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Energy transition to a future low-carbon energy society in Japan's liberalizing electricity market: Precedents, policies and factors of successful transition

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ABSTRACT

This paper investigates the precedents, policies and factors relevant to a successful energy regime transition which may be applied in the Japanese case, through a review of national leaders in renewable energy deployment. The examples of Germany, Italy and Spain are of particular note for their progress along the transition pathway toward a low carbon energy regime. Transition theory is used as a framework to enable this assessment, and exogenous impacts specific to Japan such as recent and ongoing market liberalization and the Fukushima nuclear incident are considered as pertinent factors which impact upon the transition landscape. Through a comparative assessment of policy approaches, technologies deployed, and social factors impacting upon deployment, lessons are drawn for comparison with current Japanese transition progress, identifying factors critical to the future estimation of the Japanese transition pathway. Future energy transition pathway projections will need to incorporate policy approaches and mechanisms as well as being cognizant of Japan's geographic and cost-competitive RE resource deployment limitations. These limitations alongside existing generation assets (including nuclear energy) are expected to have a significant impact upon Japan's transition from the current pre-development phase toward take-off, acceleration and the stabilization of a new, low-carbon energy regime.

1. Introduction: transition theory and its relevance to Japan in a liberalizing electricity market

Japan is heavily reliant on foreign fuel imports to meet its energy demands, and faces the risk of supply instability based on cost, availability and other geo-political factors. To ameliorate this risk, Japan has undertaken reform of its long-term energy policy in order to incorporate a higher portion of domestically sourced energy [1]. The Fukushima incident reinforced the need for such a transition to a stronger domestic supply of energy, and additionally to source low-carbon generation options in the absence of nuclear-based generation. Additionally, some 5 years after the Fukushima incident, liberalization of the energy market was begun when the market was opened up to competition from 1 April 2016. The ten regional retailers now face competition with start-ups and small competitors, who may attract customers through pricing and energy source based incentives. The next phase of deregulation occurred in the gas industry in April 2017. Finally, the transmission, distribution and generation of electricity in Japan will be 'unbundled' in 2020. There are three key stages in the change of Japan's energy market which may have an impact on future energy transitions to low carbon energy generation alternatives as shown in Fig. 1.

Along with the liberalization of its energy market, Japan also released the 4th Strategic Energy Plan in 2014 which outlines four major issues to be addressed from a structural viewpoint:

1. Vulnerability of the energy supply system due to dependency on overseas resources.
2. Population decrease and technological innovation changes to energy demand structure.
3. Instability of resource prices due to exogenous factors.
4. Increase in global greenhouse gases (GHGs).

In order to address these issues, energy policies are described beginning with a diversified energy supply and demand structure, re-affirmation of the 3E+S policy (Energy security, Environmental conservation, Economic growth & Safety), and a consideration of energy sources, potential deployment timeframes, the development of a system which promotes efficient energy supply through the use of smart metering [2], and the final energy mix. The disruptive nature of

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Fig. 1. Stages of Japanese energy market liberalization.

the Fukushima incident upon the energy supply structure (notably the minimization of nuclear inputs) and the need to reconsider previous ambitious targets (up to 70% zero-emission power) for transition to low carbon fuels by 2030 is expressed early on in the plan [1].

With regard to transition theory, Verbong and Geels describe a multi-level perspective of energy transitions [3]. According to this perspective, the three levels or dimensions in an electricity system are 1) Material and technical elements – resources, grid infrastructure, generation assets etc., 2) Actors and social group networks – utilities, government bodies, industrial and household users, and 3) Rules (formal, normative and cognitive) which guide the activities of actors within the system – regulations, principles, behavior, beliefs etc. By understanding these three dimensions an assessment of the nature of factors which affect, hinder or influence a transition can be made.

