The Past and Present of Extremes in Japan's Energy Economy

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Introduction

Modern Japan has long been an outlier among the developed economies. The world's third-largest economy, Japan has the advanced industrialized countries' lowest level of foreign investment, immigration and other indicators of internationalization. Japan's comparatively limited external engagement on these fronts, however, is sharply contrasted by its inordinate external dependence on conventional energy and great distance from sources of supply. Japan is also perhaps most distinctive in its record of costly — in geopolitical, pecuniary, and other terms — dependence on particular sources of energy, such as coal, oil, and nuclear. And as we shall see, Japan is also an outlier in terms of its exposure to climate change and thus incentives to lead a shift to a more climate-resilient urbanization that may also resolve energy insecurity.

Indeed, Japan's post-Fukushima impasse over nuclear versus renewable energy, discussed in detail below, belies the expansion of an increasingly robust green policy regime and energy economy. Japan's transformation may outpace the energy shifts ongoing elsewhere because it is part of a larger information and communications technology (ICT) revolution wherein Japan has especially promising policy, capacities and incentives. With Japan's post-Fukushima difficulties in restarting nuclear capacity, well over 90% of its primary energy is derived from burning natural gas, coal and oil sourced almost entirely from overseas. This increased reliance on carbon-intensive and imported fossil fuels dramatically exposes Japan to depletion risks, price volatility and geopolitical shocks while also undermining its ability to play a leadership role in fighting climate change. At the same time, in 2014 Japan is one of the world's largest solar markets, a leader in distributed generation, and accelerating its diffusion of the ICT that is the enabling infrastructure for the ongoing rollout of "smart cities" (Townsend, 2013; URENIO, 2014), the "resource revolution" (Heck and Rogers, 2014) and sustainability (Koomey et al, 2013).

Prewar Japan's Rise and its Energy Dependence

Meiji Japan's (1868-1912) elites chose rapid industrial and military modernization in response to the perceived threat of colonialization. In consequence, within just a few decades Japan went from being an isolated feudal economy to a rising, resource-intensive global power. Energy resources in particular emerged to play a pivotal role. Japan was neither a resource-rich continental power such as the US, nor—like Germany then or China now—the core of a continental region. Neither was Japan an established colonial island power like the UK, whose rich endowment of coal reserves and far-flung markets for manufactures fueled the first industrial revolution (Miller, 2005: 32). Japan was (and remains) an island nation, distant and detached from its region, with comparatively poor conventional resource endowments.

Yet Japan's domestic energy sources were sufficient during the first few decades of the country's modernization. There was even a surplus for exports. In 1880, wood, charcoal and other traditional and domestically sourced biomass supplied 85% of Japan's primary energy demand. Coal followed at 14%, with oil accounting for only 1% of consumption. Coal overtook biomass two decades later in 1901, and continued grow. Prior to the 1920s, Japan's coal production fueled its own needs and still left roughly 40% for export to Southeast Asia. This surplus provided an important source of foreign exchange (Iwama, 2011). The role of coal in Japan's primary energy demand peaked in 1917 at 77% (Smil, 2010: 93). Coal's share was still at 66% in 1940, just prior to the Pacific War of 1941 to 1945 (Odano, 2007).

In advance of the Pacific War, Japan's trade with the global economy centred on exporting raw silk and textiles in exchange for such commodities as cotton. The state had initiated strategic industries, such as textiles, mining, railways and shipbuilding, and then privatized them in the 1880s (Tang, 2011). State strategy soon turned to securing resources, especially coking coal (essential for making steel)[1] from

1) Coke is the remnant of coal after destructive distillation (heating), and is used as fuel as well as in making steel.

an expanding list of colonial possessions, including Formosa[2] (1895-1945), Karafuto[3] (1905-1945), Korea (1910-1945), and Manchuria (1931-1945). Japan had adequate supplies of coal to export, but most of it was not of very high quality for power or for coking.

Between 1920 to 1940, Japan's energy use increased by 260% (Smil, 2010: 93). The role of oil grew from 2.2% in 1920 to just over 7.0% in 1940, especially in such crucial military applications as fuel for warships. Procuring coal in Japan was a dirty business, often reliant on virtual (and literal) slave labour (Hein, 1990: 41), and was also a factor in pursuing colonial possessions. Manchuria in particular was often depicted as a "lifeline" for a Japanese "lebensraum" as well as a "cornucopia of resources" (Young, 1998: 94).

But the strategic role of oil helped drive the country into a catastrophic war and defeat. This latter outcome was largely determined by geology, Japan's late entry into the contest for colonies, and sheer bad luck. As to geology, the highly seismic Japanese archipelago has very limited domestic reserves of oil. This fact became evident not long after 1891, when modern oil production in Japan started with the Amaze oil field in Niigata Prefecture. Japanese observers were avid students of new industry, and quickly adopted American drilling technology (Najima, 2002: 59). And in spite of Japan's miniscule production capacity, its consumption was low enough that the output fueled about two-thirds of its domestic needs in 1920[4]. But thereafter, Japan's growing naval force in particular rendered the country increasingly dependent on imports.

Oil posed a mounting strategic quandary as the 1930s progressed because Japan sought autonomy in an increasingly hard-line, militarized policy to expand its colonial empire in Asia, and especially in China. The Americans had already occupied a resource-rich continent, objected strenuously to Japan's expansionist policies, and for most of the 1930s were also the source of about 85 percent of Japan's oil imports. For

2) Now Taiwan.

3) Now Southern Sakahalin.

4) According to the Japanese Association for Petroleum Technology, this was the "golden age" of the Japanese oil industry: http://www.japt.org/abc/a/rekishi/rekishi.html

Japan and other powers, such as Britain, growing dependence on oil—symbolized by the oil-fuelled navies—had made diversity in supply a key element of national policy (Dahl, 2000; Yergin, 2006). The militarized Japanese state—animated by keen awareness of strategic risk encapsulated in the saying “a drop of oil is a drop of blood”—sought to cut civilian consumption to a bare minimum and pressured the Dutch East Indies (now Indonesia) for alternative supplies.

