ARTICLE IN PRESS

Energy Policy xx (xxxx) xxxx–xxxx

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Comparing electricity transitions: A historical analysis of nuclear, wind and solar power in Germany and Japan

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ARTICLE INFO

Keywords:
Germany
Japan
Renewable electricity
Nuclear power
Energy transitions

ABSTRACT

This paper contributes to understanding national variations in using low-carbon electricity sources by comparing the evolution of nuclear, wind and solar power in Germany and Japan. It develops and applies a framework for analyzing low-carbon electricity transitions based on interplay of techno-economic, political and socio-technical processes. We explain why in the 1970s–1980s, the energy paths of the two countries were remarkably similar, but since the 1990s Germany has become a leader in renewables while phasing out nuclear energy, whereas Japan has deployed less renewables while becoming a leader in nuclear power. We link these differences to the faster growth of electricity demand and energy insecurity in Japan, the easier diffusion of onshore wind power technology and the weakening of the nuclear power regime induced by stagnation and competition from coal and renewables in Germany. We show how these changes involve the interplay of five distinct mechanisms which may also play a role in other energy transitions.

1. Introduction

Though internationally comparative analyses of energy transitions remain rare (Geels et al., 2016), they are necessary for understanding variation in the use of low-carbon electricity across countries (Lipp, 2007; Schneider et al., 2011), which in turn is important for governing energy transitions required to mitigate climate change (GEA, 2012). Since contemporary energy transitions are driven by political goals, approaches for their analysis should come not only from economic and technology history (Fouquet, 2010; Kander et al., 2013) but also from political economy.

Political economy of energy dates back to the 1970s and 1980s when scholars sought to answer why nations responded differently to the oil shocks (Hughes and Lipscy, 2013; Keohane, 1984). In a seminal piece from that era, Ikenberry (1986) pointed out that in the 1960s-1980s Germany and Japan pursued a similar energy policy of ‘competitive accelerated adjustment’: they expanded nuclear power, restructured industries, and promoted efficiency to counteract insecurities of oil supplies. However, in the 1990s, their energy paths diverged. While Germany expanded wind and solar and is phasing out nuclear power, Japan deployed much smaller amounts of renewables but became a world leader in nuclear power.[1] The classic theories do not explain these diverging energy paths and should be revisited to better account for contemporary energy transitions (Hancock and Vivoda, 2014; Hughes and Lipscy, 2013).

The divergence of Germany's and Japan's energy paths is more than a theoretical problem. In recent years, there have been numerous calls on Japan (and other countries) to learn from Germany's energy policies (Hake et al., 2015; Huenteler et al., 2012; Lovins, 2014; Nature News, 2013). Yet, such calls only make sense if we understand the reasons for the original divergence. In this paper we compare and explain the difference in the use of nuclear, solar and wind power in Germany and Japan in order to contribute to a theory and policy of sustainable energy transitions.

The starting point for our analysis is the same as it was for Ikenberry: analyzing '*the way in which … problems were defined*

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[1] In 2014, Germany produced more than 20% of its electricity from non-hydro renewables and was within the top five countries in terms of installed solar PV, wind and biomass-based capacity as well as investment in renewable power and fuels (REN21, 2015). In parallel, Germany plans to phase-out nuclear power by 2022; and has reduced the share of nuclear in its electricity mix from 28% in 2002 to 16% in 2012. In contrast, in 2010 Japan operated the third largest nuclear fleet in the world but produced less than 2% of its electricity from new renewables.

http://dx.doi.org/10.1016/j.enpol.2016.10.044
Received 24 November 2015; Received in revised form 3 May 2016; Accepted 30 October 2016
Available online xxxx

and … the policy responses perceived as possible' (1986, 105). However, we do not assume that the two countries faced the same problems. Such an assumption was valid in the 1970s when the risk of oil embargoes and price volatility was *the* energy problem that all industrial countries tried to solve (Katzenstein, 1977). We show that since the 1980s the challenge of secure electricity supply has become increasingly different for Germany and Japan. We also show how the capacity of the two states to introduce (or discontinue) energy technologies was influenced by the dynamics of socio-technical regimes. Therefore, our analysis relies on three distinct fields of knowledge: political science, energy systems analysis, and socio-technical transition studies.

2. Existing theories and analytical framework

A comparative study of energy transition should start with justifying the case selection and the scope of analysis with respect to the technologies and time period covered. Though some existing studies (Hermwille, 2016; Huenteler et al., 2012; Strunz, 2014) focus only on post-Fukushima period when the German government declared *Energiewende* an official policy and Japan changed its nuclear plans, other literature (see Hake et al., 2015; Jacobsson and Lauber, 2006) points out that the changes in Germany can be traced back to the 1970s. We agree with the latter observation and thus compare transitions in both countries starting from 1970. However, such a long time period includes many entangled change processes presenting a methodological challenge.

