Energy Policy 46 (2012) 135–143

Contents lists available at SciVerse ScienceDirect

Energy Policy

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

Japan's energy security predicament post-Fukushima

Vlado Vivoda*

Griffith Asia Institute, Griffith University, N50, Room 1.33, Nathan, QLD 4111, Australia

ARTICLE INFO

Article history:
Received 21 October 2011
Accepted 16 March 2012
Available online 17 April 2012

Keywords:
Japan
Energy security
Fukushima

ABSTRACT

If energy security is defined as the availability of energy at all times in various forms, in sufficient quantities and at affordable prices, without unacceptable or irreversible impact on the economy and the environment, Japan is facing an energy security predicament. For a country that was already uneasy about energy security, the March 11, 2011 earthquake and tsunami, which caused a nuclear catastrophe in TEPCO's Fukushima Daiichi nuclear power plant, turned this unease into outright anxiety. With the temporary and/or permanent closure of many nuclear reactors Japan has had to replace lost power. Tokyo has had no choice but to secure additional fossil fuels, a strategy that has negatively affected Japan's economy due to rising fuel costs. The increase in Japan's fossil fuel consumption has also caused a significant increase in greenhouse gas emissions, and affected Tokyo's commitment to Kyoto targets. This paper analyzes the consequences of the 2011 nuclear disaster for Japan's energy security. Recognizing that Japan's future energy policy choices are constrained and path dependent, the paper outlines energy policy recommendations for Japan's government.

© 2012 Elsevier Ltd. All rights reserved.

1. Introduction

Japan is the world's fifth largest energy consumer, and a resource-poor country, which imports close to all of its fossil fuel requirements. Large demand for energy and high import dependence has made energy security as one of the priorities of any government in Tokyo, particularly since the two oil crises in the 1970s. The 1973 and 1979 oil crises caused the Japanese economy to record negative growth rates for the first time in its post-war history. Their impact on the lives of ordinary Japanese remains deeply etched on people's minds. As a result, the Japanese government adopted policies aimed at improving energy efficiency and reducing the demand for oil. These policies have resulted in unprecedented success. Consequently, Japan is now the most energy-efficient country in the world (The Economist, 2011). In addition, Japan's oil demand dropped from 5.4 million barrels per day (bpd) in 1979 to 4.4 million bpd in 2010, due to vehicle efficiency gains and conversion to other electricity sources. The share of oil in total energy consumption has declined from about 72% in 1979 to 40% in 2010 (BP, 2011).

Today after three decades, energy security is once again at the center of attention among Japanese policy-makers and the general public. However, unlike in the 1970s, when the focus was on affordability and security of oil supplies, the current challenge is multidimensional. While the renewed interest in energy security issues was triggered by record oil prices in 2008, it was brought to the forefront of public debate in the aftermath of March 11, 2011 (hitherto referred to as 3/11) earthquake and tsunami, which caused a nuclear catastrophe in TEPCO's Fukushima Daiichi nuclear power plant. Such was the extent of the shock caused by the events on 3/11 on Japan's economy, the existing energy system and energy security, that in 2011 Japan recorded its first trade deficit (¥2.5 trillion) since the aftermath of the oil crisis in 1980. This trade deficit was mainly caused by a jump of 25.2% (¥4.3 trillion) in fossil fuel imports, which in 2011 made up close to one-third of Japan's import spending (World Nuclear News, 2012).

Consequently, largely absent since the two oil crises in the 1970s, the energy security debate in Japan has been revived in the aftermath of the 3/11 disaster. Some analysts have suggested that Japan should move away from nuclear energy citing safety concerns in an earthquake prone country which lies on several fault lines. For example, the Japanese government has claimed it is scrapping plans to build as many as 14 new nuclear reactors over the next two decades. It is worth recalling that the government-stated plans were to increase nuclear's share of total electricity generation from 24% in 2008 to 40–50% by 2030, according to the Ministry of Economy, Trade and Industry (METI) (Ferguson, 2011). The former Prime Minister (PM) Naoto Kan announced that the government would have to "start from scratch" in devising a new energy policy for the country. He has announced a major energy policy review that would promote solar and other alternative energies, stating that Japan should increase the share of renewable energy in power generation to

* Tel.: +61 7 373 54251.
E-mail address: v.vivoda@griffith.edu.au

0301-4215/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.enpol.2012.03.044

20% by the early 2020s (Johnston, 2011). In September 2011, the new PM Yoshihiko Noda, confirmed previous PM's decision, and decided to review energy policy with a mind to possibly reducing future dependence on nuclear power.

Building on previous studies of Japan's energy security policy and other relevant literature this paper evaluates Japan's current energy security situation and places future energy policy options in the appropriate context. As such, the paper contributes to the literature on Japan's energy security and policy. While acknowledging the polysemic nature of the concept (Chester, 2010), the paper adopts UNDP's (2004) definition of energy security as the availability of energy at all times in various forms, in sufficient quantities and at affordable prices, without unacceptable or irreversible impact on the economy and the environment. When this conceptualization is applied in the present Japanese context, the analyses indicate that Japan is facing an energy security predicament. The country's energy policy has to address challenges related to the future availability of diverse energy sources, increasing cost of fuels, and adverse impact of its energy and power demand trajectory on the economy and the environment. Japan is the key case not only because of pressure on the existing energy system caused by 3/11 but it is also a resource-poor country, which has an established track record of reacting to energy crises in the 1970s.

Numerous studies focus on Japan's energy policy. Some studies focus broadly on Japan's energy security (Atsumi, 2007; Evans, 2006; Hideaki, 2000; Nakatani, 2004; Toichi, 2006; Yokobori, 2005). Other studies focus on single issue-areas such as overseas oil development policy (Koike, 2006; Koike et al., 2008), energy diversification (Lesbirel, 2004); oil import diversification (Vivoda and Manicom, 2011), public perception of energy security (Valentine et al., 2011), the role of nuclear power in energy security (Suzuki, 2000; Lidsky and Miller, 2002; Medlock and Hartley, 2004), nuclear politics (Lesbirel, 2003), electricity and petroleum industry regulatory reform (Hartley, 2000; Oyama, 2000; Asano,2005; Hosoe, 2006) and improved energy efficiency (Morita, 2010; Stewart, 2009).

While relevant in their own way, previous work overlooks the social, political and economic context within which Japan's energy choices are embedded. In addition, the existing literature pre-dates 3/11. Duffield and Woodall (2011) have analyzed Japan's 2010 Basic Energy Plan (BEP) and argued that even prior to 3/11, achievement of many targets was likely to be challenging. This is exacerbated in the aftermath of 3/11. In many ways, the scale of the Fukushima disaster is the equivalent of 9/11 in the energy sector, and previous energy security thinking needs to be reassessed in lieu of a changed environment. Consequently, Section 2 analyzes the consequences of 3/11 on Japan's economy and energy security. While recognizing the significance of 3/11, Japan's energy future is path dependent. It is embedded in a specific political, economic and social context, constrained by Japan's existing energy system, but also affected by changes in the global energy system. Therefore, Section 3 examines historical energy demand trends in Japan and globally in order to illustrate that substantial changes in proportions of energy use from various sources take decades. Section 4 highlights the three main sources of path dependency, which affect and/or constrain Japan's future energy policy choices. The final section discusses the feasibility of various energy policy options for Japan.