As bad luck would have it, only long after the Pacific War, in 1959, was the Daqing oilfield—in the heart of Japan's colony in Manchuria—found and developed to become the world's fourth largest (UPI, January 4, 2013). Three decades before, Japan's total demand for oil and oil products more than doubled from about 2.5 million kiloliters (15.7 million barrels) in the early 1930s to 5.4 million kiloliters at the 1937 outbreak of the second Sino-Japanese War (1937-1945). Domestic production supplied only 10 to 15 percent of this demand. The Japanese imposed severe rationing on civilian use, cutting total consumption in 1941 to 3.8 million kiloliters, with military demand being half of this total (Hein, 1990: 47). Through these means Japan was able to reduce its dependence on imports from the US to about 60 percent in 1940 (Maeschling, 2000). But the Japanese could not make further progress on either conservation or diversifying supply. And meanwhile, relations with the Americans continued to deteriorate through 1941.

Then, on July 25 1941, the Roosevelt Administration froze Japanese assets and placed an effective embargo on petroleum product and steel exports to Japan. The Japanese military clique thus perceived their choices as constrained to two:

1) complying with US demands, and giving up the aim of becoming a great power,

2) continuing with their ambition to be a major industrial and military power by getting their own supplies of oil through taking the Dutch East Indies and other areas in the region that possessed significant oil resources.

Since complying with American demands was deemed unacceptable, and would likely have been so for any national government (Record, 2009: 20-23), the Japanese leadership settled on the latter choice.

But choosing the latter policy of securing oil supplies, and the prospect of autonomy, brought a further round of fateful decisions. The Japanese authorities also determined that they would have to nullify the strategic military threat from the American Pacific fleet based at Pearl Harbor. Japan's attack on Pearl Harbor has thus been dubbed the world's first energy war (Elhefnawy, 2006).

The Japanese were virtually fated to lose against the resource-rich continental power 10 times their size and already the workshop of the world. But the Japanese compounded their plight by not prioritizing destruction of the US Pacific Fleet's fuel supplies and infrastructure along with the warships themselves. Without fuel, Ameri ca's warships were mere lumps of metal. Had Pearl Harbor's immense and vulnerable fuel tanks been taken out, America would have had to ship oil 4,000 kilometres from California to Hawaii in order to prosecute the Pacific War. The logistics would have been forbidding, especially in the face of the threat from Japan's excellent submarine fleet. Instead, the Japanese themselves became the victim of logistics as American submarines, aircraft and mines virtually eliminated all their tanker capacity for importing oil. **Table 1** shows that crude and refined imports from the colonies, occupied areas and elsewhere dwindled to zero in the last year of the war. By 1944, Japan was reduced to desperate efforts to ramp up synthetic fuels projects (Stranges, 1993) and had even organized hundreds of thousands of citizens to scrounge for pine needles under the slogan that "Two hundred pine roots will keep a plane in the air for an ho ur" (Hein, 1990: 75). Kurita Takeo, Vice-Admiral of the Imperial Japanes Navy, con-

Table 1 Japanese Oil Sources 1938–1945, barrels per day

	Crude Imports	Refined Imports	Domestic Production	Synthetic/ Substitutes	Total
1938	50,422	38,477	6,753	912	96,564
1939	51,625	32,378	6,389	2,011	92,403
1940	60,411	41,398	5,652	3,984	111,445
1941	8,576	14,361	5,318	5,159	33,414
1942	22,318	6,515	4,630	7,345	40,808
1943	26,981	12,745	4,970	5,551	50,247
1944	4,496	9,334	4,342	5,693	23,865
1945 (first half)	0	0	4,432	4,874	9,306

Source: Goralski and Freeburg (1987, pp. 337 and 348) cisely summarized his wartime fix to the US Strategic Bombing Survey, Naval Analysis Division: “We ran out of oil” (King, 2006).

Oil brought Japan a painful lesson in extreme energy dependence. Oil’s critical role in military mobility, coupled with America’s skillfully wrought construction of Japan’s undue dependence on American oil, appears to have been the primary driver of the Pacific War (Lehmann: 2009). The December 7, 1941 attack on Pearl Harbor followed as the Japanese “sought to preserve some hope of future economic and military autonomy in the face of their economic dependence on the United States, which was purposefully created by the United States and based primarily on oil” (Lehmann, 2009: 143-44).

High Growth and Japan's Postwar Energy Policy

Atom-bombed into submission and occupied by a power at first bent on deindustrializing it, Japan’s postwar years began with severe privation. Roughly one-quarter of national wealth had been lost through over a decade of warfare, especially in America’s intensive strategic bombing from June of 1944. Even undamaged working capital and infrastructure was badly depleted and often obsolete after long years of conflict and underinvestment. Conventional economic activity itself was moribund: Japan’s exports were roughly one-ninth, imports about one-sixth, and the production of industrial inputs down to a mere 8% of prewar levels. Per-capita energy supply (measured in 1,000 kilocalories) declined from a peak of 8,874 in 1940 to a low of 3,744 in 1946.

Desperate, Japanese policymakers determined to revive the economy through an emphasis on domestic coal. In the chaos of defeat, production of this core commodity had dropped to 36% of its prewar peak (Hein, 1990: 64). Between 1947 and 1948, coal therefore became the key component in a “Priority Production System.” The system centred on ramping up coal production as an input for the steel industry. Priority production then used the increased steel output as a material input for producing yet more coal, in a reciprocal cycle of capacity expansion. As it gained momentum, the system was then enlarged to include more industries—such as electricity generation—in its ambit (Nakayama, 2013: 2). Prostrate in surrender, the entire nation was thus galvanized by the slogan "Dig 30 million tons of coal." Daily output levels were posted in large cities, and the Minister of Commerce personally stripped down to a "fundoshi" loincloth and went into the Joban Mine at Sendai (in Fukushima Prefecture) to cheer on the workers, who were also congratulated in evening radio broadcasts and exhorted to even greater efforts (Ohno, 2006: 153-4).

Japan's energy consumption began to recover in 1947. And as high growth started in 1952, energy use grew by 11.1%, with coal providing 49.7% of primary energy. Oil's contribution of 11% was just ahead of the 10.8% afforded by traditional biomass and well behind the 28% of energy derived from hydropower (EMDC, 2011: 234). The fact that overall energy consumption per se was still below the wartime peak shows how deep was the crater left by the war (Smil, 2010: 93). Indeed per-capita energy consumption did not surpass the 1940 figure until 1959 (Ohno, 2006).

