heavily on imported fuels. In addition the radioactive contamination of areas near the plant has led to an increased social recognition of the dangers of nuclear power generation. The difficulty of rehabilitation of the affected areas suggests that people will be unlikely to forget these consequences, making a complete return to nuclear power generation highly unlikely.

For Japan, dealing with serious systemic risks, the need for a transition from a large scale centralized system to a small scale distributed system has been considered broadly.

Change towards a small scale distributed electricity system necessitates a massive deployment of renewable energy to alleviate the current dependence on fossil fuels, thus reducing CO_2 levels, and presenting a solution to the climate change issue. This change increases the sustainability of the electricity system and is considered desirable by many scholars [23, 24]. Moreover, compared to the currently vertically integrated large scale grid, a small scale system is more independent and can more easily avoid blackouts and recover quickly from any stoppages, so, from a resilience point of view it is increasingly considered a more desirable system [22] although it is important what boundaries are placed on such an assessment [25].

2.2 Power consumers and system transition viewed from the multi-level perspective

This study identifies the development of a small-scale distributed energy system based on renewable energy as one of the more desirable, sustainable and resilient energy systems that could eventuate, based on a consideration of academic literature and policy (described above). Thus the purpose of this study is to examine whether such a shift appears to be occurring. One key framework that can be applied to this analysis is the multi-level perspective (MLP), which is the core analytic conceptual tool utilized by transition theory. MLP is a quasi-evolutionary theory, inspired by historical technological change analysis, whose main focus is the role of time and structure in systemic innovation processes [26]. MLP attempts to visualize and systematically understand the dynamics of radical socio-technical system movement and transition through a long term assessment of changes emerging via the interaction and coevolution of the three levels of regime, niche and landscape (outlined in Figure 2 modified from [26] for the study at hand).

According to MLP, the most important and dominant elements of the system are characterized as a regime. A regime is a configuration whose structures and institutions are established by both technical infrastructure and actors (and their networks). Interaction between these elements may provide a technically and socially strong regularity and inertia (or path dependency) to the behavior, awareness and preferences of the actors who constitute such a regime (i.e., regime actors). The regime actors thus support, maintain and reinforce its current functions. Because the consumers, as electricity users taking on the demand side of the system, have been utilizing the structures and institutions of the regime for a long time, their preferences and awareness can be considered as essentially path dependent and locked-in, with basic tendencies to resist change [4, 27, 28]. This is described in Figure 2 as the smaller, gentler or more subtle influences (thin dotted lines) from the landscape on the regime and regime on the niche level, gradually causing a co-alignment or coalescence of niche innovations.

In the case examined here, a "one in one thousand years" scale disaster has caused a change at the landscape level. This has in turn caused immense pressure on the current regime and the actors supporting it (i.e. electricity companies and the national government), whose legitimacy and effectiveness are being brought into question by those considered niche actors or 'outsiders' (i.e. consumers, holders of public opinion, local governments, environmental NGOs/NPOs etc.). The niche actors' desire for change has become irrepressible, and as a result some changes to the system have occurred. It is reasonable to say that the occurrence of the March 11 Disaster has fundamentally changed the landscape, exogenous environment surrounding Japan's electricity system, so that it has opened a providential window of opportunity to effect change, potentially overcoming lock-in. In Figure 2 we show this influence as the thicker dotted lines from landscape to regime and then to niche. This study seeks to examine whether this sudden and extreme pressure has enabled greater coalescence of certain niche innovations through improved support and changes of the socio-technical regime (in terms of preferences and culture).

In fact, over the 3 years since 2011, such policies as the expanded Feed-in-Tariff (FiT) (including renewable energy sources other than just solar power), the complete liberalization of the retail sale market (scheduled to start from 2016), and the legal unbundling of transmission and generation assets (all of which were once thought to be too difficult to be realized) have arrived at the stage of gradual realization. Through the deployment of such policy measures, many sectors of society and various niche actors (e.g. IT companies, gas companies, trading companies, house builders, traders, co-ops and local governments) have increased their expectations for transformation and begun to interact as new entrants in the processes across multiple-levels where intent and potential for systemic reforms are considered to be higher than ever before.

2.3 Understanding multiple transition pathways and their consequences

It is easy to think that the consideration of the implementation of a multitude of new policies mentioned above will have the potential to cause a breakthrough in the change from a large scale centralized system based on conventional generation towards a more distributed system, or at least more diverse system containing more renewable energy. However, as dynamic processes that co-evolve and have a nonlinear transition curve, multiple transitional pathways can co-exist and thus the consequences of such multiple pathways are inevitably pluralistic and cannot be clearly defined or foreseen *ex ante*. Indeed, considering the time axis, over the long term, the dynamic processes of transition pathways can develop into multiple new regimes where the degrees and patterns of change differ depending on how the relevant actors interact[2].

In light of this, transition theory also provides a framework in which the current Japanese electric system could be seen as between the 'Take-off' phase and 'Breakthrough' or 'Acceleration' phase. As shown in Figure 3, understanding the current phase of transition allows us to begin investigation and frame our analysis.

It is understood that change is occurring along a certain pathway, by identifying increasing influences (although as yet weakly structured) of experimental and innovative practices, discourses, networks and developments that are taking place at

---

[2] As shown below, an argument can be made as to whether the current reformist dynamics are effective in weakening the incumbent institutional and commercial networks which have dominated power generation to date [2] Countering this trend would appear to be the resilience of the electricity system which has shifted readily from one centralized configuration (centered on nuclear power) to another (centered on fossil fuels).

the niche level imparting a disruptive force on the current 'locked-in' regime. However, the dynamic nature of the transition pathways to this point means that for the new system to move through to the 'Stabilization' phase, we need to consider the actors who occupy both supply and demand sides of this equation to structuralize and institutionalize a new set of rules for the new game to engender the creation of a new regime which is markedly different to that of today. To attain the 'Stabilization' phase strong structuralizing forces are needed to lead to a new state of equilibrium. In order for this to happen, it is necessary to have consumers whose awareness and preferences are newly formed and different from that of today in order to function as a stabilizing force for the new regime.

If such a development does not occur at this stage, as is described in Figure 4, pathways called `Backlash' or 'Lock-in' may occur – this is where the transformation either ends in failure or when the designed system cannot impart the desired effect. This is an issue this study aims to consider. In summary, we examine whether actual changes are occurring in the wake of the Great Disaster to consumers' awareness and preferences and explore whether any of the changes found can contribute to moving towards a different state of equilibrium from the status quo where a new regime can be established.

On this point, employing MLP, Verbong and Geels [29] developed a typology by which they sought to analytically clarify this undefined nature of having a multiplicity of transition pathways. Their argument suggests that there are possibilities that a certain pattern of actors' interactions across each level can eventually yield yet another large scale concentrated system (though this new system is more sustainable than the current one) as a result of reforming efforts (this is reflected in Figure 4 as "Lock-in").

In this case, it is understood that reforms and changes progress in a more top-down oriented process and that technical innovations are introduced and carried out by cooperative interactions between comparatively large niche actors (such as large scale suppliers) and regime actors (such as the current electric companies) and are supported by a series of public policies by an upper level of government (in this case, the national government). For this reason, the measures taken mainly focus on the augmenting and strengthening of the current grid (i.e. High Voltage Direct Current lines etc.) and the resultant system from such measures is one that mostly relies on a large scale power sources, including both fossil fuels and renewable energy being located at points far away from where the consumers and customers reside.

To enable CO_2 emissions reduction to occur, the deployment of large scale renewables such as mega solar and offshore wind farms is to be pursued, and previously installed coal and oil fired plants are to be retrofitted with Carbon Capture and Storage (CCS) technologies. For the purposes of this paper, this type of transition pathway is called a 'reorganization' transition.

On the other hand, for a small-scale distributed system to be possible, reforms and changes need to progress in a more bottom-up oriented process and in such process a competitive interaction among many divergent emerging niche actors occurs and such competition gradually determines an actor (or a network of actors) who plays an influential leading role in a newly formed regime [5].

In this type of transition pathway, small-scale organizations such as NGOs/NPOs, co-operatives, and associations will cooperate with and leverage off lower level governmental organizations such as local governments so that they can develop small scale grids (such as micro-grids) into a more sophisticated version of smart grids in order to move away from dependence on the current large scale grid and to enable all consumers to install such technologies as small scale PV and onshore wind close to the consumption point. Additionally, storage technologies will be invaluable to enable local balancing and distribution of generated energy. Indeed a combination of these technologies is a systemic pillar of the transition process. In this case, the policy to reduce CO_2 tends to move away from the reliance on CCS-augmented fossil fuel generation and nuclear generation, and towards the mass deployment of small scale renewables in each household, or at the community level, progressed by the improvement of the demand side through management of consumption. This type of transition, as seen above is an even more extreme version of 'reorganization', and could indeed have the potential to form a system which is more sustainable [5]. From this point forward, this paper will refer to this type of transition pathway as a 'conversion' transition.

In both 'reorganization' and 'conversion' type transitions, users and consumers have an important but different role to play. With regard to 'reorganization', the large scale grid takes on a large amoun, of large scale renewables, and consumers' role as 'prosumers' is not pronounced, so there is no great need for a significant 'smartening' of the grid to better balance between demand and supply. From here on, consumers and associated actors, when envisioning policy objectives embodied in a new electric system in the future, express their preferences as ordered: stability of supply > environmental concerns > economic efficiency. However, in the case of a 'conversion' transition, the order is different. In this type, there are certain constraints and understandings associated with the success of the system, including a more significant smartening of the grid with more sophisticated demand response, enabling a locally-governed energy system that seeks self-management and/or ownership of small scale systems in each residential region. In this case, electricity consumers and associated actors within the proposed system will have the following preferences and merit order: self-sufficiency (local production, local consumption) > stability of supply > environmental concerns > economic efficiency [29]. In order to accomplish the transition to a successful small scale, distributed electricity system, it is essential to visualize and materialize such a value judgment as 'local production, local consumption' and to acquire strong support for realizing that objective.

From the above discourse we can identify that it is important to explore the possibilities for making political decision-making and the value judgment associated with it supportive of socio-technical innovations aiming to realize "local production, local consumption" which are essential to solve the problems of the electricity system. To understand whether a transition pathway embodying such judgments can actually occur and achieve the state of equilibrium to engender a new small scale distributed system requires consideration of, as one important factor, the changes in awareness, preferences and behavior of the consumers who constitute both the current and alternative regimes.

Further to this argument, if we consider the sheer numerical majority that individuals, households and small businesses have within the consumption base, as well as the implications of their large proportion of electricity consumption (approximately 31% of total final electricity demand [17]), then the combined potential for changing the system is high. On the other hand, the distribution of this power across so many potential niche actors makes it diffuse and difficult to crystallize or focus towards creating transition.

2.4 Urbanisation, critical theory and transitions

In this research, we took into consideration recent criticisms of traditional transition theory from regional studies, economic geography and political ecology [7, 30-33]. Such critical theory identifies that according to a country`s geography, the location of each region matters and defines it. The degree of change occurring at the landscape level affects the level of change of preferences and awareness of local actors differently. In this regard, current theory tends to assume *a priori* that the scale of system transition is nationwide and thus the change at landscape level can impose selection pressures evenly across the country. This is one of the difficulties associated with this process, and has been adeptly argued elsewhere as a flaw in much of the application of transitions theory [7]. For this reason, the current research developed a survey which could be applied to regions that were affected by the Great East Japan Earthquake, as well as to those which were not affected directly (see Figure 5 and Table 1). The main point of interest is that perhaps those electricity consumers who live in the affected areas will have a greater awareness of the weaknesses of the current system, and in turn will have a greater propensity towards the most rapidly changing 'conversion' type transition system.

