POST-FUKUSHIMA PROSPECTS FOR NUCLEAR-POWER DEVELOPMENT IN
THE UNITED STATES, GERMANY, AND JAPAN

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The Fukushima Daiichi nuclear accident that followed the March 11, 2011 Tohoku earthquake and tsunami off the coast of Japan has had far-reaching consequences. In order to properly assess and predict the impact of this event on industry, political opinion, and government policy, it is important to examine the political aftermath of the Three Mile Island and Chernobyl accidents of March 28, 1979 and April 26, 1986 respectively. By considering these three incidents with regard to actions taken in response by the United States, Germany, and Japan, this paper grounds a dynamic issue in both temporal and geographical comparative perspective. It concludes with a closer look at the economic benefits and costs of nuclear power, and an evaluation of a few of the tenets of contemporary environmental policy as they relate to nuclear power.
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INTRODUCTION

Few events have the ability to cause as significant an impact on industry, political opinion, and government policy as a disaster like that of the Fukushima Daiichi nuclear accident following the Tohoku earthquake and tsunami of March 11, 2011. In its aftermath, images of nuclear reactors in meltdown at Three Mile Island (Harrisburg, PA) and Chernobyl were immediately recalled from the public memory. It is surprising, then, that few analyses of Fukushima have revisited these past events with a mind to putting the Fukushima emergency in comparative perspective. Indeed, considering the complex set of factors that bear influence on nuclear power’s future, it is difficult to make an accurate prediction of Fukushima’s policy effects without also examining how these factors played out in the years that followed the Three Mile Island and Chernobyl accidents of March 28, 1979 and April 26, 1986 respectively.

Today, the future of nuclear energy rests on conflicting pressures brought on by rising oil prices; environmental policies, such as ambitious targets for the reduction of greenhouse gas emissions and the refinement of alternative energy sources; and the interaction between public opinion and the government–industry regulatory nexus. Although public opposition to nuclear power is on the rise, the aforementioned issues will continue to drive the nuclear industry forward at a modest pace in some countries, and condition resistance to nuclear’s decline in others. In the meantime, governments and industry will endeavour to control the political damage and the economic knock-on effects wrought by Fukushima. While this will
involve a general reappraisal of the contribution that nuclear power could possibly make to future energy needs, the outcome of such a reappraisal is likely to vary significantly according to national political context.

The political impact of Fukushima is therefore explored here with respect to the United States, whose nuclear-power output is greater than that of any other country; Germany, representing one of the world’s most anti-nuclear political cultures; and Japan, as the site of the Fukushima crisis and other nuclear accidents. In examining how the formal and informal constitution of politics in the three countries have influenced debates in the public and scientific communities in past cases of nuclear disaster, this analysis also looks forward in an effort to forecast how the public policy responses to Fukushima by these three countries will be shaped by political conditions, both in the short- and long-term. The paper concludes with a closer look at the economic benefits and costs of nuclear power, and an examination of a few of the tenets of contemporary environmental policy as they relate to nuclear power.

II   THE UNITED STATES: NUCLEAR POWERHOUSE

At the time of the Three Mile Island (TMI) accident, March 28, 1979, the United States had already invested heavily in nuclear-generated power, with sixty-seven operational reactors producing over 250,000 Gigawatt hours of electricity (see Figures 1 and 2). Nuclear had seemed to promise an end to the woes of energy scarcity, a constant concern for any industrial
economy but one aggravated in the 1970s by a global energy crisis brought on by the supply
policies of the Organization of Petroleum Exporting Countries (OPEC). The early decades of
nuclear power development saw much excitement over its potential, particularly the
possibilities offered by fuel-breeder reactors, a concept that was explored but eventually
abandoned by Russia, Britain, Germany, India, China, France, and the United States. The
possibility of virtually-free energy, as it was envisioned at the time, was able to cut across
ideological cleavages until the post-energy-crisis era.

Whether it was spurred on by an unbridled trust in the nuclear option, an incomplete
understanding of the risks, or a combination of these, the American nuclear industry had until
1979 succeeded in erecting more reactors than any other country while operating under
horrifically poor safety standards. The severity of the safety situation was not fully understood
until the completion of President Jimmy Carter’s Kemeny Commission, prompted by the TMI
accident. The final report, concurrent with the Second Gatlinburg Conference on an
Acceptable Nuclear Future, detailed how reactor problems that were not unique to a single
reactor could be deemed ‘generic.’ Under the regulations of the time, the NRC was permitted to
“allow those safety issues labeled ‘generic’ to remain unresolved during licensing proceedings
by placing them on a separate agenda.” This expedited the licensing process but often resulted
in the operation of power plants “without resolution of major safety issues.” The report
estimates that about 200 different problems were considered generic under that policy. The
report also reveals that high-school graduates without any specialized education were permitted to operate reactors, even in the absence of an engineer’s supervision.\(^2\)

Of equal importance was the report’s condemnation of the Nuclear Regulatory Commission (NRC), specifically, its inability to adapt to its new role as sole regulator of the industry, its lack of communication and managerial competency, weak standards for operator training and certification, and failure to involve public participation in decision-making processes. In 1974, the Atomic Energy Commission (AEC), which had been responsible for both regulation and promotion of the nuclear industry, was abolished in favour of the creation of two new bodies. These were the NRC and the US Department of Energy’s predecessor, the Energy Research and Development Administration, which were given the tasks of regulation and promotion respectively. After TMI, the Institute of Nuclear Power Operations and the Nuclear Safety Analysis Centre were established in order to bolster the NRC’s supervisory capacity. However, these were not government reforms, but rather industry initiatives intended to create an institutional memory and to facilitate more-rigorous safety reviews of existing plants. This evolution of the industry’s regulatory structure was constrained and

delayed due to the secrecy that shrouded nuclear energy from the time of the Manhattan project and the post-1945 onset of the Cold War until 1979.\(^3\)

Notwithstanding important modifications to the regulatory structure, the Kemeny Commission advocated little else, neglecting to address the long-term, environmental, or health impacts of the incident and “[identifying] the most substantial effects of the TMI accident as financial.”\(^4\) In fact Alvin Weinberg, an American nuclear physicist with experience as the director of the US Office of Energy Research and Development, ventured that a moratorium on nuclear energy would have resulted in a loss of $100 billion in investments. Cleanup costs were pinned at $1 billion, the entirety of which was to be paid by General Public Utilities (GPU), the owner of TMI-II. Under the weight of these unforeseen costs, GPU nearly declared bankruptcy, and as a result, a group of American Nuclear Insurers (ANI) was organized as an insurance pool. This had two effects: firstly, it provided a means of compensation for victims of future nuclear accidents; but secondly, it relieved some of the pressure on utilities to


\(^4\) Elliot, 810.
ensure that the highest safety standards were upheld. American Nuclear Insurers now insures utilities based in several countries.\(^5\)

Because the TMI incident resulted in no loss of life, the focus of crisis-management quickly shifted not only to the financial, but also to the potential political damage of the incident. A report prepared by the Library of Congress’s Congressional Research Service noted that “the main consequence of [TMI] will be severe damage to American leadership in world

nuclear affairs.”

This assessment reflects the Cold War context in which TMI occurred and, more specifically, the context of the late Carter administration during which the American government was viewed as being on the defensive internationally in a phase of renewed nuclear-weapons competition with the Soviet Union. Avoidance of a loss-of-face took precedence over other concerns.

The American government-industry response to the explosion of Chernobyl-IV, April 26, 1986, was even less substantial. Indeed, the United States’ response was again heavily conditioned by the Cold War dynamic and the obvious humiliation of the Chernobyl incident for the Soviet Union. Both government and industry took the opportunity to argue not only for the superiority of American safety protocol and reactor designs, but also to explicitly attribute the disaster to the faults of a corrupt, communist system. This was in addition intended to convince the American people that an accident of Chernobyl’s magnitude could never occur domestically. The restricted flow of information out of the USSR was conducive to these claims, allowing American media coverage to produce, and reproduce, fictitious death tolls that erred

on the side of sensationalism. For example, the New York Post reported a death toll of 15,000, when in fact the real number of deaths attributable to radiation at that time was fewer than thirty. This again speaks to the Cold War element in that Moscow restricted information flow because of the prospect of international humiliation; as information was slowly released, however, the Soviet Union was both humiliated and faced with accusations of incompetence and undue secrecy, leveled against it primarily by the Reagan administration.

Attempts to pinpoint a precise death toll for the Chernobyl accident have subscribed to two methods which merit discussion here, given that similar patterns have surfaced with respect to estimating the amount of radiological release from Fukushima. One method is to include in the total only those deaths due to flying debris from the burning Chernobyl reactor, or which can be traced to exceptionally high levels of radiation exposure among the first responders to the emergency. The result is a death toll of fewer than fifty individuals; this is the figure cited by the United Nations, the World Health Organization, and the International Atomic Energy Agency (IAEA). An alternative methodology includes deaths due to a wide scope of diseases allegedly linked to radiation exposure, such as those resulting from genomic instability, circulatory problems, thyroid and other cancers.


Indeed, the cloud of radiation that drifted from Chernobyl over north-central Europe did pose a health risk to the people living in that area. Consequently, many governments were inclined to address the health threat before turning to the matter of public opposition. Attention was focused on establishing guidelines for permissible levels of radiation in water and food products, and on restoring calm. Although the United States was physically distant from the site of the accident and any considerable amount of radiological fallout, the media fed off of the European panic, which was justified considering that a nuclear accident of Chernobyl’s magnitude was unprecedented, and the long-term health effects, largely unknown.