Japan's Oil Boom

Japan's high reliance on coal in the fuels composing its energy mix continued into the 1960s, with 65% of expanded supply coming from the US and 14% from Australia. Yet it was oil that would propel Japan's rapid growth, and from within the embrace of American hegemony. Japan was becoming the stand-out example of the postwar era's oil-fuelled industrialization. Oil consumption in the US tripled between 1948 and 1972, and in Western Europe it rose by 15 times. But during the same period Japan's consumption increased a staggering 137 times, from 32,000 barrels per day to 4.4 million (Yergin, 1991: 543-46). **Table 2** shows that by the end of the 1960s

Table 2 Changes in Japan's Primary Energy Supply Share (%)

	Coal	Oil	Gas	Hydro	Nuclear	Renewable
1960	41.2	37.6	0.9	15.7	0.0	4.6
1965	27.0	59.6	1.2	10.6	0.0	1.5
1970	19.9	71.9	1.2	5.3	0.3	1.0
1973	15.5	77.4	1.5	4.1	0.6	1.0
1975	16.4	73.4	2.5	5.3	1.5	0.9
1980	17.0	66.1	6.1	5.2	4.7	1.1
1985	19.4	56.3	9.4	4.7	8.9	1.3

Source: Adapted from EDMC, 2011: pp. 30, 38 oil was providing over 70 percent of total energy driving Japan's economic miracle. And during the 1960s, Japan's total energy consumption more than tripled, from 101 million tons of oil equivalent (Mtoe) to 320 Mtoe in 1970 (EMDC, 2011: pp. 30, 31).

The speed and scale of this energy shift in Japan are testament to oil's utility. Cheap, abundant and seemingly risk-free oil supplies for Japan were delivered largely from a Mid-East region dominated by America, by an industry largely controlled by American firms, and over sea lanes patrolled by American warships. The speed and scale of this shift to oil also suggests that energy-paradigm shifts may not always require decades (cf Smil, 2010).

The extreme in Japan's oil dependence arrived in 1973. In this initial year of the first oil shock, when OPEC countries deployed “the oil weapon” (Yergin, 1992: 608-9), oil supplied fully 77.4% of Japan's primary energy. This acute reliance on oil thus matched coal's 1917 peak in Japan's energy mix. Japan was also importing the bulk of its oil from the Middle East, especially Iran, Saudi Arabia and Kuwait. Being the most vulnerable among the big economies, Japan reacted with greatest alacrity to the oil supply and price shocks.

Japan reacted by dramatically cutting dependence on oil in its power mix, increased efficiency, and diversifying its sources of supply. Japan shifted much of its electrical generation to nuclear power and natural gas. Oil was the source of 71.4% of power generation in 1973, but was down to 66% by 1974. This level fell to 10.5% in 2011, when oil-fired power generation was deliberately restricted to a back-up role rather than base-load capacity (WNA, 2013). **Table 2** shows that in just over a decade, between 1973 and 1985, the composition of Japan's primary energy mix saw oil fall from 77.4% to 56.3%. Over the same period, coal increased to just under one-fifth of primary energy, returning to roughly where it had been in 1970. And both gas and nuclear went from being marginal sources to contributing nearly one-tenth of primary energy supply.

Table 2 also shows that in 1960 the share of renewables (including black liquor from pulp refining as well as waste biomass) and hydro were significant, at 4.6% and 15.7% respectively. But their role declined over the years as their output did not keep pace with the overall rate of growth of the energy economy.

Japan also made significant gains in energy efficiency over the 1973 to 1980 period, as is evident from **table 3**. Energy efficiency in the table is measured across the entire economy, expressed as the tons of oil equivalent (toe) required to produce one million US dollars (in 2,000 dollars) of output.

Japan's incentives to pursue greater efficiency then flagged. The effect of this erosion of incentives can be seen in Japan's early 1990s increase in energy required to generate USD 1 million of economic output. There are several reasons for this outcome. Apart from behavioural and technical challenges, one prominent cause was that the 1980s saw a flood of oil from non-OPEC sources, such as the North Sea, Prudhoe Bay (Alaska), and the Soviet Union. OPEC's share of world production dropped from 52% in 1973 to 30% in 1985. The Saudi and American elite also had forged stronger bonds, which encouraged the Saudis to use their ample surplus production capacity to keep oil prices low. The ample supply of oil, coupled with the effects of post-1973 conservation and the shift to alternatives—such as natural gas—wherever possible, brought about a drastic drop in oil prices. Japan's CIF ("cost, insurance and freight") price for oil declined from USD 35.38 per barrel in 1981 to USD 16.91 in 1989. And the 1990s saw even cheaper oil, aside from a brief price spike in the lead-up to the First Gulf War. In the 1990s, oil prices plunged so far that by 1998 Japan's average per-barrel cost was USD 13.68 (EDMC, 2011: 338).

The Intense Commitment to Nuclear Power

Even as per-barrel oil prices declined, the experience of supply and price shocks continued to reverberate in Japan's energy policy circles. From the mid-1950s, these

Table 3 Changes in Primary Energy Consumption Per Real GDP (toe/USD million, 2000 prices)

	1971	1973	1980	1990	1995
USA	418	408	361	279	268
OECD Europe	288	287	263	222	211
Japan	141	144	123	107	112

Source: EDMC, 2011: 307

circles had featured a growing "nuclear village," a coterie of concentrated benefits that came to include monopoly utilities, power-unit makers (Hitachi, Toshiba, Mitsubishi), compliant regulators, collaborative academe, and other players (Kingston, 2012; Samuels, 2013: 118-122). The extent to which the Japanese state's post-oil shock fiscal and regulatory tools were used to develop and deploy nuclear are testament to the power of the village as well as Japan's keen sense of vulnerability and capacity to mobilize resources in response to it. Although Japan has no uranium deposits, the village protrayed nuclear power as domestic energy. It also insisted that nuclear power was both low-cost and clean in terms of carbon emissions. The latter two points became especially attractive arguments in the post-2000 secular increase in conventional resource prices and deepening concern about economic development and climate change.

