The Global Political Aftershocks of the Fukushima-Daiichi Nuclear Accident

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Introduction

In March 2011, Japan was hit by a 9.0 magnitude earthquake and a massive tsunami which created the conditions for a major accident at the Fukushima-Daiichi nuclear power plant. The Fukushima-Daiichi accident was the second worst in history, surpassed only by Chernobyl in 1986. This has led many countries to review their nuclear energy policy. Some countries, such as Germany, have already publicly announced their plans to phase-out nuclear energy. Meanwhile, others, such as China and Canada, are continuing with their nuclear agenda. The hypothesis of this paper is that the accident has accentuated pre-existing political and economic conditions and will not, unlike the Chernobyl accident, have a transformative effect on the international nuclear sector. The same drivers (electricity demand, energy security, and concerns over climate change) and constraints (safety concerns, cost, and links to weapons proliferation) exist for nuclear energy. In this way the paper counters predictions made by academics such as Trevor Findlay "that a major nuclear accident anywhere is a major accident everywhere and could kill prospects for a revival."[1]

This paper analyzes the global political fallout from the accident by describing and explaining the response by states. The first part describes the Fukushima-Daiichi accident. The second part identifies the countries that are either phasing out or maintaining and/or expanding nuclear energy. The phaseout countries include Japan and Germany as well as other Western European countries such as Switzerland, Belgium, and Italy. The maintain/expand countries can be further divided into the categories of the major expanding countries (China, India, Russia, and South Korea), large developed countries maintaining their nuclear fleet (ie., Canada, United

[1] Trevor Findlay, *The Future of Nuclear Energy to 2030 and its Implications for Safety, Security and Nonproliferation: Overview* (Centre for International Governance Innovation: Waterloo, 2010), 23.

States, France, and parts of Europe), and new entrants (ie., United Arab Emirates, Jordan). The third part seeks to explain the differing reactions of countries around the world. It examines the following variables to determine their impact on a country's decision-making process: the location of the disaster, the severity of the accident, public support for nuclear energy, cost issues (increased cost of new safety features, insurance, natural gas prices, access to capital), the extent of a country's energy security, the size of a county's pre-existing nuclear industry, the strength of a country's anti-nuclear coalition, and the level of a country's democracy.

Fukushima-Daiichi Nuclear Accident

On 11 March 2011 Japan was hit by a 9.0-magniture earthquake. The Fukushima-Daiichi nuclear power plant, which is about 250 kilometres northeast of Tokyo on the edge of the Pacific Ocean, automatically shut down units 1 to 3 (units 4 to 6 were not in operation at the time of the earthquake). Although the chain reactions had been stopped, radioactive materials in the reactor cores continued to produce decay heat. When this happens there is a danger that the cores will overheat if the fuel is not cooled by circulating water using electric pumps, and unfortunately, the earthquake had knocked out the electricity in the Fukushima area. The facility therefore went to its first backup safety system: thirteen diesel-powered generators on-site. Then a massive tsunami struck one hour after the earthquake and flooded all the generators, and the plant had to revert to its secondary backup system: emergency battery power. But the batteries, in turn, expired after only eight hours. In short, the Fukushima-Daiichi nuclear plant was hit by three simultaneous disasters: an earthquake, a tsunami, and a loss of all electricity.

This trio led to a series of significant accidents at the Fukushima-Daiichi nuclear plant. A loss of coolant at units 1 to 3 led to some melting of fuel, breaches of the containment vessel, and release of radioactive material. There were also several explosions in secondary buildings owing to the venting of hydrogen into the atmosphere. These incidents were compounded by the evaporation of water at spent-fuel storage bays for all six units. Spent-fuel bundles are removed from the reactor care after going through the fission process, but since they continue to produce decay heat for several years, they are also cooled in water. A lack of water in the spent fuel pools is potentially more dangerous because, unlike the situation with the reactor core, there is no metres-wide steel and concrete containment vessel protecting the pools.

For over a week Japanese authorities battled to control the nuclear crisis. They injected seawater into the reactor cores, brought in diesel generators, relied on fire trucks and helicopters to spray water, replaced damaged pumps and valves, reconnected power lines, and took other emergency actions. The nuclear crisis is now under control, although units 1 to 3 will never again be operational. On 16 December 2011, Prime Minister Noda announced that the reactors at the Fukushima-Daiichi have reached a condition equivalent to a cold shutdown, bringing the accident to a conclusion.[2]

This was the second-worst nuclear accident in history, surpassing Three Mile Island, but not hitting the death toll and environmental destruction that at Chernobyl. In fact, nobody died as a result of the nuclear accident, even though over twenty thousand people perished and there was $300 billion in damage as a result of the earthquake/tsunami. Japan has placed the Fukushima-Daiichi accident at a 7 on the IAEA's International Nuclear Events Scale meaning a "major

[2] Consul-General Susumu Fukuda, Consulate General of Japan at Calgary, "One Year and Beyond: East Japan Earthquake, Major Reconstruction Unfolds 2012." Presentation at Mount Royal University, Calgary, Alberta (5 March 2012).

accident." This is equal to Chernobyl's 7 ranking and above Three Mile Island's 5 ranking as an "accident with wider consequences."[3] The reason for the high ranking was not because of the death toll or number of injuries, but because the accident involved multiple units. A loss-of-coolant accident occurred at three reactors and all six spent fuel storage ponds.