In contrast to the deep concern expressed by the American media, the ostensible confidence of the American government in its own nuclear industry was, in turn, reflected in the proceedings of the IAEA, regarded as the highest authority of supranational atomic governance. Certainly, the movement for increased international cooperation and standardization in the area of nuclear regulation, of which Germany was a major proponent, was severely tempered by the United States, which rejected virtually all proposals to that effect on the basis of preserving national sovereignty. As a result, the IAEA was only successful
in implementing two weak conventions. It should be noted, however, that American confidence was not entirely baseless in that following TMI the industry installed direct phone lines in its facilities, as well as new control-room instruments, including instruments capable of detecting and measuring offsite radiological releases. “Professionalization of the nuclear cadre” was also achieved “through better training and better pay.”

Although the amount of radiation released from Chernobyl was nearly seven times greater than the 900 Becquerel (Bq) units of radiation released from Fukushima, the latter accident has actually prompted more concern from the United States than Chernobyl ever


did. Fukushima proved that a democratic, technologically advanced society with privately-owned utilities - superficially similar to the American context - was not immune from nuclear catastrophe. More specifically, it revealed the design faults of the Fukushima Daiichi reactors, which are General Electric Boiling Water Reactors (BWR) Marks III, IV, and V, with Mark I and Mark II containment systems; one quarter of the reactors in the United States are of the same General Electric BWR design. Because of this considerable overlap in design, the technical strengths and weaknesses of such designs are briefly explored.

The BWR has a few key weaknesses, including the use of a single coolant circuit; modern reactors have two. In BWRs, the spent-fuel pool is placed in the weaker secondary containment unit, rather than in the primary containment unit. The safety of the BWR is also compromised by the length of time required after shutdown for its core to cool to the point

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11 This figure is based on the conversion of the radiological release from Chernobyl to iodine.


that a core meltdown is no longer possible. In most cases, it takes at least five days of active cooling to bring a BWR below this critical temperature. At Fukushima, other weaknesses included the placement of the diesel fuel tanks above ground and on a waterfront - these tanks powered the emergency core cooling system (ECCS) - and the lack of hardened wet-well vents, which are designed to prevent the buildup of hydrogen gas inside the buildings that house reactors. At Fukushima Daiichi, the interaction between the overheated fuel and zirconium tubing in reactors produced large amounts of hydrogen inside the Fukushima containment buildings; when the hydrogen gas ignited, it caused a chain reaction of explosions that damaged all of the Fukushima Daiichi reactors which, up until that point, had been unaffected by the earthquake and tsunami. In 1980, the United States mandated that all of its BWR reactors be equipped with wet-well vents, as well as quenchers, deflectors, and fortified ECCSs. The same recommendations were made to Japan’s Nuclear Regulatory Commission (JNRC), but the JNRC made the installation of these upgrades optional for Japanese utilities.13

In addition to prompting a reevaluation of reactor designs, the accident brought into question two of the main conclusions of the Kemeny Commission and the Second Gatlinburg Conference: that the nuclear industry should consist of a few private monopolies, and that reactors should be concentrated at a few sites rather than spread across many. Indeed, the centralization of the Japanese nuclear industry in a few powerful utilities in combination with the close relationship between industry and government, may have contributed to a pervasive lack of regulatory accountability, and hence, the poor safety conditions which allowed the Tohoku earthquake and tsunami to wreak as much havoc as they did. Furthermore, the siting of multiple reactors at such a vulnerable site played a direct role in exacerbating the original damage inflicted by natural phenomena. Whereas only one of the reactors suffered a meltdown as a direct result of flooded emergency power systems, the failure and eventual combustion of that reactor initiated meltdowns at other reactors, forming a chain reaction of hydrogen combustion and nuclear meltdown.\(^{14}\)

Because of the similarity in reactor designs, concern over the possibility of an American incident like Fukushima may put a temporary hold on the resurgence of interest in nuclear power that began in the 1990s. This resurgence was spurred on by a modified regulatory structure that favoured the nuclear industry, by the introduction of “smaller (25 MW capacity), longer-lived (60 years), safer and easier to operate nuclear technology,” and the introduction of

\(^{14}\) Weinberg.
reactors with higher operating capacities of seventy-five to eighty-five percent. In reality, interest in nuclear energy never died, but was only suppressed by the limited public opposition that existed. Even though the United States’ ostensible reaction to Chernobyl was one of calm assurance in the security of American reactors, American reactor safety was revisited, amounting to a moratorium on the commission of new reactors that lasted for approximately three decades. The *de facto* moratorium was sustained in part by the advent of the 1971 Calvert Cliffs court rule which raised safety standards and set off a backlog of safety upgrades.\(^\text{15}\) At the same time, mandatory public hearings regarding the construction of reactors did little else than slow the building process. Often, utilities had already selected a site and made significant capital expenditures by the time a hearing was scheduled, leading sociologist Christian Joppke to conclude that such hearings merely “reaffirmed foregone conclusion[s].”\(^\text{16}\)

\(^{15}\) The Calvert Cliffs Coordinating Committee, Inc. and petitioners brought an action against the US AEC, claiming that, under the National Environmental Policy Act (NEPA) that was passed by congress in 1969 and signed by President Nixon, the AEC’s guidelines for an environmental cost-benefit analysis of constructing a new nuclear facility were insufficient. The Court ruled in favour of Calvert Cliffs. Christian Joppke, *Mobilizing Against Nuclear Energy: A Comparison of Germany and the United States* (Berkeley, CA: University of California Press, 1993).

\(^{16}\) Joppke 1993: 35.
Although not a single American reactor has been built since TMI, sixteen applications to build twenty-four new reactors have been filed within the last five years, and four to six of these are expected to be online by 2022. Two reactors have already been approved for construction in Georgia. Ninety of the 104 reactors in the United States have had their operational lifetimes extended by twenty years, for projected lifetimes of sixty years each. And the 2005 Energy Policy Act, which pledged $18.5 billion in loan guarantees to utilities, was recently extended by President Barack Obama, who allotted an additional $36 billion to nuclear development while also cutting the budget to the Department of Energy. Notably, the United States is the only country to subsidize its nuclear industry, a point which Senator Bernie Sanders of Vermont has brought before the US Senate with the intent of convincing the Obama
administration to place the nuclear industry fully in the hands of the private sector (see Figure 3 for a comparison of federal subsidies for various energy sources).\textsuperscript{17}

President Obama has not followed the advice of Senator Sanders, however, and his increased financial support for the industry testifies to his high hopes for nuclear power and its role in bolstering American energy security, asserting on February 16, 2010 that “to meet [America’s] growing energy needs and prevent the worst consequences of climate change,

[America] need[s] to increase [its] supply of nuclear power.”18 It is prudent to note that the Obama administration had initially placed its faith in alternative energy sources, but after the solar-power company Solyndra defaulted on a $535 million loan given it by President Obama in 2009, it appears that this faith in solar energy was premature and possibly misplaced. Hence, the value of nuclear-generated power to the overall energy mix is increased, and the only indication that the American nuclear industry has been tempered at all by Fukushima is in the latest round of equipment upgrades, as outlined by the Near-Term and Long-Term Task Forces. Prior to this, equipment had not been systematically upgraded since 9/11, when safety protocol were revised to protect facilities against fires and explosions.19


While critics of nuclear power will undoubtedly continue to claim that the industry has not done enough, quickly enough to ensure the safety of American nuclear plants, both of the most-recent phases of upgrades involved an in-depth and comprehensive examination of every reactor, and certain mandatory equipment installations, including new venting systems for BWRs. The NRC has also asked utilities to review seismic and flooding risks at their plants, as well as each plant’s ability to cope with a station blackout. Although such upgrades are mandatory, the deadlines by which they must be completed are flexible. For example, utilities are encouraged to implement the changes before 2017, and to complete seismic evaluations by 2019, but these dates are only guidelines. In the meantime, utilities have voluntarily ordered additional emergency diesel generators.\textsuperscript{20}

This has done little to quell the fears of certain senators, particularly Senator Barbara Boxer of California, who cites the fact that more than nine million Californians live within fifty miles of a nuclear reactor, and that California is susceptible to earthquakes and tsunamis. Although only one Californian nuclear plant remains online at the time of this writing, another two plants and the San Onofre-I reactor have yet to be fully decommissioned, meaning that spent nuclear fuel on-site could still pose a danger if containment systems were to be breached.

by a natural disaster. Not surprisingly, the State of California is averse to the presence of nuclear power plants within its borders. By 1978, the Warren Bills were passed, making it illegal to license any future nuclear power plants in California until a final waste repository was established. The result has been a lasting, *de facto* moratorium on new nuclear facilities within the state.\(^{21}\)

Unease also stems from the testimony of now-resigned NRC Commissioner Gregory Jaczko before the US Senate that evacuation procedures are not considered when safety recommendations are made. In the same senate meeting, all four NRC Commissioners in attendance dismissed the warnings of the Union of Concerned Scientists (UCS), which serves as an informal, non-governmental counterpart to the NRC. Testimony before the senate by Dr. Edwin Lyman, Senior Scientist of the UCS, also warned of the dangers inherent in Small Modular Reactors (SMRs), which the NRC claims to be the next, safer generation of nuclear reactor designs. Discontent with the NRC is juxtaposed with criticism that the nuclear industry has in fact been hindered by these investigations and shut-downs, which drive up the cost of generating electricity from nuclear fission.\(^{22}\)

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Dissension within the senate is more elevated than it is among the American public. In fact, despite Three Mile Island, Chernobyl and Fukushima, American public opinion on nuclear power has remained relatively unaffected, holding at roughly an even split between supporters and opponents. This is not to say that the impact of TMI on public opinion was negligible. Rather, 70,000 protesters gathered in front of the Capitol on May 6, 1979, to demand a moratorium. While there may have been a surge of demonstrations, actual opposition to nuclear power increased by less than five percent between 1978 and 1982, and in a recent survey, fewer than thirteen percent of respondents who opposed nuclear power indicated that they changed their view because of Fukushima. Today, forty-four percent support the construction of new reactors, and twenty-nine percent consider nuclear energy to be a viable long-term option (see Figures 9 through 13).  