2. Consequences of 3/11 for Japan's energy security

After 3/11, when considering relative cost, feasibility of increased production and availability of fuels, it comes as no surprise that Japan increased consumption of fossil fuels to make up for the lost nuclear power. With atomic stations providing close to 30% of Japan's electricity before the Fukushima disaster, utilities have been forced to rely more on oil- and gas-fired power plants to make up the difference. The increased use of thermal plants to make up for the loss of nuclear output caused higher fuel import costs, borne by Japanese consumers and industries, and leading to a first trade deficit since 1980. This trade deficit was mainly caused by an increase of 25.2% (¥4.3 trillion) in the value of fossil fuel imports (The Japan Times, 2012). With Fukushima and other nuclear plants offline, the value of Japan's imports of LNG, crude oil and petroleum products increased by 37.5%, 21.3% and 39.5%, respectively (IEEJ, 2012). This increase in import cost occurred in a year in which the overall energy consumption dropped by 3.7%. LNG prices have also risen as Japan buys more, with spot prices reaching $15 per million British thermal units (Btu) in January 2012, up over 40% from before 3/11. Regional suppliers, such as Australia, are already reaping the benefits of Japan's increased demand for coal and LNG (Wallace, 2011).

All of Japan's power utilities reported a net loss for the April–December 2011 period, due to higher fuel costs for thermal power generation (Inajima, 2012). According to Medlock and Hartley (2004), in the event of a 25% shock to oil price, the pre-Fukushima nuclear capacity in Japan reduced electricity prices by 6.55%. As a consequence of a nuclear shutdown and increased cost of energy imports, corporate customers in and around Tokyo will pay up to 18% more for their electricity beginning April 2012 (Soble, 2012). In 2012, a regular household's electricity bill is predicted to increase by ¥1,049, or 18%, and the rate for industrial consumers by 36% per month on average due to rise in fuel costs (IEEJ, 2011). Residential and industrial electricity prices are already considerably higher in Japan than in most G-20 economies (IEA, 2011). The economic burden associated with these higher electricity costs is increasing for Japan as the competitiveness of other countries is enhanced due to deregulation of their electricity sectors.

If Japan's nuclear reactions do not resume operations in 2012, there will be severe consequences for the Japanese economy. Under such a scenario, Japanese demand for thermal coal is expected to increase by 8.3% (Tsukimori, 2012), and Japan will need to boost its crude oil and petroleum products consumption by 4.7% and LNG consumption by 6.9% (IEEJ, 2012). The IEEJ (2012) predict that the cost of fossil fuel imports will increase by ¥4.6 trillion (US$61 billion), resulting in GDP growth of only 0.1%. They also estimate that the electricity supply deficit could amount to 12.2% during the summer peak demand season, severely hampering industrial production (only 1.6% growth over 2011). Another study found that Japan's GDP would decrease by 1% if nuclear-based power generation is at 20% below pre-3/11 levels, with very little effect of substituting fossil fuels for nuclear. Moreover, the deeper the cut in nuclear use for power generation, the larger the negative impact on GDP (Itakura, 2011). Alternatively, if nuclear power plants restart by mid-2012, the IEEJ predict that Japan's economy and industry will not suffer from the electricity shortage. Under such a scenario, the cost of Japan's fossil fuel imports will increase by ¥2.6 trillion (US$35 billion), resulting in GDP growth of 1.9%. Industrial production is expected to increase by 5.0% (IEEJ, 2012).

The challenge associated with Japan's increased demand for imported fossil fuels is exacerbated by the fact that major economies in the Asia-Pacific region are competing for supplies of fossil fuels, and particularly oil. The Asia-Pacific region's energy demand, especially China's and India's, has grown rapidly over the past two decades and most projections suggest their voracious thirst for energy will further expand in the coming decades (Vivoda, 2010). In the past decade, Japan has been competing with China, India and South Korea to secure long-term oil supply contracts with suppliers in the Middle East and other regions,

often failing to outbid Chinese national oil companies who are backed by deep pockets of their home government. What further limits the security of Japan's oil imports is Tokyo's close security alliance with the US, which constrains Japan's relations with oil exporters that are at odds with the US. In 2010, Japanese oil company Inpex, which was to be a major developer of Iran's Azadegan oil field, abandoned its stake in the project facing the prospect of being denied access to US financial institutions. In January 2012, Washington applied pressure on Tokyo to reduce dependency on Iranian oil and natural gas. This would be a further blow to Japan's already low diversified oil import portfolio (Vivoda and Manicom, 2011). In 2011, Iranian crude oil made up 10% of Japan's oil imports. PM Yoshihiko Noda's government has indicated its desire to cooperate (Smith, 2012). Yet, cutting Iranian imports carries risks for Japan as the country's reliance on imported energy has increased since the 3/11 disaster.

There are also severe consequences for Japan's environmental policy following a reduction in nuclear output. Japan's CO_2 emissions increased by 2.1% in 2011, and if nuclear reactors remain shut down in 2012, CO_2 emissions are expected to grow by further 5.5%. If there are no restrictions on resuming operations in Japan's nuclear reactors, a 5.3% drop in CO_2 emissions is predicted for 2012 (IEEJ, 2012). Before 3/11, nuclear power reduced Japan's CO_2 emissions by 14% per year (EIA, 2011; Nakano, 2011). Increased emissions make it virtually impossible for Japan to reach the Kyoto Protocol 2020 target of reducing CO_2 emissions by 25% of 1990 levels. Japanese leaders have been frank in dismissing any hopes of meeting Japan's climate change targets (World Nuclear News, 2012). It is worth noting that Tokyo has been a world leader in pushing for greater use of very low carbon emission sources.

If we are to define energy security as the availability of energy at all times in various forms, in sufficient quantities and at affordable prices, without unacceptable or irreversible impact on the economy and the environment (UNDP, 2004), Japan is facing a serious predicament and a dilemma regarding the direction of its future energy policy. As a consequence of 3/11, the Japanese people are paying more for energy, the supply of which is less secure. Moreover, the higher cost of the energy mix, which is heavier on the fossil fuel side, has an adverse effect on both the economy and the environment. Consequently, the nuclear crisis poses a serious challenge to the nation's economy and its energy security in terms of affordability, supply security, and the environment.

