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Nuclear Power in Japan after Fukushima: delivering energy security?

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Abstract

This paper assesses if the energy policy options currently being considered in Japan are likely to deliver energy security in the period to 2030. It examines the resource geography of Japan, contrasting it with the economic activity on which the nation relies. It highlights the attractive features of nuclear power and reviews the plutonium fuel cycle to test its necessity for Japan's energy security, as well as identifying the resultant security issues.

The paper also looks at Japan's economic and political environment to set the scene for explaining the economic challenges which must be accounted for in any future energy policy. The Fukushima disaster itself is briefly explained, followed by a summary of its impact. A detailed analysis of Japan's energy strategy options then addresses the central question of the likely energy security outcomes for the next decade. The paper concludes that while Japan's optimistic projection of renewable energy exploitation, strong public anti-nuclear sentiment, ageing nuclear infrastructure and seemingly perverse insistence on a plutonium fuel program will all impact its energy security, none of the available options will be simply realised or effectively mitigate Japan's energy security risks.

Nuclear Power in Japan after Fukushima: delivering energy security?

What must be admitted, very painfully, is that this was a disaster 'Made in Japan'. Its fundamental causes are to be found in the ingrained conventions of Japanese culture: our reflexive obedience; our reluctance to question authority; our devotion to 'sticking with the program'.

Dr Kiyoshi Kurokawa, Chairman of Japan's Parliamentary Nuclear Accident Investigation Commission, 2012¹

We will aim at realising a society which can exist without nuclear power.

Naoto Kan, Prime Minister of Japan, 13 July 2011²

Introduction

Since the mid 20th century, no country in the Organisation for Economic Cooperation and Development (OECD) has experienced economic boom followed by persistent contraction as seen in Japan, which is exceptional considering the country is internally cohesive, liberal, free of existential threats and enjoys relatively high political stability. This contradiction can be understood in part by examining the economy's major industries and the energy sector. The relative dearth of natural energy resources in Japan has left the Japanese manufacturing sector, on which the economy is so reliant, vulnerable to global energy price volatility and shocks. Successive Government of Japan (GOJ) policies have sought to address this security vulnerability over the longer term; however, the unusually close relations between key industry and GOJ players have tended to inhibit the difficult adjustments required.

As a rapidly-industrialising Pacific power in the 1920s, Japan realised that the energy intensity of an economy built on manufacturing, heavy industries and high technology could not be supported from domestic energy sources. At the completion

¹ The National Diet of Japan, 'The Fukushima Nuclear Accident Independent Investigation Commission', Tokyo, The National Diet of Japan, 2012, available at <http://www.nirs.org/fukushima/naiic_report.pdf>, accessed 24 April 2013, p. 9.

² 'Japan PM Naoto Kan Urges Nuclear-free Future', *BBC News*, London, British Broadcasting Commission, 2011, available at <<http://www.abc.net.au/news/>>, accessed 28 July 2013, p. 1.

of World War 2, after a protracted American occupation and program of rebuilding of national power and institutions, Japan's economy took on its modern form as a high technology manufacturing powerhouse, consuming resources such as coal and steel in unprecedented quantities. Initially fuelled by cheap oil, the Japanese economy grew strongly. In the 1970s, Japan's strategic vulnerability was demonstrated by global oil price shocks, which exposed a reliance on imported oil for over three quarters of all energy use in Japan.

The GOJ reacted with a radical intervention, where government and industry cooperated to introduce nuclear energy and liquefied natural gas (LNG) as preferred fuels for electricity generation, while moving to lead the world in energy efficiency in the transportation sector. Cheap coal also became prominent in Japan's electricity portfolio; however, Japan has led the way in technological solutions to coal's pollution problems. Public misgivings arising in part from Japan's history as the only nation subjected to nuclear attack were overridden by the GOJ, and Japan embraced nuclear power. With the goal to radically reduce reliance on imported energy sources while supporting a fast growing economy, Japan's nuclear pathway seemed logical to the point of inevitability in the early 1980s.

Japan became a leader in the movement to reduce the emission of greenhouse gases (GHG) to counter global warming. Unprecedented levels of energy efficiency and use of a measure of renewable energy sources helped Japan demonstrate practical leadership; however, nuclear power was at the heart of Japan's CO₂ emissions abatement strategy. Ultimately, after hosting the international collaborations leading to the Kyoto Protocol in 1997, Japan made some of the world's most ambitious emissions control commitments, all contingent on planned growth of nuclear power.

To reduce energy imports, Japan became the only nuclear state without a weapons program to seek a closed-fuel cycle, where spent reactor fuel was re-processed to yield plutonium, which could theoretically be recycled indefinitely in purpose-built reactors. The technological and commercial issues were complex and progress was slow, with some safety incidents slowing the program and heightening opposition to nuclear power. Regionally, countries were justifiably concerned that Japan's extensive plutonium stockpile, missile technology and economic capacity could enable a rapid transition to nuclear-armed status, despite a pacifist constitution and strong public opposition to nuclear weapons.

From the end of the 1980s, Japan's economic growth was increasingly limited by a series of political, regulatory, cultural and demographic constraints. The economic

miracle was over and, in its place, Japan faced stagnation and contraction. A series of GOJ administrations were unable to find workable strategies for economic recovery. The world's second largest economy was slowing and contracting just as a number of new global economic powerhouses emerged to challenge for share of traditional Japanese industries. A series of relatively minor accidents at nuclear facilities in Japan, combined with the global reactions to the Three Mile Island and Chernobyl nuclear accidents, served to harden public opposition to nuclear power in Japan. Despite this growing public opposition to nuclear power and pointed questions about the plutonium program, the continued close working relationship between the GOJ, regulators and power companies ensured a continued commitment to nuclear power into the new century.

In March 2011, a magnitude 9.0 earthquake just off the eastern coast of Japan triggered a tsunami which severely damaged the nuclear power plant at Fukushima Daiichi, leading to a release of radioactive material.³ While the situation was ultimately contained, a combination of mismanagement of the emergency response itself and inept public information about the disaster heightened reservations about the safety of nuclear power. Audiences internal and external to Japan struggled to resolve the contradiction between the country's overt safety culture and high technological base and the systemic failure to adopt best practice risk management and nuclear safety standards. Subsequently, frank revelations from the investigation of the disaster demonstrated how the close relationship between the Japanese Government and power companies had broken down the integrity of regulation of the nuclear industry.

Within a year of the disaster, the GOJ reduced the nuclear contribution to electricity generation to near zero, imports of fossil fuels had soared causing an unsustainable balance of trade, extreme energy conservation measures were instituted, rolling blackouts were anticipated, commitments to GHG emissions reductions were tacitly abandoned, and power shortages were beginning to affect industrial outputs.⁴ Significant institutional changes resulted, including a new nuclear regulatory authority to reset the former cosy culture of lax regulation enabled by the systemic movement of senior executives from government to industry, known as *Amakudari*.⁵

³ Jeff Tollefson, 'Japan Faces Power Struggle', *Nature*, Vol. 472, No. 7342, 2011, p. 144.

⁴ Masatsugu Hayashi and Larry Hughes, 'The Policy Responses to the Fukushima Nuclear Accident and Their Effect on Japanese Energy Security', *Energy Policy*, 2012, available at <<http://dx.doi.org/10.1016/j.enpol.2012.08.059>>, accessed 3 May 2013, pp. 3-4.

⁵ Susan Carpenter, *Why Japan Can't Reform: inside the system*, Basingstoke, Palgrave Macmillan, 2008.

An unprecedented debate was underway between government, industry, academics and the public on Japan's future energy policy. Japan had clearly arrived at a critical juncture, where an unprecedented crisis triggers a major shift in policy.⁶ The reinstalled Prime Minister Shinzo Abe is under pressure to craft a radically new energy strategy which will be greatly constrained by the state of the Japanese economy and public opinion.

While Japan might be considered an unusual case, where economic activity and resource distribution are fundamentally mismatched, most nations are somewhat reliant on imported energy. Other countries, including Germany, have already made political commitments to shift away from nuclear power, while the finite supply of fossil fuels continues to decline and alternative energy technologies are not proven or available on the scale required. Global prospects to reduce GHG emissions are also materially affected by the extent to which nuclear power is used, even as an intermediate approach until renewable energy technologies matures. Understanding of the Fukushima disaster and the subsequent energy policy adopted by Japan will be an important input into the global debate on the future role of nuclear power.

Energy security is defined to mean the sustainable availability of affordable energy over at least a decade, consistent with needs and causing only acceptably low levels of environmental degradation through production and use.⁷ This paper will assess if the energy policy options currently being considered in Japan are likely to deliver energy security for Japan in the period to 2030.

The paper will examine the resource geography of Japan, contrasting that with the economic activity on which the nation relies. A review of the case for nuclear power will demonstrate its attractive features from an energy security point of view. A more specific investigation of the plutonium fuel cycle will test its necessity for Japanese energy security and identify the security issues arising from that program. The recent state of the Japanese economy and political environment will be characterised to set the scene for explaining the economic challenges which must be accounted for in any future energy policy. The disaster itself will be briefly explained, followed by a summary of the impacts on Japan. A detailed analysis of the energy strategy options being considered for Japan will address the central question: what is the likely energy security outcome for Japan for the next decade?

⁶ John Hogan and David Doyle, 'The Importance of Ideas: an *a priori* critical juncture framework', *Canadian Journal of Political Science*, Vol. 40, No. 4, 2007, p. 884.

⁷ Gawdat Bahgat, 'Energy Security: what does it mean? And how can we achieve it?', *The Journal of Social, Political, and Economic Studies*, Vol. 33, No. 1, 2008, pp. 86-9.

Japan's optimistic projection of renewable energy exploitation, strong public anti-nuclear sentiment, ageing nuclear infrastructure and seemingly perverse insistence on a plutonium fuel program will all impact energy security. The paper will argue that none of the available options will be simply realised or effectively mitigate Japan's energy security risks.

An overview of Japan's geography, industry and energy policies

Japan's unique geography and limited energy resources constrain domestic industry profoundly. Japan comprises 6852 islands, stretching from just off the northern coast of Taiwan to continental Russia, with most of the population living in cities on the four main islands. Japan is the 62nd largest country in the world and supports a population of 127 million, despite the mountainous terrain and arability of less than 12 per cent of land.⁸ The resident population is ethnically more than 98.5 per cent Japanese, with a highly-distinct national identity and culture. Japan is the world's 75th largest oil producer, with all production consumed domestically, albeit this makes only a marginal contribution to energy supplies. Continental Japan and the uncontested areas of its exclusive economic zone (EEZ) have only very sparse conventional energy resources by global standards, with the limited available hydroelectric potential being exploited by 1970.⁹ Overall, Japan is almost comprehensively reliant on foreign-sourced energy, importing 99 per cent of required oil, 98 per cent of required coal and 96 per cent of required gas in 2010.¹⁰

Post-war Japan became a leader in manufacturing industries, including optics, semiconductors, vehicles, precision metal components and consumer electronics. Growth in GDP was strong, energy intensity increased quickly from the 1950s and electricity was generated from oil-fired plants, given the low oil price and seemingly increasing supply. The oil price shocks of the 1970s impacted Japan more than any other developed economy, as it was reliant on imported oil for 78 per cent of all energy consumption.¹¹ The rapid changes in global oil prices and availability shown in , coupled with subsequent volatility, prompted significant Japanese energy policy changes.

⁸ Central Intelligence Agency (CIA), 'Japan Country Brief', Washington DC, CIA, 2013, available at <<https://www.cia.gov/library/publications/the-world-factbook/geos/ja.html>>, accessed 20 May 2013,

⁹ Institute of Energy Economics Japan (IEEJ), *APEC Energy Overview 2011*, Tokyo, IEEJ, 2012, p. 83.

¹⁰ IEEJ, *APEC Energy Overview 2011*, pp. 83-4.

¹¹ John Duffield, 'The Return of Energy Insecurity in the Developed Democracies', *Contemporary Security Policy*, Vol. 33, No. 1, 2012, p. 3.

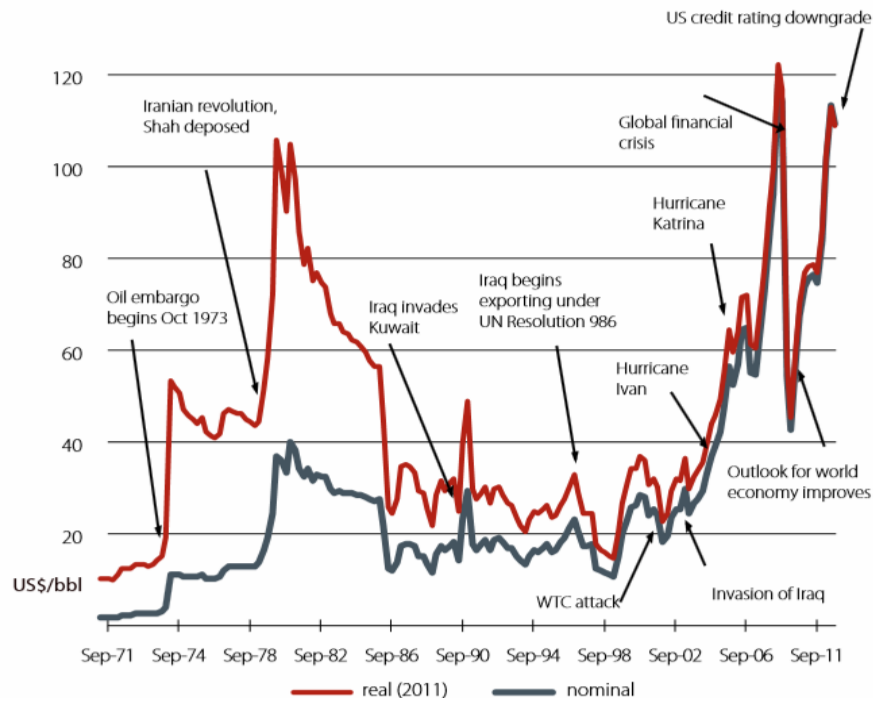


Figure 1 - World Crude Oil Prices

(Source: Australian Government, *Resources and Energy Statistics 2011*, Canberra, Bureau of Resource and Energy Economics, 2011, available at <http://www.bree.gov.au/documents/publications/res/Annual_RES_2011> accessed 27 December 2013)

The GOJ responded to the oil price shocks by increasing taxes on oil to encourage efficiency and directing the use of gas and nuclear power to support the manufacturing sector. The GOJ's 'Basic Energy Laws' were particularly important in re-shaping energy policy. The initial focus was on oil cost avoidance, however, the Japanese economy realised competitive advantage through energy efficiency and grew to export this technology. The impact on manufacturing energy efficiency was particularly important, as illustrated in Figure 2. While manufacturing activity levels and outputs rose significantly between 1970 and 2007, the actual energy consumption increase was small. Despite this, real growth in commercial, residential and transportation sectors was significant and GHG emissions continued to increase.