This comparatively weak opposition to nuclear energy constitutes a considerable but surmountable barrier to pro-nuclear policy for President Obama, who received at least $227,000 for his senate and presidential campaigns from Exelon, a power company whose portfolio of energy sources includes nuclear. President Obama’s ostensible support for the industry in combination with the lack of strong public opposition to nuclear and the centralization of the industry itself, is likely to move nuclear development forward in the

United States. To that effect, the next two decades could see a considerable increase in the American fleet of nuclear reactors, further securing the United States’ position as the top producer of nuclear energy worldwide.\textsuperscript{24}

\textit{III \quad GERMANY: THE GREEN STATE}

In contrast to the United States, Germany’s nuclear situation is characterized by a long history of staunch public opposition which is, in part, the product of Germany’s environmentally conscious governing culture. Today, opposition to nuclear power in Germany stems from the legacy of the anti-nuclear movement of the Cold War era, discontent with the German government’s response to Chernobyl, an aversion to the long-term environmental risks that are inherent in nuclear waste disposal procedures, as well as the “epistemological limits of risk analysis.”\textsuperscript{25} In the 1970s, public opinion of nuclear energy took on a Cold War dimension, which

\textsuperscript{24} There are now only twenty-five utilities operating in the United States, ten of which account for more than seventy percent of US nuclear energy generating capacity. World Nuclear Association, “Nuclear Power in the USA.” Eric Augenbraun, “Fukushima Fears Chill Obama’s Atomic Ambition,” \textit{The Guardian}, March 23, 2011.

was heightened by the installation of Cruise and Pershing II Medium Range Ballistic Missiles with nuclear warheads on German soil in the 1980s. The result was mixed opposition to nuclear weapons and hostility to nuclear power, which culminated in a critical mass of environmentalism and pacifism that was very potent politically. This combination came to be known as the Eco-Pax phenomenon, which established itself as an integral component of the Green Party’s platform. Such public opinion has consistently acted on Germany’s nuclear regulatory structure, especially at the Land level, in order to significantly affect the course of nuclear development.  

The degree of influence exerted by the environmentally conscious public became evident when the German courts declared a de facto moratorium on nuclear energy, pending an international expert review (eventually conducted from 1978-1979) of the controversial Gorleben waste disposal and reprocessing facility, against the government and industry’s wishes and at the public’s request. The courts also revoked the construction licenses for the Brokdorf, Wyhl, Grohnde, and Kalkar plants. This moratorium was already in place at the time of Three Mile Island, which only served to solidify opposition. In response, the premier of Lower Saxony forbade the construction of Gorleben within that state, effectively ending plans  

for Gorleben altogether. This immediate and unapologetic decision - an affront to the federal and industrial momentum behind Gorleben - demonstrates the influence of public opinion on the Länders and national policy. Indeed, compared to the federal government, state-level Land governments are more sensitive to the complaints of their constituents. Land and local governments were also the first to have Green-party coalition participation whose influence on policy was first exercised at that level before percolating up to the federal level. The influence of the Green Party at the Land and national level has had the effect of making environmental policy critical to the electoral appeal of all political parties. For example, a Green-led government, elected in the aftermath of Fukushima, currently runs the state of Baden-Württemberg.

Yet even at the federal level, the influence of anti-nuclear public sentiment is resilient enough that it can never be discounted. Certainly, Chancellor Helmut Schmidt was not so far-removed from public dissent as to ignore the potential political damage of TMI in 1979, and he promptly commissioned a report on the prospects of nuclear power. Yet his subsequent energy plan of July 4, 1979 revealed his continued support for the industry. The fact that Chancellor Schmidt’s political opponent, Franz Josef Strauss, advocated that nuclear constitute an even greater portion of Germany’s energy mix suggests that taking a pro-nuclear stance remained a viable political choice at that time. However, the consolidation of Germany’s green movement  

into a formidable, culturally embedded, organized force quickly became the legacy of TMI, and has proven to be an obstacle to nuclear development from the 1980s to the present.  

The German breed of environmentalism deserves special consideration here, considering that its origins are inextricably woven into the nuclear-power issue. From the early 1970s, German environmentalism constructed itself in opposition to nuclear power and the state, giving it a distinct anti-statist flavour. Because Germany has long been averse to requests for the release of information and has no legal mechanism to allow a German citizen to bring a class-action lawsuit against the government, the movement has advanced its cause by pressuring the elected political leadership, usually peacefully, rather than appealing to strictly legal routes and mechanisms.

These factors, compounded by the general dominance of the established political parties at the national level, especially the Christian Democratic Party on the right and the Social Democratic Party on the left, led to the concentration of anti-nuclear efforts in protest groups that, in the 1980s, became highly-organized electoral machines while maintaining the efficiency and vision of their predecessors. It was this drive that prevented the German environmental movement, now an integral part of the German political culture and far past the ‘movement’ stage, from being co-opted into the federal bureaucracy, as transpired in the United States. However, the movement has been co-opted in the sense that Germany’s Green

28 Greenhalgh and Patterson, 39.
Party simultaneously represents the anti-nuclear cause in the Bundestag and undermines the anti-statist nature of the original movement. Highly mobilized protest groups also served to sustain the movement at a time when the nuclear weapons dimension of the Cold War actually cleaved the American anti-nuclear movement from its nuclear-as-energy foundation, rendering it unable to command attention from either the ‘average’ citizen or politicians. The German case further stands apart in that German environmental groups in particular rely on scientific data generated by independent authorities to support their claims. While the Green Party experienced division into Realos (realist) and Fundis (fundamentalist) factions in the 1980s and 1990s, it remains a powerful political force today, now decisively dominated by realists.  

The Green Party had much ammunition with which to attack the governing Christian Democrats in the wake of Chernobyl. As it happened, neither party came out unscathed, due to the often vague, incomplete, or contradictory information about Chernobyl that the government and media disseminated. The German populace’s trust in both was eroded, and in lieu of a reliable source of information, panic ensued, prompting Germans to imbibe potassium iodide pills, and leading as much as forty-four percent of the populace to report changes to their personal diet. Many Germans were hesitant to restore their trust, in the industry

especially, following revelations in 1987 of the release of drums of nuclear waste containing undeclared plutonium from a Belgian nuclear research centre in Mol. It was later discovered that employees there had been bribed by the Transnuklear company to remain quiet on the issue.30

Still, the government’s policy response was significant. It had the IAEA’s Operational Safety Review Team conduct reviews of every German plant; it abandoned plans to build a reprocessing plant at Wackersdorf, which was being considered alongside the Gorleben facility; and it established the Federal Ministry for the Environment, Nature Conservation and Reactor Safety (BMU) within a year of the accident.31


By the 1990s, the new politics of climate change had overtaken other environmental concerns, and in 1997, the Kyoto Protocol established the effort to combat climate change as a global priority, adding a modicum of international accountability to national emissions goals. As Chernobyl faded from memory, governments turned to nuclear power as a solution to reaching these emissions targets and as a means of addressing growing energy demand. Indeed, the advantages of nuclear energy, including its impressive capacity for energy generation and the fact that it can be sold as a clean alternative to fossil fuels, were heightened. At the same time, the struggle to lower emissions conflicted with the anti-nuclear orthodoxy of environmental policy.

For Chancellor Angela Merkel, the advantages of nuclear eclipsed calls for reduced reliance on nuclear. Accordingly, she extended a timetable that was set to phase out nuclear power by 2022, to 2036. The extension was made just six months prior to Fukushima. On March 14, 2011, three days after the nuclear catastrophe, a moratorium was declared and safety reviews were ordered; within a month, the Thirteenth Amendment to the Atomic Energy Act was passed, reinstating the original 2022 schedule, with one key alteration: that the eight plants which were eventually brought back online be required to operate at 2002 output levels. Ralf Guldner, “After Fukushima: Nuclear Sunset in Germany,” Modern Power Systems 31, no. 12 (2011): 55.
output in either of 2010 or 2011 (see Figures 1 and 2). Thus, if not serendipitous, the Thirteenth Amendment represents a cunning political manoeuvre by Chancellor Merkel to ‘buy time’ while the logistics of the 2022 phase-out are revamped.