Table 4 shows Japan's striking devotion of fiscal resources to nuclear fission R&D in comparison to other International Energy Agency (IEA) member countries in the wake of the first oil shock and to 2005. The IEA itself was set up, in November of 1974, as an oil-consumer country response to the oil shocks. Japan became one of its most avid members. From the start of the 1980s, Japan took over from the previous leaders of nuclear R&D investment, the US and UK, and by mid-decade had far surpassed them. Moreover, by 1990, Japan was alone performing well more than half of all IEA spending on nuclear fission R&D.

The Nuclear-Centred Policy Regime

Japan's enormous volume of state R&D for nuclear power was matched by the

Table 4 Nuclear Fission R&D Expenditures by IEA Countries, 1975-2005 (2005 USD million)

	UK	France	Japan	USA	Other	All IEA
1975	929	0	763	2,164	952	4,808
1980	741	0	2,098	2,410	1,160	6,794
1985	638	895	2,259	1,241	1,542	6,575
1990	253	555	2,298	737	356	4,199
1995	17	599	2,455	103	442	3,616
2000	0	666	2,393	39	308	3,406
2005	4	N/A	2,398	171	N/A	3,168

Source: WNA, 2013

Three Laws for Electricity Power Promotion, enacted in 1974. These measures used taxes on energy sources and subsidies to encourage the siting of nuclear plant in economically distressed areas. Given Japan's massive R&D and other intensive investment in nuclear energy, it is no surprise that nuclear power became the central pillar of the country's energy-environmental policy regime. Prior to the 2000s, Japan had drafted and adopted a string of energy plans focused on raising the level of nuclear in the power mix (IEA, 2003). But Japan's first comprehensive energy-environmental policy was enacted in June of 2002, and emphasized the three principles of "security of supply," "environmental compatability," and "free-market principles." It was clearly designed to increase the fiscal and other resources in support of nuclear energy, whose share of Japan's power generation was 39% in 2001. As part of this pronounced policy shift, the government "gained greater authority ...... in establishing the energy infrastructure for economic growth" and also revised its fiscal tools in order to expand nuclear power and disincentivize fossil fuels (WNA, 2013).

The 2002 policy also created the legal authority to draft an "Energy Basic Plan" (*kihon enerugii keikaku*). This was to be a comprehensive and long-range assessment of energy supply and demand, led by the Ministry of Economy, Trade and Industry (METI). The plan was also to be revisited, and if necessary, revised at least every 3 years. It first version was adopted in October of 2003, and emphasized the role of nuclear power as clean, secure and reliable energy whose safety and public support required significant effort (METI, 2003).

As the 2000s progressed, rising conventional energy prices coupled with geopolitical turmoil—particularly 9-11 and the American response—led to increased energy insecurity. Adding to Japanese concerns were competition for energy resources from the rapidly growing and heavily populated Chinese, Indian and other developing economies of the Asian region. In May of 2005 Japan thus drafted a New National Strategy emphasizing energy security, compiling a Nuclear Energy National Plan in August of 2006.

The core aspect of the 2006 nuclear-energy policy was its clear commitment to 13 new nuclear reactors at existing and greenfield plants by 2030, while raising the capacity utilization ratio of existing nuclear reactors from 60% to 90%. These ratios had plummeted in the early 2000s due in part to a string of scandals concerning falsified damage reports and safety violations at nuclear facilities[5].

The most recent revision of the "Energy Basic Plan" was adopted in June of 2010, less than a year before the March 11, 2011 natrual and nuclear disasters. The policy aimed at ramping down fossil-fuel demand primarily by getting 53% of Japa n's electricity from nuclear power by 2030, compared to 26% in 2010. Realizing that scenario required 9 additional nuclear reactors by 2020 and more than 14 by 2030. It also depended on Japan's becoming a "plutonium economy," recycling nuclear waste so as to create a domestic, "renewable" energy economy and be as free of dependence on imported energy resources as possible.

The long-range vision of the industrial future developed in this context of incumbent interests and captured state institutions was evident in a Japan Atomic Energy Association (JAEA) roadmap for nuclear as the fundamental energy source. Envisioning a future of electric and hydrogen-powered cars, and massively expanded demand for electric power as well as industrial heat, JAEA planned 60% of all primary energy from nuclear by the end of the century. Its vision retained a larger role for fossil fuels than renewables, with the former composing 30% of primary energy and renewables relegated to a 10% share (JAIF, 2008).

The Emergence of the Smart City Paradigm

Sustainable forms of renewable energy, such as solar and wind, as well as energy efficiency, were underplayed in the 2010 Energy Basic Plan and its predecessors. Even so, the plan contained some ambitious targets for radical efficiency and renewables. Japan's potential in these fields was evident in the goal of making LEDs 100% of the lighting sales market by 2020 (and 100% of all lighting by 2030), increasing renewables to 21% of power by 2030, diffusing electric and other second-generation cars to 50% of new-cars sales by 2020 (and 70% by 2030), as well as making all new homes net-zero energy by 2030 (METI, 2010).

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5) One of the most serious was the September 30, 1999 incident at Tokai-mura, in which workers mistakenly mixed highly enriched uranium and generated an uncontrolled chain reaction.

These targets show that the nuclear village did not dominate all aspects of energy policy. Japan's governance was flexible enough to include a liberalization of power markets (in 1995) that ended at the "large-lot" (over 500 Kilowatts) level of customer. Yet that liberalization was limited: it satisfied the major industrial interests, in encouraging lower power costs, while maintaining Japan's unparalleled (among the developed countries) monopolization over power generation, transmission and sales (Scalise, 2009). This dense structure of vested interests was crowned by Tokyo Electric Power Company (Tepco), which was Japan's largest utility—commanding 24% of total power sales—and 4th largest in the world. Tepco was also prominent in the tripod of interests that dominated Japan's peak business association, Keidanren. The other two legs were Toyota and Nippon Steel, both heavy users of power (*Nikkei Weekly*, January 30, 2012).

The incumbent power monopolies clearly wanted renewable generation restricted as much as possible as well as closely contained within a stable framework of power and energy institutions that maintained their role (DeWit et al, 2012). As of 2011, the monopolies owned about 80% of Japan's installed generating capacity (EIA, 2013), in a power market worth roughly YEN 16 trillion, and preferred to maintain that centralized generation and the income streams it entailed. Their preference is the major reason that Japan's official target for diffusing renewable power via a "renewable portfolio standard" incentive, implemented in 2002, was a mere 1.35% for 2010 and 1.63% for 2014.