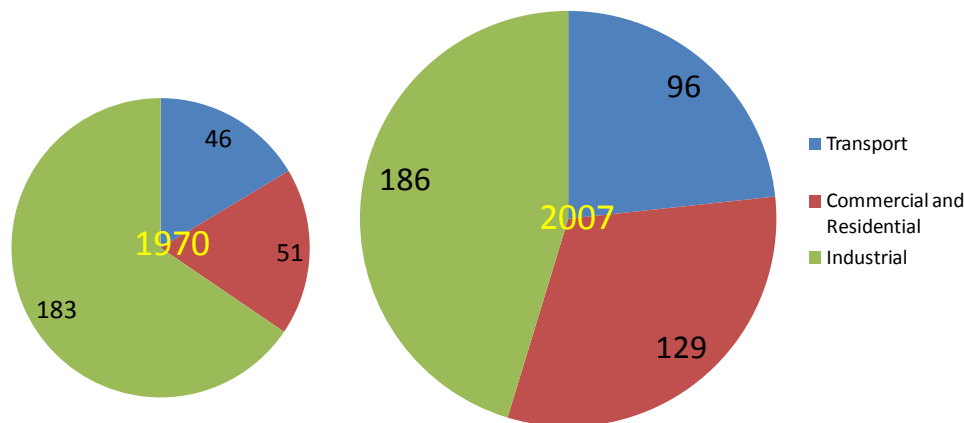


Figure 2 - Energy Use in Japan (10⁹ litres oil equivalent)

(Source: IEEJ, *Asia/World Energy Outlook*, 2010, Tokyo, IEEJ, 2010)

Japan also sought to improve oil energy security by developing a strategic petroleum reserve, where the GOJ and industry both held substantial petroleum reserves. While this is a costly approach, Japan's unique economic and geographic situation led it to develop some of the largest strategic oil reserves in the world¹² at 169 days of expected consumption, easily exceeding the 90 days required by the International Energy Agency (IEA).¹³

With awareness of global warming increasing, Japan hosted the Kyoto Protocol talks on GHG reduction in 1997 and pledged to reduce GHG emissions by 6 per cent on 1990 outputs.¹⁴ Japan suggested in 2007 the need to reduce world emissions in 2050 to 50 per cent of 1990 levels, which demonstrated Japan's intent to lead the response to climate change.¹⁵ There are significant technical limitations on how this could be achieved in the transportation and residential sectors, so the electricity generation sector became a policy focus area. Japan's electricity generation after the oil shock diversified, with nuclear power, coal and gas becoming increasingly important as shown in Figure 3. Japanese energy policy in the period 2000-2010 was contingent mainly on the continued growth of nuclear power, with an expectation that affordable clean coal could also be realised.

¹² Measured as a fraction of annual domestic demand.

¹³ Lesley Bankes-Hughes, 'Taking Stock: strategic oil reserves', *Bunkerspot*, Vol. 8, No. 2, 2011, p. 34.

¹⁴ Aki Suwa, 'Soft Energy Paths in Japan: a backcasting approach to energy planning', *Climate Policy*, Vol. 9, No. 2, 2009, p. 186.

¹⁵ Carin Holroyd, 'National Mobilization and Global Engagement: understanding Japan's response to global climate change initiatives', *Asian Perspective*, Vol. 33, No. 2, 2009, p. 74.

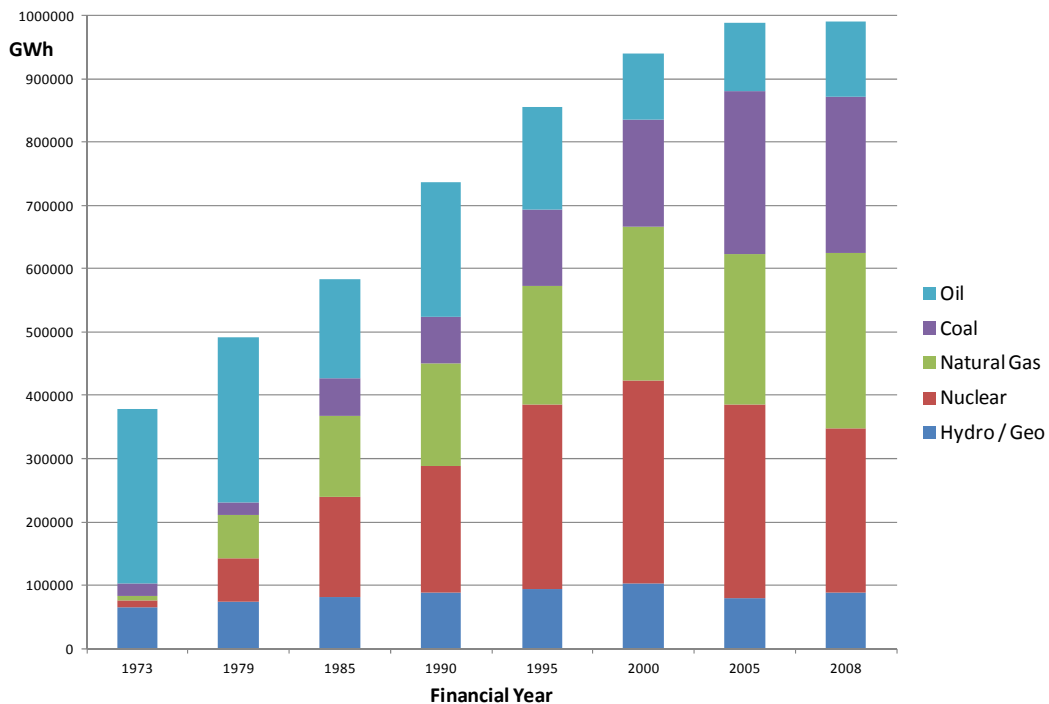


Figure 3 - Electricity Generation in Japan

(Source: Agency for Natural Resources and Energy [ANRE], *Energy in Japan*, Tokyo, ANRE, 2010, available at <http://www.enecho.meti.go.jp/english/toprunner/index.html> accessed 27 December 2013)

The pre-Fukushima case for nuclear power in Japan

Nuclear power has distinct economic and environmental advantages, especially in the case of Japan, which make its use attractive. Nuclear power stations can be built with significantly high load capacities, routinely achieve generation capacities of up to 1.5 GW, which is delivered with very high reliability. A typical nuclear plant in Japan will have between two and five reactors, and capacity at the plant level will be moderated over time by reactor maintenance and refuelling cycles. Individual reactors require replenishment of approximately 25 per cent of their fuel about every 18 months, which can be forecast and scheduled to minimise impact on station capacity. The reactor designs used in Japan require shutdown to a cold state for fuel replenishment, a lengthy process compared to a gas or coal plant. Despite this, nuclear power stations generate very high continuous load capacities when

compared with renewable or conventional sources. They also tend to generate a much greater percentage of their rated peak capacity.

Power demand in industrialised nations is highly cyclic over daily and seasonal timescales, where hot summer afternoon commercial and domestic air-conditioning requirements tend to peak demand. The power industry therefore typically must have a significantly higher peak generation capacity than the mean annual load. By way of example, in 2010 Japan had 277 GW of electricity generation capacity available but only generated 1,093,787 GWh or about 45 per cent of the rated peak capacity over the 12 month period.¹⁶ Plant maintenance requires physical redundancy in capacity to cover for down-time. Variation in availability of renewable energy inputs means that there must also be sufficient conventional capacity to cater for periods of low renewable input, albeit this risk can be managed by seasonal programming of maintenance in conventional plants, based on expected renewable performance.

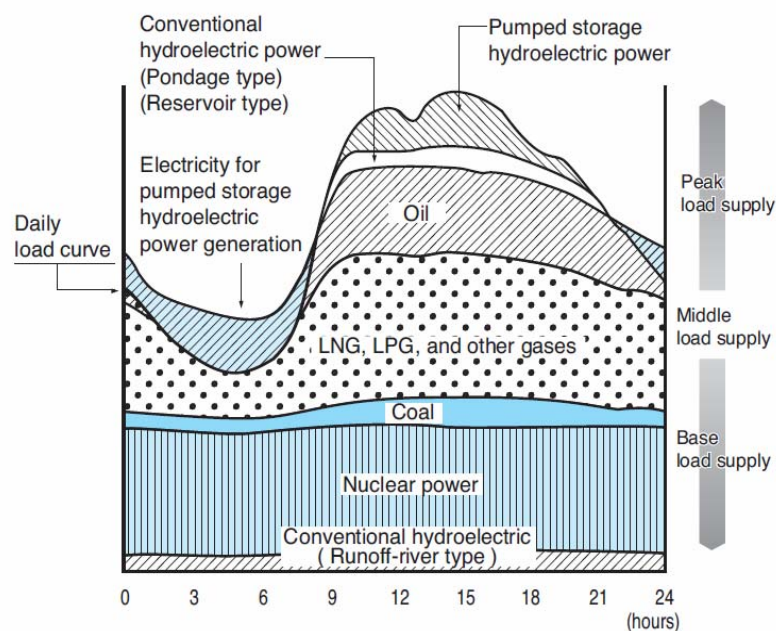


Figure 4 - Typical Daily Electricity Demand Cycle in Japan

(Source: Tokyo Electric Power Company [TEPCO], *TEPCO Illustrated 2011*, Tokyo, TEPCO, 2011, available at <http://www.tepco.co.jp/en/useful/pdf-3/11i_full-e.pdf> accessed 27 December 2013)

These nuclear reactor and demand characteristics combine to make nuclear power plants best suited to what is termed 'base-load' generation, where they operate

¹⁶ IEEJ, *APEC Energy Overview 2011*, p. 84.

relatively continuously until maintenance is required, as shown in Figure 4. Notably, nuclear power can also be used in off-peak demand periods to pump water into reservoirs for later use in hydro-electric power generation, increasing effective peak capacity. Japan also uses waste heat from nuclear power stations in water desalination and increasingly in the production of hydrogen using electrolysis during off-peak demand periods.¹⁷

Another highly attractive feature of nuclear power is the negligible CO₂ outputs produced. Emissions are generated in constructing and maintaining a plant but the actual generation of electricity does not produce GHG, as shown in Figure 5. While hydro-power and geothermal power are also low emissions sources, they are limited to relatively small and fixed capacities in Japan by the natural geography.

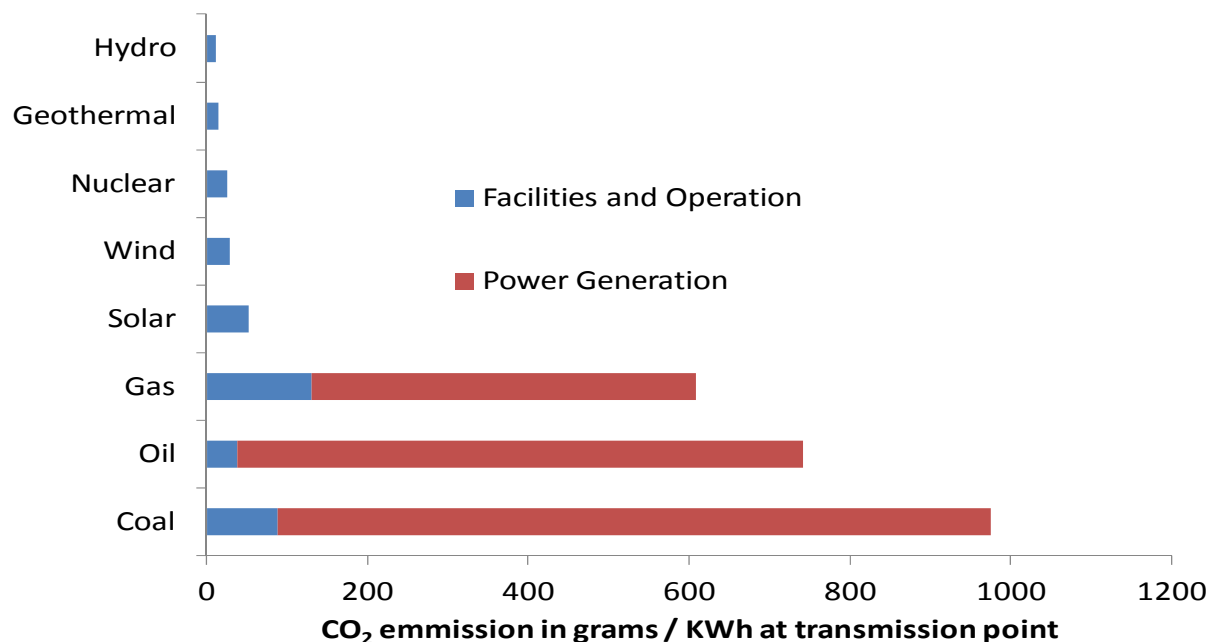


Figure 5 - Greenhouse Gas Emissions by Electricity Plant Type

(Source: ANRE, *Energy in Japan*, Tokyo, ANRE, 2011)

Another critical consideration in selecting electricity generation technology is the amortised total cost per unit of electricity produced. The 2004 comparative cost estimates published by IEEJ are shown in

¹⁷ Richard Stieglitz and Rick Docksai, 'Why the World May Turn to Nuclear Power', *The Futurist*, Vol. 43, No. 6, 2009, p. 22.

Table 1.¹⁸ Cost and low CO₂ emissions enabled the GOJ to advocate a strategy of growing nuclear energy reliance in its 2010 'Energy Strategy for Japan'.¹⁹

Generation Technology	Cost (yen / kWh)
Nuclear	5.3
Hydro	11.9
Oil	10.7
Gas	6.2
Coal	5.7

Table 1 – Traditional Assessment of Cost of Electricity by Generation Technology

(Source: IEEJ, *Asia/World Energy Outlook 2012*, Tokyo, IEEJ, 2012)

The GOJ considered that uranium supply chain dynamics made a valuable contribution to energy security, to the point where Japan, a country with no natural reserves, was prepared to designate nuclear power as a 'quasi-domestic' energy source.²⁰ The logic was that uranium can be purchased in a global commodity market with suppliers operating from established democratic states, such as Australia, Canada and the US, countries friendly to Japan.²¹ Uranium requires specialised processing and transport by sea; however, the resulting fuel is compact and has an essentially indefinite storage life. The diversity of sea lines of transportation makes effective military interdiction highly improbable. The Japanese nuclear industry includes a domestic uranium enrichment capability to further bolster energy security. Nuclear fuel demand can also be anticipated with significant

¹⁸ Yuji Matsuo, 'Summary and Evaluation of Cost Calculation for Nuclear Power Generation by the "Cost Estimation and Review Committee"', Tokyo, IEEJ, 2012, available at <<http://eneken.iej.or.jp/data/4337.pdf>>, accessed 13 May 2013, p. 1.

¹⁹ Trade and Industry Ministry of Economy (METI), 'The Strategic Energy Plan of Japan', Tokyo, METI, 2010, available at <http://www.meti.go.jp/english/press/data/pdf/20100618_08a.pdf>, accessed 27 May 2013, pp. 2-12.

²⁰ METI, *2010 Annual Energy Report*, Tokyo, Agency for Natural Resources and Energy, 2011, p. 11.

²¹ METI, *2010 Annual Energy Report*, p. 21.

accuracy, and stockpiles sufficient for several years of operation may readily be established to mitigate any supply chain reliability concerns.²²

Despite the consistent support for nuclear power within the GOJ, public opposition remained high due in large part to the disadvantages of nuclear power. Nuclear waste disposal remains a practical and emotive issue, with Japan's plans for a waste processing plant highly contested within the GOJ and by elements of the community near the Rokkasho reprocessing plant. The construction of this facility has also been hampered by construction delays and cost growth, making Japan largely reliant on contracted reprocessing in France and the UK.²³ Selection of a suitable site for long-term storage of high-level nuclear waste remains a politically-charged issue, with interim storage at nuclear plants being used until a final decision is made, heightening the safety risk at those plants. The GOJ has deferred this choice to as late as 2037.²⁴

The global nuclear safety record was also a cause for public concern in Japan.²⁵ Nuclear accidents are similar to aircraft crashes, in that they are actually infrequent but highly publicised. A number of high-profile international and domestic nuclear incidents, as shown in

Table 2, were instrumental in damaging the already poor public perception of nuclear safety in Japan.²⁶ Not all were technically nuclear accidents but negative opinion was readily reinforced and a climate of scepticism towards the integrity of

²² This argument will be revisited later in the paper in the context of the plutonium breeder program analysis, where the GOJ position may appear incongruous.

²³ Shaun Burnie and Smith Aileen Mioko, 'Japan's Nuclear Twilight Zone', *Bulletin of the Atomic Scientists*, Vol. 57, No. 3, 2001, pp. 58-9.

²⁴ METI, 'Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste', Tokyo, METI, 2008, available at <http://www.meti.go.jp/english/report/data/Japan_mainpages.pdf>, accessed 30 May 2013, p. 79.

²⁵ Alexi Kral, 'Event Summary: are Japan's energy security ambitions misguided?', Washington DC, Woodrow Wilson Centre, 2000, available at <<http://www.wilsoncenter.org/event/are-japans-energy-security-ambitions-misguided>>, accessed 29 May 2013, p. 1.