Even though Germany has experienced seconds-long blackouts and has on occasion been forced to activate cold reserves to make up supply shortfalls, the biggest energy-related problem now confronting Germany is not how to acquire the energy lost from the eleven nuclear reactors in permanent shutdown, but rather how to upgrade and reconfigure the electricity grids and other infrastructure in order to accommodate its rapidly-changing energy mix. German power grids will in the future have to transport energy from the north to the south, where demand is highest. Construction is now underway to connect the grid to the wind power being generated in the North Sea and Baltic Sea, but delays have hampered progress, and the amount of wind power being generated falls short of expectations.33

The urgency of construction is underscored by variable renewable energy (VRE) generation, which arises when a significant proportion of a country’s energy is supplied by wind and solar power. Because the amount of power generated by wind and solar fluctuates on a daily, seasonal, and regional basis, electricity grids must be carefully monitored to ensure

that they are carrying a steady supply of energy. At times, the amount of energy in the system must be reduced to prevent a power surge, but at others, demand may exceed supply. For example, solar power cannot contribute to meeting evening peaks in energy demand. Variable renewable energy generation highlights the importance of having another reliable energy source available, whether fossil fuels or nuclear, that can be drawn upon when demand is high and the amount of energy provided by renewables is low. Fortunately, less work should be required to facilitate added energy imports from France and the Czech Republic, since Germany has already made a practice of importing nuclear-generated energy from those countries. The more than €20 billion cost of upgrading Germany’s electricity grids reflects a series of component costs, including the cost of reengineering existing power lines, building new power lines, and compensating German citizens whose properties happen to coincide with the routes to be taken by new power-line installations.34

For some years, Germany has invested heavily in renewables, which it will now rely on to help fill the energy gap. In 2010, its new investments in renewables were valued at $41 billion, second only to China’s $50 billion, and comprising a substantial percentage of global

investment, which was $211 billion. Riding on the momentum of environmentalism, Germany has also implemented a system that taxes nuclear energy by kWh, levies charges of hundreds of millions of dollars on each nuclear generator, and uses these funds to subsidize renewables on a per-kWh basis. Much of Germany’s concentration on renewables has been in solar photovoltaics (more commonly referred to as solar PV), and it now boasts forty-four percent of the world’s solar PV capacity, more than any other country. In a struggle to help solar to profitability, the government has directed much of its subsidies funding to that sector. Solar PV subsidies are estimated to reach €46 billion per year by 2030. These facts help to explain why the rise in renewables stocks after Fukushima was short-lived, as oil and natural gas showed promise as the real benefactors of decreased nuclear output. Much to the environmentalists’ dismay, lignite-fired power plants will remain operational, and in some cases be recommissioned, until renewable sources can provide the desired capacity at an acceptable price. In the meantime, many analysts are anxiously waiting for a satisfactory answer to the Gretchen question from Chancellor Merkel and her government: Does the Merkel
administration in fact believe in a post-nuclear future for Germany, or does it predict that a
later administration will reverse the nuclear phase-out?\textsuperscript{35}

This brings into focus the broader European Union context of Germany’s situation. Just
as Germany is dismantling its nuclear-power program, the EU Parliament and EU Commission
have both voted in favour of “the extensive, [long-term] use of nuclear power in Europe.” A
2007 communiqué entitled the \textit{Nuclear Illustrative Programme}, produced by the EU Commission
for the EU Council and European Parliament, states that “[w]hile each Member State and
energy utility chooses its own energy mix, individual decisions relating to nuclear energy can
have an impact on other States.”\textsuperscript{36} It goes on to provide a rationale for increased investment in
nuclear energy. Hence, “shutting down these facilities in Germany [will not] make the risks
associated with atomic energy disappear. It will only add energy-technical challenges to assure
long-term supply security.”\textsuperscript{37} Yet this reality has not been a cause for reconsideration of
opposition to nuclear power among the general public of Germany, possibly because the risk of

\textsuperscript{35} Renewables 2011 Global Status Report (Paris: REN21 Secretariat), 23, 34. World Nuclear

\textsuperscript{36} \textit{Nuclear Illustrative Programme}, European Commission, Brussels, January 10, 2007: 5.

\textsuperscript{37} Martin Büdenbender, “Auswirkungen der europäischen Energiepolitik auf den deutschen
producing nuclear power will be displaced to other EU countries if Germany can meet its energy demands by importing energy from neighbours such as France and the Czech Republic.

However, the displacement of risk will surely be accompanied by a displacement of jobs, investment, energy security, and status within the EU. For example, E.ON, Germany’s largest utility, is selling its Ruhrgas (Essen) and Energie (Munich) branches, as well as a plant in Hanover, relieving 11,000 Germans from employment. Some utilities have also filed suits against the German government, taking issue with a conditional clause of the 2036 phase-out whereby the industry agreed to pay higher taxes; since the return to the 2022 timetable, those higher taxes have been kept. So far, the government has paid out €74 million and €96 million to Rheinisch-Westfälisches Elektrizitätswerk (RWE) and E.ON utilities respectively, although the lawsuits total €10 billion in claims. Siemens, the company that designed all of Germany’s nuclear reactors, will probably not suffer as much as the utilities. Its designs remain attractive.

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to foreign investors, and if it can secure a Hermes credit guarantee from the German government, it may soon embark on a project to build the Angra-III reactor in Brazil.\(^{39}\)

Whether the German nuclear industry is able to cope with its imminent downsizing, it is clear that there is no reneging on the latest 2022 phase-out plan. With memories of post-Fukushima rallies in Berlin (100,000 participants), Hanover, Munich, and Cologne (40,000 participants) still fresh in politicians’ minds, the German government seems resigned to a program of progressive abandonment of nuclear technologies as a source of energy.\(^{40}\)

\[\text{IV} \quad \text{JAPAN : FALLOUT IN THE PACIFIC}\]

Japan’s experience with nuclear fission is bookended by two disasters: the bombings of Hiroshima and Nagasaki at one end, and the triple earthquake-tsunami-nuclear catastrophe of Fukushima Daiichi at the other. After the fallout from ‘Fat Man’ and ‘Little Boy’ had dissipated, \linebreak[4]

\(^{39}\) A Hermes credit guarantee is an insurance agreement between a company and the German government, granted on a project-by-project basis. The agreement protects the company against the risk that a foreign investor in a project is unable to pay for services rendered.


it seemed Japan would never welcome nuclear technology into its labs. But by 1954, Japan had begun experimenting with atomic energy, and by the time TMI occurred in 1979, Japan had twenty-two reactors in operation (see Figures 1 and 2). Such progress in nuclear-power development was actually spearheaded by US President Dwight D. Eisenhower. Under his administration, the US Embassy, US Information Service, and the US Central Intelligence Agency implemented a campaign to promote the peaceful use of the atom in Japan, as “reconciliation” for Hiroshima and Nagasaki. Motivated by their desire for modernization, and cognizant of Japan’s lack of domestic energy resources, “the [Japanese] public allowed itself to be convinced that nuclear power was safe and clean.”41

Public support for nuclear energy was not unanimous, however. Following TMI, the government and industry suffered criticism from the Socialist Party, the Komeito Party (or Clean Government Party), and a number of organizations. Such criticism surfaced in the forms of rallies in Tokyo and Osaka as part of an international day of protest.42

In order to understand the nature and influence of Japanese public opposition to industry and government decisions regarding nuclear power, the structure of Japan’s nuclear regulatory structure is considered here. At the time of TMI, the Nuclear and Industrial Safety Agency was responsible for both regulating and promoting the industry, much like the Atomic Energy Commission in the United States prior to its dissolution in 1974. Thus, the industry was very centralized, entrusted with self-regulation, and almost immune from faltering public support. The official 2012 report of Japan’s Independent Investigation Commission, the first independent commission in the history of Japanese democracy, concluded that “the way safety regulations are deliberated and amended reveals a cozy relationship between the operators, the regulators and academic scholars that can only be described as totally inappropriate.”

Also of note is Japan’s business-oriented tax structure whereby kaisha, meaning ‘businesses, big and small,’ are given tax breaks for buying land and otherwise demonstrating an inexhaustible capacity for ‘development.’ Analyst Toshimasa Tsuruta estimates that the lost corporate tax revenue between 1950 and 1970 equated to nearly ¥3.1 trillion, or a twenty-percent cut in the corporate tax rate. In the process, environmental concerns were deemed of little importance, leading to kogai, a word that captures both the dismissive attitude that pervades much of the Japanese citizenry toward the environmentally detrimental effects that industrialization can bring, as well as the effects themselves.

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43 National Diet of Japan: 43.
Kogai reflects the unique blend of pragmatism and virtually unrestrained developmentalism that took hold of Japanese politicians soon after the end of World War II. It was manifested beginning in the late 1960s, in cadmium- and mercury-contaminated water, ground sinkage, air and noise pollution. The dynamics of kogai have been slow to change in response to the increasing frequency of the negative environmental externalities of Japan’s development. Fukushima may mark the point where pragmatism ceases to denote development at the expense of the environment, and starts to favour environmentally responsible development instead.\textsuperscript{44}

In a landmark study of Japanese industrial policy published in 1982, Chalmers Johnson attributed Japan’s unprecedented rate of growth, including that of its nuclear industry, to Japan’s Ministry of International Trade and Industry (MITI) and the many policy tools that it had at its disposal. One such tool was its indirect financing formula whereby private companies borrowed capital from city banks that, in turn, borrowed from the Japan Development Bank,

which was under MITI oversight. In this way, MITI was able to institutionalize its
‘administrative guidance’ even at the micro level. Administrative guidance is best described as
legally unenforceable directives given to businesses by MITI, where these businesses are aware
of the “various informal pressures that [MITI] can bring to bear” in the event that they fail to
comply with those directives. Administrative guidance derives its efficacy partially from the
short and highly-generalized laws on which it is based. The legal framework thus allows a great
degree of flexibility in how policy law is interpreted and enforced. Additionally, this type of
governance afforded MITI influence in areas over which it had no official jurisdiction. MITI
was, in other words, the most powerful vehicle of government influence over the strategic
direction of Japanese corporate profitability. In 2001, its role was taken over by the newly
created Ministry of Economy, Trade and Industry (METI).45

Because MITI was already a long-established and fully-bureaucratized ministry by the
1970s, it was well-positioned to phase out old industries and nurture new ones. Consequently,
when kōgai became a problem and began to generate public discontent, MITI responded by
favouring a knowledge-intensive industrial structure that included nuclear power and that put
less emphasis on energy sources that would contribute to overcrowding and pollution.46

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45 Johnson, quote from 266.

46 Johnson.
Because of the dismissive attitude of kogai and the weak regulatory structure it legitimated, Japan’s policy response to TMI was largely superficial. A number of studies were commissioned; a few plants were taken offline for maintenance; and the construction of Fukushima Daini-II, -III, and -IV was delayed by approximately two years. Japan’s Nuclear Safety Commission (NSC) joined with utilities in trying to convince the public that Japanese reactors were much safer than the one at TMI, since many of the reactor components in Japanese reactors were domestically manufactured. The NSC went so far as to definitively state that a TMI-like event could never take place in Japan.