Next, in accordance with critical theory, the differences in spatial scale and the varying amounts and levels of access to resources to establish the interactions between local actors at the niche level in each region and the impact that these interactions impart on regime change are considered. Critical theory focusses on each regions land area, endowments, innovative potential, labor force, knowledge and other resources and the availability and access to these resources which are present in regions which are innovating at the niche level, and attempts to explain why innovation is fulfilled at this level in some regions but not in others [7, 30-33]. This in turn means that one key to establishing a better transition theory is to consider how different experimental innovating dynamics occur at the niche level in each region, and whether and to what extent these differences make the niche innovation synergetic with or antagonistic to the ongoing current regime. However, current theory, or the latest research which relies upon it, has yet to consider effectively the effects of such an experiment where for example the properties and assets of local governments or regional society lead to multiple outcomes and whether or not this represents successful niche innovation and how this differentially affects the current regime. It is important to note that the current literature in transitions theory identifies scale as an important but under-included aspect of MLP applications [34], and some efforts have been made to theoretically address this issue [35]. Also, it is suggested that because of this shortfall found in current transition studies, the related governance discourse proposed to date maybe somewhat unrealistic or overly optimistic [34, 35]. In the current work, we seek to examine the differentiation across various locations of the influence of the Great East

Japan Disaster, as well as the level of urbanization. Whilst not directly looking at multiple scales, it may contribute somewhat to the expansion of knowledge in this field.

3 Survey design and hypothesis

(A) Geographical spatial differences and dynamics of niche innovation

Using the above discussion as its basis, this research seeks to understand consumer's awareness (knowledge) and preferences following the great eastern disaster. To achieve this goal, a survey was designed.

Firstly, the approach was to survey residents of regions and cities which are currently implementing innovation programs such as 'smart cities', 'Future Cities', 'Eco-model Cities', in which the government has supported large installations of renewable energy or construction of distributed small scale systems like smart grids. These regions and cities are transition theory's niche level pilot regions, and in Japan they are leading examples of regions aiming to realize a lower environmental load, and a more sustainable energy system. We attempted to establish the awareness and preferences expressed towards system transition for electricity consumers living in these pilot regions.

Considering the recent criticisms of theory described in the previous section, this research focuses on the contrasting levels of resources and assets in each region, and investigates both large scale urban and small-to-medium sized rural regions (See Figure 5 below). The main point of interest here is to determine whether, as suggested by critical theory that, regions with large amounts of infrastructural, human and financial resources and good access to these such as large-scale urban regions, when compared with small-medium sized and rural regions will have a stronger preference towards conversion type system transition or not. To more clearly demarcate this contrast, in the survey large scale urban regions included cities with in excess of 1 million residents (in all cases major cities) and rural and small-medium sized regions with populations of below 500 thousand residents were assessed (Table 1).

Table 1: Regions surveyed in the current work

	Large, Urban	Small / sparsely populated, rural
Non-disaster sites	Quadrant ① 1) Yokohama-shi* 2) Kobe-shi**	Quadrant ② 6) Obihiro-shi** 7) Minamata-shi** 8) Miyakojima-shi** 9) Shimokawa-chou in Hokkai-do* 10) Takaoka-gun Yusuhara-chou in Kochi-ken** 11) Aida-gun Nishiawakura-son in Okayama-ken** 12) Kani-gun Mitake-chou in Gifu-ken** 13) Iida-shi** 14) Keihanna-area*** 15) Kashiwa-shi* 16) Toyota-shi** 17) Toyama-shi* 18) Amagasaki-shi**
Disaster sites	Quadrant ③ 19) Sendai-shi	Quadrant ④ 20) Kamaishi-shi in Iwate-ken* 21) Souma-gun Shinchi-machi in Fukushima-ken* 22) Rikuzentakata-shi in Iwate-ken* 23) Oohunato-shi* 24) Sumita-chou* 25) Iwanuma-shi* 26) Higashimatsushima-shi* 27） *Minamisouma-shi* 28) Tsukuba-shi** 29) Fukushima-shi 30) Morioka-shi

* “Future City”

** “Eco Model City”
*** Keihanna Smart City

(B) Question settings and hypothesis

In order to base our concerns in transition theory, and to utilize the survey as empirical proof of such, questions were designed to focus on the three main points of: trust and support of the consumers toward regime and niche actors, values and policy goals embodied in a desirable future electricity system, and willingness to commit to and participate in the transition process.

(1) *Firstly, who do the electricity consumers trust and support - regime actors or niche actors?* Trust has been highlighted as a missing element in research into energy systems broadly [36]. In Japan, regime actors include both the 10 large monopoly power companies and the central government and niche actors are various new entrants to the electricity market and the local governments. These new participants are unlikely to be bound by vested interests and represent smaller scale, entrepreneurially-minded businesses and local public organizations (e.g., renewable companies, NGOs/NPOs and local residential autonomous organizations). According to MLP and transition theory, if the consumers show a stronger support and trust for those new participants (niche actors) than for the regime actors, then we can say that this is more conducive to a ‘conversion’ type transition.

(2) *How do consumers prioritize the desirable characteristics of the electricity system of the future in light of its merits, values or public interests?* According to the theory

this order will be different in alternative transition types. In order for a 'conversion' type transition to occur, values like 'self-sufficiency (local production, local consumption)' or 'local economy revitalization' should emerge as top-priorities over 'stability of supply', 'environmental concerns' and 'economic efficiency'.

(3) *To what extent do the consumers participate in or commit themselves to the innovating dynamics and processes being developed at niche level in each region?* According to the theory, when consumers have a stronger intent to share their own time and money for measures leading to the establishment of smart cities or electric systems that are locally owned and managed (governed) in each region, we can expect that there will more likely be a 'conversion' type transition.

In order to answer each of these points, a number of survey questions was devised, listed in Appendix A.

Here we can draw the hypothesis: compared to unaffected small scale regions, affected large scale urban areas will be more likely to have effective and innovative niche experiments and that this in turn will more likely manifest in the electricity consumers' awareness and preferences supporting the 'conversion' type transition, not the 'reorganization' type.

4 Survey results and analysis

4.1 Overview of the survey conducted

This survey was undertaken through an internet survey company with respondents over the age of 20. The investigated regions and number of respondents varied greatly, and so bias correction was undertaken sample weighting in 5 year and 10 year age brackets (to fit the census data age proportions of the communities considered). 7887 surveys were sent, with 2581 surveys returned – ultimately 2532 of these were used after weighting.

In order to better frame the results directly related to the transitions question that this paper seeks to respond to, it is useful to understand some of the contextual elements understood from the survey regions. Figure 6 shows the average monthly energy spend in each of the groups on both a cost and energy basis, broken down by energy type. Though self-reported, the energy range per household per month is in reasonable agreement with the average national energy usage based on reported national residential energy [17] and number of households [37] – around 3.3 GJ / household / month (electricity, gas and fuel oil). The rural communities are shown to pay more overall for energy than the urban communities, corresponding to a larger usage of energy (assuming that the pricing is consistent across the country). From the technical perspective, this offers an insight into the potential areas for improvement. Critically, the rural areas had a higher spend on petrol for transport and oil for heating.

The respondents were asked whether they had undertaken or considered a variety of activities related to the reduction in energy usage or the improvement of self-sufficiency at the residential or community level, and what the barriers to such activities were. A large percentage of respondents had been considering undertaking these activities Figure 7, although of those considering them not everyone was able to achieve them Figure 8.

The important items to note here were perhaps that there was a greater achievement of activities that did not require significant investment or capital outlay – reduction of electricity and fuel usage for heating in particular. Whereas the purchasing of generating equipment or electric vehicles was more difficult to achieve. Interestingly, changes from the use of gas and electricity to all-electricity and vice versa were both relatively common in regards to their achievement, despite potentially requiring some capital investment. It was apparent that many people had considered energy-related activities in the aftermath of the March 11 disaster – as 40% or higher had considered even the capital intensive activities, although in most cases (typically 70 – 80%) it was reported that the cost was inhibitive.

The responses here were further supported by the responses in Figure 9, indicating what actions the respondents were willing to undertake to reduce greenhouse gas emissions. Energy saving activities not requiring excessive cost or change of lifestyle were the preferred activities.

Willingness to pay (WTP) for installation of PV systems was also found to be somewhat variable, with the rural and disaster-affected groups more likely to pay more (on average) (Table 2). Although utilizing a different questioning method and group of respondents, this corresponds to a higher WTP than observed by other groups before the Great Disaster [38], while at the same time finding a larger percentage of respondents unwilling to pay anything at all (27-32% across the different groups).

Table 2: Average willingness to pay for photovoltaic systems

	Group 1	Group 2	Group 3	Group 4
WTP PV	$ 8,342	$ 9,772	$ 9,327	$ 10,460

4.2 Survey outcomes

The major survey outcomes directly connected to our key questions are reported and discussed in this section.

The response to the first key question – of which entity would be best to promote and realize the interests of the local community – is displayed in Figure 10. Using standard statistical t-tests the responses were found to be statistically significant. From these responses, we can determine the appropriate entity to progress local residents and community interests and profits, and also gauge the support and trust for this entity. Under this kind of general policy proposition (although easily understood) support for public actors such as the State (national) and local government is at its highest level. However, between the two, support for local governments is higher and this applies to all of the 5 regions. Also, among private actors, support for existing electricity companies and local residential organizations was very similar, at the highest level for non-government actors. From this we can understand that from the point of view of the issue of 'local' benefits and profits, the local government is the most strongly supported niche actor and most supported overall, while regime actors such as national government and electricity companies enjoy a reasonable level of support the smaller support for other niche actors shows a mixed support for the “conversion” type transition, although it is as yet unclear whether the support for niche actors is at a critical level or not.

Next, we assess the answer to Question 1-2, expressed in Figure 11. The intent of this question is to determine the level of trust for the entity which will undertake the future reform of the electrical system. Note that compared to the previous question, this one deals with a more specified policy issue.

It is interesting to find that the responses regarding the level of trust of the State and local government are reversed when compared to 1-1. Also, the responses indicating both are suitable or uncertainty as to which is preferable are comparatively close to ‘local government’. This differs from the response from the previous question and shows that with regard to the capability of undertaking policies we are unable to establish the dominance of ‘local government’. Perhaps this result suggests that with regard to the reform of the electrical system many consumers still feel that the national government is more suitable than local government to achieve this reform, while it may also be that “policy” is considered the realm of national level regime actors and not associated closely with the local area.

Interestingly, across region types, a statistically-significant distinction was noted that small-medium sized regions trusted the State more, and local government less than large urban regions. This result may suggest that as the population size (scale) of a region diminishes, so too do the size and resources available to the local government thereof, meaning that as an entity undertaking polices they are less likely to be trusted. However, the hypothesis that people in disaster affected areas would support local governments more than the State was not upheld.

The answers to Question 1-3 are shown in Figure 12. Here, in a similar fashion to Question 1-2 the focus is on a more specific policy and seeks to determine the preferred entity to lead the energy efficiency and saving measures that are intended to avoid blackouts.

From the results we can see that trust of the public actors, the State and local governments are in close competition, and private actors including the general population, current electricity companies and large scale industry enjoy a high level of trust. Also, whereas among niche actors NGOs/NPOs and community-based organizations enjoy a relatively high level of support, that level does not exceed that which the respondents gave to the regime actors (i.e., current electricity and large scale industry companies). There is also an important recognition of the role of individuals in reducing energy consumption – an awareness that may be in part influenced by the campaigns post-Fukushima to save energy across the country.

With regard to important regional differences, in disaster affected areas – particularly in the large scale urban region - we found that their support for NGOs/NPOs and community organizations was quite low. This does not agree with our hypothesis. However, we did not find any opposing trend in unaffected regions (i.e. wide support for such niche-actors which would otherwise contradict the hypothesis).

The trend of answers from Question 1-3 was the same as answers to Question 1-4, as outlined in Figure 13. With regard to climate change mitigation policy, as with energy efficiency policy, perhaps consumers feel that it is best undertaken at the national scale, however there is a larger shift towards local actors in the energy consumption case. This could arguably be due to the sense that energy consumption is locally relevant or controllable, whereas greenhouse gas emissions are perceived to be disconnected from individual actions or sphere of influence. When compared with urban areas, rural areas – in both disaster and non-disaster regions —indicate greater responsibility placed in smaller scale actors within the business sector and individuals, but not in other local scale (niche) actors. Disaster-affected areas place slightly less emphasis on government actors at each level.

Considering the answers to the above 4 questions as a whole, we can see that consumers are more likely to support niche actors who have an affinity towards 'conversion' transition when the topic area is seen as closer to the local sphere of influence. However, we can also see a trend of continued support for regime actors who have an affinity for 'reorganization' transitions because they regard these policy decisions as better taken at the national scale.

Figure 14 shows the responses to Question 1-5. The question posed to consumers was which company they would prefer to buy electricity from in a liberalized electricity market.