²⁶ Mindy Kotler and Ian Hillman, 'Japanese Nuclear Energy Policy and Public Opinion', Houston, Center for International Political Economy and James A. Baker III Institute for Public Policy at Rice University, 2000, available at <<http://bakerinstitute.org/publications/japanese-nuclear-energy-policy-and-public-opinion>>, accessed 29 May 2013, pp. 3-5.

nuclear utilities and the transparency into GOJ regulatory and safety agencies was clearly emerging.²⁷

Date	Location	Description
28 March 1979	Three Mile Island, Pennsylvania, United States	Loss of coolant and partial core meltdown due to operator errors. There is a small release of radioactive gases.
26 April 1986	Chernobyl, the Soviet Union	Operator error leads to overheating, steam explosion, fire and meltdown, necessitating the evacuation of 300,000 people from Chernobyl and dispersing radioactive material across Europe. Fifty six workers were killed, and radiation affects as many as 300,000.
8 December 1995	Tsurgua, Japan	Sodium leak from experimental reactor, initially covered up by operator. Public scandal, delay in reactor development, one official commits suicide.
30 September 1999	Ibaraki prefecture, Japan	Tokaimura nuclear accident involved the accidental achievement of critical mass during spent fuel reprocessing. Two workers died with another exposed to radiation above permissible limits.
25 September 2002	Fukushima and Niigata prefectures, Japan	TEPCO fails to act on or disclose cracking in shrouds around nuclear reactors, public outcry, no actual nuclear incident. Seventeen reactors closed for extended maintenance, protracted impacts. Particularly damaging for public confidence, given the negative safety culture at TEPCO. ²⁸
9 August 2004	Fukui prefecture, Japan	Steam explosion at Mihama nuclear power plant kills 4 workers and injures 7. Not strictly a nuclear accident but distinction is generally lost.
16 July 2007	Niigata prefecture, Japan	Magnitude 6.8 quake damages Kashiwazaki-Kariwa plant, which is revealed to be located on a fault line, releasing radioactive contamination into the sea. ²⁹

Table 2 - Selected Nuclear Incidents to 2010

²⁷ Stephen Barker, 'Fast Reactor Leak Hits Nuclear Safety Image', *Nature*, Vol. 378, No. 6558, 1995, p. 654; David Swinbanks, 'Sodium Leak Blots Japan's Nuclear Prospects', *Nature*, Vol. 379, No. 6562, 1996, p. 196.

²⁸ 'Business: Darkness Falls on Tokyo; Japan's energy crisis', *The Economist*, Vol. 368, Issue 8333, 2003, p. 57.

²⁹ David Cyranoski, 'Quake Shuts World's Largest Nuclear Plant', *Nature*, Vol. 448, No. 7152, 2007, p. 392.

Despite the growing opposition, Japan's energy policy in 2010 assumed a growth in nuclear power to 40 per cent of the electricity demand through construction of eight additional plants by 2017 and a further six by 2030, as well as an improvement in the efficiency of all plants. Demand for electricity was planned to be constrained by extension of one of the most effective national energy efficiency programs, especially in the residential and commercial sectors. Overall, this was anticipated to retain Japan's world-leading position in GHG reduction and enhance energy security to acceptable levels. Japan's nuclear 2010 power plant location and disposition is summarised in Figure 6.

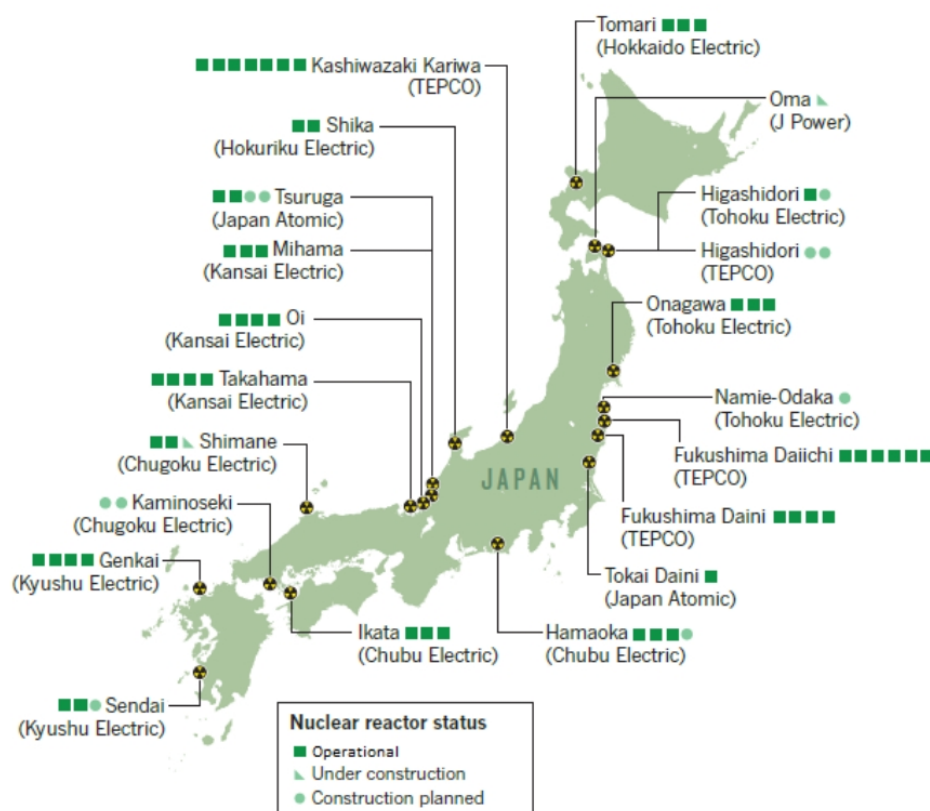


Figure 6 - Status of Nuclear Reactors in Japan at the end of 2010

(Source: Jeff Tollefson, 'Japan faces power struggle', *Nature*, Vol. 472, No. 7342, 2011, pp. 143-4.

Energy independence – the dream of a closed nuclear fuel cycle

The most common nuclear reactor fuel strategy is based on using uranium a single time. This nuclear fuel cycle involves the mining, separation and enrichment of uranium, where the proportion of U^{235} is then increased from the 0.711 per cent abundance in naturally-occurring material.³⁰ Japan's electrical power generation reactors were all constructed to use low enriched uranium (LEU) with 4 per cent U^{235} . By contrast, weapons grade uranium is enriched to more than 90 per cent U^{235} and is extremely radioactive, while advanced nuclear weapons utilise plutonium exclusively.

A typical 1 GW nuclear reactor core contains 75 tonnes of LEU, of which around 25 per cent is replaced every 18 months to maintain optimal performance.³¹ The 54 reactors in Japan at the end of 2010 required approximately 675 tonnes of LEU each year. While this may appear an onerous requirement, a single tonne of LEU generates the same energy output as 20,000 tonnes of black coal or 8.5 million m³ of gas. As Japan has no useful reserves of natural uranium, nuclear fuel is another external energy dependency despite its 'quasi-domestic' status noted earlier. This external dependency may go some way to explaining an internationally unique element of Japan's nuclear fuel cycle strategy.

The process of nuclear fission using LEU taking place in power reactors generates another potential fuel cycle option. Spent reactor fuel includes a number of exotic radioactive products which were not present in the original LEU. This process ultimately limits the performance of the reactor and drives LEU replenishment. In the 'single cycle' process, the spent fuel is processed and stored as radioactive waste. A significant quantity of plutonium is actually created from U^{238} during the reactor burn cycle. Plutonium can be separated for use in nuclear weapons or it can be re-used as fuel for nuclear reactors. A specially configured reactor can generate electricity using mixed oxide (MOX) fuel, where the U^{235} is replaced by plutonium. The quantity of plutonium recovered from spent LEU fuel is useful but typically

³⁰ Data in this paragraph from World Nuclear Organisation, 'Uranium and Depleted Uranium', London, World Nuclear Organisation, 2009, available at <<http://www.world-nuclear.org/info/Nuclear-Fuel-Cycle/Uranium-Resources/Uranium-and-Depleted-Uranium/#.UacoyNIwd8k>>, accessed 30 May 2013, pp. 1-5.

³¹ World Nuclear Organisation, 'The Nuclear Fuel Cycle', London, World Nuclear Organisation, 2012, available at <<http://www.world-nuclear.org/info/Nuclear-Fuel-Cycle/Introduction/Nuclear-Fuel-Cycle-Overview/#.UacsTtIwd8k>>, accessed 30 May 2013, pp. 1-6.

insufficient to provide a true closed-fuel cycle where a finite amount of fuel is re-used indefinitely.³²

There is another approach which is much closer to a closed-fuel cycle. A specially designed 'breeder' reactor, which uses more highly-enriched uranium and operates at a markedly higher temperature, will produce more plutonium. One key issue with breeder reactors is their high operating temperature, which in the Japanese design necessitates cooling via sodium, a highly-volatile metal which combusts on contact with air or water and introduces significant operational risks. The advantage of a breeder reactor strategy is that in principle, with complex re-processing, nuclear fuel can be re-utilised indefinitely.³³

Japan pursued closed-fuel cycle research in close partnership with the US from the 1960s. At this time, the international marketplace for uranium was immature and there was a very significant global demand for nuclear material as the two superpowers stockpiled nuclear weapons. As such, there was a rational interest in breeder technology, and research programs existed in the US, Japan, Russia, UK, France and Germany. By 1985, the GOJ sought to put its research into limited operation by construction of the Monju breeder reactor. This reactor would produce a relatively insignificant 28MW of electricity but would demonstrate the industrial production of plutonium. Based on achieving this milestone, the GOJ then planned to construct larger breeder and re-processing plants to supply the necessary MOX fuel for the entire country.

The global nuclear arms race ended in 1989, just as the international uranium marketplace was maturing, so the cost of LEU plummeted. The US and Russia agreed to markedly reduce their nuclear arsenals, which generated a significant stockpile of HEU and plutonium.³⁴ They agreed to use the excess weapons material as nuclear fuel, blending the HEU back down to LEU and using the plutonium in MOX, which would in time see them both converted to spent fuel, from which it is much more difficult to extract plutonium. Most of the resulting nuclear fuel was agreed to be used in the US domestic electricity generation sector, depressing the

³² World Nuclear Organisation, 'Mixed Oxide (MOX) Fuel', London, World Nuclear Association, 2013, available at <<http://world-nuclear.org/info/Nuclear-Fuel-Cycle/Fuel-Recycling/Mixed-Oxide-Fuel-MOX/#.Ub6x6Ocwd8k>>, accessed 17 June 2013, p. 1.

³³ In practice, the breeder process requires the addition of some uranium, albeit this is a very small fraction of the fuel otherwise required.

³⁴ John Holdren, John Ahearne, Richard Garwin, Wolfgang Panofsky, John Taylor, and Matthew Bunn, 'Excess Weapons Plutonium: how to reduce a clear and present danger', *Arms Control Today*, Vol. 26, No. 9, 1996, pp. 2-4.

international price of uranium. All nations other than Japan and Russia suspended breeder reactor commercialisation due to the plentiful supply of nuclear fuels.³⁵

The re-processing of spent nuclear fuel provides material suitable for nuclear weapon development. As such, technology for re-processing is highly proscribed under the Nuclear Non-Proliferation Treaty (NPT), second only to transfer of plutonium and HEU. This 1968 treaty was designed to block the spread of nuclear weapons beyond the original countries: US, Russia, China, UK and France. As a high-technology nation with an advanced nuclear power industry and organic missile technology, Japan today has many of the ingredients already in place to become a nuclear-armed state.

In theory, having the nuclear-armed states of China and North Korea as regional neighbours would suggest that it might be logical for Japan to develop organic nuclear deterrence, were it not for the US nuclear umbrella.³⁶ President Eisenhower established a security treaty in 1960 that meant in effect nuclear attacks on Japan would be considered attacks on the US, with the intent in part to preclude the need for an organic nuclear weapons program in Japan.³⁷ This is especially important given Japan's relatively poor security relationship with South Korea, the only powerful neighbour with relatively-aligned geostrategic interests, which leaves Japan with no close regional allies.³⁸

A number of significant barriers exist to a nuclear-armed Japan, including a pacifist post-war constitution, a highly adverse domestic public opinion and a strict external monitoring regime implemented by the International Atomic Energy Agency (IAEA), a body of the UN.³⁹ Japan was actually working on a nuclear weapons program during World War 2 but was unable to amass enough fissile material, ironically in part due to limitations on the energy available to power the cyclotrons

³⁵ Research work on fast neutron reactors, which may operate as breeders, continued in China, Russia, France and the US.

³⁶ Toshimaru Ogura and Ingyu Oh, 'Nuclear Clouds over the Korean Peninsula and Japan', *Monthly Review*, Vol. 48, No. 11, 1997, pp. 1-7.

³⁷ Yuri Kase, 'Japan's Non-nuclear Weapons Policy in the Changing Security Environment: issues, challenges, and strategies', *World Affairs*, Vol. 165, No. 3, 2003, p. 123.

³⁸ Kevin J. Cooney and Alex Scarbrough, 'Japan and South Korea: can these two nations work together?', *Asian Affairs, an American Review*, Vol. 35, No. 3, 2008, pp. 173-5.

³⁹ IAEA, 'Promoting Nuclear Security: what the IAEA is doing', Vienna, IAEA, 2013, available at <<http://www.iaea.org/Publications/Factsheets/English/nucsecurity.pdf>>, accessed 10 May 2013, p. 1. Also IAEA, 'Nuclear Safety Review for the Year 2012', Vienna, IAEA, 2012, available at <http://www.iaea.org/About/Policy/GC/GC56/GC56InfDocuments/English/gc56inf-2_en.pdf>, accessed 10 May 2013, pp 1-2. And IAEA, 'Safeguards Legal Framework', Vienna, IAEA, 2013, available at <<http://www.iaea.org/safeguards/framework.html>>, accessed 21 June 2013, p. 1.

and also due to the impact of allied air raids.⁴⁰ Opinion within the GOJ has historically been opposed to adopting nuclear weapons, in part because of the US assumption of the security guarantor role but also out of genuine pacifist sentiment and practical considerations like cost.⁴¹

One early exception was the view by Japanese Prime Minister Kishi in 1957 that the constitution 'didn't specifically preclude defensive nuclear weapons', albeit this view was never widely embraced.⁴² As the only nation ever subject to atomic attack, the Japanese population has perhaps the most ardently anti-nuclear weapons opinion in the world. In a small aberration, Vice-Minister Shingo Nishimura of the Japan Defense Agency expressed a 'personal' view in 1999 that Japan ought to develop nuclear arms, which necessitated his immediate resignation after a massive outcry in the population and the GOJ.⁴³ Overall, Japan retains the strongest anti-nuclear weapon sentiment in the world.

Despite the formal position that Japan does not possess nuclear weapons, a number of factors cause regional and international concern about that possibility. Japan is the only nation without nuclear weapons to have a spent fuel reprocessing capability. Japanese holdings of plutonium continue to grow as spent fuel is reprocessed internationally. In an effort to address regional concerns about plutonium stockpiles and the continued delays in domestic reprocessing facilities, the GOJ articulated a policy of 'minimum plutonium holdings', where spent fuel was processed abroad and stored beyond direct Japanese control.⁴⁴ By 2010, Japan had amassed over 35 tonnes of plutonium by reprocessing spent fuel in France and the UK,⁴⁵ and also held

⁴⁰ Kim Dong-Won, 'Yoshio Nishina and Two Cyclotrons', *Historical Studies in the Physical and Biological Sciences*, Vol. 36, No. 2, 2006, p. 266.

⁴¹ Toshi Yoshihara and James R. Holmes, 'Thinking About the Unthinkable: Tokyo's nuclear option', *Naval War College Review*, Vol. 62, No. 3, 2009, p. 16.

⁴² Douglas MacArthur, 'Telegram From the Embassy in Japan to the Department of State', Tokyo, US State Department, 1957, available at <<http://www.history.state.gov/historicaldocuments/frus1955-57v23p1/d132>>, accessed 21 June 2013, p. 1.