Nuclear energy development soon resumed. Any public opposition that remained was somewhat subdued by Japan’s desire to be self-sufficient in terms of energy and by the limits of available and reliable alternatives to a policy of generating its own power. This was, and remains to be, a major consideration of the Japanese government in developing its energy policy. Certainly, Japan’s energy dilemma is compounded by the fact of its advanced technological and industrial base, requiring a reliable energy supply, and Japan’s lack of considerable natural energy resources like those of the United States or, in the alternative case, the friendly nuclear-powered neighbours that border Germany. Japan had never been comfortable with relying on foreign oil for its energy needs, particularly after the oil shock of
the 1970s. By the end of that decade, Japan was exporting nuclear energy to Asian neighbours, an achievement largely due to the immense powers of MITI.\textsuperscript{47}

The Chernobyl accident was also met with little response from government or industry in terms of modification to the regulatory structure. This time, the reaction of the Japanese public mirrored that of the Germans. Worry about exposure to radiological fallout gripped the nation, and an extremely low tolerance for allowable quantities of radioactive particles in food products and imports was put in place. Japan’s limit was even more restrictive than the limit set by the European Commission.\textsuperscript{48}


\begin{itemize}
\item \textsuperscript{48} Japan’s NSC set the following limits: for one Litre of tap water, 300 Bq from iodine, 200 Bq from caesium; for one Litre of milk, 100 Bq. The European Commission set a limit of 500 Bq from iodine for one Litre of milk (although the German state of Hessia set its own, very restrictive limit of 20 Bq). Takeo Ohnishi, “The Disaster at Japan’s Fukushima-Daiichi Nuclear Power Plant after the March 11, 2011 Earthquake and Tsunami, and the Resulting Spread of Radioisotope Contamination,” Radiation Research 177, no. 1 (2012): 6-7. Halbritter, 150-151.
\end{itemize}
breeder reactor, a design which had long-ago been abandoned by other industrialized
countries due to the number of technical failures to which it was prone. The 1999 incident
stands out as the landmark for the creation of nuclear emergency response headquarters
placed off-site from reactors throughout Japan. But despite the recurring problems, the
regulatory structure resisted further significant change.49

In light of these repeated failures and scandals, a disaster like Fukushima could have
been predicted, but the uncoordinated, untimely, and resoundingly poor response from
government and industry to an emergency of unprecedented scale has also laid bare the extent
of Japan’s nuclear dilemma. To begin with, there were multiple design flaws. Tokyo Electric
Power Company (TEPCO), the utility that owns the Fukushima facility, neglected to build a wall
of sufficient height to guard against tsunamis, even though it was well aware that tsunamis
higher than the 2011 tsunami were historically documented in the same region. In this respect,
the disaster was not unprecedented, but the combined effects of a nuclear catastrophe made
the political and economic damage exponentially worse than could be predicted by historical

49 Felix Doege and Patrick Kölner, “Trotz Fukushima-1: Japan’s ‘atomares Dorf’ hält an der
Review: A Complex Disaster, A Disastrous Response,” Bulletin of the Atomic Scientists 68, no. 2
record. The tsunami succeeded in knocking out the emergency generators which powered the
ECCS; had the generators been placed out of the tsunami’s reach, the resulting loss of power to
the cooling system may have been avoided. The nuclear emergency response headquarters
were also incapacitated by the earthquake and tsunami, due to blocked roads and power
outages.50

Additionally, there were systematic shortcomings coupled with human error. The
System for Prediction of Environmental Emergency Dose Information (ironically abbreviated
as SPEEDI) failed to release details about the possibility of radiological release to the Prime
Minister’s Office in time for them to be considered in evacuation orders. Meanwhile, Prime
Minister Naoto Kan commanded TEPCO workers to return to the Fukushima facility to put out
the blaze, even though such a directive could not be legally given and resulted in the exposure
of some workers to fatal doses of radiation. The industry as a whole shares some collective
guilt for ignoring warnings issued by the IAEA to the effect that Japan’s protocol for an
emergency response to a nuclear accident was inadequate and had not sufficiently addressed
issues such as the line of command to be followed in the event of an emergency. According to

50 The walls constructed around the Fukushima Daiichi plant were able to withstand waves of
5.7 metres in height. The 2011 tsunami reached heights of 14 metres. Tsunamis exceeding 30
metres in height have been recorded off the shores of Japan. Hagmann, 3. Funabashi and
Kitazawa, 13.
the official report of Japan’s Independent Investigation Commission, “the boundaries defining
the roles and responsibilities of the parties involved were problematic due to their
ambiguity.”

In short, the emergency response was incoherent. This is reflected in the results of
public opinion polls conducted in the aftermath. When asked to rate the response to the crisis
as either ‘good’ or ‘bad,’ only twenty percent of Japanese viewed the national government’s
response as ‘good’; Prime Minister Kan fared worse, with eighteen-percent approval; and
TEPCO received a negligible eleven-percent positive rating (see Figure 4).

Such public-relations damage will be difficult to mend. For the approximately 150,000
individuals who were evacuated from the fallout area (a thirty-kilometre radius from the
Fukushima Daiichi plant), the elimination of their livelihood and communities serves as a daily
reminder of the tragedy. The evacuation process itself was, for many, exceedingly confusing
and disorganized. Many evacuees were forced to relocate themselves more than six times as
the boundaries of the evacuation zone were expanded; some residents were even mistakenly
evacuated from low-radiation to high-radiation areas.

Radiation figures are contested, given wildly-varied data provided by the Japanese
government, independent research teams and international experts, with some measures
based on predictive computer simulations, others on actual measurements taken in Japan, and

still others taken from Europe and North America. However, many of these data fall within a range that is lower than the radiological release of Chernobyl, but high enough to pose a concern. The Independent Investigation Commission estimates that 1,800 km$^2$ of Japanese land is receiving five millisieverts (mSv) of radiation per annum.$^{52}$ As such, displaced citizens will likely not be permitted to return to their homes for more than twenty years; even then, radiation levels will be about twenty mSv, or twenty times the preferable limit of one mSv within the evacuation zone. These levels are below the maximum allowable dose of 100 mSv per annum, although certain radiological ‘hotspots’ in Fukushima and surrounding prefectures continue to give off levels of radiation significantly higher than twenty mSv. Consequently, the Japanese government will allow displaced persons to remain in approximately 16,000 temporary housing facilities until sometime in 2013, when they will be required to find accommodation elsewhere. In the meantime, Environment Minister Goshi Hosono is

\[52\text{ The Standard International Unit of millisieverts (mSv) per annum expresses the biological effect of an amount of radiation that is absorbed by body tissue in a given year, in a given geographical location.}\]
requesting permission to store spent nuclear fuel in the evacuated towns until they are once again inhabited.\textsuperscript{53}

This move is indicative of the pragmatic outlook which the Japanese will be forced to maintain in order to recover from both the destruction of the disaster and the energy crisis that now follows in its wake. While fourteen of Japan’s reactors were damaged or immediately put into permanent shutdown because of Fukushima, the remaining forty reactors were also taken offline for maintenance and safety inspections, leaving Japan without a single reactor in operation for the first time since 1966. At the time of this writing, Japan has restarted two of its reactors and is debating which of three long-term energy strategies the country should follow: (1) phase out nuclear power by 2030; (2) reduce dependence on nuclear power to fifteen percent of total energy demand by 2030; (3) maintain pre-Fukushima dependence levels of

twenty to twenty-five percent of total energy demand. A decision is set to be made in September 2012.\textsuperscript{54}

The ramifications of this massive loss were already felt in the summer of 2011, when the government issued setsuden measures (restrictions on energy usage) in order to compensate for decreased energy production. Setsuden and the unusually cooler summer, which contributed to lowering air-conditioner usage, helped to curb the risk of a severe, widespread blackout. But that risk returned in the summer of 2012, when energy usage again reached a seasonal peak. Although setsuden has now been lifted, the incumbent Prime Minister Yoshihiko Noda is drawing on the remaining worries associated with the economic tumult in order to push for a raise in the sales tax from its current five percent to eight and eventually ten percent, which is sure to be as politically unpopular now as when Prime Minister Kan first proposed the same tax increase during his tenure. The proposed tax could alter consumer behaviour and thereby decrease energy demand. The added burden of funding the cleanup of Fukushima Daiichi may serve as the basis for a consensus on what has been a contentious

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proposal so far. Tokyo Electric Power Co is also raising its electricity rates by seventeen percent, and other utilities will likely follow suit.\textsuperscript{55}

However, fiscal incentives for businesses and consumers will not be enough to ensure that Japan is able to bring its supply of energy into line with its demand. It is becoming increasingly apparent that a return to foreign oil is required. In 2011 alone, Japan imported ¥4.7 trillion in liquified natural gas, and it is now exploring trade deals with Australia, Indonesia, Iraq, and others. Japan’s predicament is compounded by the fact that, unlike Germany, it is an island without any geographically proximate allies willing to provide it with energy. Any energy that is imported will need to be redistributed via a reconfiguration of the

\textsuperscript{55} Under \textit{setsuden}, industrial production is to be carried out on nights and weekends only; families are encouraged to reduce energy consumption; and large businesses are required to reduce energy consumption by fifteen percent. Altogether, the implementation of these protocol reduced Tokyo’s energy consumption from 60 GW in the summer of 2010 to 49 GW in the summer of 2011. Lincoln L. Davies, “Beyond Fukushima: Disasters, Nuclear Energy, and Energy Law,” \textit{Brigham Young University Law Review} 6 (2011): Section III, Subsection C. David Pilling, “A Shrrill Debate In ‘The Land of Consensus,’” \textit{The Financial Times}, April 18, 2012.