From these answers we can see that irrespective of regional features, consumers are most supportive of existing electricity companies. Also, of the new entrants to the market, in all regions gas companies had the highest support – although this was particularly strong in urban non-disaster areas, potentially reflecting the amount of existing infrastructure and the fact that those areas had not experienced gas service stoppages in the post-disaster period. Following gas companies, oil companies were the next most supported with IT and telecommunications or electrical and home appliance makers in third place or fourth place. The most trusted entities were therefore in general the energy-related companies or utilities that were already established in other sectors and well-known to the respondents. Interestingly, the new-entrant companies that already have arguably more experience in electricity generation (due to operating their own onsite power plants for example) – automobile manufacturers, steel companies and even some house makers have not got the same level of support. The strength of the telecommunications company may be due to the efforts of the company SoftBank™ in investing in megasolar plants since the Great Disaster, while the electronics companies are also involved in the development of energy generating technologies such as fuel cells and PV panels, which may promote their relevance in the perspective of respondents.

Within the results, urban areas tended to show greater support for new entrants in the large business sectors (the top 4 new entrant company types), while rural areas showed greater support for local community organizations.

Overall consumers, whilst supporting new entrants to a certain degree, still strongly support existing electricity companies, trending towards a pattern resistant of change and more likely to follow a reorganization transition. Looking at the answers as a whole, we can see that in disaster affected areas, and in large urban regions, support for new entrants, as proposed by our hypothesis, was not found overall. When examining individual responses, it was found that support for gas companies was higher in large urban regions than in small-medium regions. Comparing with the urban areas, rural areas use more oil and petrol, and less gas (Figure 6), so the lower support for gas companies is possibly attributable to this.

In the responses to Question 1-6, described in Figure 15, it is indicated that the urban areas were more likely than rural areas to trust most large companies or entities with their data. On the other hand, rural areas were more trusting of local community organizations and NGO`s / NPO`s. Overall however, the most dominant response was that there was no suitable entity, although the most trusted of the selected entities was the current electricity provider.

Figure 16 below outlines the response to Question 2. The question asked about the preferred order of desirable characteristics for a future electricity system that should be the focus of policy.

From these responses it was understood that 'stable power supply' was a top priority selected with the highest level of support, followed by safety and low cost. Reducing emissions, using local resources, employment and renewable energy followed. The order of these responses was more characteristic of a 'reorganization' transition than a conversion transition. The above described preference patterns were irrespective of any specific regional features, and therefore, we can say that the responses to this question do not agree with our hypothesis. In addition, although the invigoration of local economies is regarded by theorists as a merit of the deployment of small distributed systems with regard to this point, support was lower than other categories. However, looking specifically at the responses to the importance of using local resources and employment, the rural areas indicated a higher preference in disaster affected areas. It was also surprising that the safety aspect was not considered as important in disaster-affected areas as in unaffected areas.

Figure 17 outlines the responses to Question 3-1. The question inquired about intent (willingness) to participate in progressing policies which create smart cities. We can see that participation intent (willingness to participate) is low, and the majority of respondents had an undetermined stance. This response pattern is followed generally, with no statistical difference between groups. Therefore, our hypothesis was not verified.

Interestingly, largely the same trend is observed for the responses to Question 3-2, as displayed in Figure 18. Question 3-2 showed greater participation intent, but this was not statistically significant and the opposition to the hypothesis was not overturned. Importantly, consumers were more interested in participating in local systems (with local ownership) than in state-devised systems. This is further identified in cross-comparison, where the majority of respondents supporting the state system were also in favor of participation in local systems however, among those who would support only one of these, the local systems were most strongly supported in groups 1 and 2 (but in groups 3 and 4 the difference was not statistical).

5 Discussion and conclusions

To the best of the authors` knowledge, this study is a first-of-its kind, attempting to use direct consumer data to understand the tendencies of an energy system towards a given type of transition – particularly in the wake of such a significant disaster. In this section we discuss some of the findings with relation to policy and governance and theory.

5.1 Policy and governance implications

As seen above, for all of the questions prepared, the theoretical hypothesis that disaster affected areas and large urban regions are more likely to show preference and support for a more radical and innovative transition and progressing transitional policies than small-medium sized regions and unaffected areas was not able to be thoroughly verified. This survey`s results, even in the face of the Great East Japan Disaster, whose scale and magnitude was unprecedented, and put significant pressure for radical change at the landscape level, does not appear to have induced a ‘conversion’ type transition with enough critical mass to change to a small scale distributed system. At the same time, the current Japanese electricity regime shows potential towards moving down the 'reorganization' transition (corresponding to 'lock in') pathway. The reforms will be carried out only to the extent that the regime actors can accept. In this way, the reforming measures turn out be synergetic and cooperative with the current regime in a sense that they support and reinforce the regime's functions. As taught by transition theory, the embedded nature of large scale technical infrastructure which has put down roots in society over many years, tends to develop an electricity regime whose structures and institutions have a strong viscosity, resistant to change. This trend is suggested by the outcomes[3].

It should be noted that the reason for using the term 'viscosity' is because of the nature of the consumers' survey responses, preferences and awareness levels, in that they are, irrespective of local regional features, somewhat monotone. This sense of incongruity is somewhat unexpected to the authors (not due to the rejection of the hypotheses). Even though consumers have experienced the massive, unprecedented earthquake and nuclear accident, where are they really locked in? Perhaps if the same survey had been undertaken at a point in time closer to March 2011, there is a chance that consumers' responses may have differed. This survey was undertaken three years (this could be

---

[3] Verbong and Geels state [25] that for such large scale infrastructure as the electricity system to be able to achieve a transition away from the path of dependence, and avoid lock in, considering the time line it may be easier to begin with the more mild form of change: 'reorganization' transition, before transitioning into a 'conversion' phase. The obvious question that is posed then is, what factors or forces can bring about processes that can break down the subsequent equilibrium in the "reorganization' transition pathway and then enables a system transition of the 'conversion" type? The identification of the issues and interactions of such a transition process need to be made clear.

considered either a short or a long time from the point of view of to people's awareness and preference development) after the disaster occurred. During this time, and due to the nature of responses elicited through this survey, it may be possible that people's awareness and preferences may have changed to a certain degree and then returned to their previous state. At the same time, however, no one can absolutely say that a group of reform measures will have the desired outcome. In fact, even after the complete liberalization of the electricity market, it still is unclear as to whether the entry of many new players will lead to real competition and a lowering of electricity prices. We argue that the lock-in of the Japanese electrical regime is extremely path dependent, with a viscous rather than fluid response.

It is important to pay attention to the fact that this kind of reasoning is not just the use of jargon, or word play. This is because the regime's viscosity will impact whether or not the next stage of transition reaches 'take off' or conversely undergoes 'backlash'. The 'backlash' pathway is where a series of reform measures, though once implemented, fail to realize their purpose and this in turn leads the system to go back to where it was – in this case to the state before the occurrence of Great Eastern Disaster. From the sustainability perspective, this type of transition will result in an inferior regime to one led by locked-in 'reorganization.' According to Verbong and Geels' categorization, this transition pathway fits well with 'transformation type,' the least changing and reforming transition even compared to 'reorganization type,' thus the most unsustainable. In this category, if we argue in the Japanese context, once nuclear plants are restarted, new and/or add-in constructions will be back on track and this will ease the problems of heightened imported oil prices so that the regime can be once again largely dependent on large scale power plants. Also, in this category, the existing power companies (or maybe newly-formed large scale energy companies allied with those existing power companies) will outplay the market competition and overwhelm such new entrants such as mid-scale power producers and suppliers (over 50kW) (niche actors) and this will in turn lead to the de-facto reestablishment of monopoly and dominance of production, distribution and retail where small scale renewables (PV for households and on-shore wind turbines) is introduced only to the extent that those large scale energy companies allow. In this case, required CO_2 reduction will be achieved by the installation of nuclear power or CCS attached to large scale thermal power plants functioning as the system's main facilities. That is, in short, the large scale concentrated system that we had prior to the Disaster will be established once again

The performance of different regions of Japan and the persistence of energy saving measures beyond the immediate aftermath of the Fukushima disaster have been examined elsewhere, indicating a surprising trend of non-disaster areas reducing electricity consumption at the household level in a persistent manner [3]. However, the national government`s lack of meaningful action to reduce dependence on nuclear power and induce renewable, decentralized energy may act to stifle the burgeoning niche actors as observed with climate change communications [39]. Hopes for positive transitions may well be encouraged by the presentation and discussion of the alternatives [40].

Regarding the shift in the power generation mix, many models have been run and it has been widely indicated that a return to some scale of nuclear energy is useful as a transition to wider spread renewable energy integration [19, 41]. The Great East Japan Disaster led to a noticeable weakening of support for nuclear power, and has damaged the image and business-as-usual approach of the power companies, which may be effective in destabilizing the current regime, offering a chance for change to occur [42]. At the same time, institutional settings have been strengthened to support renewable energy [43] and the network of actors has been mobilized, both potentially important supportive factors [44].

Governance in the new decentralized grid will occur at different levels and have different requirements on participation of individuals, transparency and privacy. It requires governance with multiple stakeholder involvement [45]. Barriers of cost and knowledge (shown elsewhere as important for smart grids [46]) are also recognized in the current study as important challenges to distributed energy.

5.2 On some methodological and/or theoretical perspectives

In response to our hypothesis that non-disaster, rural areas would be less supportive of niche actors than disaster-affected urban areas, we found that this might be the case with regards to certain issues, but it was far from a clear determination either way when all issues were viewed as a whole. While the hypothesis appears somewhat verified when observing the relative selections of each region, in the absolute responses it appeared to be reversed (Table 3).

Table 3: Summary of positions of regions with reference to the support for regime or niche actors

Region	Response reflecting greater support for regime (R) or niche (N)

	1-1	1-2	1-3	1-4	1-5	1-6	2	3-1	3-2
1 Non-disaster, urban	N	R	~	R	R	R	R	N	N
2 Non-disaster, rural	N	R	~	R	R	R	R	N	N
3 Disaster, urban	N	R	~	R	R	R	R	R	N
4 Disaster, rural	N	R	~	R	R	R	R	N	N
Compare 3 vs 2 favoring N	2>3	3>2	2>3	3>2	3>2	3>2	2>3	2>3	3>2

While the results do not verify incontrovertibly that a conversion type transition is occurring, there is some indication that there is a transition towards more centralized renewable energy in the energy mix.

In this research we have kept in mind the critical assessment of transition theory and used the differences in regional assets and features as the basis for our hypothesis. The fact that this was not verified in our survey would then raise an issue as to whether we should doubt the validity of the critical theory. On this point, although the hypothesis used was not statistically verified, we need to heed that this does not mean that the critical theory has no meaning. The verification of the hypothesis in this paper, whilst complying with the suggestions of critical theory, was done in a quantitative manner, and consequently we summed up cities and regions in 4 categories as our unit of measure. This mass approach may have led to some regional level differences being hidden. For example, in our survey, it was noticed that the city of Sendai, which experienced the great eastern disaster has some highly irregular response patterns when compared to consumers in other regions. The quantitative nature of the survey has identified the need to develop a qualitative method which considers transition pathways in each region (for example: hearings of affected persons and case studies) to further assess and clarify the dynamics which leads to uniqueness and diversity. It may also be important to examine the data at a higher level of detail (town-by-town). Furthermore, it may be the case that over the passing of 3 years since the great eastern disaster, once-varied preferences and awareness of the consumers have rapidly converged and become somewhat monotone. In such a case, we can see a strong viscosity associated with the electricity system whose importance we cannot overlook when we debate system transitions from both disciplinary and theoretical perspectives.

5.3 Historical energy transitions and the future

This section returns to Figure 1 to refocus on the transitions of the past and the new potential transition in progress. There are a number of key considerations that make the new transition different from earlier transitions. Firstly, considering the drivers of earlier transitions, the initial rapid growth of oil-based electricity was driven by rapid population increase, rapid economic growth and the low cost of imported oil. The drivers of the diversification of energy – particularly electricity – in the second transition were energy security (in avoiding the supply problems of the oil crises), the lower or more stable cost of alternatives and the availability of alternative technology (LNG had only recently become feasible and nuclear power was developing rapidly). In the latter case, population and economy were still growing rapidly and the sense of urgency about energy security was politically and popularly prevalent.