⁴³ Kase, 'Japan's Non-Nuclear Weapons Policy in the Changing Security Environment', p. 124.

⁴⁴ Japan Atomic Energy Commission, 'Framework for Nuclear Energy Policy', Tokyo, Japan Atomic Energy Commission, 2005, available at <http://www.aec.go.jp/jicst/NC/tyoki/taikou/kettei/eng_ver.pdf>, accessed 16 May 2013, p. 10.

⁴⁵ IAEA, 'Communication received from Japan Concerning its Policies Regarding the Management of Plutonium', Vienna, IAEA, 2012, available at <<http://www.iaea.org/Publications/Documents/Infcircs/2011/infcirc549a1-14.pdf>>, accessed 1 May 2013, pp. 2-3.

9.9 tonnes of plutonium at home.⁴⁶ This holding is frequently cited as a violation of the GOJ's plutonium policy and a practical basis on which to develop nuclear weapons, even using only the 9.9 tonnes actually located in Japan. Despite this, even 9.9 tonnes of plutonium could be used to create 9900 nuclear weapons each with a yield of 20 million tonnes of TNT.⁴⁷

The development of Japan's breeder reactor program has continued with no obvious relationship to nuclear fuel cost or other clear economic basis, further exacerbating international concerns at the intent of the breeder program. While the major changes in global nuclear fuel strategy were occurring from 1980 to 2000, construction at Monju experienced a number of technical setbacks and the project cost rose. When the reactor was finally brought on-line, a major sodium leak, fire and cover-up in 1995 further damaged the reputation of the Japanese nuclear industry and regulator.⁴⁸ Monju remained off-line for over a decade while the GOJ considered its policy.⁴⁹ All the while, reactors in Japan continued to burn LEU, generating tonnes of spent nuclear fuel which could not be re-processed in Japan due to delays in the Rokkasho reprocessing plant. In 2005, the GOJ elected to continue work on Monju, which resumed operation in 2010 and the development was progressing at the time of the Fukushima disaster.⁵⁰ Only four reactors in Japan were able to utilise MOX fuel and the combined breeder/reprocessing programs would only increase the size of the plutonium stockpile.⁵¹ The very lack of a clear economic case for breeder

⁴⁶ International Panel on Fissile Materials, 'Global Fissile Material Report 2011 Nuclear Weapon and Fissile Material Stockpiles and Production', New Delhi, International Panel on Fissile Materials, 2011, available at <<http://fissilematerials.org/library/gfmr11.pdf>>, accessed 4 July 2013, p. 23.

⁴⁷ Thomas Cochran and Christopher Paine, 'The Amount of Plutonium and Highly Enriched Uranium Needed for Pure Fission Nuclear Weapons', Washington DC, The Natural Resources Defense Council, 1995, available at <<http://www.nrdc.org/nuclear/fissionw/fissionweapons.pdf>>, accessed 17 June 2013, p. 12.

⁴⁸ Swinbanks, 'Sodium Leak Blots Japan's Nuclear Prospects', p. 196.

⁴⁹ David Cyranoski, 'Japan Pins Hopes on Fast-Breeder Nuclear Option', *Nature*, Vol. 408, No. 6814, 2000, p. 759.

⁵⁰ Ichiko Fuyuno, 'Agency to Bring Fast-Breeder Reactor out of Mothballs', *Nature*, Vol. 434, No. 7029, 2005, p. 6.

⁵¹ Masafumi Takubo and Frank von Hippel, 'Ending the Separation of Plutonium: an alternative approach to the management of Japan's spent nuclear fuel', Princeton, New Jersey, International Panel on Fissile Materials, 2013, available at <<http://fissilematerials.org/library/Japan-Roadmap-14-May-2013.pdf>>, accessed 2 July 2013, p. 1.

technology, given the plentiful global supply of nuclear fuel, made Japanese insistence on using the technology all the more suspicious regionally.⁵²

The reality in Japan at the end of 2010

Energy policy in Japan is influenced by a unique set of relationships between government and industry. While the GOJ had been a stable democratic and representative institution since World War 2, this masks an underlying lack of concentrated political authority on key challenges, a lack of strategic debate on policy and an inability to progress contentious issues quickly. In practice, a single conservative party effectively ruled Japan since 1955.⁵³ The Liberal Democratic Party of Japan (LDP) operates as a centre-right conservative party, with tendencies to nationalism and a strong affinity for the role of the Emperor in Japanese society. Electoral processes have tended to produce marginal mandates and changes of Prime Minister are routine. The Japanese place significant cultural value on consensus in an electoral and party system which does not have a strong tradition of executive power in the office of the Prime Minister or the cabinet. This tends to empower the ministries of government and cedes relative power to key industries and major companies, especially the highly inter-related manufacturing and energy sectors.

The capacity of the GOJ to adopt a strategic nuclear energy goal in defiance of popular opinion needs to be understood in terms of the institutional power beyond the parliament, not the strong leadership within it. Conversely, the GOJ has controlled the nature of the nuclear energy strategy effectively enough to insist on a closed-fuel cycle even when the commercial rationality of this course of action has long vanished.⁵⁴ By 2010, the GOJ was moving on regulatory reform but had much to do in labour generally and electricity more specifically,⁵⁵ albeit the increasingly independent commercial mindset within electrical power companies was leading to

⁵² Asako Saegusa, 'Japan's Fast-Breeder Loses Money Fast Too', *Nature*, Vol. 399, No. 6733, 1999, p. 191. Also Kenneth Solomon, 'Plutonium for Japan's Nuclear Reactors Paying Both the Proliferation and Dollar Price to Assure Long Term Future', Santa Monica, Rand Corporation, 1993, available at <http://www.rand.org/pubs/monograph_reports/MR186.html>, accessed 21 June 2013, pp. 3-5.

⁵³ The Democratic Party of Japan was in power for one year straddling 1993 and 1994, and again from 2009 to 2012.

⁵⁴ Saegusa, 'Japan's Fast-Breeder Loses Money Fast Too', p. 191.

⁵⁵ Steven Vogel, 'Why Freer Markets Require More Rules', in Marc Landy, Martin Levin and Martin Shapiro (eds.), *Creating Competitive Markets: the politics of regulatory reform*, Washington DC, Brookings Institution Press, 2007, p. 31.

significant tensions on the wisdom of the breeder strategy and domestic re-processing capacity, given the significantly higher cost than a 'once through' fuel cycle.⁵⁶

The Japanese government is relatively unique in affluent Western democracies in being both highly bureaucratic by international standards and also very closely engaged in the direction of banking, finance and strategic industries.⁵⁷ Ministries of the GOJ directed the formulation of domestic marketplaces, carefully managing the degree to which competition operated, through segregation of domestic markets and erection of barriers to external competitors. Their authority to do so was informal, built on shared cultural ideals of Japanese autonomy and conventions about how senior bureaucrats transitioned to industry and regulatory bodies. In a practice known as *Amakudari* (descent from heaven), senior public servants transitioned to equivalent roles in industry, ensuring extremely close relationships.⁵⁸ While the practice of *Amakudari* occasionally generated some scandal, legislative and regulatory efforts to abolish the practice were marred by consistently lax enforcement.⁵⁹ In the extreme, agencies of the GOJ provided *Gyoseishido* (administrative guidance) to control business strategy development and execution, creating cartels and protecting sectors of industry.⁶⁰ Given the complexities of nuclear science and policy, the technical skills required are significant and industry plays an important role, along with academia, in providing expert advice to government. This practice created an unhealthy symbiosis between MITI (later METI) and the energy industry which ensured that nuclear safety regulation was prejudiced by a lack of impartial oversight.⁶¹

In the case of the electricity industry, the effects were profound. Electricity generation in Japan was initially organised as a state-run utility as part of the war reconstruction effort, evolving into highly-regulated operations that were only quasi-commercial at best. To illustrate the scale of the problem, the *Asahi* newspaper

⁵⁶ Takubo and von Hippel, 'Ending the Separation of Plutonium', p. 6.

⁵⁷ Peter Ferdinand, *Governance in Pacific Asia: political economy and development from Japan to Burma*, London, Continuum International, 2012, pp. 94-8.

⁵⁸ Tetsuro Mizoguchi and Nguyen Van Quyen, 'Amakudari: the post-retirement employment of elite bureaucrats in Japan', *Journal of Public Economic Theory*, Vol. 14, No. 5, 2012, pp. 816-9.

⁵⁹ Chalmers Johnson, *Japan: who governs? The rise of the developmental state*, New York, Norton & Company, 1995, p. 143.

⁶⁰ Carpenter, *Why Japan Can't Reform*, p. 71.

⁶¹ Yoichi Funabashi and Kay Kitazawa, 'Fukushima in Review: A complex disaster, a disastrous response', *Bulletin of the Atomic Scientists*, Vol. 68, No. 2, 2012, p. 12.

documented an investigation of the petroleum industry in 1974 which disclosed that most oil companies in Japan employed more than 50 former senior MITI officials (director level or above).⁶² By regulatory facilitation of geographically-based areas of exclusive supply, the GOJ created a set of ten companies with geographic monopolies on electricity supply, which ensured that Japan experienced some of the most inefficient networks and expensive electricity prices in the world by the 1980s.⁶³ In addition, a perverse historical arrangement meant that Japan was divided into two incompatible electricity supply regions of different operating frequency. In the east of Japan, including Tokyo, the grid operates at 50Hz, while in the west 60Hz power is used. While this would not affect the performance of some domestic equipment, this frequency difference affects industry and limited the ability of the national grid to effectively share power around the country in times of need.⁶⁴ At the end of 2006, less than 1GW of electrical power could be transferred between the eastern and western networks, greatly limiting emergency response options.⁶⁵ The resultant network arrangements are shown in Figure 7.

⁶² Johnson, *Japan*, pp. 154-5.

⁶³ Toru Hattori, Tooraj Jamasb and Michael Pollitt, 'Electricity Distribution in the UK and Japan: a comparative efficiency analysis 1985-1998', *The Energy Journal*, Vol. 26, No. 2, 2005, pp. 3-6.

⁶⁴ Kensuke Kanekiyo, 'Japan Energy Brief No. 12', Tokyo, IEEJ, 2011, available at <<http://eneken.ieej.or.jp/>>, accessed 1 July 2013, p. 2.

⁶⁵ Hiroshi Asano, 'Regulatory Reform of the Electricity Industry in Japan: what is the next step of deregulation?', *Energy Policy*, Vol. 34, No. 16, 2006, p. 5.

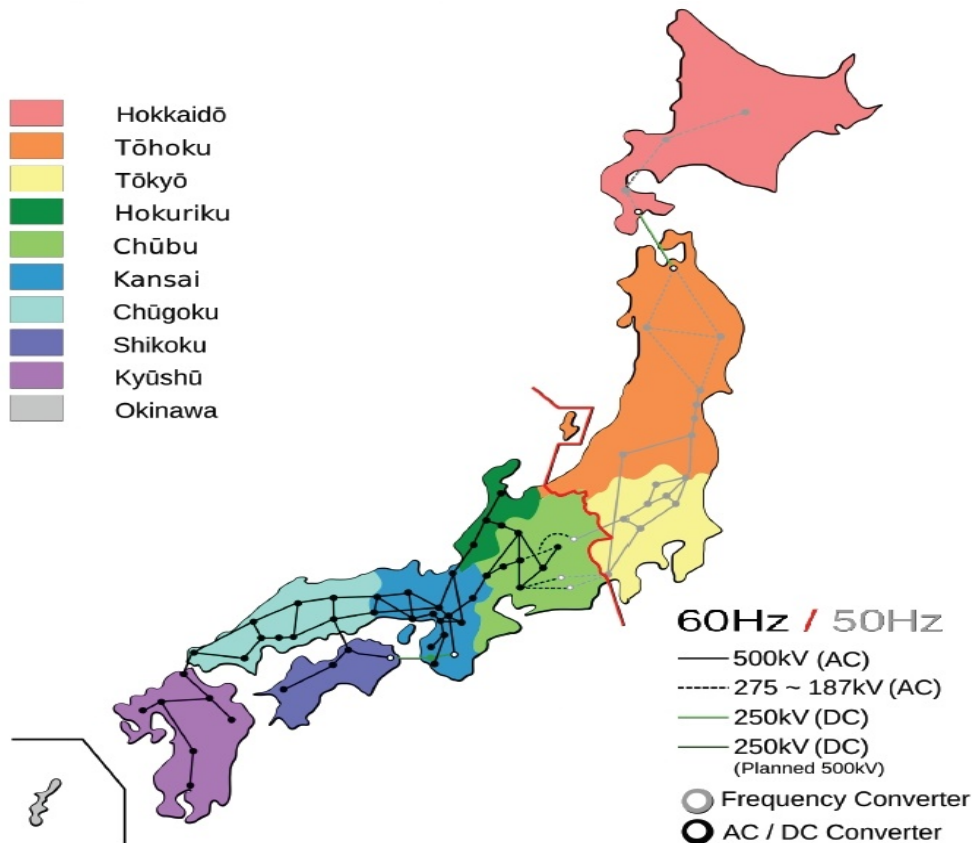


Figure 7 - Japan's Segregated Retail Electricity Markets, Transmission Lines and Areas of Supply Frequency

(Source: METI, with adjustments by the author)

In a rational response to the network and geographical segmentation, Japanese utilities tended as in the US to each develop generation capacity consistent with their peak load scenarios and there was also little or no effective strategic facilitation of investment planning for electricity transmission network development.⁶⁶ In comparison to other developed nations, the GOJ was very late to act to establish a unified electrical network or to promote effective competition for electricity, perhaps out of fear of the failure seen in some markets to competitively reconcile supply and demand.⁶⁷ The resultant monopolies were very effective in funding the nuclear infrastructure, which was being sponsored by the GOJ but hampered electricity system development and inflicted significant economic penalties on Japan, as consumers were subject to some of the highest global electricity prices.

⁶⁶ Richard O'Neill and Udi Helman, 'Regulatory Reform of the US Wholesale Electricity Markets', in Landy, Levin and Shapiro, *Creating Competitive Markets*, pp. 129-33.

⁶⁷ Asano, 'Regulatory Reform of the Electricity Industry in Japan', pp. 4-6.

The health of the Japanese economy has also been a significant factor in the energy security strategies adopted by the GOJ. Japan's remains the world's third largest but stagnated from the 1990s after a lengthy period of strong post-war growth.⁶⁸ The oil price shocks of 1973 and 1979 had a significant impact on the Japanese economy, given the heavy dependence at that time on imported oil for 78 per cent of total energy.⁶⁹ A real-estate boom in the 1980s was the apex of post-war economic growth; however, the 1991 collapse in property prices exposed poor risk management and regulatory failures in the banking sector.⁷⁰ From the mid 1970s, international experts in economics and governance had begun to expose the true risks inherent in how the GOJ and industry were collaborating to drive the economy⁷¹ but institutional and cultural reforms on the necessary scale proved very difficult while prosperity ensued. As economic stagnation became persistent, criticisms became more strident⁷² and directly implicated weakness of the Diet, strength of the bureaucracy and the entanglement with industry⁷³ but little actual institutional reform occurred due to the complex and entrenched nature of the dysfunctional relationships. As a result, economic policy was ineffectual, trade barriers remained firmly in place and the fundamental underpinnings of credit, competition and productivity remained flawed within Japan. Figure 8 demonstrates the plateau effect in Japan's real GDP, showing the stagnation and contraction effects. The Japanese government was slow to reform banking regulations for fear of further short-term economic impacts, leading to a lengthy period of stagnation and contraction from the mid 1990s. The Asian financial crisis exacerbated the situation in Japan, as did underlying demographic problems, including ageing of the population and constrictive labour practices.⁷⁴ Japan's economy had yet to recover to sustained growth by 2010, limiting GOJ revenues, impacting industrial profitability and impacting projected standards

⁶⁸ Takeo Hoshi and Anil K. Kashyap, 'Japan's Financial Crisis and Economic Stagnation', *The Journal of Economic Perspectives*, Vol. 18, No. 1, 2004, pp. 3-10.