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electricity grid, in order to supply the energy-hungry east of Japan with energy from western Japan.\textsuperscript{56}

Despite the decreased demand for domestic nuclear energy, the industry itself may not fare as poorly as expected. Indeed, 2010 saw the establishment of the International Nuclear Energy Development of Japan Co Ltd (JINED), which aims to expand the traditionally neglected revenue stream of exporting nuclear goods and services.\textsuperscript{57} Of course, it remains to be seen whether other nuclear utilities and national governments will be receptive to Japanese technology, considering the industry’s abysmal safety record.

Evidently, the choices that Japan makes in the next few years will have as dramatic an impact on its energy mix, political landscape and culture, as did its nuclear development of the 1970s. Given that Prime Minister Kan’s own cabinet pressured him to retract his anti-nuclear statements, which are in contrast with Prime Minister Noda’s more moderate plans for the industry, these key decisions remain contentious, and the commitment to a post-nuclear future, tentative. The Fukushima Daiichi disaster is widely regarded as a key factor in the replacement of Prime Minister Kan with former Finance Minister Noda as the new Prime Minister, although Prime Minister Kan’s popularity had already drastically declined in the


\textsuperscript{57} World Nuclear Association, “Nuclear Power in Japan.”
months prior to the Tohoku earthquake, due to his indecisive leadership. Prime Minister Noda now faces the challenges of supporting an aging population, which will put stress on the already burdened social welfare program, amid a stagnant economy, a strong yen, and a national debt nearing $13 trillion, more than double the national GDP. Prime Minister Noda plans to spend $248 billion over the next five years as part of the clean-up effort, leading some analysts to venture that the massive capital injection will stimulate the economy in a post-disaster bump.  

Yet the fact that the economies of some towns are essentially dependent on the jobs provided by local reactors means that pockets of nuclear energy support from the public may feed into existing support at the national level. Indeed, this is already the case in the town of Oi, in the west prefecture of Fukui, where a vote of eleven to one in the Oi town council gave permission for the two local reactors there to be restarted. The Oi-III and -IV reactors came back online in July 2012.


Following Fukushima, discussions concerning the Rokkasho reprocessing plant have also taken on a new sense of urgency. Construction of the Rokkasho facility began in 1993 and was to be completed in 1997. Fifteen years and eighteen postponements later, Rokkasho has yet to commence operation. This leaves Japan without a single nuclear-waste repository, a predicament made more dire by the recent expiration of contracts with the United Kingdom and France, whereby 7,100 tonnes of waste were transported there from Japan for intermediate storage. With spent fuel pools filling up and posing an increased risk of overheating, as happened at the Fukushima Daiichi site, Rokkasho should be regarded as a key factor in Japan’s possible decision to move forward with nuclear energy, especially considering the issue of liability for the damage caused by Fukushima. Indeed, the ¥2.4 trillion currently set aside for the Rokkasho project may now be diverted to help cover compensation costs. Whereas the Law on Compensation for Nuclear Damage requires all Japanese utilities to make available ¥120 billion per operating site for the purposes of compensating victims of a nuclear accident, the law does not apply to accidents caused by natural disasters. The government is therefore forced provide the appropriate funding. Ironically, TEPCO is one of the major financiers of Rokkasho, so regardless, it will suffer a considerable financial loss.60

While Prime Minister Noda wishes to restore much of the nuclear industry to operation under the auspices of the new, more-independent Nuclear Security and Safety Agency (NSSA), the sheer magnitude of the Fukushima accident will surely cause a scaling back of the 2010 Basic Energy Plan’s goal of meeting fifty percent of Japan’s energy needs with nuclear by 2030. Also probable is a reconsideration of Japan’s emissions targets, currently set at a reduction of twenty-five percent of carbon emissions by 2020 from 1990 levels. Progress on the Monju fast-breeder reactor is also being reexamined; commercialization of fast-breeder reactors is not expected until around 2050.

Clearly, some adept political manoeuvring will be required to navigate the ongoing Fukushima Daiichi crisis. As public opinion slowly breaks away from the kogai mentality that has facilitated Japanese development for decades, Prime Minister Noda will be confronted with an additional factor to balance against the realities of Japan’s lack of alternative energy sources, its geographic isolation, existing infrastructure, and stratospheric national debt.  

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61 Targets to reduce carbon emissions are as follows: Germany, thirty percent by 2020 from 1990 levels; Japan, twenty-five percent by 2020 from 1990 levels; the United States, “[i]n the range of 17%” by 2020 from 2005 levels. Framework Convention on Climate Change, “Appendix I: Quantified Economy-Wide Emissions Targets for 2020,” United Nations.

This paper’s analysis of public opinion in the United States, Germany, and Japan makes clear the fact that public opposition to nuclear power in these countries is increasing, albeit at different rates. But if this is the case, then what continues to make nuclear power attractive to the governments of these countries? While the previous analysis demonstrates the breadth of factors that influence trajectories of nuclear-power development, it seems that the universal consideration most able to transcend variations in political culture is that of economics. In the 1950s and 1960s, before the dangers inherent in the construction of nuclear power plants were widely known, nuclear energy’s tremendous production potential made it an economically competitive option, at least in the idealized long-term energy plans of its advocates.

Today, however, the nuclear industry is moving farther away from, rather than toward, a reality where nuclear energy is decidedly at an economic advantage over alternative energy sources. Without discounting nuclear’s production capacity and ability to complement the intermittent energy supplies offered by renewables, the CEO of General Electric, Jeff Immelt, concedes that nuclear is in no position to compete with oil, shale gas, renewables, and other energy sources on economic terms.63

There are a few factors that continue to compromise nuclear’s past economic allure. Firstly, the nuclear industries in Germany and the United States have experienced construction

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delays of more than a decade in some cases, and incurred unexpected costs as a result. Many of these delays are attributable to the inertia of the anti-nuclear movement. This adds another element of uncertainty to the many uncertain factors influencing government efforts to develop a long-term energy policy. Some utilities may try to avoid construction delays by switching to small modular reactors (SMRs), which are yet to be approved by the NRC. If approved, SMRs would afford utilities many advantages. For one, SMRs are smaller and therefore less costly; they can be used individually or in series; and they can be built in a factory and shipped to location, making them immune from on-site construction delays. Small modular reactors are also being heralded as the safest generation of reactors. One design puts the reactor underground, encased in concrete; it would only need to be exposed for refueling every seven years. However, one must question whether such designs will ever be put to use, even if given approval. At least in the United States, the trend has been to extend existing reactors’ operational lifetimes from forty years to sixty years, instead of building new reactors. Given the resistance to new nuclear facilities that was only beginning to weaken


before Fukushima, utilities may never allow existing reactors to retire, the effect of which would be to favour aging infrastructure over the implementation of safer designs. Political resistance to new nuclear facilities may have the perverse impact of moving governments to rely on existing facilities for much longer than originally planned, thereby increasing the chances of a major nuclear accident.

Secondly, uranium, the principal fuel used in reactors, is becoming scarce, so the cost stability of nuclear fuel may become a thing of the past. This stability used to be one of nuclear’s greatest advantages, given the comparatively drastic price fluctuations to which oil and gas are prone. For decades, the price of uranium remained fairly stable between $7.24 and $24.00 per pound. But between January 2003 and June 2007, the price spiked from $10.16 to $136.22 per pound, before falling to $40.78 per pound in June 2010. Since then, the price has hovered between $40 and $65 per pound (see Figure 5). This does not bode well for the United States, whose uranium production is now at a mere ten percent relative to peak production levels as domestic supplies run out, forcing it to become reliant on other countries to supplement its reserves.66

Thirdly, a 2009 study conducted by the Massachusetts Institute of Technology reveals that the cost of building a nuclear power plant in the United States has tended to increase by

fifteen percent per year since 2003, resulting in a current cost of 8.4 cents per kWh for nuclear energy in comparison to 6.2 cents per kWh for coal and 6.5 cents per kWh for gas. The report attributes the margin on nuclear energy to the risk premium and construction delays, but adds that this margin is virtually eliminated by implementing a $25 tax on each tonne of CO$_2$ produced by the processing of coal and gas.\textsuperscript{67}

Fourthly, financial estimates often fail to include the cost of proper radiological waste disposal or, more accurately, waste storage. Because the most toxic radiological waste must be stored for up to 250,000 years, the cost of proper disposal is potentially exorbitant. Indeed, during her career as Environment Minister, Chancellor Merkel permitted toxic waste to be dumped in the Morsleben salt mines which must now be stabilized with concrete at a cost of €2.2 billion. Germany’s Asse salt mines were intended to accommodate toxic waste for the next 100,000 years, but already water is leaking into the mines, causing the barrels that house the waste to rust and release radiation into the surrounding underground area. The latest

proposed solution is to painstakingly transport the waste to the Konrad facility, set to open in 2014.\textsuperscript{68}

The United States has experienced waste-related problems of its own, akin to those that plague the Rokkasho reprocessing plant in Japan. All American nuclear utilities are required to pay a tax of one cent per kWh on energy generated, to a fund controlled by the US Department of Energy. The fund receives approximately $750 million every year, and has so far administered $7 billion to the controversial Yucca Mountain waste-disposal project in the State of Nevada. If completed, the single facility would store all of the United States’ radiological waste underground for the full 250,000-year period that is required for enriched-plutonium and enriched-uranium isotopes to decay.\textsuperscript{69}

The Yucca Mountain project is unique in that, thanks to a 1983 US Supreme Court ruling, individual states have the legal right to reject new nuclear facilities, “provided their objection [is] based on economic grounds, not on radiation hazards.” In the case of Yucca Mountain, Nevada’s rejection of the facility was ignored by federal authorities, so that it remains a sore spot in Nevada’s relationship with the nuclear industry. It is clear that the


\textsuperscript{69} World Nuclear Association, “US Nuclear Power Policy.”
United States is in desperate need of a waste-disposal facility to house the toxic byproducts of nuclear fission which currently rest at 121 different sites across the country.\textsuperscript{70}

It is this issue of waste storage which forms part of the Green paradox: namely, that many abhor the idea of waste posing unknown risks for many millennia, but at the same time advocate lower carbon emissions, something that nuclear is able to provide if it assumes a larger rather than a smaller role in the total energy production mix. This helps to explain concurrent government policies that support nuclear development and that invest in renewables, as well as targets that outline what proportion of a country’s future energy portfolio should consist of renewables. For example, some US states require that any utility operating within their borders, nuclear or otherwise, be able to provide consumers with ‘green pricing’ or ‘clean energy’ options. A total of 850 American utilities now offer this choice to consumers. In the same vein, Germany’s growing renewables sector accounts for 337,000 full-

\textsuperscript{70} Bryce, 272.
time and part-time jobs. (See Figures 6 and 7 for statistics on countries’ renewable energy capacities.)