3. Energy transitions

The global energy system is in the early stages of a transition from carbon intensive fossil fuels to a variety of substitutes, bringing economic, strategic, and environmental risks. Scholarship on energy transitions suggests that these transitions have been both gradual and complex. As Grübler (1991) notes, "Along its growth trajectory, an innovation interacts with existing techniques … and changes its technological, economic, and social characteristics…. Decades are required for the diffusion of significant innovation, and even longer time spans are needed to develop infrastructures." Smil (2008) makes the point even more concisely: Energy transitions "are prolonged affairs that take decades to accomplish and the greater the scale of prevailing uses and conversions the longer the substitutions will take." Coal had been in use for thousands of years, but it was not until growing urbanization led to a shortage of wood that the use of coal became more commonplace. Similarly, oil derivatives were used in lamps throughout the nineteenth century, decades before they became the world's dominant source of energy.

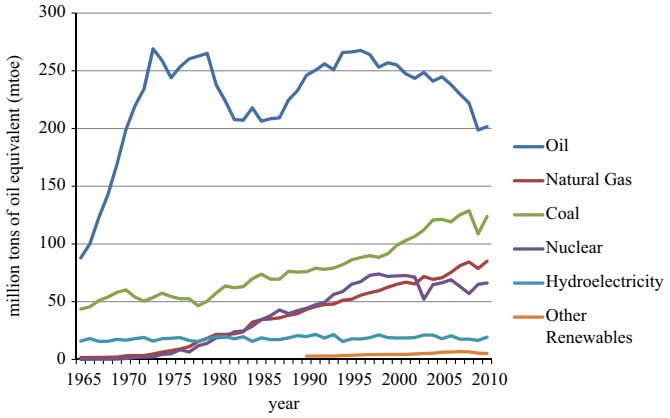

Fig. 1. Japan's energy demand structure, 1965–2010.
Source: BP, 2011) (Note: "Other Renewables" from 1990).

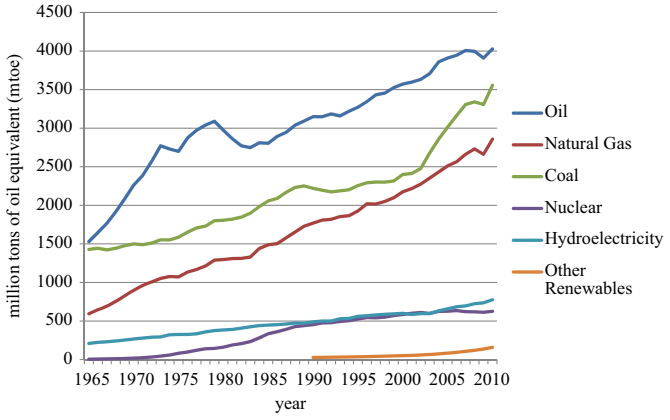

Fig. 2. Global energy demand structure, 1965–2010.
Source: BP, 2011) (Note: "Other Renewables" from 1990).

An examination of historical energy demand trends in Japan (Fig. 1) and globally (Fig. 2) reveals that substantial changes in proportions of energy use from various sources take decades. Having said this, the discovery of superior sources of energy has sometimes resulted in a relatively rapid transition to a new energy source, as in the case of coal and oil. Occasional supply shocks, such as the 1970s oil crises, only marginally affect the historical pattern, with return to pre-shock shares within two decades. Currently, fossil fuels make up 87% of global and 82% of Japan's energy demand, with no serious competitors on the horizon.

Japan is the world's largest importer of liquefied natural gas (LNG) and coal and the third-largest importer of oil. As Japan is heavily dependent on energy imports, the government has been promoting nuclear energy as a means to diversify its energy sources. Re-evaluation of energy policy in the aftermath of the 1973 oil crisis resulted in diversification and, in particular, a major nuclear construction program. A high priority was given to reducing the country's dependence on oil imports and more broadly curbing oil demand. Consequently, with improvements in energy efficiency and substituting natural gas and nuclear power for oil in electricity generation, Japan's oil demand dropped significantly by the mid-1980s, only to return to pre-crises levels by the mid-1990s. The Japanese government has treated nuclear power as a semi-indigenous form of energy supply. As a country with virtually no natural resources, it perceived nuclear power as a central pillar in reducing dependence on imported oil and enhancing energy security (Lesbirel, 2003). Since the 1980s,

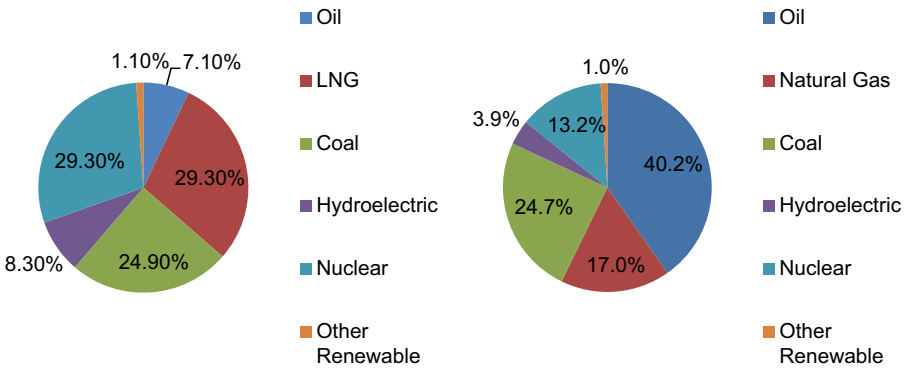

Fig. 3. Japan's electricity demand (left) and primary energy demand (right) by source.
Sources: The Federation of Electric Power Companies of Japan, 2011; BP, 2011).

nuclear energy has been an integral part of Japan's energy supply system (Fig. 1). As illustrated in Fig. 3, it provides close to 30% of electricity and 13% of primary energy supply (BP, 2011); World Nuclear Association, 2011a).

The realities of energy transitions and the particularities of Japan's energy system hinder any *quick* move away from fossil fuels. Japan has reduced its nuclear power output and this reduction is likely to remain for the foreseeable future. In January 2012, only 3 out of 54 of Japan's commercial nuclear reactors have been operating. Japan will lose its last nuclear- generated power in April at the current rate of shutting down reactors for safety checks (Bloomberg, 2012). Although many of these reactors might restart once the government and regulators reassure the public that operation can safely recommence, the only viable short to medium term alternative to nuclear power is fossil fuels. There is, in fact, nothing on the energy horizon in Japan to displace fossil fuels (Smil, 2010).

In addition, short of a major technological breakthrough, which makes renewable energy competitive with other energy sources on a large scale, it will take decades before renewable energy becomes competitive with fossil fuels in electricity generation and transportation sectors. A glance at past energy consumption trends (Fig. 2) indicates that, with the exception of hydroelectric power, renewable energy is a newcomer. Other renewable energy sources are negligent as sources of energy in the current global energy system. The same applies for Japan, where they start from a very small base (see Fig. 1; Fig. 3). In Japan, they account for only 1% of both electricity and primary energy supply. While the share of renewable energy in global terms and Japan's energy mix will grow, this will happen at a very slow pace due to relative higher costs and other structural impediments (discussed below) that inhibit a fast uptake of renewables.