In addition to these described dimensions, at the micro-level, niches are formed in order to shield and develop new technologies outside of the market. Transition occurs when these technologies break through, replacing the current regime, however in systems such as the Japanese (or any) electricity system, the sunk investments (i.e. costs which have already been incurred and are unable to be recovered) and high barriers to entry make this breakthrough and transition less likely without additional support or willingness in terms of investment or subsidization etc. [3]. Complete transition is defined by Fouquet as the shift from a 5% market share to 80%, or the peak attainable by a certain technology [4]. In the case of a transition to low carbon generation technology in Japan, this is unlikely to be achieved by any one source of generation, due to the high number of alternative generation technologies available for selection. This glut of options is also cited as a reason for delay in uptake [4]. The proposed intermediate structure of supply and demand for Japan includes a total of 22–24% of electricity generation from renewables by 2030 according to the Long-term Energy Supply and Demand Outlook [5]. Under these target parameters and without significant additional intervention by 2030, the renewable energy (RE) regime alone is unlikely to replace the current fossil fuel backed regime.

In terms of the time required for a transition to occur, academics broadly agree that at least a 30–50-year timeframe is required [4,6–8]. While this figure is considered reasonable for post industrial revolution transitions, there is some evidence that governed energy transitions, particularly in a post-globalization world in which international climate change agreements are being made, that this timeframe could be reduced [6,9]. This is largely because the majority of post-industrial revolution transitions were not planned or governed, and are described as emergent processes (an exception in Japan was the planned, pre-Fukushima incident transition to a greater than 40% share of electricity from nuclear sources [10]). With governments acting more proactively to create conditions which engender transition to a low carbon future, the coming energy transition may be considerably shorter than those experienced in the past. Additionally, global cooperation adds to the momentum building behind such transitions around the globe [6].

An assessment of the development of renewables in the global energy market since 1990 shows an approximate doubling, at a growth rate of approximately 3% per annum. When compared to the transitions to coal (> 5% per annum 1850–1870), oil (8% per annum 1880–1900), and natural gas (6% per annum market share growth 1920–1940), the growth rate is lethargic and, since 1990, 25 times more energy supply derived from fossil fuels has been added than from renewable sources [11]. These numbers suggest that there is considerable untapped potential for RE supply growth towards a transition to a low-carbon energy system in Japan, given sufficient political will [6].

The overall aim of this study is to identify the factors relevant to Japan's energy transition to a low-carbon society based on transition theory, historical precedent and current Japanese energy policies and political environment. This study focusses on the transition of the power sector, with some linkages to the transport sector through electrification of transport systems using battery electric vehicles and fuel cell electric vehicles and the residential, commercial and industrial sectors through electrification of heat supply using heat pump technology and increasing use of information and communication technology including smart metering and smart city approaches [12].

2. Dimensions and potential pathways for the energy transition in Japan

Considering the theoretical transition framework detailed by Verbong and Geels [3], components of the three transition dimensions can be defined, specific to the Japanese electricity system, as summarized in Table 1.

In addition to the components of the transitional nested hierarchy, an understanding of the 'ideal paths' that transitions may follow can provide information useful for determining the critical factors and likely timing of a potential energy transition for Japan. Fig. 2 describes potential transition pathways relevant to an energy system transition as initially defined in [13].

Based on the potential pathways presented it is reasoned that Japan, and indeed the world are likely following the transformation or reconfiguration pathway, whereby niche innovations, particularly wind and solar PV are reaching varying levels of maturity, and are gradually being incorporated into the electricity system in response to climate change, or the achievement of agreed energy goals.

Previous energy transitions were driven largely by innovation, an increase in energy use, and in order to enable a complete transition, cost [4,15]. In Japan, although innovation is high, current energy prices are relatively low. RE or conversion of existing fossil fuel

Table 1
Japan's transition dimensions.

Dimension	Components
Material and technical elements	Resources, electrical grid (50/60 Hz), fossil and RE generation assets.
Actors and social group networks	Utilities (Electric, Gas, Transmission and Distribution), Ministry of Economy, Trade and Industry (METI), Organization for Cross-regional Coordination of Transmission Operators (OCCTO) and other government bodies, industrial and household users.
Rules	Tariff settings, regulations, culture, principles, behavior, beliefs (opinions about nuclear, RE etc.).