The drivers and potentialities for a transition at the present time are different – the basic drivers of economic growth and population growth are not present, so an increase in energy usage is not required. This implies that the change to be undertaken is almost purely structural rather than there being a need for additional capacity which would not necessarily imply the need for reduced output from incumbent players. The current transition (if it is to occur) is one of fundamental restructuring in which the regime actors cannot rely on their existing institutional and physical infrastructure. The driver in this case is the combined physical infrastructure damage and psychological impact of a natural and manmade disaster. Moreover, the return to oil, coal and LNG to maintain energy supply has increased cost – which in this case may be sufficient to prevent a wide-scale transition and force a return to the stable state of nuclear power. At the same time, the cost barrier to renewable energy uptake is being degraded through the introduction of the expanded FiT and the landscape level factors of global PV cost reductions. Additional to this, or as an enabler to this transition is the availability of the technologies – particularly for PV and wind – and the public recognition and acceptance of them (depicted in Figure 19).

The PV association of Japan`s statistics indicate that there has been a dramatic increase in the amount of solar panel installations by power companies and in non-residential applications [47]. This would lend credence to the position that rather than a conversion transition towards distributed renewables, we are seeing a reorganization transition towards centralized renewables favoring a minimal shift in the regime structure.

It may also be that the full liberalization of the electricity and gas markets from 2016 onwards provide sufficient additional restructuring at the regime level in order further promote decentralized energy and the development of active prosumers or further development of current niche actors in this market.

6 Conclusions

This study has presented an application of transition theory to the situation of Japan in the post-Fukushima era. In particular, it was anticipated that a differentiation between areas with different capital potential and different exposure to an enormous, sudden landscape pressure may show differences in consumer preferences. While some differences are observed with regard to specific issues, in the overall picture it was not possible to clarify a statistical difference – although it is possible to interpret, there is a need for greater qualitative research in this area. Important to the overall application of transition theory is that this case study applies the theory in a forecasting perspective, using consumer preference as an indicator to examine the nature of preferred and apparent trends that may converge into transitions of different types.

In the case at hand, under the specific interpretations of the consumer response data, we observed that it is most likely that a "reorganization" type transition – where large regime actors are realigning themselves to produce more centralized renewable energy – is happening rather than a "conversion" type transition to more decentralized renewables. This may be an intermediary stage, but that is not possible to clarify at this juncture. Importantly as a theoretical contribution, the extreme nature of this "viscosity" that is preventing the rapid coalescence of dispersed sentiment and niche actors towards a conversion transition should be considered as it indicates a high level of lock-in.

Acknowledgements

This research was funded by a Feasibility Study grant from the Research Institute for Humanity and Nature, Japan.

References

1. Ueta, K. and H. Kajiyama, eds. *Kokuminnotamenoenerugiigenron (Principles of Peoples' Energy)*. 2011, Nihonkeizaishimbunshuppansha: Japan. 318.
2. Vivoda, V., *Energy security in Japan: Challenges after Fukushima*. 2014, Surrey, England: Ashgate Publishing Limited A. 224.
3. Wakiyama, T., E. Zusman, and J.E. Monogan Iii, *Can a low-carbon-energy transition be sustained in post-Fukushima Japan? Assessing the varying impacts of exogenous shocks.* Energy Policy, 2014. **73**(0): p. 654-666.
4. Geels, F.W., *Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study.* Research Policy, 2002. **31**(8–9): p. 1257-1274.
5. Verbong, G.P.J. and F.W. Geels, *Exploring sustainability transitions in the electricity sector with socio-technical pathways.* Technological Forecasting and Social Change, 2010. **77**(8): p. 1214-1221.
6. Grin, J., J. Rotmans, and J. Schot, *On patterns and agency in transition dynamics: Some key insights from the KSI programme.* Environmental Innovation and Societal Transitions, 2011. **1**(1): p. 76-81.
7. Lawhon, M. and J.T. Murphy, *Socio-technical regimes and sustainability transitions: Insights from political ecology.* Progress in Human Geography, 2012. **36**(3): p. 354-378.
8. National Policy Unit. *Options for Energy and Environment - The Energy and Environment Council Decision on June 29, 2012* 2012 [cited 2012 August 22nd]; Available from: http://www.sentakushi.go.jp/english/.
9. Kikkawa, T., *Denryokukaikaku: Enerugiiseisakunorekishitekidaitenkan (Electricity Reforms: Major Historic Changes in Energy Polices)*. 2012: Koudansha. 245.
10. Surrey, J., *Japan's uncertain energy prospects: the problem of import dependence.* Energy Policy, 1974. **2**(3): p. 204-230.
11. IEA, *Energy balances of OECD countries*. 2010, International Energy Agency: Paris, France.
12. Perkins, F.C., *A dynamic analysis of Japanese energy policies: Their impact on fuel switching and conservation.* Energy Policy, 1994. **22**(7): p. 595-607.
13. Ushiyama, I., *Renewable energy strategy in Japan.* Renewable Energy, 1995. **16**(1-4): p. 1174-1179.
14. Lesbirel, S.H., *Implementing nuclear energy policy in Japan top-down and bottom-up perspectives.* Energy Policy, 1990. **18**(3): p. 267-282.
15. Pickett, S.E., *Japan's nuclear energy policy: from firm commitment to difficult dilemma addressing growing stocks of plutonium, program delays, domestic*

opposition and international pressure. Energy Policy, 2002. **30**(15): p. 1337-1355.
16. Nakata, T., *Analysis of the impacts of nuclear phase-out on energy systems in Japan.* Energy, 2002. **27**(4): p. 363-377.
17. IEA, *Energy balances of OECD countries*. 2012, International Energy Agency: Paris, France.
18. McLellan, B.C., et al., *Analysis of Japan's post-Fukushima energy strategy.* Energy Strategy Reviews, 2013. **2**(2): p. 190-198.
19. Zhang, Q. and B.C. Mclellan, *Review of Japan's power generation scenarios in light of the Fukushima nuclear accident.* International Journal of Energy Research, 2014.
20. Vivoda, V., *Japan's energy security predicament post-Fukushima.* Energy Policy, 2012. **46**(0): p. 135-143.
21. Motoki, Y. and K. Aoki, *Case Study Analyses of Introduction Processes of New Local Power Systems Called 'Microgrids' in Japan.* Journal of Science and Technology Studies, 2008. **6**: p. 13.
22. McLellan, B., et al., *Resilience, Sustainability and Risk Management: A Focus on Energy.* Challenges, 2012. **3**(2): p. 153-182.
23. Esteban, M. and J. Portugal-Pereira, *Post-disaster resilience of a 100% renewable energy system in Japan.* Energy, 2014. **68**(0): p. 756-764.
24. Esteban, M., et al., *Methodology to estimate the output of a dual solar-wind renewable energy system in Japan.* Energy Policy, 2010. **38**(12): p. 7793-7802.
25. Karger, C.R. and W. Hennings, *Sustainability evaluation of decentralized electricity generation.* Renewable and Sustainable Energy Reviews, 2009. **13**(3): p. 583-593.
26. Geels, F.W. and J. Schot, *Typology of sociotechnical transition pathways.* Research Policy, 2007. **36**(3): p. 399-417.
27. Grin, J., *The politics of transition governance in Dutch agriculture. Conceptual understanding and implications for transition management.* International Journal of Sustainable Development, 2012. **15**(1): p. 72-89.
28. Kemp, R., J. Schot, and R. Hoogma, *Regime shifts to sustainability through processes of niche formation: The approach of strategic niche management.* Technology Analysis & Strategic Management, 1998. **10**(2): p. 175-198.
29. Verbong, G. and F. Geels, *Future electricity systems: Visions, scenarios and transition pathways.* Governing the Energy Transition: Reality, Illusion or Necessity, 2012: p. 203-219.
30. Hodson, M. and S. Marvin, *'Urban Ecological Security': A New Urban Paradigm?* International Journal of Urban and Regional Research, 2009. **33**(1): p. 193-215.
31. Monstadt, J., *Conceptualizing the political ecology of urban infrastructures: insights*

from technology and urban studies. Environment and Planning A, 2009. **41**(8): p. 1924-1942.

32. Truffer, B. and L. Coenen, *Environmental Innovation and Sustainability Transitions in Regional Studies.* Regional Studies, 2012. **46**(1): p. 1-21.
33. Bulkeley, H. and V. Castán Broto, *Government by experiment? Global cities and the governing of climate change.* Transactions of the Institute of British Geographers, 2013. **38**(3): p. 361-375.
34. Coenen, L., P. Benneworth, and B. Truffer, *Toward a spatial perspective on sustainability transitions.* Research Policy, 2012. **41**(6): p. 968-979.
35. Raven, R., J. Schot, and F. Berkhout, *Space and scale in socio-technical transitions.* Environmental Innovation and Societal Transitions, 2012. **4**(0): p. 63-78.
36. Greenberg, M.R., *Energy policy and research: The underappreciation of trust.* Energy Research & Social Science, 2014. **1**(0): p. 152-160.
37. MIAC. *Japanese Government Statistics*. 2015 [cited 2015 July 23rd]; Available from: http://www.stat.go.jp/english/data/index.htm.
38. Ida, T., K. Murakami, and M. Tanaka, *A stated preference analysis of smart meters, photovoltaic generation, and electric vehicles in Japan: Implications for penetration and GHG reduction.* Energy Research & Social Science, 2014. **2**(0): p. 75-89.
39. Stoknes, P.E., *Rethinking climate communications and the "psychological climate paradox".* Energy Research & Social Science, 2014. **1**(0): p. 161-170.
40. Stirling, A., *Transforming power: Social science and the politics of energy choices.* Energy Research & Social Science, 2014. **1**(0): p. 83-95.
41. Portugal-Pereira, J. and M. Esteban, *Implications of paradigm shift in Japan's electricity security of supply: A multi-dimensional indicator assessment.* Applied Energy, 2014. **123**(0): p. 424-434.
42. Turnheim, B. and F.W. Geels, *Regime destabilisation as the flipside of energy transitions: Lessons from the history of the British coal industry (1913–1997).* Energy Policy, 2012. **50**(0): p. 35-49.
43. Muhammad-Sukki, F., et al., *Feed-in tariff for solar photovoltaic: The rise of Japan.* Renewable Energy, 2014. **68**(0): p. 636-643.
44. Darmani, A., et al., *What drives the development of renewable energy technologies? Toward a typology for the systemic drivers.* Renewable and Sustainable Energy Reviews, 2014. **38**(0): p. 834-847.
45. Goldthau, A., *Rethinking the governance of energy infrastructure: Scale, decentralization and polycentrism.* Energy Research & Social Science, 2014. **1**(0): p. 134-140.

46. Muench, S., S. Thuss, and E. Guenther, *What hampers energy system transformations? The case of smart grids.* Energy Policy, 2014. **73**(0): p. 80-92.

47. JPVEA. *Website of the Japan Photovoltaic Energy Association*. 2015 [cited 2015 July 6]; Available from: http://pvjapan.org/en/statistic/index.html.

48. Kemp, R. and D. Loorbach, *5. Transition management: a reflexive governance approach.* Reflexive Governance for Sustainable Development, Cheltenham, UK and Northampton, MA, USA: Edward Elgar, 2006: p. 103-30.

49. Rotmans, J. and D. Loorbach, *Towards a better understanding of transitions and their governance. A systemic and reflexive approach.* Transitions to sustainable development–new directions in the study of long term transformation change. Routledge, New York, 2010: p. 105-220.

Appendix

Question (1)-1 In the region in which you live, which entity do you think is best suited to realize the interests and profit of the local community? Please choose from the companies and institutions below. (You may grade from 1-5, 1-3 is compulsory).