4. Path dependence

Path dependence can be referred to as the constraints on the choice set in the present that are derived from historical experiences. Understanding the process of change entails confronting the nature of path dependence in order to determine the nature of the limits of change that it imposes in various settings (North, 1990). A movement away from the present pattern of energy use is constrained by a combination of three sources of path dependency: *beliefs and perceptions*; *institutions and organizations*; and *relative prices and structural constraints*. These constraints make energy transitions slow. At the same time, a significant disruption to any of these sources of path dependency comes at an enormous cost to energy and economic security. In Japan's case, one such major disruption has been the 3/11 disaster. This event has shaken the foundations of Japan's energy system and has affected its path dependency.

4.1. Beliefs and perceptions

There is a strong commitment in Japan that a move from nuclear power toward other sources of energy is desired, both in terms of public opinion and government policy. While public opposition to nuclear energy is not a new phenomenon, the change of government policy is. Driven by high dependency on imported fossil fuels and negative impact of the two oil crises, the government has been committed to nuclear power as a preferable energy source because it is domestically produced, and thereby more secure. As outlined in Japan's New National Energy Strategy of 2006, the aim has been to increase the share of nuclear from approximately 30% to up to 50% by 2030 (ANRE, 2006).

At the same time, the Japanese public has been opposed to nuclear power since a series of nuclear accidents in the 1990s, and the public has also been opposed to Japan's ambitious nuclear expansion policy (Fesharaki and Hosoe, 2011). The 3/11 nuclear disaster, although most severe, has not been the only nuclear accident in Japan. In fact, several reactor accidents occurred during the 1990s (documented in Beder, 2003; World Nuclear Association, 2011a), the most serious of which was the 1999 accident in Tokaimura, which killed two workers. These accidents have contributed greatly to negative public confidence in government and corporate nuclear oversight. The share of Japanese people feeling "very uneasy" about nuclear power grew from 21% before the 1999 Tokaimura accident to 52% afterward. In an October 1999 Japan Public Opinion Company survey, only 11% supported government plans to increase the share of nuclear power, 51% favored maintenance of current plans, while another 33% wanted to see a reduction in, or end to, nuclear power. Given a choice, the public preferred non-nuclear options (solar/wind generation 62%, conservation 55%, compared to 20% for nuclear power). In a survey released in March 2000 by the Japan Productivity Center for Socio-Economic Development (JPC-SED), 64% of energy experts surveyed expressed strong concerns about the risk to energy security posed by limitations to securing sites for nuclear power plants; and 49% about risks posed by large accidents at nuclear power facilities (JPC-SED(Japan Productivity Center for Socio-Economic Development), Energy and Environmental Policy Section, Special Committee of Energy Issues, 2000; Kotler and Hillman, 2000). This survey data shows that both the public and the experts did not accept the government's argument that nuclear power is safe well before 3/11.

However, after 3/11, this opposition has become even more pronounced. In the *Asahi Shimbun* poll in June 2011, 74% of

Japanese respondents favored a gradual phase-out of nuclear energy and only 14% were against such a gradual reduction. The poll also showed 64% of respondents believed "natural energy", such as wind and solar power, would replace nuclear power in the future (The Australian, 2011). Over the months since the accident there have also been several public protests against nuclear power. Mirroring public opinion, in early July 2011, former PM Kan has urged a nuclear-free future for Japan, stating that the country should aim to develop alternative energy sources such as solar, wind and biomass (BBC News, 2011). More recently, the new PM Noda backpedaled from such a strong commitment to nuclear-free future, yet suggested reduction in future dependence on nuclear power. Nevertheless, this is a significant policy shift and a clear indication that the Japanese government and key policy-makers are starting to judge the future of nuclear energy in Japan dispassionately, rather than primarily on supply security grounds.

4.2. Institutions and organizations

Institutions are commonly defined as the rules of the game, or the humanly devised constraints that structure human interaction. They are made up of formal constraints (such as rules, laws, constitutions), informal constraints (such as norms of behavior, conventions, self-imposed codes of conduct), and their enforcement characteristics. Organizations comprise a group of individuals bound by some common purpose to achieve objectives. Organizations include political bodies (political parties, regulatory agencies), economic bodies (firms, trade unions), social bodies and educational bodies (North, 1990). Japanese energy policy and its future direction are embedded in the country's institutional and organizational structure, with the METI as the energy policy-making hub, the nuclear industry, and the utility monopolies at the center. This energy policy-making structure has remained remarkably stable for almost four decades (Moe, 2012). However, as argued above, post-3/11 societal pressure to move away from nuclear power has translated into a significant force for change.

Traditionally, energy policy has been the purview of METI, which has close ties to the business community. Among METI's chief private-sector allies are the 10 regional utility monopolies. These utilities monopolize control over Japan's major electricity-usage regions and collectively produce more than 85% of Japan's electricity. Given their regional monopoly status, these utilities charge much higher electricity prices than those in the US and Europe (Hosoe, 2006). Nuclear energy generation differs with each of the ten utilities in Japan, but ranges between 21% and 45% (EIA, 2011). Except for Okinawa Electric Power Company, all of the utilities own and manage nuclear power plants and prefer a marginal role for renewables (Scalise, 2012). Nuclear power is one of their preferred sources in the energy mix as it is relatively cheap.

Consequently, they are unlikely to simply give in to societal pressure to move away from nuclear power. These deep-pocketed monopolies and industrial energy users have cultivated salubrious ties with influential politicians through generous campaign contributions (Duffield and Woodall, 2011). Their size, de facto monopoly position, control over pricing data, and privately owned assets put them at an advantage to comparable companies in most other industrial democracies (Scalise, 2012). Lobbyists from large power utilities have in the past opposed more ambitious renewable energy goals. They have substantial influence at the local and national governmental levels (Ferguson, 2011). Given the relative cost of nuclear power, any future plan to downsize or eliminate nuclear energy is certain to face considerable opposition from the utilities.

Japan's nuclear regulators are also not independent of industry influence. In the aftermath of 3/11, the government largely left the response up to the plant's operator, TEPCO, which demonstrates a cozy relationship between government and the utilities. TEPCO, the largest of the regional monopolies, supplies over one-third of Japan's electricity (The Federation of Electric Power Companies of Japan, 2011). Some of Japan's most densely populated and economically important regions get their power supply from TEPCO. Yet, the company has lost much credibility and trust from the Japanese public in its handling of nuclear crises following the 3/11 disaster (Asahi Shimbun, 2011). It has a track record of safety cover-ups, helped by soft regulation by a government organization tasked with promoting nuclear power. From autumn 2002 to the middle of 2003, TEPCO closed all seventeen of its nuclear reactors as a consequence of falsified reports in which the company concealed scars on the shrouds or supporting devices of fuel rods inside the reactor. This situation suggested negligence in safety and security by TEPCO (Yokobori, 2005).