There may be other solutions to the waste-storage problem. One that has existed for decades, but more in theory than in practice, is waste reprocessing, which has the potential to reduce the net amount of waste produced by nuclear fission by a factor of two or possibly three. This is accomplished by extracting certain materials from the waste and reusing them in a second round of nuclear fission. Many countries are hesitant to adopt this practice because the risk of radiological release increases during the second round of fission. Another solution could be transmutation, a process which is still being developed. If transmutation is revealed to be a viable course of action, it could shorten the lengthy half-lives of elements like Neptunium, with an untampered half-life of two million years.

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71 Renewables targets are as follows: Germany, thirty-five percent by 2020, fifty percent by 2030, sixty-five percent by 2040, eighty percent by 2050; Japan, 1.6 percent by 2014 (Japan has already surpassed this goal, at 2.2 percent); the United States has no official target, but already meets ten percent of its demand with renewables. US President Barack Obama has set an unofficial goal of meeting eighty percent of energy demand with ‘clean’ sources by 2035. Renewables 2011 Global Status Report, 47, 57, 79. Wallsten and Yang. Johnson.

72 Bryce, 273-274.
Additional factors that serve to undermine nuclear’s claim to economic advantage are bad utility management, simultaneous design and construction of plants (called ‘fast-tracking’), the relative lack of cost-lowering competition due to monopolization of domestic markets by a few utilities or suppliers of reactor parts, and the difficulties of raising sufficient capital for construction projects from investors, many of whom still question the security of an investment in nuclear power following TMI. Indeed, referring to the situation in 1982, Joppke remarks that “an unparalleled wave of nuclear cancellations, including completed or nearly completed plants; gigantic capital cost escalations (felt by consumers in the form of higher electricity bills); and glaring overcapacities of generating power had made visible for the wider public what insiders had known since 1976 - that nuclear power was an economic disaster.”

While the aforementioned problems hold true for the United States and Germany, they do not resonate as well with Japan’s nuclear program. By sacrificing regulatory robustness, Japan avoided the construction delays and various ‘inefficiencies’ that accompanied the anti-nuclear movement and, more generally, what could be considered due process in the United States and Germany. Interestingly enough, Japan’s pre-Fukushima nuclear industry officially fell under the jurisdiction of METI, which after 2001 absorbed the authority of MITI and added economic planning capacity, helping to explain why Japan’s energy and environmental policies are so divergent. Japan has only begun to invest in solar energy, and has hardly tapped the

73 Joppke 1993: 144.
potential of wind power. Moreover, METI ensures that environmental policy is separate from and subordinate to industrial policy, with its Natural Resources and Energy Agency controlling the nuclear industry, and its Environmental Protection and Service Bureau managing environmental policy.

In summary, disjunctures between public opinion and government policy, and between economic projections and current economic realities abound in the realm of nuclear energy production. The goal of significantly lowering carbon emissions is simply not compatible with opposition to any and all nuclear, and is made all the more complicated by financial considerations in the short-term and the challenge of possible energy security over the long-term.

VI CONCLUSIONS: LOOKING FORWARD

Each major nuclear accident leaves a legacy that, in turn, influences the legacy of the next. For Three Mile Island, this legacy was the galvanization of public opinion. A few of those who had been pro-nuclear became anti-nuclear, while those who were already opposed to nuclear became more convinced of their position.\textsuperscript{74} Still others took the opportunity provided by Three Mile Island to argue that the worst of their fears had already been realized, demonstrating that nuclear was therefore worth the risks. Less than a decade later, Chernobyl turned health risks

\textsuperscript{74} See Rosa and Dunlap for evidence of this trend in the United States.
and other hypothetical dangers into realities that found governments and the collective nuclear industry unprepared to deal with the public backlash. Fukushima confronted the notion of acceptable risk, and the idea that the next round of equipment upgrades or more-comprehensive protocol would eliminate the possibility of radiation leakage or nuclear meltdown. The ability of the industry to ever recover in national political contexts like Germany and Japan depends partly on the length of the public’s collective memory, and partly on the speed with which alternative energy sources can assume a greater role in energy production.

Indeed, it is clear that the Fukushima Daiichi disaster has already made what are sure to be lasting impacts on public opinion, the nuclear industry, and government policy. As the United States continues to expand its nuclear fleet, due to relatively accommodating public opinion and the semi-centralized government-industry nexus, Germany will head in the opposite direction. Its environmentally-oriented political culture and strong opposition from citizens will continue to exercise a powerful influence on industry and government, which do not feature the collaborative relationship found in Japan. Germany may choose to take advantage of energy supplies provided by its European Union neighbours, even as many of them continue to pursue nuclear energy programs of their own. Meanwhile, Japan’s trajectory is uncertain. Nuclear will probably never contribute the fifty percent to Japan’s energy mix that was forecasted, and for the foreseeable future will contribute less than the thirty percent
that it did prior to Fukushima. The confluence of its geographical location, environmental pressures, and the psychological impact of the Fukushima disaster make Japan’s predicament particularly inflexible, suspending it somewhere between the pro-nuclear United States and anti-nuclear Germany while depriving it of the alternatives of either.

Other ramifications of Fukushima which are beyond the scope of this paper but are nonetheless important include the possibility of increased investment in nuclear research and development in the United States and other pro-nuclear countries in order to increase the safety of nuclear plants and decrease the risk of running them. This is unlikely, however, given that nuclear research and development spending has consistently decreased in the US since the 1980s (see Figure 8). Another possibility is that utilities may seek out new business opportunities in the more-receptive developing nations of Africa and the Middle East while keeping a foothold on nuclear energy development in European countries beyond Germany. China would be a prime candidate to finance such ventures, considering its economic ambitions and available capital. Similarly, Russia’s Gazprom is poised to purchase nuclear facilities as they are shed by German utilities.\(^75\) These, of course, are possible options for the nuclear energy sector that could result from the future energy policy decisions made in countries discussed here. In these decisions, the impact of the Fukushima Daiichi accident will

\(^{75}\) Balser.
be felt for decades, influencing policy outcomes according to national context, as is already apparent in the cases of the United States, Germany, and Japan.
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Figure 1. Nuclear reactors, nuclear energy output, and energy imports.

<table>
<thead>
<tr>
<th>Event</th>
<th>Country</th>
<th>Operational reactors</th>
<th>Nuclear energy output GWh</th>
<th>% of Total</th>
<th>Energy imports (% of total usage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three Mile Island (1979)</td>
<td>United States</td>
<td>67</td>
<td>254,008</td>
<td>10.76</td>
<td>18.57</td>
</tr>
<tr>
<td></td>
<td>Germany</td>
<td>13</td>
<td>39,390</td>
<td>8.42</td>
<td>50.23</td>
</tr>
<tr>
<td></td>
<td>Japan</td>
<td>22</td>
<td>60,772</td>
<td>10.39</td>
<td>88.83</td>
</tr>
<tr>
<td>Chernobyl (1986)</td>
<td>United States</td>
<td>91</td>
<td>400,082</td>
<td>15.16</td>
<td>12.05</td>
</tr>
<tr>
<td></td>
<td>Germany</td>
<td>19</td>
<td>101,273</td>
<td>19.41</td>
<td>43.91</td>
</tr>
<tr>
<td></td>
<td>Japan</td>
<td>35</td>
<td>159,348</td>
<td>23.75</td>
<td>81.23</td>
</tr>
<tr>
<td></td>
<td>Germany</td>
<td>17</td>
<td>133,012</td>
<td>21.96</td>
<td>61.03</td>
</tr>
<tr>
<td></td>
<td>Japan</td>
<td>54</td>
<td>280,250</td>
<td>28.45</td>
<td>80.79</td>
</tr>
<tr>
<td>Fukushima (2011)</td>
<td>United States</td>
<td>104</td>
<td>790,225</td>
<td>19.25</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Germany</td>
<td>16</td>
<td>102,311</td>
<td>17.79</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Japan</td>
<td>53</td>
<td>156,182</td>
<td>18.14</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Germany</td>
<td>9</td>
<td>93,217</td>
<td>16.22</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2002 Levels</td>
<td>9</td>
<td>95,927</td>
<td>16.69</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Japan</td>
<td>2*</td>
<td>10,380</td>
<td>0.02</td>
<td></td>
</tr>
</tbody>
</table>

*Although the Power Reactor Information System classifies forty-eight of Japan’s reactors as “operational,” only two are online and producing energy as of August 2012.
*Although the Power Reactor Information System classifies forty-eight of Japan’s reactors as “operational,” only two are online and producing energy as of August 2012.
Figure 4. Japanese public opinion on the response to the Tohoku earthquake and tsunami.