⁶⁹ Duffield, 'The Return of Energy Insecurity in the Developed Democracies', p. 4.

⁷⁰ Mariko Fujii and Masahiro Kawai, 'Lessons from Japan's Banking Crisis, 1991-2005', Asian Development Bank Institute, 2010, available at <<http://www.adbi.org/files/2010.06.29.wp222.lessons.japan.banking.crisis.1991.2005.pdf>>, accessed 20 May 2013, pp. 2-8. Also David Weinstein, Anil Kashyap and Koichi Hamada, *Japan's Bubble, Deflation, and Long-term Stagnation*, Cambridge, MIT Press, 2011, pp. 47-8.

⁷¹ Chalmers Johnson, 'Japan: who governs? An essay on official bureaucracy', *Journal of Japanese Studies*, Vol. 2, No. 1, 1975, p. 3.

⁷² Richard Katz, *Japan: the system that soured: The rise and fall of the Japanese economic miracle*, New York, Armonk, 1998, pp. 1-20.

⁷³ Chalmers Johnson, 'The Institutional Foundations of Japanese Industrial Policy', *California Management Review*, Vol. 27, No. 4, 1985, p. 2.

⁷⁴ Ferdinand, *Governance in Pacific Asia*, pp. 201-5.

of living.⁷⁵ Government debts had risen to an OECD record of over 200 per cent of GDP, albeit most debt holders were domestic so the likelihood of precipitous action by creditors on the borrowings was low.⁷⁶

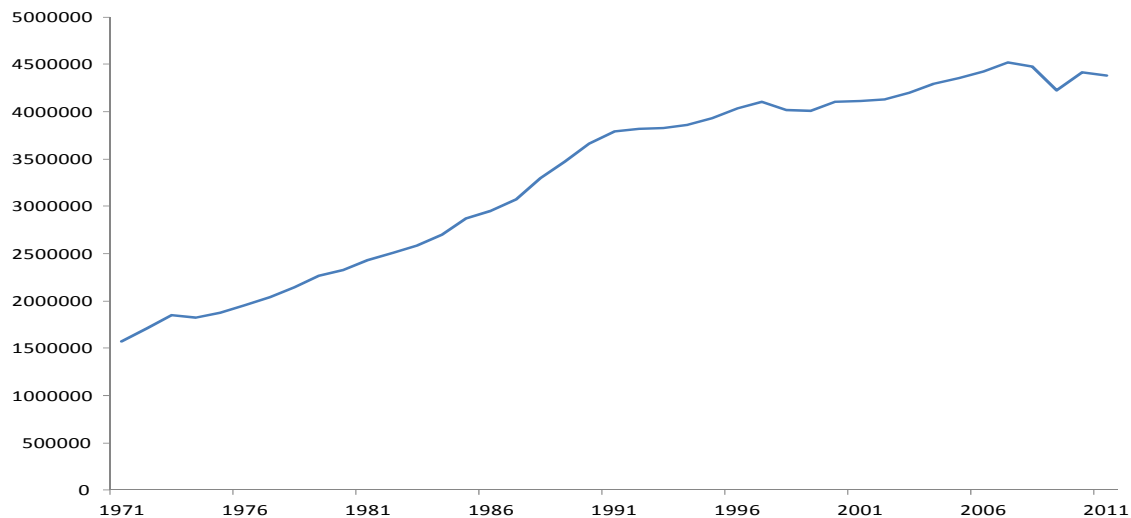


Figure 8 - Japan's Real GDP since 1971 in Millions of 2011 US\$

(Source: US Federal Reserve, see
<http://www.federalreserve.gov/econresdata/default.htm> accessed 27
 December 2013)

Japan's critical manufacturing sector, where the bulk of economic value is added, was particularly hard hit. Energy intensity in Japan was defined by heavy manufacturing industries, which were affected by difficulties with labour productivity and input energy pricing in particular. Figure 9 illustrates the stagnation of manufacturing sector growth.

⁷⁵ Jiyeoun Song, 'Japan's Labor Market Reform after the Collapse of the Bubble Economy: political determinants of regulatory changes', *Asian Survey*, Vol. 50, No. 6, 2010, p. 1031.

⁷⁶ Takeo Hoshi and Takatoshi Ito, 'Defying Gravity: how long will Japanese government bond prices remain high?', Indianapolis, Indiana University, 2011, available at http://www.indiana.edu/~econdept/workshops/Spring_2012_Papers/Hoshi.pdf, accessed 24 June 2013, p. 4.

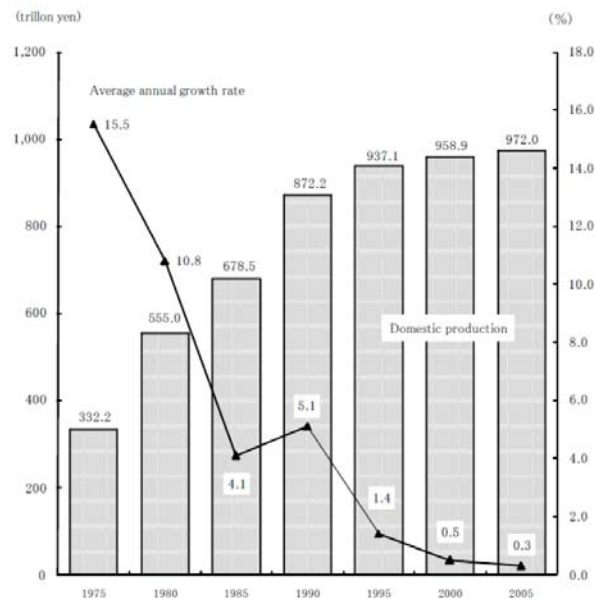


Figure 9 - Growth in Domestic Production in Japan

(Source: Ministry of Internal Affairs and Communications [Japan], available at <http://www.soumu.go.jp/english/> accessed 27 December 2013)

The international value of the Yen was also impacted by Japan's economic difficulties, with the currency generally failing to appreciate in line with historical trends. In Figure 10, the long-term change in the value of Yen can be seen, with the economic stagnation period from the 1980s clearly evident. The brief period of Yen appreciation engineered by the then-Vice Minister for Finance Eisuke Sakakibara in the period between 1990 and 1995 was overtaken by the economic impact of the Asian financial crisis, with some commentators suggesting that collaborative currency manipulation with the US actually contributed to that crisis.⁷⁷ As global oil is traded in US dollars, the appreciation of the Yen—which had helped make imported oil progressively cheaper in the 1960s and 1970s—effectively stopped by the 1980s, just as oil prices increased. The poor domestic economic situation was exacerbated by the high price of oil, which in turn negatively reinforced the economic situation but did prompt the efficiency and diversification of sources previously noted.⁷⁸ Given their economic difficulties and high borrowings, the GOJ

⁷⁷ Eisuke Sakakibara, 'Commanding Heights: the battle for the world economy', transcript of interview, Washington DC, Public Broadcasting Commission, 2001, available at http://www.pbs.org/wgbh/commandingheights/shared/miniextlo/int_eisukesakakibara.html accessed 5 November 2013, pp. 5-7.

⁷⁸ Alexandros Gasparatos and Tatiana Gadda, 'Environmental Support, Energy Security and Economic Growth in Japan', *Energy Policy*, Vol. 37, No. 10, 2009, pp. 4045-7.

had little appetite for major new investments and transferred significant proportions of the capital cost of energy programs, such as the Rokkasho reprocessing plant and the Monju breeder reactor, directly to the electricity generation utilities, relying on their cooperation to direct the commercial operations of the industry.

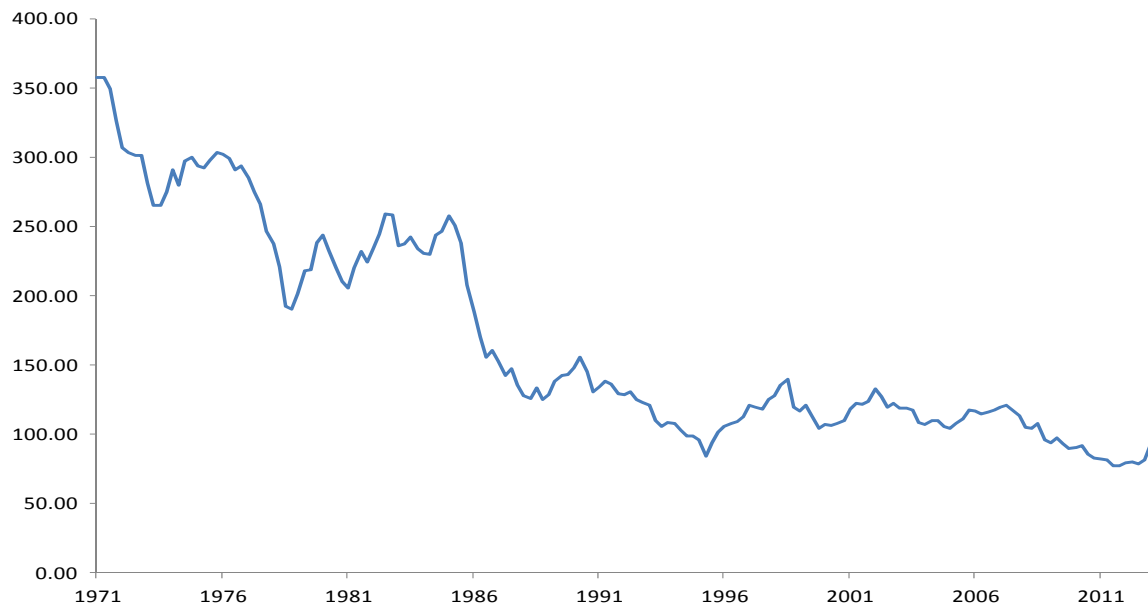
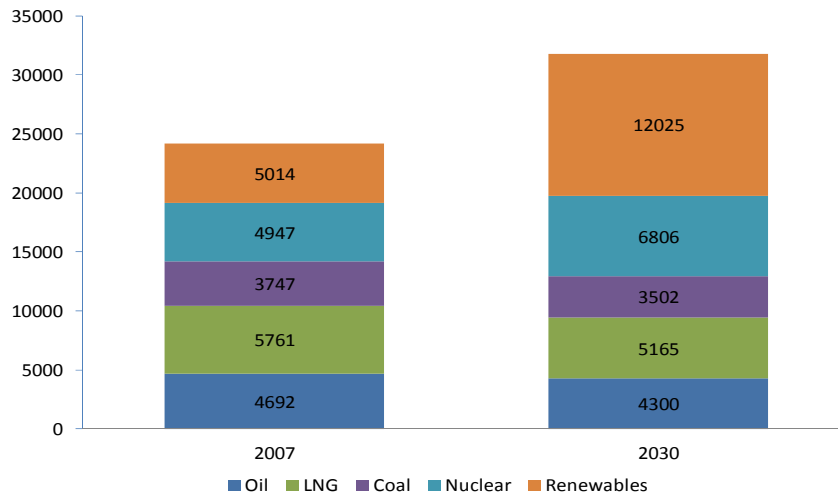


Figure 10 - Exchange rate, Yen to USD

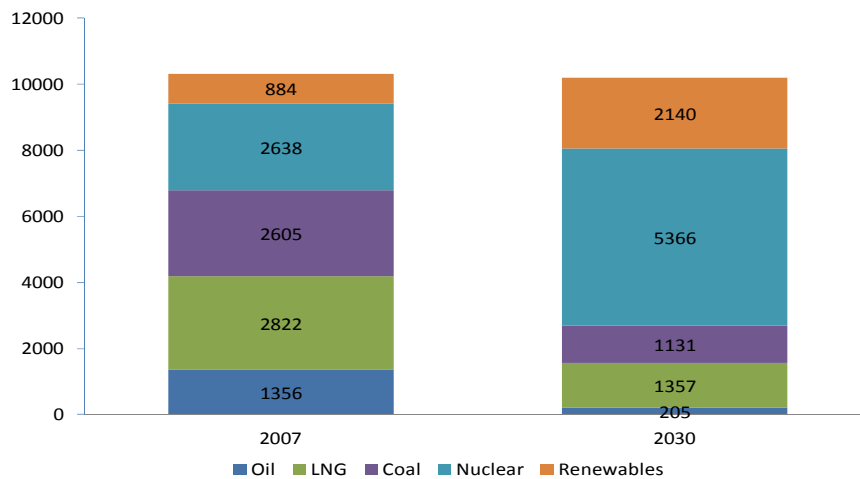
(Source: US Federal Reserve, see
<http://www.federalreserve.gov/econresdata/default.htm> accessed 27
 December 2013)

Japan's 2010 basic energy plan to 2030 is summarised in Figures 11 and 12, which show projected capacity to be constructed by 2030 and the expected generation output.⁷⁹ The plan projected the construction of very significant renewable energy capacity and 14 new nuclear reactors. It was also reliant on marked improvement in energy efficiency and economic restructuring to very slightly reduce total demand by 2030 and a large increase in the utilisation rate of nuclear plants. Interestingly, planned renewable and nuclear investments have a differing proportional contribution to actual energy generation as shown in **Error! Reference source not found.**, suggesting that—unlike nuclear plants—most renewable systems will routinely operate far under their peak capacity. The plan results in 70 per cent of electricity generation from nuclear and renewable sources, a major international contribution to GHG reduction.

⁷⁹ METI, 'The Strategic Energy Plan of Japan', pp. 3-12.



**Figure 11 - Japan's 2010 Basic Energy Plan:
Installed Electrical Capacity in 10,000 kW**
(Source: IEEJ)



**Figure 12 - Japan's 2010 Basic Energy Plan:
Projected Generation in 100 GWh**
(Source: IEEJ)

Fukushima triple tragedy and near-term effects

On 11 March 2011, an earthquake and subsequent tsunami killed more than 15,000 Japanese, injured over 3000 and triggered a significant emergency at the Fukushima Daiichi nuclear power plant.⁸⁰ The magnitude 9 earthquake occurred 70 kilometres east of Tōhoku and triggered a tsunami which swept inland up to 10 kilometres in some areas. The nearby Fukushima plant incorporated defences against earthquakes and tsunami, given Japan's location on the Pacific 'rim of fire' earthquake zone.

The initial quake severed the power supply connection from off-site. The three operating reactors automatically shut-down as intended after an earthquake, using power from local diesel generators; however, this is a lengthy process and requires substantial cooling.⁸¹ Across eastern Japan, several other nuclear plants shut down automatically according to their proximity to the quake, as shown in Figure 13.

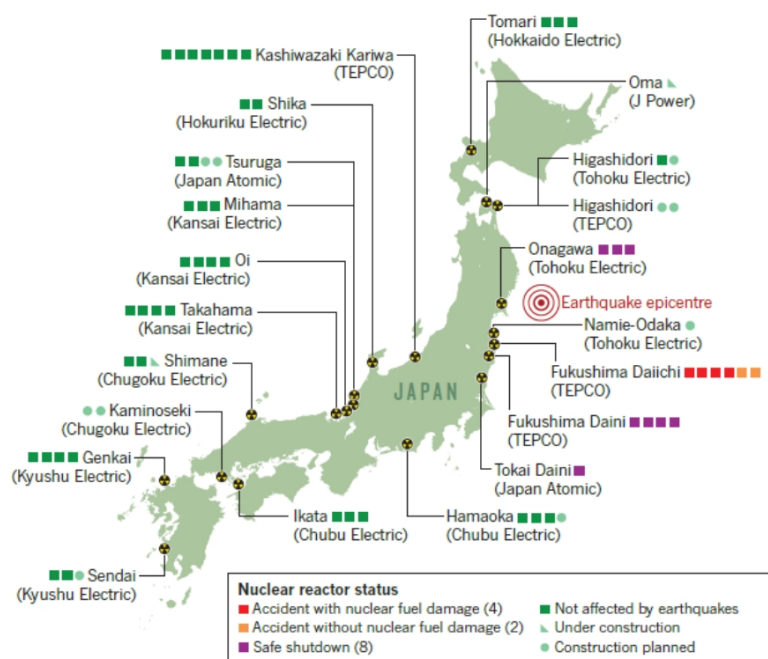


Figure 13 - Status of Nuclear power plants in Japan after Tohoku earthquake

(Source: Tollefson, 'Japan Faces Power Struggle', pp. 143-4)

⁸⁰ National Police Agency of Japan, 'Damage Situation ... associated with 2011 Tohoku ... Earthquake', media release, 2011, available at http://www.npa.go.jp/archive/keibi/biki/higaijokyo_e.pdf, accessed 26 June 2013, p. 1.