- ✓ The state
- ✓ Local government organizations (prefectural or city/village level)
- ✓ Current electricity companies
- ✓ Natural (renewable) energy businesses
- ✓ Gas companies
- ✓ Agricultural related persons
- ✓ Fishery related persons
- ✓ Forestry related persons
- ✓ Electronics and home appliance makers
- ✓ Automobile makers
- ✓ Iron and Steel makers
- ✓ Building industry
- ✓ Logistics industry (i.e. supermarkets)
- ✓ Cooperative societies (Co-ops)
- ✓ Charities, NGOs, NPOs etc. (public interest groups)
- ✓ Regional, community and local organizations
- ✓ Other entities, please explain: (free answer)
- ✓ No such entity exists that can satisfy the interests and profit of the local community
- ✓ Not sure

Question (1)-2 Following the 11 March 2011 Great Eastern Japanese disaster, wide scale blackouts and nuclear calamity was experienced, exposing the weaknesses of the electricity system. In order to improve the system, many regime and policy changes have been vaunted as necessary. In your opinion, who is the right government entity to implement these policies and measures and business development plans? (single answer).

- The State (Central Government)
- Local government organizations (prefectural or city/village level)
- Both governments are equally suitable
- Both are not suitable (if you can suggest an alternative government entity please write it here)
- Not sure

Question (1)-3 In order to stop blackouts, it is necessary to reduce our consumption of electricity even further. To achieve this, we need to begin a new series of energy saving measures. Which of the below companies or institutions do you think is best suited to leading these measures? (You may grade from 1-5, 1-3 is compulsory).

- ✓ Civilians, the general public
- ✓ The wealthy
- ✓ Charities, NGOs, NPOs etc. (public interest groups)
- ✓ Regional, community and local organizations
- ✓ The State
- ✓ Local government organizations (prefectural or city/village level)

- ✓ Current electricity companies
- ✓ Natural (renewable) energy businesses
- ✓ Gas companies
- ✓ Electronics and home appliance makers
- ✓ Automobile makers
- ✓ Iron and Steel makers
- ✓ Big industries, across all categories
- ✓ Small industry, across all categories
- ✓ Other entities, please explain: (free answer)
- ✓ There is no suitable entity

Question (1)-4 With regard to issues such as climate change, there is a need to limit the use of fossil fuels such as coal and oil, and to limit the carbon dioxide (Greenhouse gas) outputs of energy generation. From the companies and institutions outlined below, which do you think is the most suitable entity to undertake this task?

- ✓ Please answer in the same way as (1)-3

Question (1)-5 The Japanese government has decided to completely liberalize the electricity market from the year 2016. It is expected that a lot of new electric companies will enter the domestic supply market once the current monopoly is removed. Under this kind of market, where are you most likely to purchase your electricity from? (You may grade from 1-5, 1-3 is compulsory).

- ✓ Your current electricity company (i.e. TEPCO, Chubu Power, Touhoku Power, Kanden etc.)

- ✓ A gas company (i.e. Tokyo Gas, Toho Gas, Osaka Ga, etc.)
- ✓ A telecommunications company (i.e. NTT, SoftBank, KDDI etc.)
- ✓ An oil company (i.e. Showa Shell Oil, Nippon Oil, Cosmo Oil, etc.)
- ✓ A home appliance or electronics maker (i.e. Toshiba, Fujitsu, Sharp, Panasonic, etc.)
- ✓ An automobile maker (i.e. Toyota, Nissan, Honda, etc.)
- ✓ A steel or iron maker (i.e. Nippon Steel, JFE Steel, Kobe Steel works, Hitachi metals, etc.)
- ✓ A house maker (i.e. Sekisui House, Tama Home, Daiwa House etc.)
- ✓ A real estate company (i.e. Mitsubishi Estate, Mitsui Realty, etc.)
- ✓ A general trading company (i.e. Marubeni, Itochu, Mitsui & Co, etc.)
- ✓ A co-op（Seikyo）
- ✓ Environmental NPO/NGO etc. Public interest group.
- ✓ A State owned institution
- ✓ Local government organization (at the prefectural or village level) institution
- ✓ Another entity (please explain):
- ✓ I do not wish to purchase from any entity
- ✓ Not sure

Question (1)-6 With regard to 'Smart Cities', usage details such as air-conditioning, refrigeration and electric car usage patterns will be shared over an IT network to enable sectors of, or the whole city to optimize and achieve greater electricity consumption efficiency. In this case, which entity do you think is best suited to collecting, managing and operating such a system based on people's household data? (You may grade from 1-5, 1-3 is compulsory).

- ✓ Your current electricity company (i.e. TEPCO, Chubu Power, Touhoku Power, Kanden etc.)
- ✓ A gas company (i.e. Tokyo Gas, Toho Gas, Osaka Ga, etc.)
- ✓ A security company (i.e. Sougo Security, Secom, Central Security etc.)
- ✓ A financial institute (i.e. Mizuho Bank, Mitsui Sumitomo Bank, Orix Bank, Seven Bank etc.)
- ✓ A telecommunications company (i.e. NTT, SoftBank, KDDI etc.)
- ✓ An oil company (i.e. Showa Shell Oil, Nippon Oil, Cosmo Oil, etc.)
- ✓ A home appliance or electronics maker (i.e. Toshiba, Fujitsu, Sharp, Panasonic, etc.)
- ✓ An automobile maker (i.e. Toyota, Nissan, Honda, etc.)
- ✓ A steel or iron maker (i.e. Nippon Steel, JFE Steel, Kobe Steel works, Hitachi metals, etc.)
- ✓ A house maker (i.e. Sekisui House, Tama Home, Daiwa House etc.)
- ✓ A real estate company (i.e. Mitsubishi Estate, Mitsui Realty, etc.)
- ✓ A general trading company (i.e. Marubeni, Itochu, Mitsui & Co, etc.)
- ✓ A co-op（Seikyo）
- ✓ A local community organisation
- ✓ Environmental NPO/NGO etc. Public interest group.
- ✓ A State owned institution
- ✓ Local government organization (at the prefectural or village level) institution

- ✓ Another entity (please explain):
- ✓ I think no entity is suitable
- ✓ Not sure

Question (2) What do you believe is the desirable basic social infrastructure which will engender the best kind of future energy system? (You may grade from 1-5, 1-3 is compulsory).

- ✓ The least amount of blackouts, and if there are to be any blackouts, a return of power at the earliest possible time (stable electricity supply)
- ✓ No fires or explosions, and the maintenance of the safe operation of all electrical infrastructure such as power stations and transmission lines (Safe and stable electrical infrastructure)
- ✓ The smallest possible CO_2 emissions (greenhouse gases) and air pollutants at the electricity generation stage (reduced burden on the environment from electricity generation)
- ✓ The status quo, or, electricity available for use at the lowest possible cost (reduction of electricity prices)
- ✓ Use of local resources for electricity generation, and consumption at the local level, to increase the electricity self-sufficiency of the local area (local production and consumption of electricity)
- ✓ Increase the employment associated with the electrical system, and by doing so increase the local economy through local profits and benefits (supporting the local economy)
- ✓ Through exports to foreign markets, and international sales, increase

businesses which generate profit through new innovation (supporting industrial profit opportunity)

- ✓ Instead of nuclear power, use more fossil fuels such as oil and coal (review of the power supply configuration)
- ✓ Instead of using fossil fuels such as oil and coal, use additional nuclear energy generation (review of the power supply configuration)
- ✓ Instead of using fossil fuels such as oil and coal, use natural (renewable) sources of energy such as solar and wind(review of the power supply configuration)
- ✓ Other (please explain):
- ✓ It does not matter the makeup of the system, I do not think that one is better than the other.
- ✓ Not sure

Question (3)-1 With regard to State or local government devised 'smart cities', do you have intent to participate or cooperate either through the giving up of your own time, or through the investment of your private funds? (one answer)

- ✓ I do
- ✓ I do not
- ✓ I don't know

Question (3)-2 Moving forward, it is reasonable to expect that the region in which you live, or it's organizations will seek to implement a local energy system so that your city or local area provides and retails electricity. In other words, a system in which you will generate and consume electricity yourself. If this became a reality, would you be willing to contribute to the establishment of such a system through giving up your own time, or investing your own private funds or through other active means? (one answer)

- ✓ I do
- ✓ I do not
- ✓ I don't know

Figure Captions

Figure 1: Energy transition in Japan (a) Total primary energy; (b) Electricity generation; (c) Solar power [11]

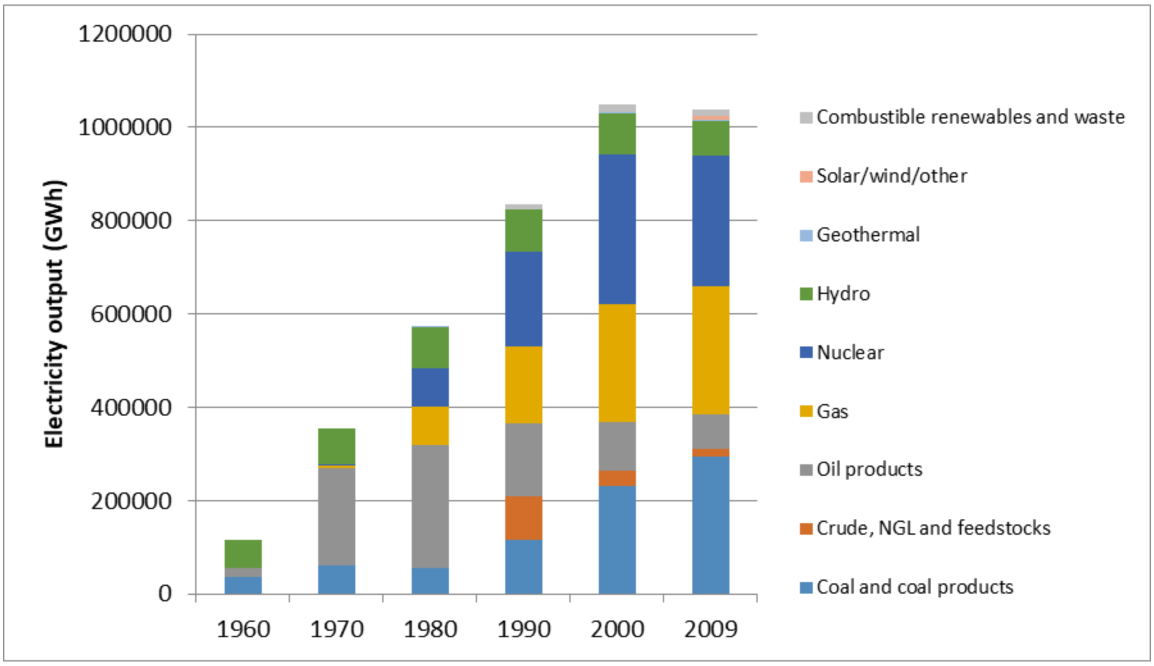

Figure 2: Multi-level perspective and transitions [Source: Geels and Schot, 2007]

Figure 3: The four phases of transition (after Kemp and Loorbach [48])

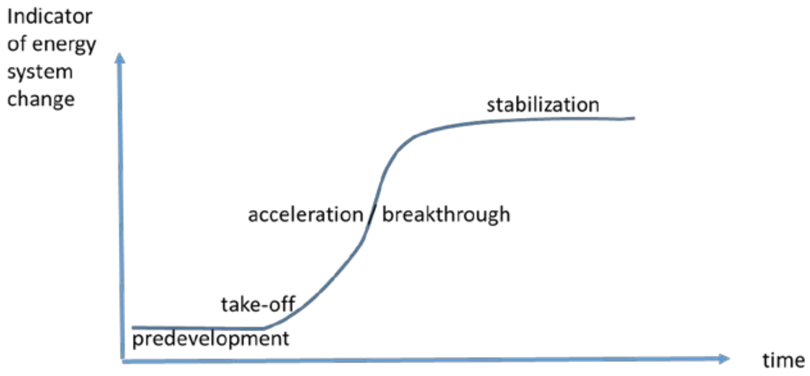

Figure 4: Transition pathways represented by an S-Curve (adapted from [49])