At the same time, Toyota and other interests, including relevant divisions within conglomerates such as Toshiba and Hitachi, also wanted to be leaders in smart grids, solar, wind, storage and other green technologies that Japanese assessments indicated would total a cumulative USD 40 trillion between 2010 and 2030 (Nikkei BP, 2010). Japan's energy policy confronted the challenge of maintaining monopolies in the domestic market while fostering world-class innovation. The core vehicle for achieving this aim was "smart city" initiatives that allowed for green innovation in a context that sought to encompass the legacy players along with their business models and infrastructure (Samuels, 2013: 145).

The March 11, 2011 Fukushima Shock

On March 11, 2011, Japan's energy policy and energy political economy were hit very hard by history's largest and most expensive natural and nuclear disasters (Lochbaum, Lyman and Stranahan, 2013). The total damage from the Great East Japan earthquake and tsunami per se has been assessed at YEN 16.9 trillion (*Nihon Keizai Shimbun*, June 24, 2011).

The cost of the nuclear accident itself, including the melt-down of three reactors at Tepco's Fukushima Daiichi plant, remains uncertain. Much depends on the extent to which radionuclides are removed from affected areas, how much land is purchased, decisions on levels of compensation, and other factors. On July 23 of 2013, a research team from Japan's National Institute of Advanced Industrial Science and Technology (AIST) determined the cost of cleaning up just Fukushima Prefecture alone to be over YEN 5 trillion, more than 4 times the YEN 1.15 trillion that had been used in official accounting (*Mainichi Shimbun*, July 24, 2013). The total cost of the nuclear accident is often ball-parked at about YEN 10 trillion. Yet recalculations such as the above, by AIST, give credence to the YEN 50 trillion figure that was mooted by Ban Hideyuki, Co-Director of the Citizens' Nuclear Information Center to a March 19, 2012 meeting of the METI's Advisory Committee for Natural Resources and Energy. Prior to that, the Japan Center for Economic Research had submitted a May 31, 2011 assessment to the Japan Atomic Energy Commission of the Cabinet Office, judging that costs could exceed YEN 20 trillion even without including costs for cleaning up irradiated water and soil as well as compensating area farmers and fishermen (*Asahi Shimbun*, June 1, 2011).

Covering even a portion of these costs is well beyond the capacity of Tepco. The firm's total market capitalization, just before the disaster, was YEN 3.2 trillion and its assets of YEN 13.2 trillion netted out at YEN 2.5 trillion after the subtraction of debts (Ramseyer, 2011). Resolving pressing matters such as clean-up, compensation, decomissioning and the like are beyond the firm's means, and beyond that of Japan's entire power industry, whose annual sales in 2012 were roughly YEN 16 trillion.

Tepco itself was soon rendered effectively bankrupt, and hence was nationalized in June 2012 via a YEN 1 trillion injection of public capital, “the biggest state intervention into a private non-bank asset since America’s 2009 bail-out of General Motors (*Economist*, 2012). Some specialists question whether the other nuclear-dependent utilities are viable as well (Kaneko, 2013), and in early April of 2014 Kyushu Electric and Hokkaido Electric were revealed to be in discussion with the public sector Development Bank of Japan for bailouts (*Financial Times*, April 2, 2014). Since Fukushima, the Japanese public sector has thus been in a powerful position vis-à-vis the utilities, in order to press for reform. But this authority has not been used aggressively by the central-government, and the Tepco bailout was notable for protracted negotiations between Tepco and its politico-bureaucratic allies and state officials. The process was “bewildering” to outsiders and “underscored the depth and resilience of Tepco’s resilience, and that of the ‘nuclear village’ of utility executives, bureaucrats and lawmakers that built Japan’s atomic power industry” (*Financial Times*, October 21, 2012).

Although it is not possible to predict what will eventuate from this still-unfolding shock, it is possible to detail broad scenarios that frame the early 2014 debate over a new energy policy. The power monopolies’ 48 viable nuclear reactors, representing about 46 gigawatts of capacity and 30% of Japan’s electricity generation potential, were all off-line as of September 2013. The September 19, 2012 emergence of a new regulator, the Nuclear Regulation Authority (NRA), brought new rules into play. Calculations by the Japanese cross-party “Club for Zero Nuclear” indicated that decommissioning all viable reactors would cost YEN 4.57 trillion. On the other hand, compliance with revamped safety measures announced in July of 2013 would at a minimum cost YEN 2.69 trillion, with the added uncertainty of restarts (*Tokyo Shimbun*, May 31, 2013). No matter what happens, resolving the nuclear crisis will thus require passing massive costs onto ratepayers and taxpayers.

Those costs could be deployed to buy back as much as possible of the status quo pre-Fukushima, which is one potent line of argument. Or they may be invested in moving to a new energy paradigm, abandoning nuclear power in favour of an accelerated deployment of renewable energy, radical efficiency, smart grids, and the innovative power-service and other business models that are part of power-sector modernization globally (Ebinger and Banks, 2013; Lovins, 2011). This option is a powerful counter-argument, advanced by such actors as many of the previous prime ministers, especially Koizumi Junichiro (DeWit, 2014b). There are of course a range of options in between these polarized positions, as theoretically the power mix (and energy mix more generally) admits of a vast number of scenarios concerning the blend of energy sources, including nuclear, not to mention the "fifth fuel" of energy efficiency. Yet the "nuclear vs renewable" choice appears to be the core issue in the larger context of Japan's desperate search for sustainable growth and an equilibrium in post 3-11 energy policy.

Back to the Nuclear Paradigm?

The December 16, 2012 national elections saw the return of the Liberal Democratic Party (LDP) to power, with a massive majority, under Prime Minister Abe Shinzo. A staunch nationalist, Abe also made it clear that he would seek to return as much as possible to the status quo before the Fukushima shock. Abe also aggressively promoted nuclear exports, declaring himself Japan's "top salesman" for nuclear-centred infrastructure exports (*Wall Street Journal*, November 12, 2013). Moreover, LDP Secretary General Ishiba Shigeru made it clear on November 16, 2013 that restarts were seen as a steppingstone to new reactor build inside Japan (NHK, November 16, 2013).