⁸¹ Although the plant had six reactors, three were inoperative undergoing routine inspections.

The tsunami arrived soon after and, at 14 metres tall, was significantly higher than the 4 metres that local breakwaters (see Figure 14) had been designed to resist.⁸² Flooding damaged the fabric of reactor and turbine hall buildings, immersed most back-up diesel generators, destroyed control rooms, damaged and dispersed emergency equipment, damaged most other infrastructure and covered the plant in debris.

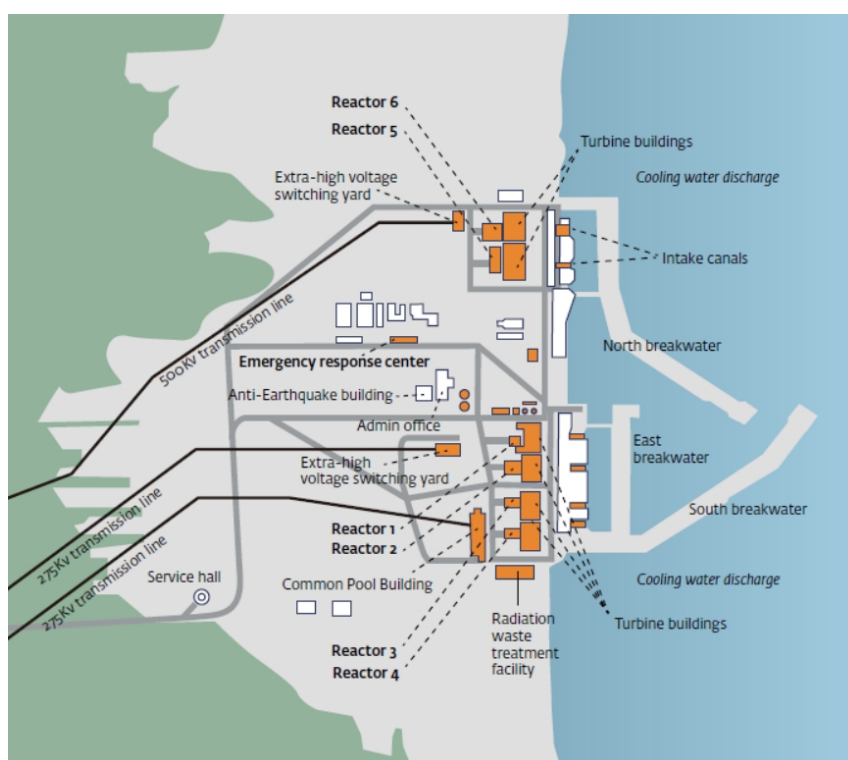


Figure 14 - Fukushima Daiichi Power Plant March 2011

(Source: GOJ, 'The Official Report of the Fukushima Nuclear Accident Independent Investigation Commission')

While the tsunami damage did not directly release radiation from the reactor vessels, by destroying the reactor cooling systems it set in motion the thermal run-away of four reactors over the next week, and all six reactors experienced major damage. The

⁸² GOJ, 'The Official Report of the Fukushima Nuclear Accident Independent Investigation Commission', 5 July 2012, pp. 13-4, available at <<http://reliefweb.int/report/japan/official-report-fukushima-nuclear-accident-independent-investigation-commission>> accessed 27 December 2013.

presence of significant quantities of spent fuel at the site only complicated the situation further, as these repositories also required ongoing cooling, a challenge foreseen after the Three Mile Island accident but not acted on in Japan.⁸³ Efforts to cool the three operational reactors failed in three cases and they each experienced partial melt-down of their fuel modules, leading to the production of hydrogen and a series of explosions which further devastated the facility.⁸⁴ Reactor four, although not operational at the time of the tsunami, had much of its fuel loaded and therefore also experienced a hydrogen explosion due to a cooling failure.

These chemical (not nuclear) explosions released significant quantities of radioactive materials, including iodine and caesium, which contaminated the local water table, atmosphere and sea. While there were no immediate casualties from radiation exposure, medium- and long-term health risk levels were materially increased.⁸⁵ The contaminants generally had a much shorter half-life than uranium but will require a significant clean-up on land, and some areas will not be suitable for human habitation for many years.⁸⁶ Damage to Japan's infrastructure for the entire earthquake and tsunami event was estimated by the GOJ at more than US\$200 billion, further weakening the Japanese economy.⁸⁷

The GOJ commissioned an independent review of the disaster, which was emphatic and far-sighted in its appraisal of the causal factors. The chair of the independent investigation, Dr Kiyoshi Kurokawa, was unusually frank in his appraisal of the organisational and cultural factors which led to the disaster, making it clear in his opening narrative that the severity of the natural disaster was greatly exacerbated by a number of human failings unique to Japan, saying:

What must be admitted—very painfully—is that this was a disaster 'Made in Japan'. Its fundamental causes are to be found in the ingrained conventions of Japanese culture: our reflexive obedience; our reluctance to question authority; our devotion to 'sticking with the program'; our ... [tendency to groupthink]; and our insularity. Had other Japanese been in the shoes of those who bear responsibility for this accident, the result may well

⁸³ Nick Pidgeon, 'In Retrospect: normal accidents', *Nature*, Vol. 477, No. 7365, 2011, p. 404.

⁸⁴ Nuclear fuel pellets are arranged in fuel rods made of zirconium, which when heated and exposed to oxygen (due to the loss of cooling water) will result in hydrogen generation.

⁸⁵ Talha Khan Burki, 'Fukushima: no Chernobyl', *Lancet Oncology*, Vol. 14, No. 4, 2013, p. 140.

⁸⁶ IAEA, 'Remediation of Large Contaminated Areas Off-site the Fukushima Dai-ichi NPP', Vienna, IAEA, 2011, available at <http://www.iaea.org/newscenter/focus/fukushima/final_report151111.pdf>, accessed 20 April 2013, pp. 24-51.

⁸⁷ Armand Vervaeck, 'Japan Tohoku Earthquake and Tsunami', CATDAT 41 report, Earthquake Report, Belgium, 2013, available at <<http://earthquake-report.com/2011/10/02/japan-tohoku-earthquake-and-tsunami-catdat-41-report-october-2-2011/>>, accessed 26 June 2013, p. 5.

have been the same. Following the 1970s 'oil shocks,' Japan accelerated the development of nuclear power in an effort to achieve national energy security. As such, it was embraced as a policy goal by government and business alike, and pursued with the same single-minded determination that drove Japan's post-war economic miracle. With such a powerful mandate, nuclear power became an unstoppable force, immune to scrutiny by civil society. Its regulation was entrusted to the same government bureaucracy responsible for its promotion. At a time when Japan's self-confidence was soaring, a tightly-knit elite with enormous financial resources had diminishing regard for anything 'not invented here'. This conceit was reinforced by the collective mindset of Japanese bureaucracy, by which the first duty of any individual bureaucrat is to defend the interests of his organization. Carried to an extreme, this led bureaucrats to put organizational interests ahead of their paramount duty to protect public safety.⁸⁸

The body of the independent report offered ample proof of collusion between regulators and industry, and a significant cultural willingness to ignore risks deemed unlikely to be realised, however significant their estimated consequences might have been. In particular, the closeness between the GOJ, the Nuclear and Industrial Safety Agency (NISA)⁸⁹ and the nuclear industry was seen as a major causal factor in permitting continued operation of Fukushima Daiichi when the plant was actually not constructed to withstand foreseeable natural disasters. Other nuclear facilities were also implicated as being potentially unsafe, especially the oldest reactor in Japan, which was located on an active fault line at Tsuruga and was subsequently closed permanently.⁹⁰ An investigative report developed by an eminent private Japanese foundation found that the wider disaster management responses were more effective and provided a roadmap for national recovery. The 'Restore Japan Foundation' report only reinforced the view that organisational and cultural causes at work in the nuclear power sector were unacceptable.⁹¹ The essential lesson was that international standards of reasonable safety analysis and design response in the nuclear industry had advanced but the lack of independent safety regulation had left Japan out of these developments.

Like other maturing technologies, best practice nuclear safety design will continue to evolve and there will be an ongoing cost of modernisation and obsolescence for

⁸⁸ GOJ, 'The Fukushima Nuclear Accident Independent Investigation Commission', p. 9.

⁸⁹ NISA was an arm of METI, which also had responsibility for economic policy and growth, which was proven to be an unreconcilable conflict of interest.

⁹⁰ Risa Maeda, 'Japan Takes First Step to a Permanent Reactor Shutdown after Fukushima', *Reuters*, Tokyo, 2013, available at <<http://www.reuters.com/article/2013/05/15/japan-nuclear-faultline-idUSL4N09X0JN20130515>>, accessed 17 June 2013, p. 1.

⁹¹ Yoichi Funabashi and Heizo Takenaka, 'Lessons from Japan's Disaster', London, Chatham House, 2012, available at <<http://www.chathamhouse.org/publications/papers/view/182634>>, accessed 19 June 2013,

fielded plants. First-generation boiling water reactors are not as safe as second-generation pressurised water reactors. Truly contemporary designs, such as the Westinghouse AP1000 which employ passive cooling, tend to fail-safe in the sense they go sub-critical when all power is lost.⁹² All extant Japanese nuclear reactors are dependent on active cooling, requiring a continuous electricity supply to operate water pumps. Some of the oldest boiling water reactor designs used in Japan may not be considered intrinsically safe enough by comparison with modern designs, so they may need to be retired.

Public anti-nuclear sentiment in Japan soared after the disaster, especially given the history of distrust of the government and the often incendiary role played by the domestic and international media on nuclear incidents.⁹³ There were allegations that the operator had sought to protect its assets at the plant rather than minimise the radiation discharge. Handling of public safety information by the GOJ was also problematic, albeit this was hampered by the concurrency and scale of the disasters.

The composition of electricity supply in Japan changed markedly as nuclear power plants went off-line during the disaster and a program of new safety inspections required lengthy shut-down of other nuclear plants.⁹⁴ Public opinion was such that most reactors were shut down after the disaster and only two were operational by mid 2013, albeit this was a policy choice not a technical necessity. Consumption of LNG rose by 20 per cent as thermal power plants sought to take up the former nuclear load, despite the reduction of net electricity demand by 4.7 per cent.⁹⁵ Power shortages and physical damage to plant and infrastructure affected the manufacturing sector and exports suffered; however, the steep increase in fossil fuel imports affected Japan's economy more significantly. The cost of LNG, oil and petroleum products imports from March 2011 onwards increased by 37.5, 21.3 and 39.5 per cent respectively.⁹⁶ Japan's balance of trade quickly changed from surplus to unsustainable deficit, largely due to the cost of energy imports and has remained negative as shown in Figure 15. The scale of Japan's new conventional energy

⁹² Westinghouse, 'AP1000 Nuclear Reactor Safety Features', Westinghouse, 2013, available at <http://www.ap1000.westinghousenuclear.com/ap1000_safety.html>, accessed 5 July 2013, p. 1.

⁹³ Martin Dusinger and Daniel P. Aldrich, 'Hatoko Comes Home: civil society and nuclear power in Japan', *The Journal of Asian Studies*, Vol. 70, No. 3, 2011, pp. 686-9.

⁹⁴ Tomoko Hosoe, 'LNG figures Heavily in Japan's Postdisaster Energy Demand', *Oil & Gas Journal*, Vol. 109, Issue 15, 2011, pp. 74-5.

⁹⁵ Tomoko Hosoe, 'LNG's Role in Post-Fukushima Japanese Energy Policy', *Oil & Gas Journal*, Vol. 110, Issue 4, 2012, p. 128.

⁹⁶ Vlado Vivoda, 'Japan's Energy Security Predicament post-Fukushima', *Energy Policy*, Vol. 46, 2012, p. 136.

demand also affected market prices, especially for LNG, as Japan now consumed 33 per cent of world production.⁹⁷ This was cushioned by a relative surfeit of LNG in the marketplace from new production from Qatar and Australia, albeit Japan faced consistently higher LNG spot prices than seen in Europe. Significant increases in domestic US production⁹⁸ have yet to depress the international LNG price and the economic cost to Japan has been significant.⁹⁹

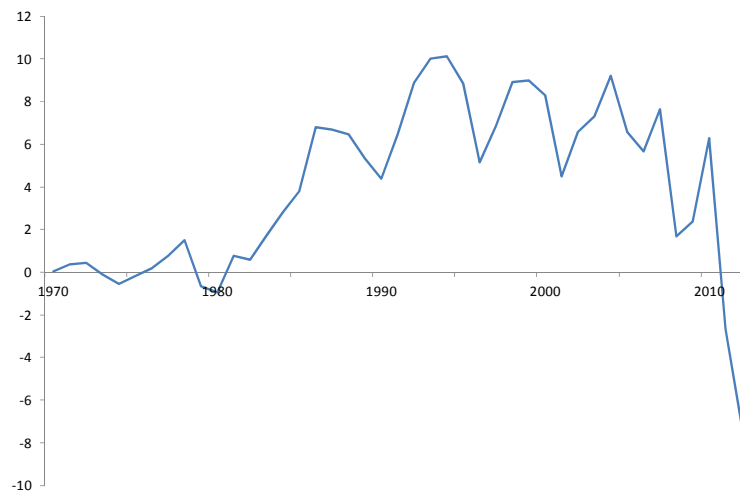


Figure 15 - Japan's Balance of Trade in Billions of USD

(Source: OECD, 'StatExtracts', available at
<http://stats.oecd.org/index.aspx?queryid=166> accessed 27 December 2013)

While energy policy had always been important in Japan, it was now irretrievably intertwined with economic prosperity and the hitherto most suitable energy solution from an economic and environmental point of view had finally become untenable in the public eye. Energy had become an existential issue for Japan and the relatively politically weak GOJ and institutions of state were poorly placed to craft a fundamentally new energy security strategy for the nation. Japan had arrived at a critical juncture in energy security policy with the population and the polity

⁹⁷ Ken Koyama, Yoshikazu Kobayashi, Ichiro Kutani and Tetsuo Morikawa, 'Outlook for the International Oil and Gas Markets in 2013', Tokyo, IEEJ, 2013, available at <http://eneken.ieej.or.jp/data/4838.pdf>, accessed 13 May 2013, p. 3.

⁹⁸ John Mitchell, 'US Energy: the new reality', Briefing Paper, London, Chatham House, 2013, available at <http://www.chathamhouse.org/publications/papers/view/191405>, accessed 19 June 2013, pp. 2-3.

⁹⁹ Gawdat Bahgat, 'United States' Energy Security: challenges and opportunities', *The Journal of Social, Political, and Economic Studies*, Vol. 35, No. 4, 2010, p. 416.

disunified on energy policy, an internationally controversial nuclear fuel cycle and the nation in poor economic condition to effect any major change of energy strategy.