In fact, the string of nuclear accidents in Japan in the 1990s has revealed a lack of regulatory oversight and preparedness. Over a decade ago experts have called for an adversarial regulatory culture with appropriate laws and institutions. They called for an effective nuclear safety and regulatory commission, which is independent, transparent and encourages public participation (Kral, 2000). Yet the Nuclear & Industrial Safety Agency (NISA) within the METI remained responsible for nuclear power regulation, licensing and safety (World Nuclear Association, 2011a). The fact that the Japanese government did not restructure its nuclear regulatory framework since the accidents in the 1990s is an indication of the strength of nuclear lobby in the country.

In early 2012 most of Japan's nuclear reactors were offline. In what mirrors public opinion, after 3/11, many local governments have been vehemently opposed to nuclear power. Before reactors can restart, METI needs agreements from local governments, even after routine inspections. Yuhei Sato, governor of Fukushima, where TEPCO has two nuclear stations including the wrecked Daiichi plant, has vowed to make the region a nuclear-free zone. Hirohiko Izumida, the governor of Niigata, where TEPCO's Kashiwazaki Kariwa plant is located, will "never" negotiate with the power utility on restarts until all of the deficiencies exposed by the Fukushima accident are explained and corrected (Bloomberg, 2012). In any case, and regardless of societal and local opposition to nuclear power, it is hard to imagine that the powerful nuclear lobby and its allies will relinquish their cause. The structural adjustment in the coal industry in Japan serves as an important precedent. In 1968, a decision was made to gradually phase out Japan's inefficient coal industry in response to the increased costs of domestic coal. Yet two decades later, for its Eighth Coal Program (1986–1991), the government had only agreed to some minor adjustments and decided to maintain price differentials and protect the industry more heavily with subsidies for domestic producers and tariffs on imported coal (Lesbirel, 1991). It was only in 2002 that Japan stopped domestic coal mining (Ferguson, 2011).

4.3. Relative prices and structural constraints

A glance at Table 1 reveals that nuclear power is the cheapest source of electricity in Japan, followed by coal and LNG. Renewable alternatives are considerably more expensive. In their survey of energy security perceptions in Japan, Valentine et al. (2011) found that most Japanese citizens are acutely aware of the need to minimize energy costs both to support industrial competitiveness and household energy expenditure. Their preferences for affordable energy services temper any policies that might commit Japan to costly low-carbon technological transition initiatives in the

Table 1
Power generation cost in Japan for major energy sources (¥ per kW h).
Sources: Dale, 2011; IAE, 2009; METI (Ministry of Economy, Trade and Industry), Government of Japan, 2010; Scalise, 2011.

	Nuclear	Coal	LNG	Oil	Solar	Wind	Geothermal	Hydro
METI	5.0–6.0	…	7.0–8.0	…	49.0	10.0–14.0	8.0–22.0	…
IAE	4.8–6.2	5.0–7.1	5.7–7.1	10.0–17.3	37.0–46.0	10.0–14.0	…	8.2–13.3
TEPCO	6.1	9.1			30.5			…
Scalise	…	8.8	13.1	19.6	30.0–45.0	14.0	10.0	…

energy sector (Valentine et al., 2011). Any increased cost of electricity caused by the uptake of renewable energy will be distributed among consumers, who already pay among the highest electricity prices in the world. This is a clear indication that there may be little public support or economic incentive for utilities to move away from traditional energy sources to renewable energy. Yet, besides high direct cost, renewable energy faces other structural constraints in Japan, all of which add to indirect costs related with the uptake of these sources of energy. Therefore, renewable energy cannot be regarded as the next "silver bullet" for Japan's energy woes.

Since Japan's hydroelectric potential is largely exploited, geothermal power would appear to be an attractive option given that there are more than 100 active volcanoes and thousands of hot springs. But some of the best locations are in national parks, which have strict limits on their development, and hot springs, which are attractive for tourists. The Japanese onsens – spas which rely on underground hot water – are opposing the development of geothermal energy because of concerns it will reduce the availability of hot water. Consequently, the ability for Japan to develop this energy source is constrained, as geothermal power faces political opposition from environmental activists and small business owners alike, who disapprove of unpredictable exploration prospects in environmentally fragile locations.

Most of the increase in renewable energy is expected to come from solar energy by encouraging the installation of solar panels on roofs and developing larger-scale solar facilities. Solar power is quiet and clean, but its prohibitive cost per kW h and low utilization rate ensure its marginalization for energy-intensive industries requiring stable baseloads to operate efficiently during business hours. Without adequate subsidies for lower income households to install solar power, Japan's promotion of solar power will be economically regressive as mainly businesses and wealthier households will be able to afford to install solar power and to sell the surplus energy back to the grid (Meltzer, 2011). In addition, the existing power system could accommodate enough photovoltaic generating capacity to provide only about 6% to 8% of the electricity supply (Duffield and Woodall, 2011).

In contrast, the cost of wind power in Japan is largely economically viable. Consequently, offshore wind farms appear worthy of consideration. Yet, they are likely to draw the ire of fishermen and environmentalists as they pose a danger to fish habitats and avian wildlife. In addition, the most productive sites for wind power are located far from where the electricity is needed, necessitating the construction of new power lines often in the face of local resistance. Moreover, the capacity for Japan to significantly expand its wind power is limited by a lack of space and frequent hurricanes which can damage wind turbines (Meltzer, 2011).

Given the intermittent nature of many renewables, the amount of capacity that must be built to produce every kW h of electricity will be several times greater than for other sources, greatly reducing their cost-effectiveness. According to one estimate, even 100 GW of installed photovoltaic capacity, or the equivalent of nearly 40% of current power generating capacity, would meet only 12% of Japan's electricity demand. For all these reasons, METI predicted in 2009 that the share of the primary energy supply provided by renewables in 2030 would reach only 11.6%, even with "maximum introduction of technology" (Duffield and Woodall, 2011).

The government has also been promoting energy efficiency since the 1970s oil crises. Further increases in energy efficiency in order to reduce dependence on fossil fuels are desirable, yet unrealistic. Japan is the most energy-efficient country in the world with its energy efficiency enhanced by over 30% since the 1973 oil crisis (Masaki, 2006; The Economist, 2011; Valentine, 2011). The energy consumption per unit of output in America and Europe is around twice that of Japan's, and China and India's is eight times as much, making Japan the most energy efficient among the world's major economies (IEA, 2011). In fact, the Japanese industry uses a similar amount of energy as it did during the oil shock of 1973. From the 1990s, Japan has also attained the highest level of efficiency in thermal power generation, a level it still maintains (Sano, 2011). Given that the easiest gains to energy efficiency have already been made (Duffield and Woodall, 2011), there are particular challenges ahead for Japan to develop technologies, which may further improve energy efficiency. Without a doubt, while minor efficiency gains are possible, any significant gains are highly unlikely in all sectors.

5. Conclusions and policy recommendations

The analyses above indicate that future energy choices for Japan are constrained and/or affected by three sources of path dependency. They are constrained by (1) the public opinion, which is predominantly anti-nuclear in the aftermath of the Fukushima disaster; (2) by energy-policy making apparatus centered around the METI and the powerful utilities and nuclear industry that are pro-nuclear; and (3) by relative energy prices and other structural constraints which make nuclear energy and fossil fuels the most economically feasible energy choices for the already weak Japanese economy. Given these constraints, what are the future energy policy options for Japan?