The return of a prime minister and cabinet explicitly committed to nuclear restarts suggests, for some, that the weight of sunk costs and other factors will drive policy and the political economy back to the trajectory it was on prior to the crisis (Kilisek, 2014). As noted in the introduction, Japan has largely turned to fossil fuels to fill the gap in generation caused by the post-Fukushima shut-down of nuclear capacity. In its October 29, 2013 country report of Japan, the US Energy Information Agency notes Japan's share of consumption of globally traded Liquefied Natural Gas (LNG) rose from 33% in 2011 to 37% in 2012. The increase in LNG imports represents a rise of 24% over the amount imported in 2010, from 3.5 Trillion Cubic Feet (TCF) to 4.3 TGF (EIA, 2013). The cost of the fossil fuels is thus one common element in the argument that Japan will return to significant or even expanded use of nuclear power.

Indeed, though Japan's oil dependence as a share of primary energy supply bottomed out in 2010, at 43.7%, it then rose in the following two years to 46.1% in 2011 and 47.4% in 2012. Over the same period, Japan's reliance on fossil fuels rose from 82.6% (2010) to 88.8% in 2011 and 92.5% in 2012. The postwar low had been achieved in 1998, when oil dependence was 51.8% but fossil fuels over all were 80.5% of energy supply (METI, 2013).

Other arguments generally deployed by interests and observers who argue a scenario of pretty much a return to the status quo prior to Fukushima is that renewable and other alternatives have a limited prospect in Japan. Common assertions include space constraints, the low level of renewables installed due to the long dominance of the nuclear village, investor risk stemming from the unresolved problem of independent governance of the transmission grid, and other factors (*Economist*, 2013).

Disruptive Change?

On the other hand, a scenario of disruptive change has to be included because it is propelled by public opinion, policy and growth opportunities. For one thing, Japanese opinion poll on nuclear restarts remained stubbornly opposed even three years after Fukushima. The March 18, 2014 survey by the *Asahi Shimbun*, for example, indicated that 59% of the Japanese public opposed restarts of any nuclear capacity, even those with safety upgrades, whereas only 28% supported restarts. The poll's results also indicated that only 12% of the Japanese public have either no or minimal concern regarding the risk of further nuclear accidents at facilities other than the infamous Fukushima Daiichi. By contrast, 50% had a fair degree of concern, and 36% had a very high degree of concern. In addition, the poll showed that only 4% of respondents regarded the lack of nuclear waste disposal facilities as of no or only minimal concern. By contrast, 19% believed it is to some extent a problem. And an overwhelming 76% regarded it as a serious problem (*Asahi Shimbun*, March 18, 2014).

At the same time, a separate *Asahi Shimbun* survey of the utilities themselves indicated that fully 60% of Japan's 48 viable nuclear reactors, meaning 30 reactors, were not being considered for application to the NRA for restart. And of these 30 reactors, at least 13 were apparently write-offs due to age, proximity to a seismic fault, and other factors that render them incapable of satisfying the NRA's new safety standards. For that reason, as of March 2014 there were only 17 reactors for which restart applications had been filed (*Asahi Shimbun*, March 12, 2014). Of these, it appeared—even to Japanese supporters of nuclear power—that perhaps only 8 will finally get approval and be restarted. Energy specialist Tom O'Sullivan, of Mathyos Japan, noted that "[t] his level of restarts would only amount to 56 TWh of power output or 6% of Japan's total power requirements and thus may not constitute a base-load power supply[6]."

The stubbornness of public opposition was also reflected in local government. Nationwide, 135 local communities lie within 30 kilometers of a reactor, and 21 prefectures are host to one or more reactors. The news service Kyodo Tsushin surveyed these 156 subnational governments in mid — to late — February of 2014, and found that only 13 were ready to agree to restarts without conditions. A further 24 would agree to restarts, but with conditions. Of the remainder, 32 declared their opposition to restarts, 66 replied that they could not decide, and 21 offered no reply at all (*Tokyo Shimbun*, March 2, 2014). The NRA decided on March 13 of 2014 to prioritize Kyushu Electric's Sendai rectors 1 and 2 (in Kagoshima Prefecture) for restart (*Nikkei Shimbun*, March 13, 2014). But that decision itself came under criticism, due to perceptions of undue haste amid suggestions that seismically active zones are nearby.

Even the argument that nuclear is low-cost appears questionable. The rise of an independent regulator, through the NRA, subject to intense scrutiny by domestic and global specialists, has led to compensation, decommissioning, safety and other costs that have raised the price for nuclear generation. The most comprehensive assessment, with calculations for each reactor, suggests that the cost of nuclear generation in Japan exceeds that of conventional fossil fuels. This assessment includes natural gas, which is the key comparative referent when debating whether and by how much a return to nuclear would resolve the power-cost problem in Japan (Kaneko, 2013).

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6) Tom O'Sullivan's survey of various established Japanese policy institutes that are close to Japan's industrial interests estimates that only eight reactors may re-start (March 20, 2014 e-mail from Tom O'Sullivan, Mathyos Japan).

The narrative of disruptive change thus centres on the Fukushima shock and the delegitimization of nuclear power in a very seismically sensitive country. Diffusion of that awareness underlies the sustained shift in public opinion towards an antinuclear stance. This shift of public opinion also became manifested in regional and local governments' opposition to restarting nuclear capacity. The German case became a model for much of the Japanese energy policy debate whether within the central government and subnational governments and more broadly in civil society and among the ranks of businesses (Tsubogu, 2013). After Fukushima, the Japanese public debate received a very accelerated course of instruction on how various political economies were responding to the risks of resource price increases as well as climate change and the opportunities of developing new industries in renewable energy and related fields. The public debate also became apprised of just how far behind Japan was in its deployment of energy alternatives such as solar and wind. Moreover, the old arguments that these forms of power generation were not suited to Japan lost their purchase in the public debate.

In addition, local governments exhibited increasing efforts to seize opportunity in the emergence of alternatives to highly centralized and concentrated nuclear power. Centralized power led to concentrated economic benefits for a few communities whereas the risks of accident were distributed among a much broader range of communities. Fukushima Prefecture's post-3-11 commitment to 100% renewable energy by 2040 encouraged other prefectures and cities, including Tokyo, Kyoto, and Osaka, to adopt ambitious targets (DeWit, 2014a).