To overcome this challenge, we use the 'comparable case – most similar system' study design (Przeworski and Teune, 1970) where the cases are different on a dependent variable and similar on as many explanatory variables as possible. Germany and Japan have advanced market economies, lack of domestic oil and gas reserves, and a similar history of post-war reconstruction. These overarching similarities make it easier to pinpoint differences that could explain variations in energy transitions. Further in line with this design, we compare the use of specific technologies – nuclear, wind and solar power[2] – between the two countries. This makes it possible to take the differences between *technologies* out of the equation and concentrate on the differences between *countries*.

2.1. Existing theories

While only a few papers (Feldhoff, 2014; Hermwille, 2016; Huenteler et al., 2012; Lovins, 2014) specifically compare Germany and Japan, more general literature offers many explanations of low-carbon energy transitions. A common starting point is that differences in transitions result from differences in national energy policies. For example, Lovins (2014) argues that Japan does not expand renewable electricity fast enough because '*its leaders* [...] *worship old policies that retard wide use of* [renewable] *energy sources*' (see Huenteler et al. (2012) for a similar view). Such arguments lead Jacobsson and Lauber (2006, p. 257) to ask: "*Why do … some countries choose policies which apparently are superior in terms of inducing transformation whereas other countries choose policies which work less well?*". This question invokes others: what do countries seek to achieve with their energy policies? Are countries free to choose their energy policies? Do energy policies reflect common national or special interests? Do energy policies always work as intended and if not, why? The remainder of this sub-section explains how the existing literature addresses these questions.

[2] We exclude other low-carbon electricity sources because these either did not change much (hydro power), followed comparable trajectories in both countries (waste and biomass), or have not been significant (geothermal power) (Figure SM-1).

2.1.1. Secure supply-demand balance and other state goals

An influential body of political science literature views *states*[3] as relatively autonomous actors that adopt policies in order to achieve their specific goals, such as internal order, external independence, or economic growth (Dryzek et al., 2002; Skocpol, 1979). One of the main energy policy goals is what Helm (2002) formulated as balancing demand with secure supply. Others pointed out that 'secure' often meant 'domestic' (Yergin, 1988). The history of state-backed nuclear power is a good illustration. For example, Nelson and Sprecher (2008) linked the use of nuclear power to lack of domestic coal reserves, and Fuhrmann (2012) and Gourley and Stulberg (2013) – to energy import dependence, while Jewell (2011) observed that periods of rapid electricity demand growth preceded the launch of national nuclear power programs.

Ikenberry (1986) described how both Germany and Japan sought to reduce their dependence on oil imports. More recently, governments of both countries used projections of demand growth and targets of energy self-sufficiency in formulating their energy strategies: Germany's 2010 *Energiekonzept* (Knaut et al., 2016) and Japan's 2010 Basic Energy Plan (BEP) (Duffield and Woodall, 2011). Germany, with its large coal reserves, has been less concerned about importing fuels for electricity generation. In contrast, Japan always connected energy self-sufficiency with national security (Atsumi, 2007), something that Calder (2008) called Japan's "energy angst". Suzuki (2014) and Price (1990) linked these energy security concerns to the fast development of nuclear power in Japan and Feldhoff (2014) further explained this development by the isolation of Japan's electric grid (in contrast to Germany which can trade electricity with its neighbors). These theories explain faster expansion of nuclear power in Japan in the 1990s, but not why nuclear power was growing similarly fast in both countries in the 1970s–1980s or why Germany initiated a nuclear phase-out in the early 2000s. More importantly, they do not explain why it was the coal-rich Germany[4] and not the coal-poor Japan that more actively developed domestic renewables?

States can, of course, act on concerns other than energy security. For example, Joas et al. (2016) identify 14 diverse goals of *Energiewende* supported by German political elites and dominated by climate change mitigation, a goal also frequently mentioned by other authors (Duffield and Woodall, 2011; IRENA, 2015a; Jacobsson and Lauber, 2006; Lauber and Mez, 2004). The climate imperative cannot explain the difference between Germany and Japan. Although climate-related arguments have been used in both countries to support nuclear power, renewables or both, there is no evidence that commitment to climate mitigation has been higher in either country[5] and, more importantly, climate concerns cannot explain the policy focus on either nuclear or renewables as both are low-carbon options. There are also no obvious reasons why other state goals (employment, economic growth, technology leadership etc.) would differ between Germany and Japan.

2.1.2. Vested interests

Energy policies may be shaped not only by autonomous goals of the state but also by special interests of particular social groups (Hall, 1993). For example, pro-nuclear interests may have promoted nuclear power and suppressed renewables in Japan (Huenteler et al., 2012; Kingston, 2013; Valentine and Sovacool, 2009). In contrast, a pro-

[3] In this paper we refer to 'the state' as state bureaucracy rather than 'a nation' (which includes all citizens).

[4] According to Laird and Stefes (2009), the difference in fossil fuel endowments cannot explain faster deployment of renewables in Germany compared to the US. Keller (2010) disagreed with this argument.

[5] According to Pew Research Center (2009, 2015), in 2009 65% of Japanese considered global warming as a very serious problem and 64% were prepared to protect the environment even if it slows growth and costs jobs, whereas in Germany the relevant numbers were 60% and 77%. In 2015, 42% of Japanese and 34% of Germans considered global climate change as a very serious threat.