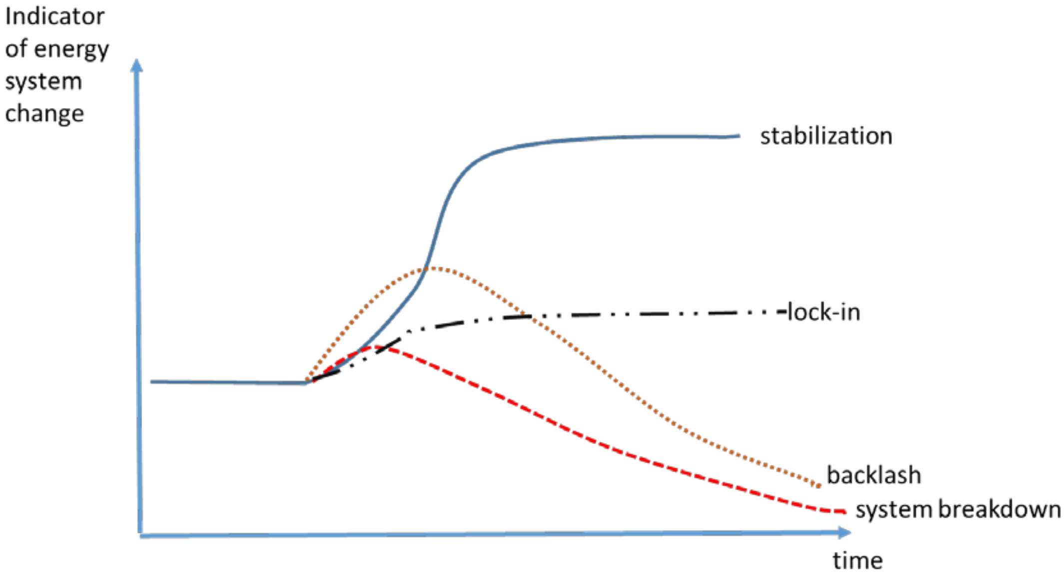

Figure 5: Quadrants for selection and classification of survey sites

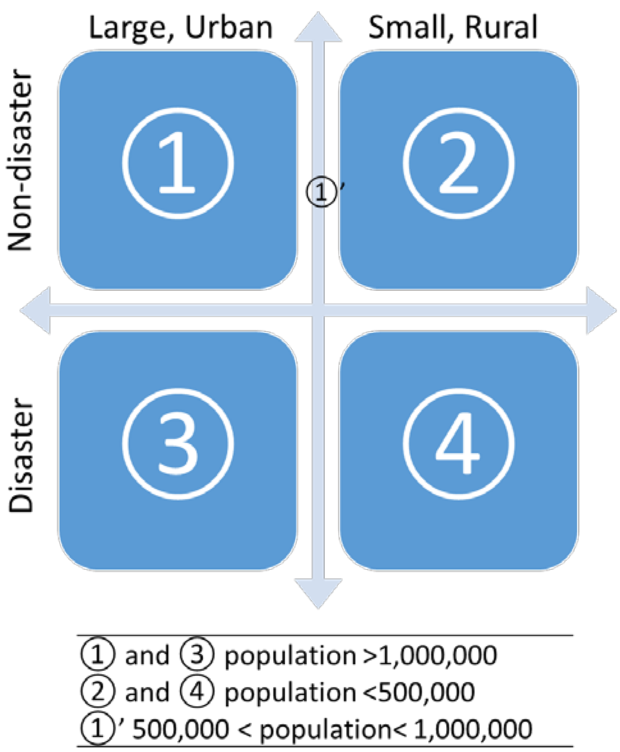

Figure 6: Energy breakdown by cost and estimated energy content

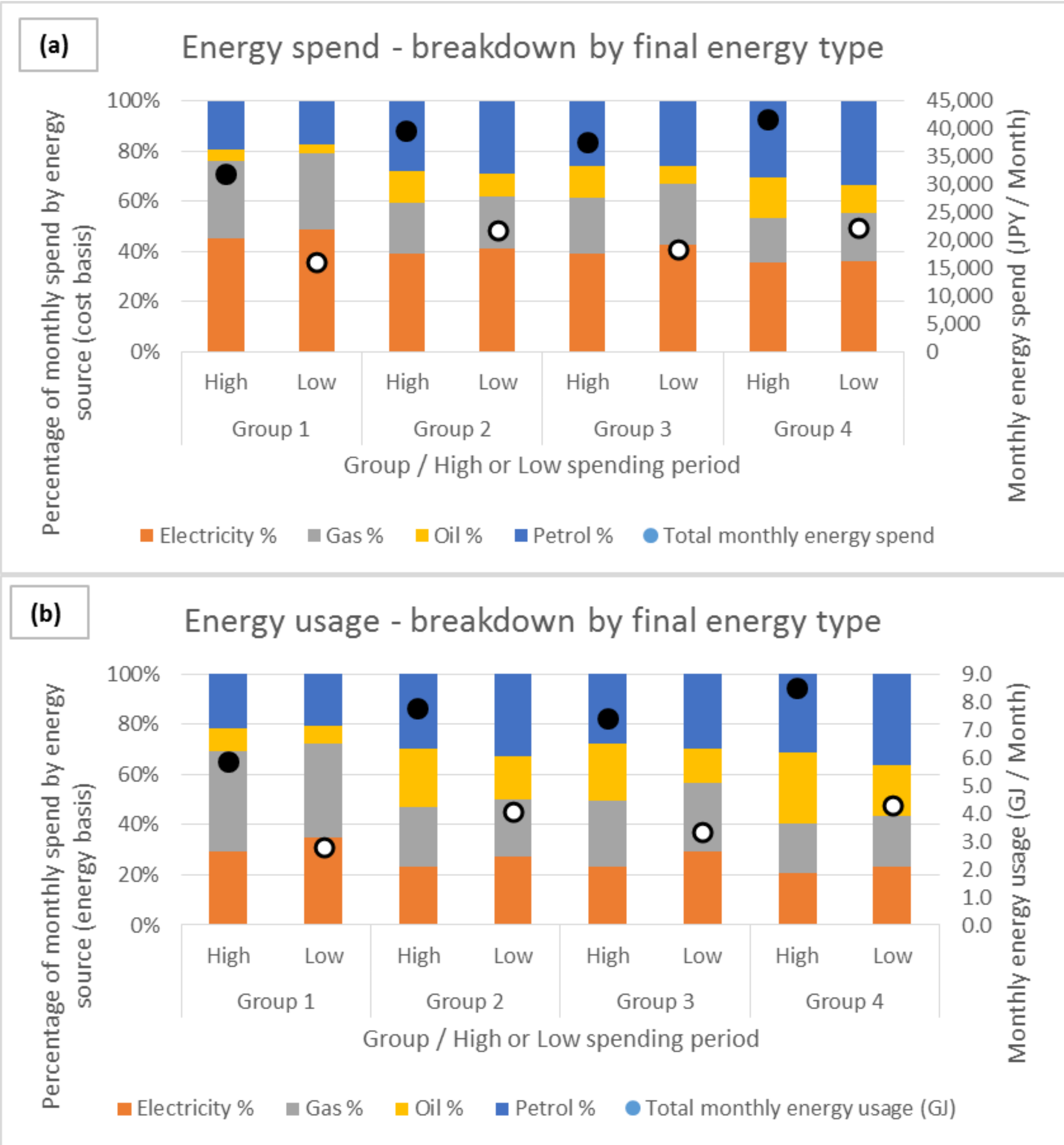

Figure 7: Respondents in each group who had considered these energy-related activities in the wake of the Great East Japan Earthquake