Japan's energy policy is at a crossroads. Japan prioritized resource diversification, with a nuclear emphasis, after oil shocks in the 1970s; it prioritized China's resource nationalism, global warming awareness, and one last oil price spike between in the last two decades. Japan now needs an integrated energy policy that is grounded in a new post-Fukushima reality. Such an energy policy will require a reassessment of priorities for Japan. Japanese policy-makers are faced with the difficult test of building a new energy policy that can appease growing anti-nuclear public sentiment without adverse effects to the powerful nuclear lobby, regional utility monopolies and industry. Energy security, the environment and the economy have long been the three pillars of Japanese energy policy. The new energy policy cannot overlook any of these three pillars. Yet, as discussed in this paper, there are significant challenges associated with each of the pillars, and the government is in an extremely difficult position of finding the best policy with which to tackle a multitude of interconnected challenges.

One of the origins of Japan's ambitious nuclear policy lies in the concerns of Japanese leaders who have interpreted history as a series of unreasonable assaults on an island nearly devoid of natural resources. They perceive Japan as exposed to inexplicable supply disruptions and argue that Japan would be too weak without recourse to an independent energy supply (Samuels, 1994). Nuclear energy has been an integral part of Japan's energy supply system. The benefits of nuclear energy for Japan have been manifold. Nuclear energy adds to energy diversification (Lesbirel, 2004), reduces dependency on oil, can be produced at a stable price, and is a clean fuel in terms of emissions.

In late January 2012, only 3 out of 54 nuclear facilities in Japan were operating. The assertion by former PM Kan's government that sufficient electricity can be conserved seems a touch naive. Savings can definitely be made, but not to the extent to offset all of the loss from nuclear power. Without nuclear reactors, Kansai Electric Power Co. (KEPCO), the main supplier to Japan's second-largest industrial region, may see demand exceed generation capacity by 9.5% in February 2012, the biggest shortfall among suppliers. KEPCO, which serves a region with an economy the size of Mexico's and hosts Sharp Corp. and Panasonic factories, is asking customers to voluntarily reduce consumption by more than 10% during the winter of 2012. Kyushu Electric Power Co. will also be short of capacity after it shuts down its last operating reactor for maintenance.

Removing up to 30% of Japan's electricity generating capacity is not possible without inflicting serious harm to Japan's already vulnerable economy. If industries are required to cut electricity demand in summer 2012, some Japanese manufacturers may relocate their operations overseas, where electricity is in stable supply and cheaper, ushering in higher unemployment and further squeezing public funds. In fact, some have suggested, "electricity restraint is the largest issue for the growth of Japan's economy" (World Nuclear Association, 2011b). In this context, the future of nuclear energy must be weighted wisely if Japan is to remain an economic power.

Convincing Japanese people that nuclear power is safe will be a major challenge. This is not just because of the distrust of TEPCO, but also the government's perceived mishandling of the nuclear crisis. Yet, even if public opposition to nuclear power could be overcome, the scale of the Fukushima crisis will undoubtedly delay the expansion of existing nuclear plant capacities and the construction of new plants. The 1999 Tokaimura nuclear accident slowed down the rate of subsequent nuclear development. Various projects were delayed or canceled. In 2001, the Japanese government planned to increase the number of nuclear power plants from 52 to between 62 and 65 by 2010 (Lesbirel, 2003). Yet, by 2010, only two new power plants have been in operation. Given its scale, the Fukushima disaster will result in a drop in the number of operational nuclear reactors in Japan.

Yet, energy policy cannot be relegated to industry either. There is a growing perception that the revolving door of nuclear officials going into nuclear power companies has created a culture where Japanese nuclear regulators were too close to the nuclear operators, compromising their independence. Moreover, the agency responsible for regulating Japan's nuclear sector (NISA) is part of the agency responsible for promoting nuclear power (METI), creating the perception of conflicting interests (Meltzer, 2011). A firewall needs to be created between regulators, government and industry. Only when regulators are independent from government and industry-capture will Japan's nuclear industry receive proper oversight, which will likely prevent future accidents.

It is commendable that in August 2011, the Japanese government has taken a first step in this direction. A new independent regulatory structure was proposed that would be separated from the METI and would report to the Ministry of the Environment. This regulator would have the combined functions of the old NISA and a special Cabinet advisory board known as the Nuclear Safety Commission. The transition to the new structure is due to take place in April 2012 (World Nuclear News, 2011). As the next step, the Japanese government should also reassess the value of preserving Japan's regional electricity monopolies, who some have blamed for relatively high relatively electricity prices in Japan. One of the key issues that the government will need to consider when formulating its energy policy is the already high cost of energy in Japan and the adverse impact this has had on the competitiveness of the Japanese economy and which has already contributed to the trend for Japan's heavy industry to relocate overseas (Meltzer, 2011). Japan's regional power companies dominate the electricity business from generation to transmission and distribution, with a full monopoly over supply to households in their areas of operation and a near-monopoly to commercial customers. The government should engage in a comprehensive reassessment of this structure and the future operations of the power industry while developing its new energy policy. A specific challenge is the need for power grid alignment between electric power companies between eastern and western Japan.

Japan's traditional energy security concerns do not disappear after 3/11 and some have been exacerbated in the aftermath of the disaster. Even before the earthquake, there was recognition that the nuclear energy expansion would not save Japan from oil dependency in the transportation sector (Barrett, 2011). Japan's energy situation begins and ends with structural constraints. Because Japan is a resource-poor industrial giant, it imports much of its primary energy supply (Vivoda and Manicom, 2011). The lessons that Japan has learnt from the 1970s oil crises attest to the dangers of increased reliance on imported fossil fuels, which remain today. In fact, they are exacerbated by the increased imports of oil to fuel thermal plants; zero-sum competition for oil with China, India and South Korea; and the US pressure to reduce oil imports from Iran. Yet, the reactor shutdown post-3/11 showed that Japan is as vulnerable to an internal energy disruption as it is to an external disruption associated with the security and affordability of oil supplies. This would suggest that the policymakers should rethink their traditional assumption of energy security risk arising *only* from an interruption of foreign sources of oil. They should consider the cost of enhancing the reliability of domestic energy sources and the degree to which Japan needs domestic emergency response measures.