Japan's post-Fukushima energy security policy

Six Prime Ministers (PM) of Japan served in rapid succession between 2006 and 2012, so the administration was weak at the time of the Fukushima disaster, even by Japanese standards. The Democratic Party of Japan (DPJ) had come to power in late 2009 with relatively little experience in government and it was less ideologically committed to nuclear power than the LDP; however, its energy policy on assumption of government included substantial reliance on nuclear power on pragmatic grounds.¹⁰⁰ In the direct aftermath of the Fukushima disaster, PM Naoto Kan gave every indication that he intended to eliminate nuclear power from Japan.¹⁰¹ The business community and utilities prevailed on him to redact this position and he was caught between these public and vested interests, so he embarked on a process of institutional reform and public policy consultation unprecedented in Japan.¹⁰² His resignation in September 2011 was prompted by public outrage at the handling of the disaster. The Diet under the leadership of PM Yoshihiko Noda of the DPJ subsequently accepted the entire independent report in July 2012, including a recommendation that all nuclear plants must pass an independent 'stress test' safety review before they could be re-started. Public opinion about the GOJ's handling of the 'triple tragedy' remained scathing.¹⁰³

Campaigning on economic reform and reconstruction issues, the LDP won a landslide election victory in the lower house of parliament on 26 December 2012, returning Shinzo Abe as PM with a majority unprecedented in recent decades. Abe has outlined an uncharacteristically direct and fundamentally new approach to a

¹⁰⁰ Scott Valentine, Benjamin K. Sovacool and Masahiro Matsuura, 'Empowered? Evaluating Japan's National Energy Strategy under the DPJ Administration', *Energy Policy*, Vol. 39, No. 3, 2011.

¹⁰¹ Masami Ito, 'Energy Policy Revised to Cut Nuclear Role', *The Japan Times*, Tokyo, 2011, available at <http://www.japantimes.co.jp/news/2011/07/30/national/energy-policy-revised-to-cut-nuclear-role/#.UdPl_zswd8k>, accessed 3 July 2013, p. 1.

¹⁰² METI, 'Major Discussion Points Toward the Establishment of a New "Basic Energy Plan for Japan"', Fundamental Issues Subcommittee of the Advisory Committee on Energy and Natural Resources, Tokyo, METI, 2011, available at <http://www.meti.go.jp/english/press/2011/pdf/1220_05a.pdf>, accessed 30 May 2013, pp. 1-19.

¹⁰³ 'Noda to Meet with Antinuclear Rally Organizers', *The Japan Times*, Kyodo, 2012, available at <<http://www.japantimes.co.jp/news/2012/08/03/national/noda-to-meet-with-antinuclear-rally-organizers/#.UdPnczswd8k>>, accessed 3 July 2013, p. 1.

wide range of economic and social problems within Japan.¹⁰⁴ A subsequent half-election in the upper house on 21 July 2013 is widely expected to deliver LDP emphatic control of both houses of parliament and pave the way for broad economic and social reforms in Japan. In the period between elections, where his political power is checked by the DPJ-dominated upper house, PM Abe has concentrated on fiscal reform,¹⁰⁵ liberalising trade¹⁰⁶ and disaster reconstruction, affirming the need for nuclear power but maintaining ambiguity about the details of his energy policy other than re-starting reactors in the short term.¹⁰⁷ By taking more control over the Bank of Japan, Abe has sought to trigger inflation and growth in Japan through increasing liquidity and forcing the value of the Yen lower.¹⁰⁸ This strategy will have the undesirable effect of increasing the price of imported fossil fuel and makes the re-starting of nuclear plants more important than ever.

Abe's mix of assertive nationalist posturing and blunt fiscal policy has maintained the domestic popularity of the GOJ but also tended to inflame regional tensions.¹⁰⁹ PM Abe has been drawn into conflict with regional neighbours on a range of historical and practical issues, in part due to his nationalist rhetoric which also inflames a small but vocal extremist minority in Japan.¹¹⁰ Tensions with Korea over legacies of World War 2 have materially set back discussions on the potential for energy collaborations, despite the clear advantages of a joint approach to everything from LNG procurement to petroleum stockpiling. In a more significant development, the stalemate between Japan and China about the ownership of a set of islands they know as Senkaku or Daioyu respectively has progressively escalated into a major regional dispute, albeit the issue was inflamed before Abe assumed

¹⁰⁴ Shinzo Abe, 'Japan is Back', Policy Speech by Prime Minister Shinzo Abe at the Center for Strategic and International Studies, Tokyo, 22 February 2013, available at <http://www.kantei.go.jp/foreign/96_abe/statement/201302/22speech_e.html>, accessed 8 May 13. See also 'Japan's master plan', *The Economist*, Vol. 407, Issue 8836, 2013, pp. 13-5.

¹⁰⁵ 'Japan and Abenomics - Once more with feeling', *Reuters*, Tokyo, 2013, available at <<http://www.economist.com/news/briefing/21578052-shinzo-abe-shaking-up-japans-economy-seems-different-man-one-whose-previous>>, accessed 20 May 2013, pp. 1-6.

¹⁰⁶ Shinzo Abe, 'PM Abe Commits Japan to Enter the TPP negotiations', Trans-Pacific Partnership Press Conference, Tokyo, 15 March 2013, available at <http://www.kantei.go.jp/foreign/96_abe/statement/201303/15kaiken_e.html>, accessed 8 May 2013.

¹⁰⁷ Reiji Yoshida, 'Abe Plays it Safe in Diet Speech', *The Japan Times*, 28 February 2013.

¹⁰⁸ Anthony Rowley, 'Japan's Abe Claims Election Victory as a Mandate for Looser Monetary Policy', *Institutional Investor*, 2012, pp. 1-8.

¹⁰⁹ Kaori Kaneko, 'Japan Shrine Visits, Isles Dispute Stir East Asia tensions', *Reuters*, 23 April 2013.

¹¹⁰ 'Beware the Populists; Nationalism in Japan', *The Economist*, Vol. 405, Issue 8805, 2012, p. 45.

office.¹¹¹ Japan controls these uninhabited islands, which are claimed by both parties based on competing historical claims. The dispute matters in energy security terms because the area is thought to be rich in petroleum deposits but the potential for regional conflict in the short term cannot be ignored. There is potential for the aggressive military and coastguard posturing between the nations to be misjudged,¹¹² or that the strong domestic reactions occurring might spur further rash political action, leading in either case to actual conflict.¹¹³

On the energy security front, reform of the regulation of the electrical power generation industry and nuclear regulatory safety system in Japan has proceeded quietly with bipartisan support within the Diet. PM Abe realises pragmatically that Japan cannot afford to do without nuclear energy in at least the medium term, so he needs to regain public confidence by reforming the industry.¹¹⁴ While Abe's other structural and institutional reforms in the finance sector thus far have been modest and attracted international criticism for their ineffectuality,¹¹⁵ the mandate for nuclear regulatory reform is clear even without control of the upper house. Against a backdrop of new nuclear safety regulatory development internationally, Japan moved to create a new safety regulator dubbed the Nuclear Regulatory Agency (NRA).¹¹⁶ The new NRA was created in the Ministry of Environment, to be independent of METI (and potentially adversarial given their advocacy for renewable energy), and also enjoyed significantly more powers.¹¹⁷ After resolving the conflict of interest by reorganisation, the NRA was specifically directed by the

¹¹¹ Wenran Jiang, 'China Makes "Great Leaps Outward" in Regional Diplomacy', *International Journal*, Vol. 61, No. 2, 2006, p. 333.

¹¹² Anonymous, 'Chinese Officials Admit to MSDF Radar Lock Allegations', *The Japan Times*, 18 Mar 2013, p. 2.

¹¹³ Yasuhiro Matsuda, 'Engagement and Hedging: Japan's strategy toward China', *The SAIS Review of International Affairs*, Vol. 32, No. 2, 2012, pp. 110-112.

¹¹⁴ Ulrike Schaede, 'Abenomics Cannot Succeed Without Cheap Nuclear Power', *The Japan Times*, New York, 2013, available at <<http://www.japantimes.co.jp/opinion/2013/06/05/commentary/abenomics-cannot-succeed-without-cheap-nuclear-power/#.UdNRJjswd8l>>, accessed 3 Jul 2013, p. 1.

¹¹⁵ 'Misfire; The third arrow of Abenomics', *The Economist*, Vol. 407, Iss. 8840, 2013, p. 37. 'Not so super; Abenomics', *The Economist*, Vol. 407, Iss. 8840, 2013, p.13.

¹¹⁶ Kenzo Oshima, 'Lessons From Fukushima Response and Changes to Regulatory Framework and System', Ottawa, Nuclear Regulation Authority, 2013, available at <<http://www.nsr.go.jp/english/data/20130422lff.pdf>>, accessed 13 May 2013, pp. 4-5.

¹¹⁷ 'New Japanese Regulator Takes Over', *World Nuclear News*, 2012, available at <http://www.world-nuclear-news.org/RS-New_Japanese_regulator_takes_over-1909125.html>, accessed 13 May 2013, pp. 2-3.

GOJ to address several issues.¹¹⁸ Review of the legacy safety analysis for extant nuclear plants was urgently required to make recommendations on their continued operation. Several are unlikely to be operated again due to concerns at their proximity to active fault lines. A more fundamental task was to consider the international state of the art in nuclear reactor design and probabilistic safety analysis and to revise Japan's nuclear safety regulations based on the results, potentially requiring the upgrading or closure of some older plants.¹¹⁹ Improved guidance for disaster response agencies and better design for disaster resistance are also to be instituted.¹²⁰ In the electricity generation marketplace, the GOJ has also tried to expedite regulatory reforms in an effort to reduce consumer costs by improving performance and reducing the fragmentation of network design and operation,¹²¹ although success will be contingent on control of the upper house.¹²²

Evolution from NISA to the NRA is not without challenges, as there are problems with expertise and culture given the high level of staff commonality between the two agencies and the history of poor safety culture.¹²³ The more fundamental failings of *Amakudari* will prove particularly difficult to address, given the profound reliance on this scheme to address otherwise modest remuneration during government service and provide a suitable safety net for the retrenchment of bureaucrats. Even a large nuclear industry like Japan's will experience significant movement of personnel between industry, academia and government, perpetuating extant culture and making the establishment of parliamentary and international oversight essential. The

¹¹⁸ Kenzo Oshima, 'ENSREG Conference Presentation: post-Fukushima assessment and actions', Brussels, European Nuclear Safety Regulator, 2013, available at <http://www.nsr.go.jp/english/data/20130620_presentation.pdf>, accessed 17 July 2013, pp. 25-6.

¹¹⁹ Toyoshi Fuketa, 'How PSA Results Are to be Utilized in New Nuclear Regulation in Japan', Tokyo, Nuclear Regulation Authority, 2013, available at <<http://www.nsr.go.jp/english/data/20130415fuketa.pdf>>, accessed 13 May 2013, pp. 3-5.

¹²⁰ Sohei Sato, Kazuya Yamamoto, Shigeo Muto, Masahiro Fukumoto and Hiromi Katagiri, 'Lessons Learned and Recommendations According to Nuclear Disaster Prevention Based on the Support Activities to the Accident at Fukushima Nuclear Power Stations', Tokyo, Japan Atomic Energy Agency, 2011, available at <<http://jolissrch-inter.tokai-sc.jaea.go.jp/pdfdata/JAEA-Review-2011-049.pdf>>, accessed 13 May 2013, pp. 26-38.

¹²¹ Aaron Sheldrick and Risa Maeda, 'Japan Government Takes Aim at Electricity Monopolies', *Reuters*, 2013, available at <<http://www.reuters.com/article/2013/05/15/japan-power-deregulation-idUSL3N0DU0DC20130515>>, accessed 16 June 2013, p. 1.

¹²² 'DPJ Ruins Chance at Power Reform', *The Japan Times*, Tokyo, 2013, available at <<http://www.japantimes.co.jp/opinion/2013/07/03/editorials/dpj-ruins-chance-at-power-reform/#.UdNSSjswd8l>>, accessed 3 July 2013, p. 1.

¹²³ Richard Nielsen, 'Whistle-Blowing Methods for Navigating Within and Helping Reform Regulatory Institutions', *Journal of Business Ethics*, Vol. 112, No. 3, 2013, p. 389.

IAEA will therefore also take an increased role in Japan and internationally as it promulgates and enforces technical and regulatory lessons from Fukushima.¹²⁴ The GOJ and NRA will have to take the lead on regulatory reform and overhaul of the nuclear safety culture. They will also need to make tough choices on closing plants near fault lines and modernising or retiring older reactors¹²⁵ (see Figure 16).

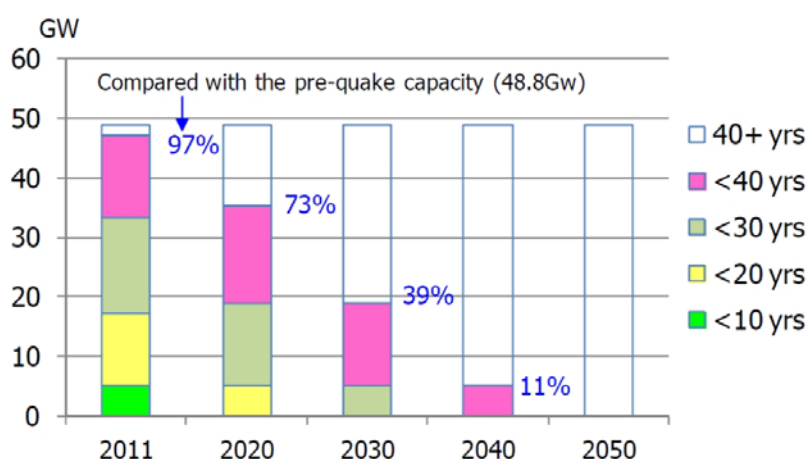


Figure 16 – Age-out of Japan's nuclear reactors, assuming a 40 year life

(Source: IEEJ, 'Japan Energy Brief', Bulletin No. 17, January 2012, available at <http://eneken.ieej.or.jp/en/jeb/1201.pdf> accessed 27 December 2013)

Japan developed a set of energy options during the Kan and Noda administrations, which evolved under PM Abe.¹²⁶ This work occurred at the institutional level and has not been formally adopted as national policy. In May 2013, the IEEJ reported the latest options being canvassed by the Advisory Committee on Natural Resources (ACNR), which are shown in Table 3Table 3.¹²⁷ The committee itself referred to was actually convened by METI to examine policy options and appears to have the

¹²⁴ Lucille Langlois, 'IAEA Action Plan on Nuclear Safety', *Energy Strategy Reviews*, Vol. 1, No. 4, 2013, pp. 302-6.

¹²⁵ IEEJ, 'Japan Energy Brief No 17', Tokyo, 2012, available at <http://eneken.ieej.or.jp/>, accessed 1 July 2013, p. 3. The author of the brief notes that a 'safety by inspection/analysis' approach may be possible to 60 years for some reactors.

¹²⁶ The fourth option with greater nuclear utilisation was added just after the Abe administration was installed, see: Masakazu Toyoda, 'Energy Policy in Japan - Challenges after Fukushima (24 Jan)', Tokyo, IEEJ, 2013, available at <http://eneken.ieej.or.jp/data/4699.pdf>, accessed 28 April 2013, p. 23.

¹²⁷ Toyoda, 'Energy Policy in Japan - Challenges after Fukushima (28 May 2013)', p. 23.

institutional lead within the GOJ for energy strategy.¹²⁸ Although the IEEJ is an independent think tank, it is funded by the GOJ and has close links within government on policy matters, so its reporting on emergent GOJ policy is credible. As such, these options are likely to have a significant input into eventual energy strategy decisions within the Diet and Japanese cabinet, albeit the process is highly politicised and other outcomes remain possible. There is no overt declaration accompanying the options as to when the eventual solution was intended to be in place, and the document notes cabinet guidance from PM Abe that a final energy source mix would be selected ‘in the next ten years’.¹²⁹ The earlier sections of the options document make extensive reference to the Basic Energy Plan 2010, which describes the expected energy mix in 2030, so it may be reasonable to assume when assessing the options that this is the earliest intended realisation date.