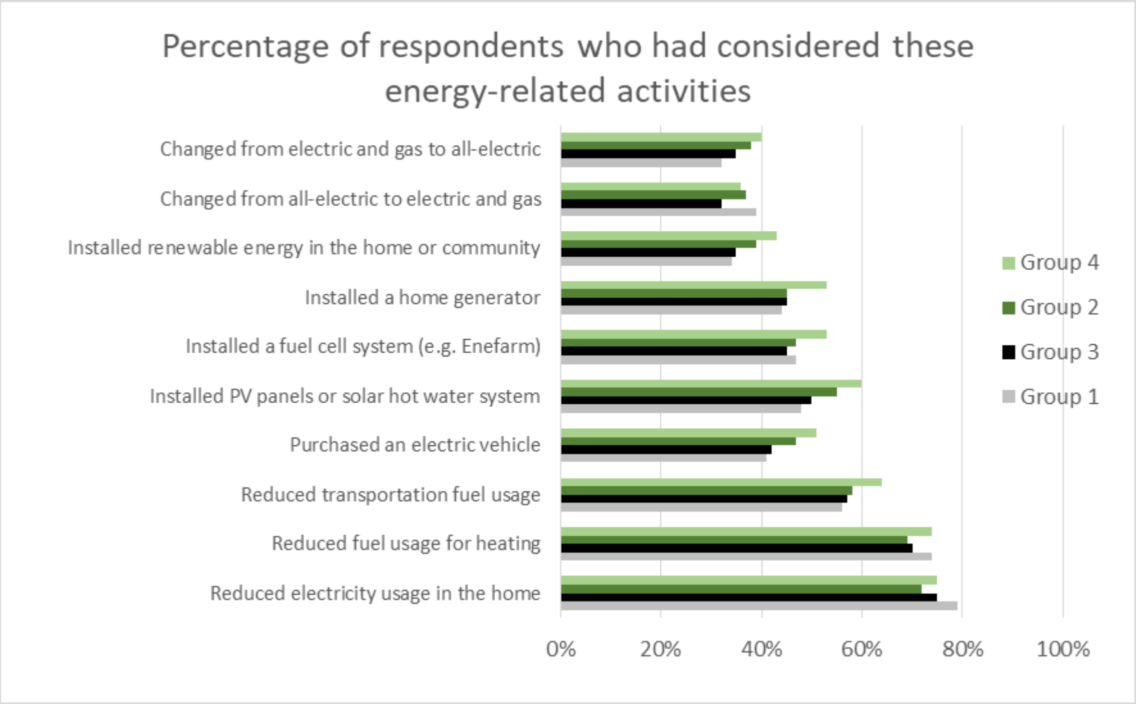

Figure 8: Percentage of those who considered these activities who achieved them

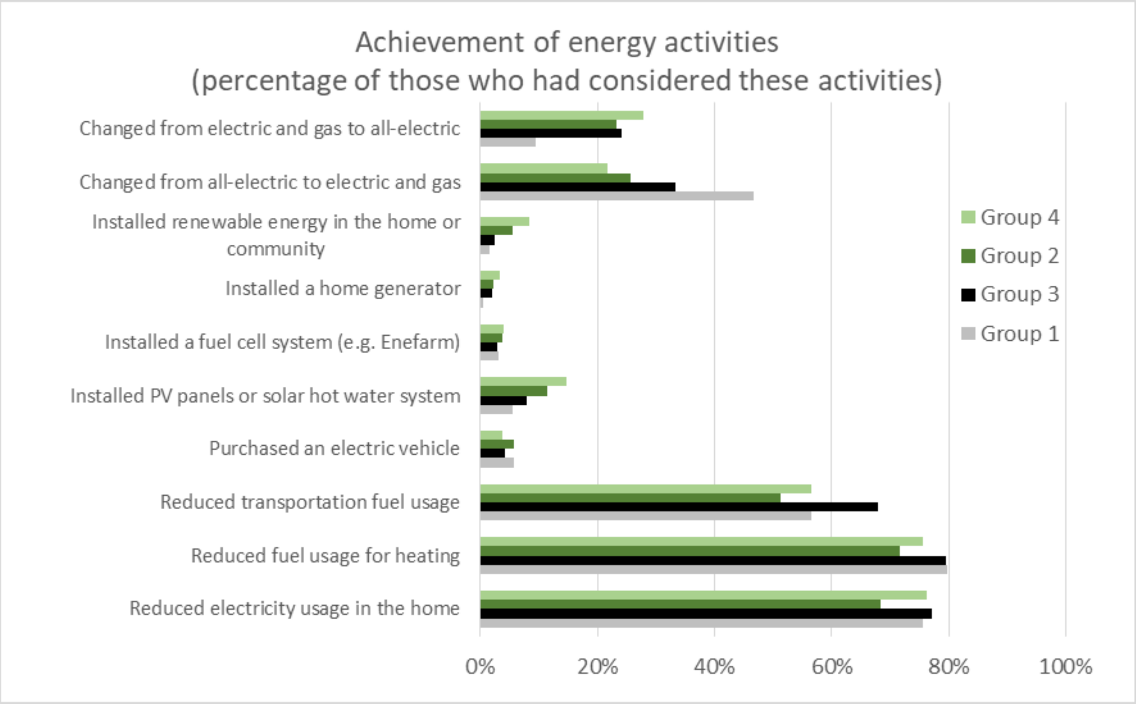

Figure 9: Willingness to undertake activities to reduce greenhouse gas emissions

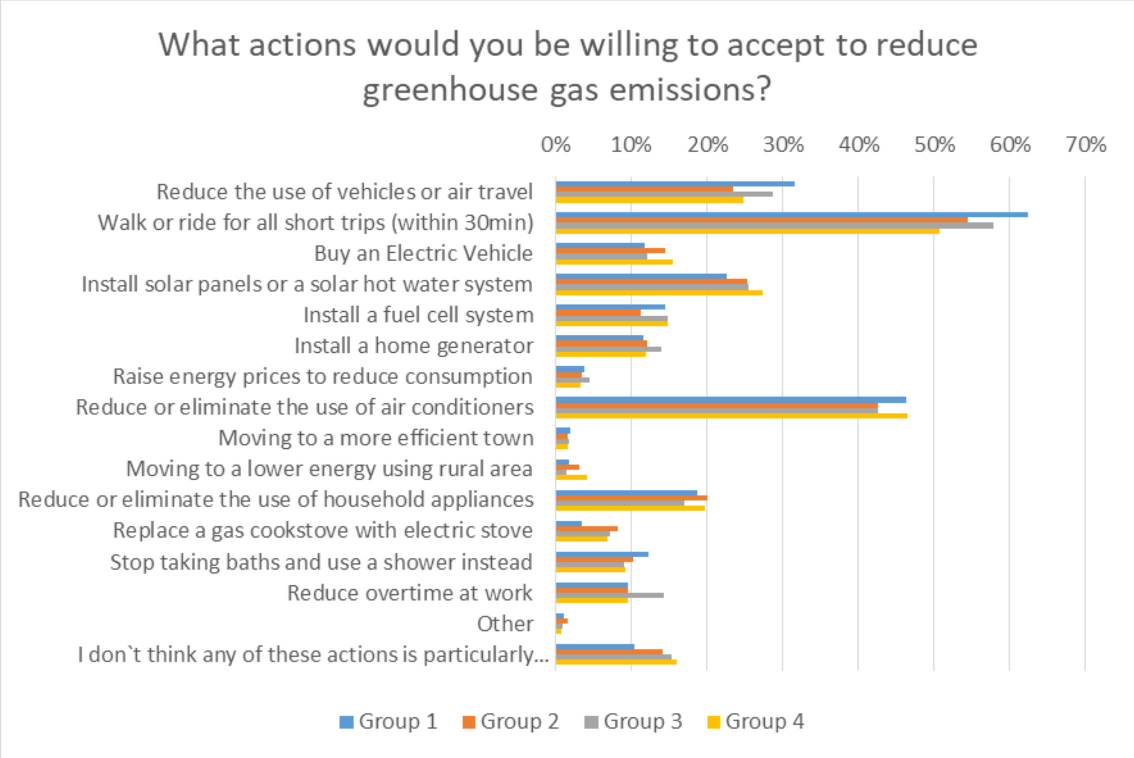

Figure 10: Preference of entity most suited to realizing local interests

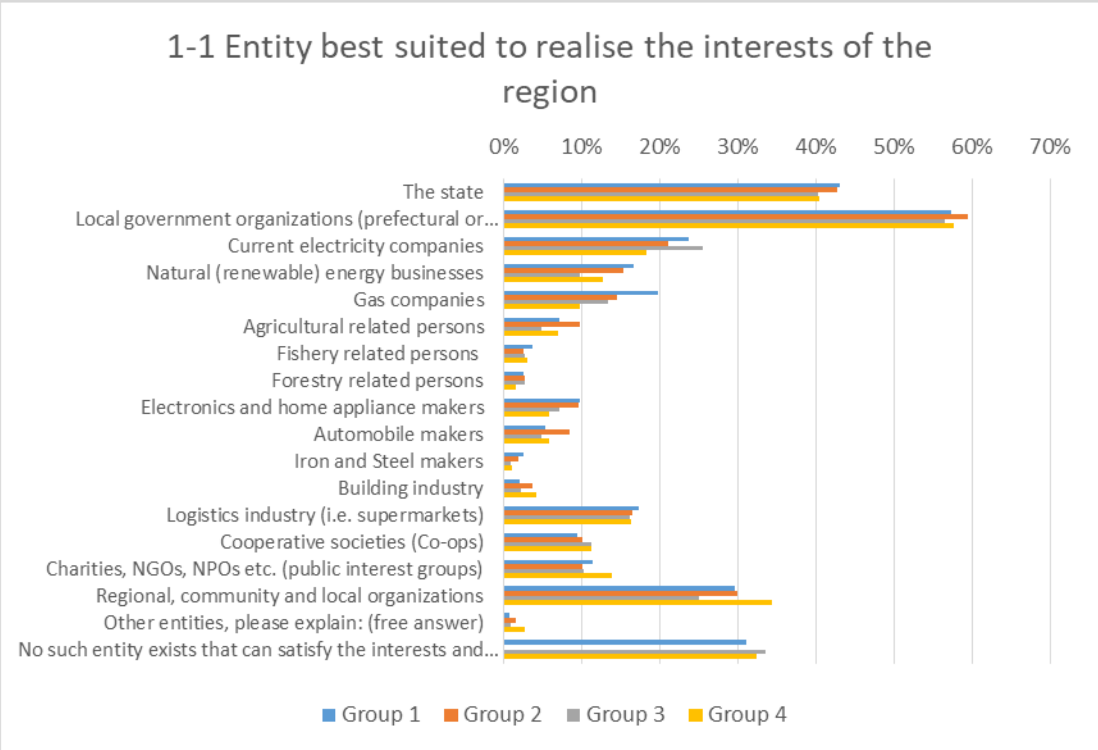

Figure 11: Preference of entity to implement energy policy changes

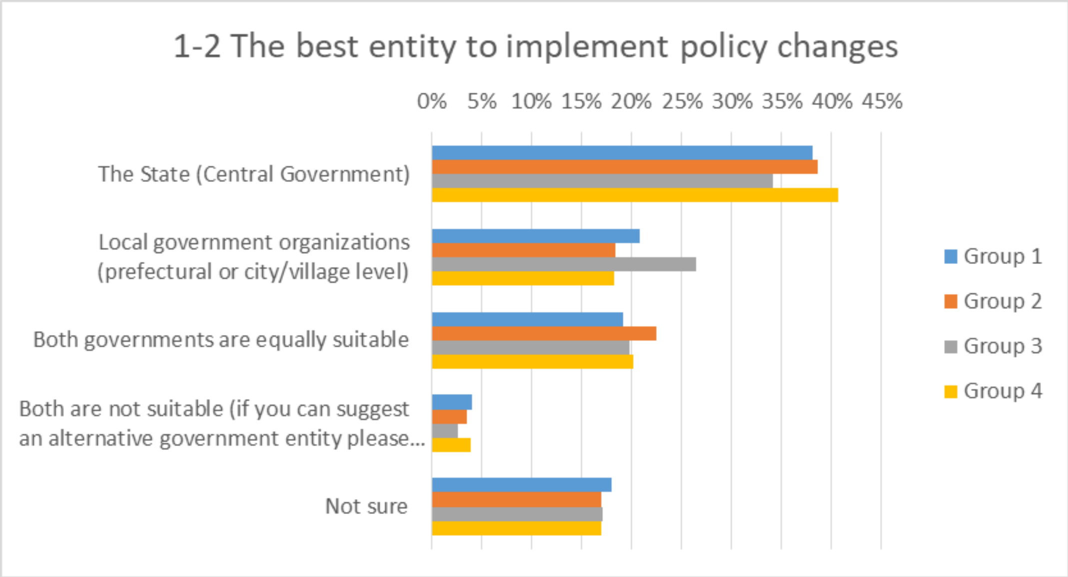

Figure 12: Which entity should lead in reducing energy consumption to avoid blackouts

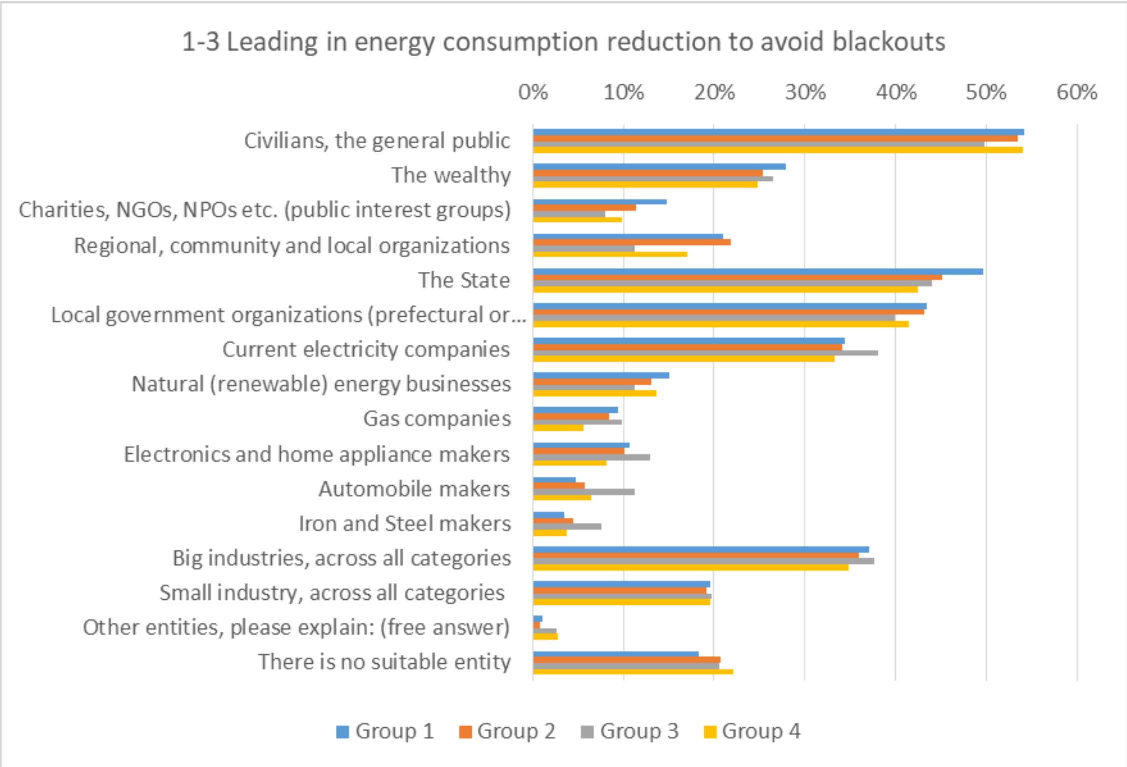

Figure 13: Which entity should lead in reducing greenhouse gas emissions

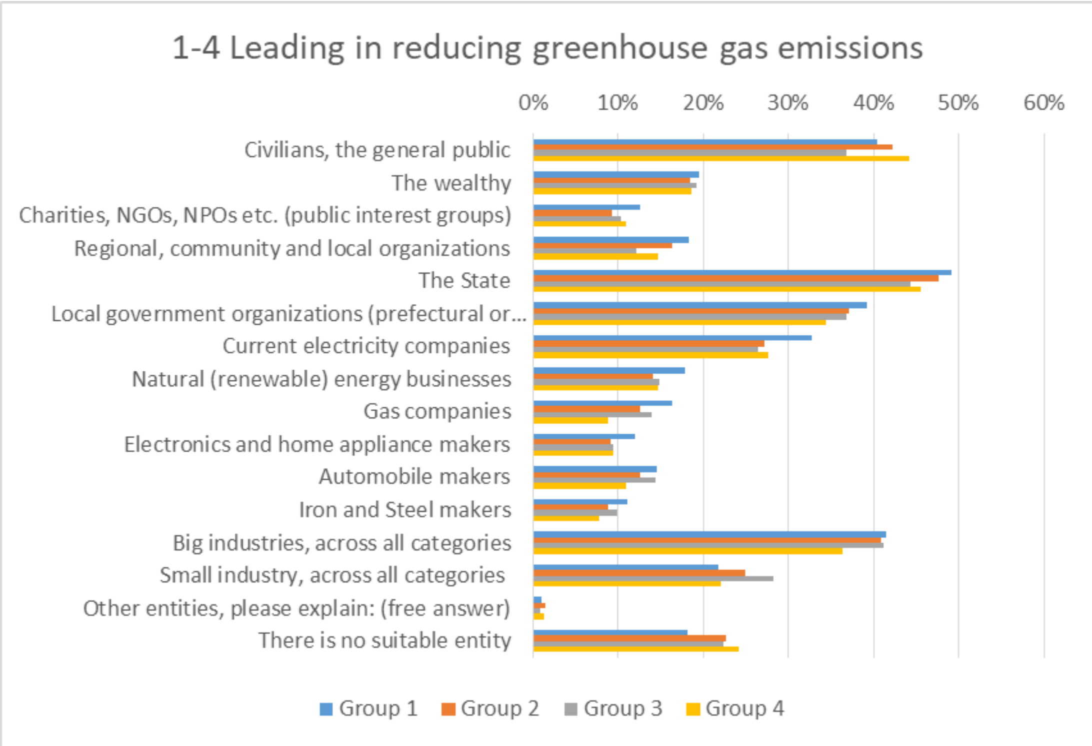

Figure 14: Preferences for electricity suppliers under liberalization of the market