<table>
<thead>
<tr>
<th>Organization</th>
<th>Percentage 'good'</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self Defense Force</td>
<td>95</td>
</tr>
<tr>
<td>News organizations</td>
<td>54</td>
</tr>
<tr>
<td>National government</td>
<td>20</td>
</tr>
<tr>
<td>Prime Minister Naoto Kan</td>
<td>18</td>
</tr>
<tr>
<td>TEPCO</td>
<td>11</td>
</tr>
</tbody>
</table>

Figure 5. World uranium price from January 2003 to January 2012, US dollars/lb.

Trend line follows equation $y = 0.3983x + 24.521$
**Figure 6. Country rankings based on existing shares of renewable-energy capacity as of January 2011.**

<table>
<thead>
<tr>
<th></th>
<th>Renewables capacity</th>
<th>Wind</th>
<th>Biomass</th>
<th>Geothermal</th>
<th>Solar PV</th>
<th>Solar thermal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>W/ hydro</td>
<td>W/out hydro</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>United States</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Germany</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>*</td>
<td>1</td>
</tr>
<tr>
<td>Japan</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>3</td>
</tr>
</tbody>
</table>

*Not in top 5

**Figure 7. Country rankings based on additions made to renewable-energy capacity in 2010.**

<table>
<thead>
<tr>
<th></th>
<th>New capacity investment</th>
<th>Wind</th>
<th>Biodiesel production</th>
<th>Ethanol production</th>
<th>Solar PV</th>
<th>Solar thermal</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>3</td>
<td>2</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td>*</td>
</tr>
<tr>
<td>Germany</td>
<td>2</td>
<td>5</td>
<td>1</td>
<td>*</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Japan</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>4</td>
<td>*</td>
</tr>
</tbody>
</table>

*Not in top 5
Figure 8. Expenditure on fission research and development as a percentage of GDP.

- United States
- Japan
Figure 9. Public opinion on the response of Japanese officials to the Fukushima accident.

“Based on what you know, how do you think Japanese officials and their government leaders communicated the nature and impact of the Fukushima accident to the Japanese people and others? Would you agree very much, agree somewhat, or disagree that they communicated (1) honestly; (2) in a timely manner?

<table>
<thead>
<tr>
<th></th>
<th>Agree very much</th>
<th>Agree somewhat</th>
<th>Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States (1)</td>
<td>13</td>
<td>43</td>
<td>44</td>
</tr>
<tr>
<td>United States (2)</td>
<td>15</td>
<td>43</td>
<td>42</td>
</tr>
<tr>
<td>Germany (1)</td>
<td>6</td>
<td>19</td>
<td>75</td>
</tr>
<tr>
<td>Germany (2)</td>
<td>10</td>
<td>27</td>
<td>63</td>
</tr>
<tr>
<td>Japan (1)</td>
<td>4</td>
<td>24</td>
<td>72</td>
</tr>
<tr>
<td>Japan (2)</td>
<td>4</td>
<td>19</td>
<td>77</td>
</tr>
</tbody>
</table>
Figure 10. Public opinion on nuclear energy, and changes in opinion due to the Fukushima accident.

“Please indicate your opinion on nuclear energy.”

<table>
<thead>
<tr>
<th></th>
<th>Strongly Support</th>
<th>Somewhat Support</th>
<th>Somewhat Oppose</th>
<th>Strongly Oppose</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>19</td>
<td>33</td>
<td>31</td>
<td>17</td>
</tr>
<tr>
<td>Germany</td>
<td>5</td>
<td>16</td>
<td>28</td>
<td>51</td>
</tr>
<tr>
<td>Japan</td>
<td>5</td>
<td>36</td>
<td>30</td>
<td>28</td>
</tr>
</tbody>
</table>

“Did you decide to strongly/somewhat oppose nuclear energy because of the events in Japan, or did you previously hold this view?”

<table>
<thead>
<tr>
<th></th>
<th>Recently</th>
<th>Previously</th>
<th>Neither</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>26</td>
<td>55</td>
<td>19</td>
</tr>
<tr>
<td>Germany</td>
<td>16</td>
<td>77</td>
<td>7</td>
</tr>
<tr>
<td>Japan</td>
<td>52</td>
<td>42</td>
<td>6</td>
</tr>
</tbody>
</table>
Figure 11. “Which view is closest to yours?”

- Continue to build new reactors
- Do not build any more reactors

<table>
<thead>
<tr>
<th>Country</th>
<th>Continue to build new reactors</th>
<th>Do not build any more reactors</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>44</td>
<td>56</td>
</tr>
<tr>
<td>Germany</td>
<td>15</td>
<td>85</td>
</tr>
<tr>
<td>Japan</td>
<td>37</td>
<td>63</td>
</tr>
</tbody>
</table>

Figure 12. “Do you think that any modernization of electricity’s production in [respondent’s country] using existing or new nuclear power plants should be undertaken?”

- Yes; Modernize using nuclear power
- No; Do not modernize using nuclear power

<table>
<thead>
<tr>
<th>Country</th>
<th>Yes; Modernize using nuclear power</th>
<th>No; Do not modernize using nuclear power</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>49</td>
<td>51</td>
</tr>
<tr>
<td>Germany</td>
<td>46</td>
<td>54</td>
</tr>
<tr>
<td>Japan</td>
<td>71</td>
<td>29</td>
</tr>
</tbody>
</table>
Figure 13. Public opinion on the long-term viability of nuclear power as a source of energy.

“Overall, do you think that electricity produced from nuclear energy will be a viable long-term option for countries who need to produce it in that way, or do you think that it is only a limited and soon-to-be-obsolete form of producing energy for the future?”

<table>
<thead>
<tr>
<th>Geographical Area</th>
<th>Viable in the long-term</th>
<th>Limited and soon to be obsolete</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>29</td>
<td>71</td>
</tr>
<tr>
<td>Germany</td>
<td>9</td>
<td>91</td>
</tr>
<tr>
<td>Japan</td>
<td>45</td>
<td>55</td>
</tr>
</tbody>
</table>
APPENDIX B : NOTES TO FIGURES

Figures 1 - 2  Data on imports and nuclear energy output as a percentage of total energy output up to and including 1986 figures are available from the World Bank Databank. Remaining data are available from the International Atomic Energy Agency’s Power Reactor Information System.

Figure 3  Data available from the Energy Information Administration, “Federal Financial Interventions and Subsidies in Energy Markets 2007,” April 2008.

Figure 4  Surveys conducted between April 8 and 27, 2011, with a sample size of 700 adult respondents. Results are not weighted. Data available from Pew Research Center, “Japanese Resilient, But See Economic Challenges Ahead,” June 1, 2011, http://www.pewglobal.org/2011/06/01/japanese-resilient-but-see-economic-challenges-ahead/.

Figure 5  Data available from Index Mundi, “Uranium Monthly Price - US Dollars per Pound,” updated monthly.


Surveys conducted between May 9 and 21, 2011, with an approximate sample size of 1,000 respondents per country. For the second question displayed in Figure 9, only those respondents who indicated in their response to the first question that they opposed nuclear energy were surveyed. Results are weighted to reflect each country’s adult demographic, according to the most-recent census data. Data available from Ipsos MORI, “Global Citizen Reaction to the Fukushima Nuclear Plant Disaster,” June 2011, http://www.ipsos-mori.com/Assets/Docs/Polls/ipsos-global-advisor-nuclear-power-june-2011.pdf.
## APPENDIX C: ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>AEC</td>
<td>Atomic Energy Commission (US)</td>
</tr>
<tr>
<td>ANI</td>
<td>American Nuclear Insurers</td>
</tr>
<tr>
<td>BMU</td>
<td>Ministry for the Environment, Nature Conservation and Nuclear Safety (Germany)</td>
</tr>
<tr>
<td>BWR</td>
<td>Boiling Water Reactor</td>
</tr>
<tr>
<td>ECCS</td>
<td>Emergency Core Cooling System</td>
</tr>
<tr>
<td>GPU</td>
<td>General Public Utilities</td>
</tr>
<tr>
<td>IAEA</td>
<td>International Atomic Energy Agency</td>
</tr>
<tr>
<td>JINED</td>
<td>International Nuclear Energy Development of Japan Co Ltd</td>
</tr>
<tr>
<td>JNRC</td>
<td>Nuclear Regulatory Commission (Japan)</td>
</tr>
<tr>
<td>METI</td>
<td>Ministry of Economy, Trade and Industry (Japan)</td>
</tr>
<tr>
<td>MITI</td>
<td>Ministry of International Trade and Industry (Japan)</td>
</tr>
<tr>
<td>NRC</td>
<td>Nuclear Regulatory Commission (US)</td>
</tr>
<tr>
<td>NSC</td>
<td>Nuclear Safety Commission (US)</td>
</tr>
<tr>
<td>NSSA</td>
<td>Nuclear Security and Safety Agency (Japan)</td>
</tr>
<tr>
<td>OPEC</td>
<td>Organization of Petroleum Exporting Countries</td>
</tr>
<tr>
<td>Acronym</td>
<td>Full Form</td>
</tr>
<tr>
<td>---------</td>
<td>-----------</td>
</tr>
<tr>
<td>SMR</td>
<td>Small Modular Reactor</td>
</tr>
<tr>
<td>Solar PV</td>
<td>Solar photovoltaics</td>
</tr>
<tr>
<td>SPEEDI</td>
<td>System for Prediction of Environmental Emergency Dose Information (Japan)</td>
</tr>
<tr>
<td>TEPCO</td>
<td>Tokyo Electric Power Company</td>
</tr>
<tr>
<td>TMI</td>
<td>Three Mile Island</td>
</tr>
<tr>
<td>UCS</td>
<td>Union of Concerned Scientists</td>
</tr>
<tr>
<td>VRE</td>
<td>Variable Renewable Energy</td>
</tr>
</tbody>
</table>
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