While the Japanese leaders have been frank in dismissing any hopes of meeting Japan's climate change targets, they still remain committed to increasing the role of renewable energy in Japan's future energy mix. A recently passed feed-in tariff (FIT) will go some way in supporting the government's renewable energy targets. Yet, an inability to overcome public opposition to nuclear power would likely counteract any gains achieved by the FIT. More generally, it is unrealistic to expect that the renewables take up the nuclear's share. Renewable sources start from a very low base. Renewables cannot meet the demand and are prohibitively expensive. If we also consider other limitations to renewable energy in Japan, discussed in the previous section, the idea that renewable energy can replace nuclear energy could not be further from reality. Renewables can contribute, but to make up for most of lost nuclear power would take massive investment, probably too much for a country where government net debt is close to 200% of GDP. Although former PM Kan spoke of replacing the canceled reactors with renewable energy systems such as wind and solar, this policy option will remain wishful thinking unless Japan is ready to forego economic growth for the foreseeable future. This has been recognized by new PM Yoshihiko Noda, who

just over six months after the earthquake, acknowledged that while public safety concerns will make it tough to build new reactors, decisions on operational reactors and those already under constructions will be made on a "case-by-case" basis (Saoshiro and Sieg, 2011).

The evidence in this paper indicates that the most feasible option for Japan to remain economically competitive is that, if public opposition can be overcome, as many nuclear reactors are restarted as soon as possible. In the short-to-medium term, energy expansion should come from more imported oil, coal, and LNG, with gradual reduction in the share of nuclear power in Japan's energy mix. The commitment to emissions-intensive fossil fuels will result in a difficult-to-accept increase in greenhouse gas emissions that can be minimized by restarting nuclear reactors. Japan's new national energy plan is also likely to place emphasis on increasing the share of renewable energy. The long-term commitment to renewable energy will result in severe consequences for the already struggling economy, with higher electricity prices making Japanese corporations less competitive and fueling the movement of jobs offshore. Positive news is that Japan's energy consumption is set against a declining population, which is expected to decrease by one-third by 2060 (The Guardian, 2012). This will also reduce the growth in energy demand in Japan. In any case, if any lessons are to be taken from previous energy transitions as witnessed by economic depression in former major coal-mining regions, the government needs to manage Japan's energy transition with extreme caution in order to minimize the socioeconomic dislocation.

References

ANRE (Agency for Natural Resources and Energy). 2006. New national energy strategy. Press Release, 31 May.

Asahi Shimbun. 2011. TEPCO Safety Management at Nuclear Plants Described as Lax. 26 March.

Asano, Hiroshi, 2005. Regulatory reform of the electricity industry in Japan: what is the next step of deregulation? Energy Policy 34 (16), 2491–2497.

Atsumi, Masahiro, 2007. Japanese energy security revisited. Asia-Pacific Review 14 (1), 28–43.

Barrett, Brendan, 2011. Can Nuclear Power Save Japan from Peak Oil?. United Nations University, Tokyo.

BBC News. 2011. Japan PM Naoto Kan Urges Nuclear-Free Future. 13 July.

Beder, Sharon, 2003. Power Play: The Fight to Control the World's Electricity. W.W. Norton & Company, New York.

Bloomberg. 2012. Atomic-free Japan by April Roils Debate on Economic Risks. 27 January.

BP (British Petroleum), 2011. BP Statistical Review of World Energy 2011. British Petroleum, London.

Chester, Lynne, 2010. Conceptualizing energy security and making explicit its polysemic nature. Energy Policy 38 (2), 887–895.

Dale, Craig. 2011. Energy Angst: Japan's Post-Tsunami Power Crisis. CBC News, 30 May.

Duffield, John S., Woodall, Brian, 2011. Japan's new basic energy plan. Energy Policy 39 (6), 3741–3749.

The Economist. 2011. Powerful Savings. 27 April.

EIA (Energy Information Administration), US Department of Energy. 2011. Japan Energy Data, Statistics and Analysis. March.

Evans, Peter C. 2006. Japan. The Brookings Foreign Policy Studies, Energy Security Series. December.

Ferguson, Charles D. 2011. The need for a resilient energy policy. Bulletin of the Atomic Scientists. 16 March.

Fesharaki, Fereidun, and Hosoe, Tomoko. 2011. The Fukushima crisis and the future of Japan's power industry. Asia Pacific Bulletin, No. 106, East–West Center, 12 April.

Grübler, Arnulf, 1991. Energy in the 21st century: From resource to environmental and lifestyle constraints. Entropie 164/165, 29–33.

Hartley, Peter. 2000. Reform of the electricity supply industry in Japan. Japanese Energy Security and Changing Global Energy Markets: An Analysis of Northeast Asian Energy Cooperation and Japan's Evolving Leadership Role in the Region. Prepared in Conjunction with an Energy Study Sponsored by The Center for International Political Economy and The James A. Baker III Institute for Public Policy, Rice University, May.

Hideaki, Fujii, 2000. Japan. In: Stares, Paul B. (Ed.), Rethinking Energy Security in East Asia. Japan Center for International Exchange, Tokyo, pp. 59–78.

Hosoe, Nobuhiro, 2006. The deregulation of Japan's electricity industry. Japan and the World Economy 18 (2), 230–246.

IAE (Institute of Applied Energy, Japan). 2009. '発電方式別の発電コストの比較' [Cost Comparison of Different Power Generation Systems]. 7 July, available: 〈http://www.iae.or.jp/energyinfo/energydata/data1012.html〉 (accessed 18 October 2011).

IEA (International Energy Agency). 2011. Key World Energy Statistics Paris: OECD/EIA.

IEEJ (Institute of Energy Economics, Japan). 2011. Analysis of electricity supply and demand through FY2012 regarding restart of nuclear power plants'. Special Bulletin, 13 June.

IEEJ (Institute of Energy Economics, Japan). 2012. Japan Energy Brief. No. 17, January.

Inajima, Tsuyishi. 2012. Japan utilities losses reach $6 billion after Fukushima crisis. Bloomberg, 17 January.

Itakura, Ken. 2011. The economic consequences of shifting away from nuclear energy. Economic Research Institute for ASEAN and East Asia (ERIA), Policy Brief, No. 2011-04, December.

JPC-SED (Japan Productivity Center for Socio-Economic Development), Energy and Environmental Policy Section, Special Committee of Energy Issues. 2000. Enerugii sekyuriti no kakuritsu to 21 seiki no enerugii seisaku no arikata – yûshikisha ankeeto chôsa ni motozuite [The Establishment of Energy Security and Ideal Energy Policies in the 21st century – Based on a Survey of Learned Persons]. Tokyo, 30 March.

Johnston, Eric, 2011. Son's quest for sun, wind has nuclear interests wary. The Japan Times. 12 July.

Koike, Masanari, 2006. Japan looks for oil in the wrong places. Far Eastern Economic Review 169 (8), 44–47.

Koike, Masanari, Mogi, Gento, Albedaiwi, Waleed H., 2008. Overseas oil-development policy of resource-poor countries: a case study from Japan. Energy Policy 36 (5), 1764–1775.

Kotler, Mindy L.,and Hillman, Ian T.. 2000. Japanese nuclear energy policy and public opinion. Japanese Energy Security and Changing Global Energy Markets: An Analysis of Northeast Asian Energy Cooperation and Japan's Evolving Leadership Role in the Region. Prepared in Conjunction with an Energy Study Sponsored by The Center for International Political Economy and The James A. Baker III Institute for Public Policy, Rice University, May.