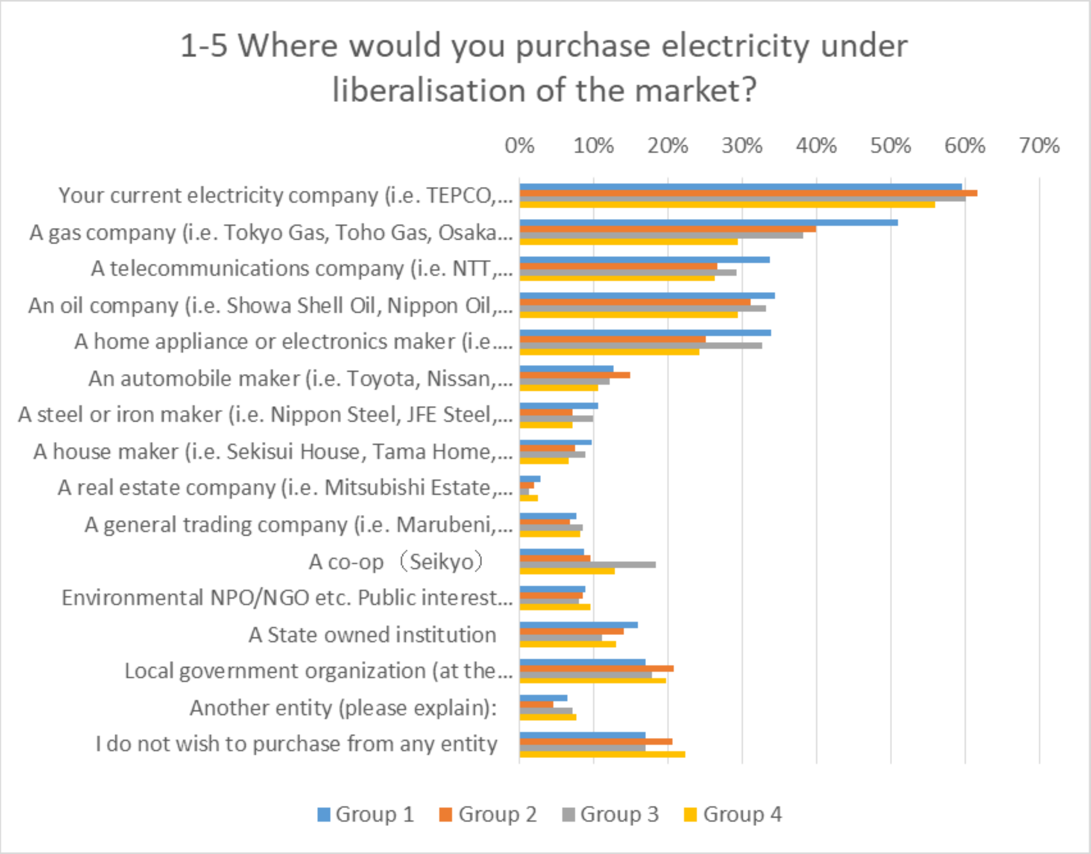

Figure 15: Preferred entity to manage and utilize consumers' data

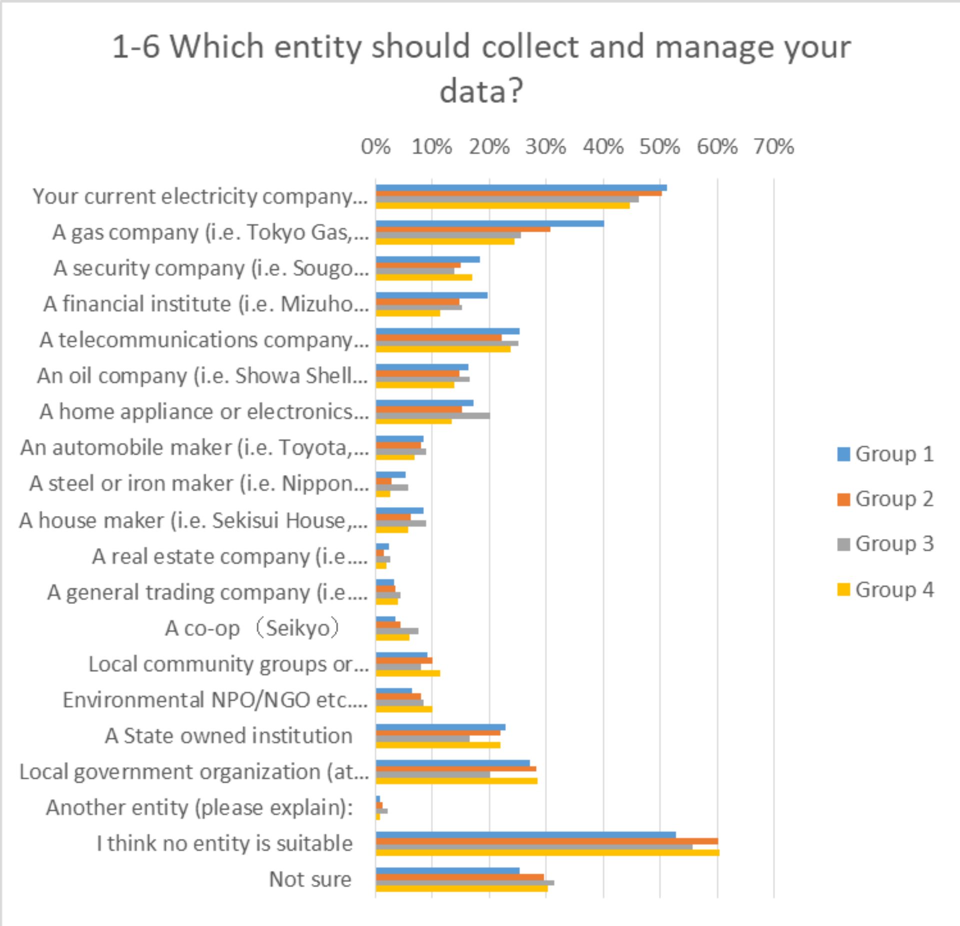

Figure 16: Characteristics of a desirable future energy system

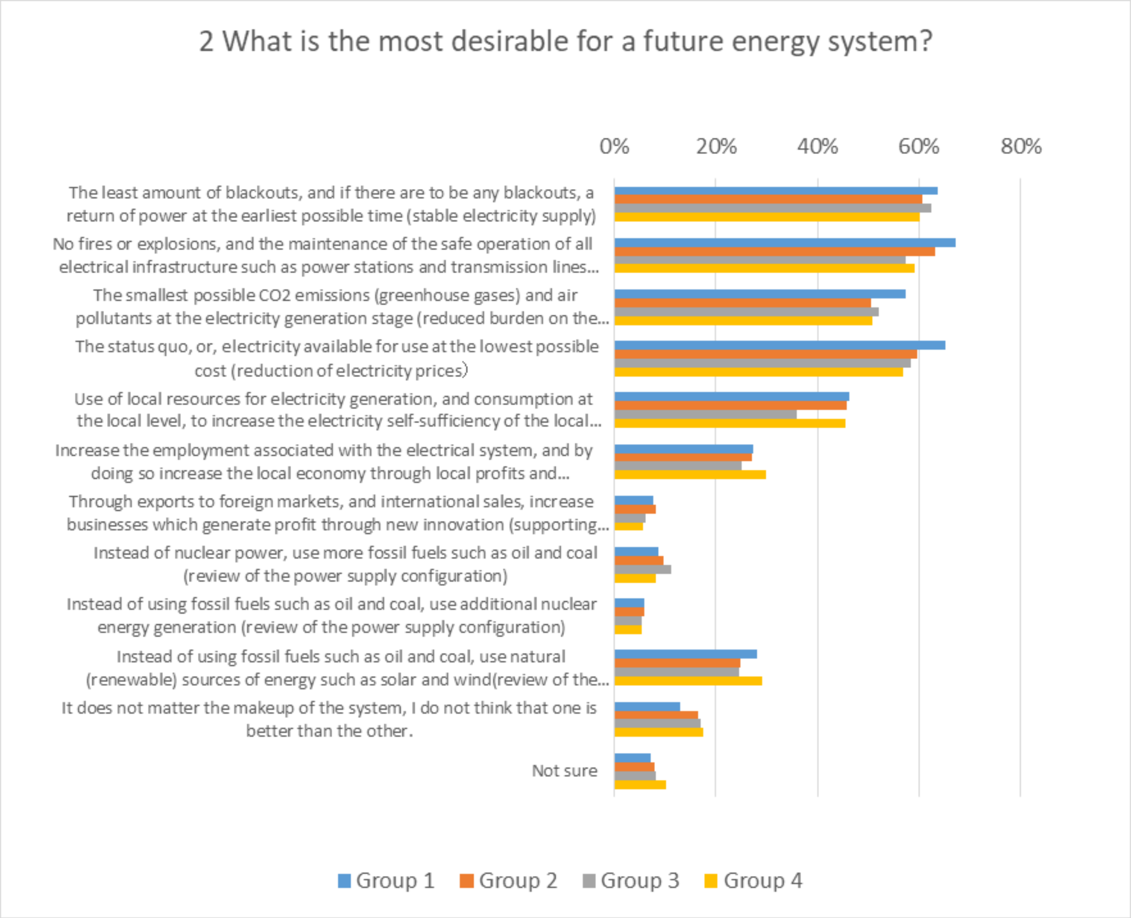

Figure 17: Willingness to participate in a government-derived smart city

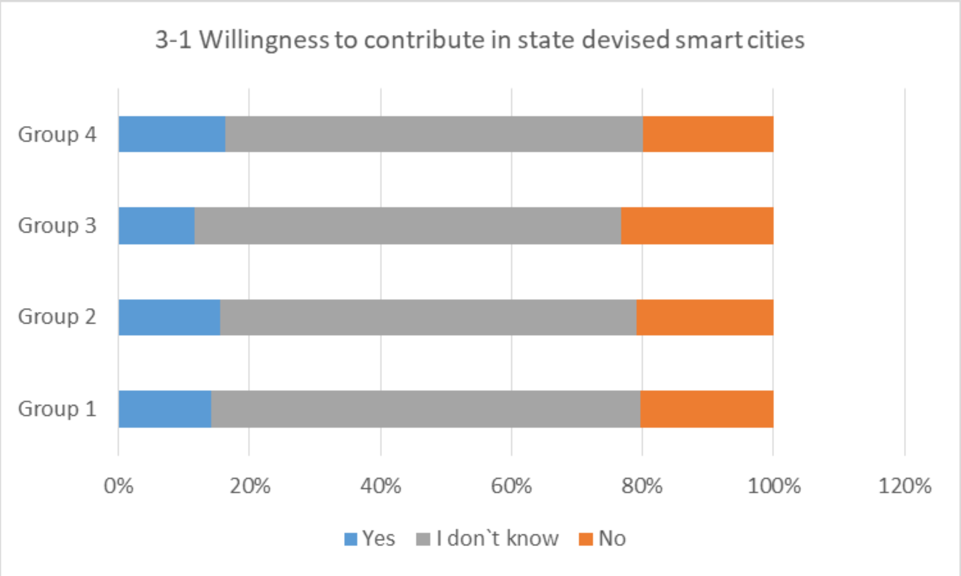

Figure 18: Willingness to contribute to setting-up a local energy system