Moreover, at the end of 2013, Japan's 16 trillion yen power market featured 192 independent power producers, including such new entrants as Toyota (*Denki Shimbun,* April 2, 2014). In September 2012, that number was 64. And Japan's "feed in tariff" policy support for diffusing renewables, effective from July of 2012, saw over four gigawatts (roughly four large nuclear reactors worth) of new renewable capacity deployed in the initial year. Moreover, Japanese domestic shipments of solar cells and modules during July-September of 2013 leapt to 2.075 gigawatts, over triple the 627 megawatt level of a year earlier (Ishida, 2013). These data points are indicative of the speed with which Japan's energy landscape began to change.

Indeed, the Japanese bureaucratic-political elite at the national level also shifted to support of renewables and efficiency. For example, METI's Natural Resources and Energy Agency Manager Kimura Youichi called for accelerated deployment of renewables via the FIT and other policies (Kimura, 2013). This statement from Kimura followed a previous call for more renewables and efficiency from Yamamoto Taku, Chair of the LDP's Natural Resources and Energy Commission and a Dietmember from Fukui Prefecture (Yamamoto, 2013). Fukui Prefecture is also called "nuclear alley" because it hosts 13 reactors, the largest number for any prefecture in Japan. Arguments that were beyond the pale pre-Fukushima—such as ambitious targets for smart grids, renewables and efficiency—became common sense and attracted significant fiscal and regulatory support.

The Smart Cities Paradigm Spreads

The destabilization of the nuclear village thus saw the diffusion of new ideas and influence in power and energy policymaking spread out among a larger range of actors in the central government and the regional governments. In the wake of 3-11 many of these actors used regional blocs and other vehicles to collaborate and apply pressure to central government agencies for accelerated rollout of distributed generation and other aspects of power-and energy-economy modernization. This collaboration also focused on the smart cities and smart grids and other ICT-centered infrastructure that—as noted earlier—the nuclear village was quite wary of. The nuclear village recognized the threat to their paradigm of centralized power production and highly concentrated income streams. But the rebuild of the devastated region provided a significant foothold to expand the rather constrained smart city projects that had been under way since the late 2000s and increase their diversity as well as their deployment of renewables and more radical efficiency (DeWit, 2014b).

As to scale of the opportunity, the Japanese Ministry of Internal Affairs and Communications (MIC) indicates that the role of ICT in the Japanese economy is already large. Its 2013 White Paper on Communications indicates that nominal output by the various sectors of the Japanese economy totaled YEN 918.6 trillion in 2011. The ICT industry represented ９% of that output, or YEN 82.7 trillion. This total was considerably larger than such sectors as wholesale, which accounted for 6.5% of economic activity or YEN 59.4 trillion. Construction, once the obese king of Japan's domestic economy, accounted for 5.6% of economic activity or YEN 51.2 trillion. Transportation followed, at 4.3% of economic activity, or YEN 39.4 trillion (MIC, 2013: 48).

The MIC data also suggest that a strategic focus on ICT can help countries grow their economies by consuming less. The data also demonstrate that investment in ICT has a significantly larger multiplier effect than general investment. The "mu ltiplier effect" refers to the amount of economic activity generated as a result of a given volume of investment. Drawing on a growing body of work suggesting that investment in software and other such "intangibles" (as opposed to such "tangibles" as plant and equipment) is very productive, the MIC project that the multiplier effect of ICT investment in 2015 may be as high as 1.98 versus 1.19 for general investment.

This ICT-centred growth strategy was approved by the Abe Cabinet on June 14 of 2013. The growth strategy is also very powerfully informed by the disruptive potential opened up by the rebuild of the devastated regions on the basis of renewable and distributed energy (DeWit, 2013b). But it also has a larger purchase in the political economy debate because—as with ICT-centered "industrial Internet," "machine to machine," "big data," and related emergent paradigms—it is aimed at a profound restructuring of the energy economy as well as much of the rest of the infrastructures that make up the modern urban community and the exchange of resources and information among citizens, businesses and their governments. This emergent paradigm is not peculiar to Japan. The smart city model had begun to accrete, as idea and practice, in the early 2000s. But from the beginning of the 2010s, worsening resource, economic, and climate crises were paralleled by such technical advances as the diffusion of "big data" analytics via the cheapening and miniaturization of sensors (Townsend, 2013). These and other developments increasingly point to the disruption not just of centralized power generation and transmission but also of a resource-intensive growth dynamic that has characterized the developed economies over the past six decades (Koomey et al, 2013).

The "dematerialization" of the economy has been an aim in Japan and Germany since the 1980s, with an increasing sophistication of policies and programs for reducing resource waste through greater efficiency and recycling, development and deployment of more sustainable practices, and the other initiatives. But these initiatives were generally seen as more or less costly interventions in the mainstream economy to reformat and reduce its throughputs and polluting outputs. The ICT strategy, through its deployment of sensors that monitor a multitude of aspects of the ambient environment as well as system parameters, is already working to accelerate this transformation of the conventional economy.

Indeed, some of the most aggressive deployment of ICT is evident in conventional energy. The mining firm Rio Tinto, for example, revealed in early 2014 that its initial deployment of “big data” ICT to enhance efficiencies saved it USD 80 million over 2013 (*Sydney Morning Herald*, March 14, 2014). The oil industry’s use of “big data” in what it refers to as the “digital oil field” is another example of very hard-pressed actors deploying the technology in the face of rapidly rising costs of discovery and extraction (Leber, 2012).

As noted earlier, prior to 3.11 Japan’s smart-city initiative centred on building a low-carbon and more efficient model in a few cities, with a focus on export opportunities. METI and other policymakers were constrained by the larger context of the monopoly utilities, the centralized and nuclear paradigm in the power economy, and other strictures of the pre-disaster status quo.