Kral, Alexei, 2000. Are Japan's energy security ambitions misguided? Nuclear policy in Japan. Event Summary, Woodrow Wilson International Center for Scholars. 29 February.

Lesbirel, S.Hayden, 2004. Diversification and energy security risks: the Japanese case. Japanese Journal of Political Science 5 (1), 1–22.

Lesbirel, S.Hayden, 2003. Markets, transaction costs and institutions: compensating for nuclear risk in Japan. Australian Journal of Political Science 38 (1), 5–23.

Lesbirel, S.Hayden, 1991. Structural adjustment in Japan: terminating "old king coal". Asian Survey 31 (11), 1079–1094.

Lidsky, Lawrence M., Miller, Marvin M., 2002. Nuclear power and energy security: a revised strategy for Japan. Science and Global Security 10 (2), 127–150.

Masaki, Hisane, 2006. Japan's new energy strategy. Asia Times Online. 13 January.

Medlock, Kenneth B.,and Hartley, Peter. 2004. The role of nuclear power in enhancing Japan's energy security. Prepared in Conjunction with an Energy Study Sponsored by Tokyo Electric Power Company Inc. and The James Baker III Institute for Public Policy, Rice University, March.

Meltzer, Joshua, 2011. After Fukushima: what's next for Japan's energy and climate change policy? Global Economy and Development at Brookings 7 September.

METI (Ministry of Economy, Trade and Industry), Government of Japan. 2010. 2010 Annual Report on Energy. June.

Moe, Espen, 2012. Vested interests, energy efficiency and renewable in Japan. Energy Policy 40 (1), 260–273.

Morita, Yuji, 2010. Energy saving in the Japanese industrial sector and international cooperation.. In: Virendra Gupta, Kwa, Ching Guan (Eds.), Energy Security: Asia Pacific Perspectives. Manas Publications, New Delhi, pp. 85–108.

Nakano, Jane, 2011. Japan's energy supply and security since the March 11 earthquake. Center for Strategic & International Studies, Commentary. 23 March.

Nakatani, Kazuhiro, 2004. Energy security and Japan: the role of international law, domestic law, and diplomacy.. In: Barton, Barry, Redgwell, Catherine, Rønne, Anita, Zillman, Donald N. (Eds.), Energy Security: Managing Risk in a Dynamic Legal and Regulatory Environment. Oxford University Press, Oxford, pp. 413–427.

North, Douglass, 1990. Institutions, Institutional Change and Economic Performance. Cambridge University Press, Cambridge.

Oyama, Kosuke. 2000. Trends and prospects of deregulation in Japan. Japanese Energy Security and Changing Global Energy Markets: An Analysis of Northeast Asian Energy Cooperation and Japan's Evolving Leadership Role in the Region. Prepared in Conjunction with an Energy Study Sponsored by The Center for International Political Economy and The James A. Baker III Institute for Public Policy, Rice University, May.

Samuels, Richard, 1994. Rich Nation, Strong Army. Cornell University Press, Ithaca, NY.

Sano, Toshihiro, 2011. Improving efficiency of thermal power generation in Japan. Journal of Power and Energy Systems 5 (2), 146–160.

Saoshiro, Shinichi,and Sieg, Linda. 2011. Nuclear seeps back into favor as Japan begins energy debate. Reuters, 3 October.

Scalise, Paul J. 2011. Rethinking national energy policy: Japan's electricity crisis, nuclear power, and the fate of TEPCO, Temple University, Institute of Contemporary Asian Studies, 27 May.

Scalise, Paul J. 2012. Japanese energy policy after Fukushima. Policy Innovations.
Smil, Vaclav, 2010. Energy Transitions. Praeger, Santa Barbara, CA.
Smil, Vaclav. 2008. Moore's curse and the great energy delusion. The American Magazine, 9 November.
Smith, Sheila A. 2012. 'Japan's Iran sanctions dilemma'. Council on Foreign Relations, Asia Unbound, 31 January.
Soble, Jonathan. 2012. Tepco raises electricity price by up to 18%. The Financial Times, 17 January.
Stewart, Devin, 2009. Japan: the power of efficiency.. In: Gal Luft, Korin, Anne (Eds.), Energy Security Challenges for the 21st Century: A Reference Handbook. Praeger Security International, Santa Barbara, CA, pp. 176–190.
Suzuki, Tatsujiro. 2000. Nuclear power generation and energy security: the challenges and possibilities of regional cooperation. Japanese Energy Security and Changing Global Energy Markets: An Analysis of Northeast Asian Energy Cooperation and Japan's Evolving Leadership Role in the Region. Prepared in conjunction with an Energy Study Sponsored by The Center for International Political Economy and The James A. Baker III Institute for Public Policy, Rice University, May.
The Australian. 2011. Japanese Back Nuke Free Future – Poll. 14 June.
The Federation of Electric Power Companies of Japan. 2011. Electricity Review Japan.
The Guardian. 2012. Japan Population to Shrink by a Third by 2060. 30 January.
The Japan Times. 2012. 'A Worrisome Trade Deficit. 31 January.
Toichi, Tsutomu. 2006. International energy security and Japan's strategy. Presented at the Conference on India's Energy Security, Jointly Organized by TERI and the Konrad Adenauer Foundation, Goa, India, 29–30 September.
Tsukimori, Osamu. 2012. China overtakes Japan as world's top coal importer, Reuters, 26 January.
UNDP (United Nations Development Programme), 2004. World Energy Assessment, 2004 Update. UNDP, New York.
Valentine, Scott V., 2011. The fuzzy nature of energy security. In: Sovacool, Benjamin K. (Ed.), The Routledge Handbook of Energy Security. Routledge, New York, pp. 56–73.
Valentine, Scott V., Sovacool, Benjamin K., Matsuura, Masahiro, 2011. Empowered? Evaluating Japan's national energy strategy under the DPJ administration. Energy Policy 39 (3), 1865–1876.
Vivoda, Vlado, 2010. Evaluating energy security in the Asia-Pacific region: a novel methodological approach. Energy Policy 38 (9), 5258–5263.
Vivoda, Vlado, Manicom, James, 2011. Oil import diversification in Northeast Asia: a comparison between China and Japan. Journal of East Asian Studies 11 (2), 223–254.
Wallace, Rick. 2011. Japan's energy loss, our LNG gain. The Australian, 20 September.
World Nuclear Association. 2011a. Nuclear Power in Japan. 27 May.
World Nuclear Association. 2011b. Policy Responses to the Fukushima Accident. 7 October.
World Nuclear News. 2011. Regulatory Shake-up in Japan. 16 August.
World Nuclear News. 2012. Trade Figures Reveal Cost of Japan's Nuclear Shutdown. 25 January.
Yokobori, Keiichi, 2005. Japan.. In: Kalicki, Jan H, Goldwyn, David L. (Eds.), Energy & Security: Toward a New Foreign Policy Strategy. Woodrow Wilson Center Press, Washington, D.C, pp. 305–328.