Table 3 - Energy Mix Options for Japan

Option	Proportion of Generation				Demand Reduction	CO ₂ (Change from 1990 levels)
	Nuclear	Renewable	Fossil Fired	Cogeneration		
1	0%	35%	50%	15%	-20%	-16%
2	15%	30%	40%	15%	-20%	-20%
3	20-25%	25-30%	35%	15%	-20%	-23%
4	35%	25%	25%	15%	-20%	-28%

(Source: IEEJ, ‘Japan Energy Brief’, 2012)

A number of critical assumptions underpin the IEEJ/ACNR energy option set being considered in Japan and there are real questions of feasibility. All options are predicated on a significant 20 per cent reduction in electricity demand from 2010

¹²⁸ METI, ‘Review of Japan’s Energy Policy’, Tokyo, METI, 2013, available at <http://www.meti.go.jp/english/policy/energy_environment/review/>, accessed 2 July 2013, pp. 1-2

¹²⁹ Toyoda, ‘Energy Policy in Japan - Challenges after Fukushima (28 May 2013)’, p. 29.

levels, which might appear theoretically possible¹³⁰ but will be a significant challenge given Japan already leads the industrialised world in energy efficiency per unit of GDP.¹³¹ If the energy utilisation data from Figure 2 is recalled, it seems likely that the residential commercial and transportation sectors must bear the brunt of the demand reduction goal. Remembering that transportation in Japan already is the most fuel efficient in the world, the residential impact would need to be significant, as only 31 per cent of total energy was consumed in this sector in 2007. Unfortunately, on inspection of Figure 17, it is clear that this energy use sector is also already one of the most energy efficient in the world.¹³² While Japan has achieved impressive reductions in electricity consumption since the disaster, cutting summer peak demand by up to 15 per cent through draconian measures, finding economically viable solutions that are acceptable to the population but reduce net demand by 20 per cent will be a significant challenge.¹³³

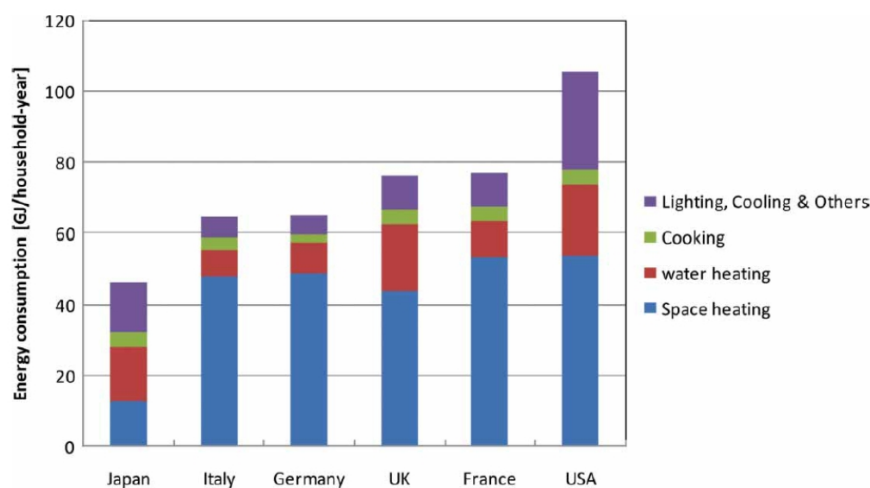


Figure 17 - Residential Sector Energy Use Comparison

(Source: Lun and Ohba, 'An Overview of the Cause of Energy Shortage and Building Energy Strategy after Fukushima Disaster in Tohoku District of Japan')

¹³⁰ Shuichi Ashina, Junichi Fujino, Toshihiko Masui, Tomoki Ehara and Go Hibino, 'A Roadmap Towards a Low-Carbon Society in Japan Using Backcasting Methodology: feasible pathways for achieving an 80% reduction in CO₂ emissions by 2050', *Energy Policy*, Vol. 41, No. 1, 2012, p. 597.

¹³¹ Ministry of Economy, *2010 Annual Energy Report*, p. 16.

¹³² Isaac Lun and Masaaki Ohba, 'An Overview of the Cause of Energy Shortage and Building Energy Strategy after Fukushima disaster in Tohoku District of Japan', *Advances in Building Energy Research (ABER)*, Vol. 6, No. 2, 2012, p. 273.

¹³³ David Cyranoski, 'Japan Rethinks its Energy Policy', *Nature*, Vol. 473, No. 7347, 2011, p. 263.

By comparison with the modest 2008 contribution of 9 per cent shown in Figure 3, increasing renewable energy contributions in 2030 to between 25 and 35 per cent also appears particularly ambitious. The renewable energy target data from the 2010 Basic Energy Plan (see **Error! Reference source not found.** and **Error! Reference source not found.**) demonstrated that to make a 21 per cent contribution to the generated energy by 2030, the installed capacity must be 38 per cent of the then-available capacity. Despite this, there remains considerable enthusiasm in Japan for high-technology renewable energy solutions.¹³⁴ The problem is that renewable sources such as solar, wind and hydro are somewhat seasonal, diurnal and otherwise inherently variable in their output, necessitating far greater installed capacity to assure adequacy of supply. Renewable energy sources typically require complex networks to transform, store and transmit the energy over useful distances, which may be nearly as difficult to site as generation sites.¹³⁵ The best energy storage technique to smooth supply from renewable sources is pumped hydro but the capacity is already largely exploited in Japan. There are also significant problems with interest groups blocking access to the best geothermal sources and wind farm sites, as noted earlier in this paper. The cost per kWh of solar is also very problematic as it is approximately ten times more expensive than nuclear energy.¹³⁶ Despite the significant energy available globally, the likely effect will be that far less solar generation capacity is realised in Japan than projected, especially as insolation in Japan is relatively poor.¹³⁷

The nuclear reactor construction program implied by the options is also worthy of inspection. For a first approximation, Figure 16 data on nuclear plant age-out could be combined with the energy mix for 2030 in Table 3 and the current baseline nuclear capacity in Figure 3 to determine the number of new nuclear reactors to be constructed. In 2008, 54 nuclear reactors supplied 26 per cent of the electricity at 85 per cent utilisation rate. To supply 35 per cent of the 2030 total at 90 per cent utilisation rate, if that total is a 20 per cent reduction on 2008 requirements, implies a nuclear capacity of 35.2GW. This is a real reduction in nuclear plant capacity and appears unchallenging; however, Figure 16 tells us that if plants are retired after 40 years, only 19GW of current capacity will remain in service in 2030. Replacement of

¹³⁴ Climate Change Policy Division, *Study of Potential for the Introduction of Renewable Energy (FY 2010)*, Tokyo, Ministry of the Environment, Japan, 2011, pp. 3-11.

¹³⁵ 'Tilting at Windmills: energy', *The Economist*, Vol. 407, Issue 8840, 2013, p. 11.

¹³⁶ Ministry of Economy, *2010 Annual Energy Report*, p. 25.

¹³⁷ Quanhua Liu, Gengfa Yu and Jue Liu, 'Solar Radiation as Large-Scale Resource for Energy-Short World', *Energy & Environment*, Vol. 20, No. 3, 2009, pp. 322-4.

the 16.2GW of capacity required to make up the deficit implies that about 18 new reactors must be in service by 2030, a higher number of new reactors than ever previously contemplated in Japan over that period. Worse still, a further 13.7GW of nuclear capacity will have less than ten years' residual life, suggesting a further 15 reactors will need to be under construction at that time. The mooted reactor life extension to 60 years is unproven and only defers the block obsolescence effect, so recapitalisation remains a strategic challenge for Japan. Reactor decommissioning is a lengthy process and there is only limited potential to construct replacement reactors at extant facilities, heightening the challenge given the relative success local governments have had in blocking new reactor construction.

Overall, the challenges to achieving any of the options mooted are significant. Any judgment about which provides the 'best' energy security outcome needs to consider on what criteria that judgment is made. Factors such as affordability, reliability and sustainability all trace to the definition of energy security and therefore form a useful lens with which to view the options. Setting aside demand reduction as the common feature of all options, some useful conclusions can be drawn. Options high in fossil fuel usage are likely to most adversely impact the balance of trade, especially given the planned persistent devaluation of the Yen and poor economic fundamentals. Additional thermal power plant capacity would also be required and there are obsolescence effects in the current portfolio of thermal plants. Environmental considerations might favour options high in nuclear power for greatest GHG reduction, if trust in nuclear power could ever be regained.¹³⁸ While much further analysis will be required to truly identify the best energy policy for Japan, and this would need to be tempered by assessment of the likely political will to address what will always be a difficult choice, option four appears the most affordable and makes the greatest contribution to GHG reduction.

The GOJ also has to determine a course of action for the nuclear fuel reprocessing, breeder and long-term waste storage programs. The economic situation in Japan, high public sensitivity, regional weapons proliferation concerns and fundamental lack of a business case for breeder technology all suggest the breeder program ought to be abandoned. Japan's persistent advocacy of the Fissile Material Cut-Off treaty,¹³⁹ a successor and interim complement to the Nuclear NPT, is perplexing given its

¹³⁸ Sanghyun Hong, Corey J. A. Bradshaw and Barry W. Brook, 'Evaluating Options for the Future Energy Mix of Japan after the Fukushima Nuclear Crisis', *Energy Policy*, Vol. 56, No. 1, 2013, p. 423.

¹³⁹ Steve Fetter and Frank von Hippel, 'A Step-by-Step Approach to a Global Fissile Materials Cutoff', *Arms Control Today*, Vol. 25, No. 8, 1995, pp. 3-5.

continued work on plutonium separation.¹⁴⁰ Some commentators find other signs of confusion and willingness to change in the GOJ's commitment to plutonium; however, there is no clear GOJ policy yet and PM Abe has not included these elements in his ten-year energy mix deadline.¹⁴¹ Some measure of GOJ intent may be inferred from the significant decline in funding of the Monju reactor program and breeder research more generally, suggesting that the commitment is wavering but a formalised policy shift may be unpalatable due to organisational inertia and vested commercial interests of local prefecture governments.¹⁴²

A solution still needs to be found for nuclear waste management as the on-site storage pond capacity at most Japanese reactors is filling up; however, reprocessing capability is not strictly required as part of a waste disposal strategy¹⁴³ and a simpler dry storage solution for unprocessed nuclear waste would be a real possibility if a suitable site could be located.¹⁴⁴ This has proven even more difficult after Fukushima, with a call for volunteer localities failing to identify any suitable sites. There are, therefore, views that the GOJ may be retaining reprocessing principally as a way of securing a *de facto* interim waste storage site, which if true would be a massively expensive subterfuge.

Conclusion

All of the energy options for Japan are reliant on nuclear generation, meaning that the issue of public acceptance needs to be surmounted, so that the Japanese public is engaged factually and constructively.¹⁴⁵ Perhaps the most important question to be resolved after Fukushima is how to engage the public in a rational discourse about

¹⁴⁰ Yoshihiko Noda, 'Address by H.E. Mr. Yoshihiko Noda, Prime Minister of Japan, at Seoul Nuclear Security Summit', Seoul, 27 March 2012, available at <http://www.mofa.go.jp/policy/un/disarmament/arms/nuclear_security/2012/pm_address.html>, accessed 4 June 2013.

¹⁴¹ Daniel Horner, 'Strains Seen in Japan's Plutonium Policy', *Arms Control Today*, Vol. 42, No. 9, 2012, p. 24.

¹⁴² Thomas Cochran, Harold Feiveson, Walt Patterson, Gennadi Pshakin, M. Ramana, Mycle Schneider, Tatsujiro Suzuki and Frank von Hippel, 'Fast Breeder Reactor Programs: history and status', Princeton, New Jersey, International Panel on Fissile Materials, 2010, available at <<http://fissilematerials.org/library/rr08.pdf>>, accessed 4 July 2013, pp. 55-8.

¹⁴³ Harold Feiveson, Zia Mian, M. Ramana and Frank von Hippel, 'Managing Spent Fuel from Nuclear Power Reactors: experience and lessons from around the world', Princeton, New Jersey, International Panel on Fissile Materials, 2011, available at <<http://fissilematerials.org/library/rr10.pdf>>, accessed 4 July 2013, p. 15.

¹⁴⁴ Robert Alvarez, 'Improving Spent-Fuel Storage at Nuclear Reactors', *Issues in Science and Technology*, Vol. 28, No. 2, 2012, pp. 78-82.

¹⁴⁵ Phil Richardson, Katrin Rickwood and Peter Rickwood, 'Public Involvement as a Tool to Enhance Nuclear Safety', *Energy Strategy Reviews*, Vol. 1, No. 4, 2013, p. 267.

the risks of nuclear power, what costs are reasonable to mitigate these risks and contrasting that with nuclear power's potential to contribute to global GHG reduction. The historic lack of trust in the GOJ exacerbated the difficulty of the disaster response and preconditioned the population to respond negatively. However, many nations have similar sensitivities and some have fostered a more constructive debate.¹⁴⁶ Nuclear power is intrinsically complex and has the potential for catastrophic failures, albeit their likelihood can be reduced to arbitrarily low levels with careful design, if the hazards are deemed credible and the costs can be met.¹⁴⁷ Conversely, a robust nuclear emergency response capability is always essential, no matter how unlikely catastrophic failures are deemed.¹⁴⁸ Public confidence in the Japanese nuclear industry will therefore be reliant on the elimination of poorly-sited plants, fundamental regulatory and deep cultural reform and demonstrated success in technical control of environmental disaster effects, suggesting PM Abe's ten-year timetable to finalise a new basic energy mix for Japan strategy is justified.

Recalling energy security to comprise the reliable supply of affordable energy in a sustainable fashion, the prognosis for energy security in Japan is not certain but some observations can be offered. Japan's economic recovery is contingent on many factors, perhaps none more important than the evolution of the energy sector to provide reliable and cheaper energy than has been the case. The trend of decreasing reliance on imported fossil fuels represented a real improvement to Japan's energy security but Fukushima reversed the situation by proving that many extant nuclear plants in Japan were obsolete from a contemporary design safety point of view and that the country lacked an effective safety regulatory apparatus. Conversely, while the devaluation of the Yen remains a deliberate tool of economic recovery, fossil fuel imports on the current scale will not be tenable. The fossil fuel dependency reinstated after Fukushima therefore needs to be reduced as promptly as nuclear power plants can safely be reactivated. A longer-term strategy reliant on increased hydrocarbon imports will also adversely impact Japan's energy security.

Public confidence in nuclear power will need to be restored not only to the point where nuclear plants can be re-started but also to enable construction of new nuclear

¹⁴⁶ Geoff Brumfiel and Ichiko Fuyuno, 'Fukushima's Legacy of Fear', *Nature*, Vol. 483, No. 7388, 2012, pp. 138-40.

¹⁴⁷ Stephen Kidd, 'Nuclear power – Economics and public acceptance', *Energy Strategy Reviews*, Vol. 1, No. 4, 2013,

¹⁴⁸ Joel Krupa and Cameron Jones, 'Black Swan Theory: applications to energy market histories and technologies', *Energy Strategy Reviews*, Vol. 1, No. 4, 2013, pp. 286-7.

plants, as some will never be able to be reactivated due to invalidation of their site selection decisions. The 'stress test' process and new regulations from NRA may cause block obsolescence of older nuclear plants, and exacerbate the requirement to build new nuclear plants. Optimistic projections of energy demand reduction and of the potential of renewable sources will need to be tempered, lest further hubris hide the gravity of Japan's 'critical juncture'. Fundamentally, the GOJ needs a nuclear strategy based on transparent and consultative policy, backed by science and engineering input of the highest calibre, which is possible only where the Japanese cultural tendency to obedience and the dysfunctional regulatory system have both been overcome.¹⁴⁹

Energy security in Japan will therefore remain elusive for at least the ten years PM Abe believes necessary to rebalance the energy portfolio and probably longer. Japan's energy security appears likely to remain very problematic in the short to medium term as nuclear plants remain off-line. In the medium term, reactivation of extant plants meeting new regulatory criteria will restore domestic energy supplies but the lessons from Fukushima about plant design obsolescence suggest energy security will remain elusive and the nuclear construction program will have to accelerate.

¹⁴⁹ Sebastian Pfotenhauer, Christopher Jones, Krishanu Saha and Sheila Jasanoff, 'Learning from Fukushima', *Issues in Science and Technology*, Vol. 28, No. 3, 2012, pp. 79-84.

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