After 3-11, Japan’s government-sponsored smart-city projects increased from 22 (Sato, 2013) to well over 100. As is the case globally, there is no reliable count. The projects are too diverse and too rapidly growing, with many communities implementing a broad range of smart applications while others confine theirs to one or a few areas of infrastructure. The Japanese central government’s official list of 82 “Environment Model Cities” (Kantei, nd) includes the METI-led and other smart projects. But it overlooked numerous recent local-government projects and omits entirely the growing number of private ventures. The former include several smart city initiatives in the Tohoku (Northeast) region along with such examples as Tochigi Prefecture’s Ashikaga City’s impressive power generation, conservation and storage-focused project, which took shape from April of 2012 (Ishida, 2013). And among the latter are Panasonic and 12 other firms’ 60 billion yen “Fujisawa Sustainable Smart Town”

(Hata, 2013) and Sekisui House "smart towns" in 11 locations nationwide. One of the Sekisui's projects is the "local power plant" (producing 170% of its own consumption) "Smart Common City Akaishidai" in the suburbs of Miyagi Prefecture's Sendai City.

Green Growth as an Opportunity

In 2014, then, Japan was at an impasse over retarting nuclear reactors versus adopting a full-on green growth paradigm, even as it was back at an extreme level of dependence on fossil fuels in its power mix. The potential for restarts appeared in fact too limited to provide base-load power, but serve instead to detract from deployment of alternatives (Schneider and Froggatt, 2013).

Since the public debate in Japan is so polarized, it seems useful to examine which of the two idealized options—nuclear or green—offers the better return. **Table 5** is an aid to this objective by its highlighting of the profoundly skewed energy R&D priorities of all the IEA countries. Over two-thirds of the 1980 peak in energy R&D expenditures by all IEA members was devoted to nuclear fission and fossil fuels. By contrast, only 12.3% was invested in renewables and only 6.4% in efficiency. Yet according to the IEA Energy Efficiency Market Report of 2013, global energy efficiency investment in 2011 was worth roughly USD 300 billion, "a similar scale to renewable energy and fossil fuel power investments" (IEA, 2013: 3). Directly comparative data on nuclear power investments appear not to be available, but the 2013 global total of 427 reactors with an installed capacity of 364 GWe was considerably lower than the 2010 peak of 444 reactors with an installed capacity of 375 GWe (Schneider and

Table 5 Energy R&D Expenditures by IEA Countries, 1975–2005 (2005 USD million)

Year	1975	1980	1985	1990	1995	2000	2005
Efficiency	587	955	725	510	1,240	1,497	1,075
Fossil Fuels	587	2,564	1,510	1,793	1,050	612	1,997
Renewable	208	1,914	843	563	809	773	1,113
Nuclear Fission	4,808	6,794	6,575	4,199	3,616	3,406	3,168
Total Energy R&D	7,563	15,034	12,186	9,394	9,483	9,070	9,586
Total: Japan	1,508	3,438	3,738	3,452	3,672	3,721	3,905
Total: Excluding Japan	6,055	11,596	8,448	5,842	5,811	5,349	5,681

Source: WNA, 2013

Froggatt, 2013).

Moreover, the IEA Energy Efficiency Market Report 2013 also stresses how potent efficiency has become in an era of high energy prices. Its analysis indicates that efficiency has led to avoided energy use for 2010 in 11 IEA member countries[7] that greatly exceeds even the consumption of oil. And the IEA itself stresses that there is much more efficiency potential to be exploited.

Japan's Smart Model and the Global Challenge

The Japanese MIC also stress the role of ICT and so-called "big data" in alleviating a host of contemporary crises. In a rough sketch of how fraught are our circumstances, the MIC note that the number of people living in water-stressed areas is expected to quintuple over the 45 years between 2005 and 2050. They also point out that between 2005 and 2030, emissions of carbon dioxide are expected to increase by 160%. The data also suggest that the consumption of primary energy, such as through oil and coal, is slated to climb 140% over the 20 years between 2010 and 2030. In addition, between 2010 and 2050, the consumption of minerals is likely to exceed present estimates of total reserves.

One key driver for all of these unsustainable trends is that the world's urban population is in the midst of an historic explosion. In 2011, half the global total population of 7 billion people was urbanized. This share is expected to increase even more rapidly than the global population itself over the coming years. Thus by 2025, the total global population estimate of 8 billion is projected to include 4.6 billion people living in cities. And for 2015, by current projections, the total global population of 9.3 billion people will include 6.3 billion people in cities.

In this fraught context, Japan's smart-city ICT strategy is becoming the focus of preparations for the 2020 Olympics, further accelerating Japanese initiatives. If the smart-city strategy is done well, the payoff for Japan may not only be a global showcase for Japanese technological prowess. It could also help make Japan, and

7) The countries are Australia, Denmark, Finland, France, Germany, Italy, Japan, the Netherlands, Sweden, the United Kingdom and the United States.

global city regions, more resilient to accelerating climate threats and resource crises. Japan's exposure to natural disasters, including earthquakes and typhoons, is already highest among the advanced industrialized countries and exclipses that of most developing states. The October 14, 2014 release of the World Risk Report 2014, highlighted the fact that urbanization and climate change are increasing risks in numerous countries. Along with much other work on comparative vulnerability to natural disasters, the "World Risk Report 2014" places Japan's exposure at 4^{th} most precarious in the world, just behind Vanuatu, Tonga and the Philippines (WRR 2014: 44). Also, on October 14, 2014, the US Pentagon released its "2014 Climate Change Adaptation Roadmap," warning that climate change is an immediate threat (Department of Defense, 2014). Given the degree of Japan's vulnerability, and the urgency of the threat, it is in Japan's existential self-interest to lead the smart-city paradigm shift.

Conclusion

Devoted for over a century to resource-intensive industrialization, Japan's response to energy challenges and crises have been marked by extremes of dependence and fateful strategic choices. The speed and scale of Japan's shift to oil in the 1960s also suggests that energy-paradigm shifts may not always require decades (cf Smil, 2010). This may especially be the case in a regime of resource-lite infrastructure and under unprecedentedly extreme conditions of climate damage, depletion, fraught geopolitics, and other drivers to disruptive action. In the wake of the March 11 2011 Northeast region natural disaster, Japan finds itself in the midst of a costly and continuing nuclear crisis as well as the eclipse of its resource-intensive, mass-production growth model. Japan may thus be driven into accelerating the deployment of a new and sustainable model that affords it the autonomy and status it has always sought.

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