It is important to note that in the Tohoku region, there were an additional four nuclear power plants that had nine operating reactors. Yet, all of them were immediately shut-down when the earthquake hit and then went safely into cold shut-down. None of them had the same problems as Fukushima-Daiichi. Most notably was Fukushima-Dai-ni which was located only seven miles south of Fukushima-Daiichi. Dai-ni also suffered significant damage due to the earthquake/tsunami, but there was no loss of coolant accidents, no explosions, and no need to vent core pressure. All six units are in a safe shut-down mode. The primary difference was that the Dai-ni plant also had General Electric Boiling Water reactors, but they were a decade newer. This meant that they had enhanced safety features such as newly designed core spray and auxiliary cooling systems, a redesigned containment vessel that integrated cooling and support equipment, and a containment system that could purge the reactor with nitrogen gas to prevent a hydrogen buildup.

[3] For more information on the Fukushima-Daiichi accident see International Atomic Energy Agency, "Fukushima Nuclear Accident." Accessed on 21 May 2012 at http://www.iaea.org/newscenter/focus/fukushima/; Masaya Yasui, Deputy Director General, Nuclear Safety Regulation Reform, Ministry of Economic, Trade and Industry, *Causes and Countermeasures: The Accident at TEPCO's Fukushima Nuclear Power Stations* (March 2012); and John Luxat, "Fukushima-Daiichi: A Technical Assessment of the Events and Radiological Consequences." Presentation to the West Toronto Chapter PEO and Ontario Centre for Engineering and Public Policy, Toronto, Ontario (3 August 2011).

Phase Out Countries

Prior to the Fukushima-Daiichi nuclear accident, Japan had 58 operating reactors and was constructing an additional two units.[4] In total, nuclear energy provided about 30% of Japan's electricity.[5] Japan wanted to increase its reliance on nuclear energy and the Ministry of Economy, Trade and Industry (METI) announced in June 2010 that it wanted to increase the percentage to 50% of electricity from nuclear energy by 2030 through constructing an additional two dozen reactors.[6]

As a result of the Fukushima-Daiichi accident, units 1-4 of the power plant are destroyed, and possibly units 5-6 too. Japan has also temporarily shut-down all of its remaining nuclear fleet, 54 reactors, for safety testing and scheduled maintenance. In the immediate aftermath of the Fukushima-Daiichi accident, Japan had shut-down some of its reactors for safety tests amid growing public opposition. There was to be a full review of Japan's energy plan and its high dependence on nuclear energy. In July 2011, the Japanese government went further when Prime Minister Naoto Kan announced his intention to initiate a phase-out program to gradually rid the country of nuclear energy. "Given the enormity of the risks associated with nuclear power generation, I have realized that nuclear power technology is not something that can be managed by conventional safety measures alone."[7] In August 2011, the Japanese Parliament replaced Kan as Prime Minister with Finance Minister Yoshihiko Noda. Noda also promised to gradually phase-out nuclear energy in Japan. He said that building "new reactors is unrealistic, and we will

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[4] Reactors in operation was taken from IAEA, "Number of Reactors in Operation Worldwide." Reactors under construction was taken from IAEA, "Number of Reactors under construction Worldwide." Accessed on 12 January 2012 at http://www.iaea.org/cgi-bin/db.page.pl/pris.opercap.htm

[5] World Nuclear Association, "Nuclear Share Figures, 2000-2010." Accessed on 12 January 2012 at http://world-nuclear.org/info/nshare.html

[6] Japan, Ministry of Economy, Trade and Industry, *The Strategic Energy Plan of Japan* (June 2010).

[7] Quoted in Danielle Demetriou, "Japan's PM says its time to abandon nuclear power," *Calgary Herald* (14 July 2011).

decommission reactors at the end of their life spans. But it is also impossible to immediately reduce our dependence to zero."[8]

There are sceptics, which include some other Japanese cabinet ministers and nuclear industry leaders, about whether Japan, which has very few national sources of coal, oil, and natural gas, can completely wean itself off of nuclear energy. For example, chief cabinet secretary Yukio Edano downplayed Kan's initial statement, which he said was his "private view" and not government policy. Edano indicated that Japan should have a national debate about the future of nuclear energy.[9] Even Noda acknowledged that Japan needed to restart reactors that had been shut-down in the aftermath of the Fukushima-Daiichi accident.[10] For example, Japan is considering restarting units 3 & 4 at Kansai's Ohi plant in Western Japan because each unit generates 1, 180 MW.[11]

To replace the lost electricity due to shutting down its nuclear reactors, Japan has initiated some severe rationing that has included turning off air conditioners in the summer and forcing factories to operate at night and on weekends.[12] In addition, Japan has been importing huge quantities of crude oil and LNG. In fact, electricity imports could add as much as $30 billion a year in additional energy costs.[13] This resulted in Japan posting its first trade deficit in more than three decades in 2011 and it will probably be even worse in 2012.

The Japanese government and big business are not necessarily opposed to nuclear energy, but they recognize the domestic situation and the current opposition to nuclear energy. In fact,

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[8] Quoted in Hiroko Tabuchi, "Japan Leader to Keep Nuclear Phase-Out," *New York Times* (2 September 2011).
[9] Quoted in "N-phaseout merely Kan's 'private view'/Ministers blast PM for lack of notice," *The Yomiuri Shimbun* (16 July 2011).
[10] "New Japan PM Noda in Nuclear Restart Call," *BBC News* (13 September 2011).
[11] "Japan ministers to meet on reactor restart-media," *Reuters* (14 March 2012).
[12] Aaron Sheldrick, "Japan switches off last nuclear power plant; will it cope," *Reuters* (4 May 2012).
[13] Justin McCurry, "Japan's reactors all going offline by summer," *The Globe and Mail* (10 March 2012).

Japan still supports exports of nuclear technology. It has signed nuclear cooperation agreements, which are required for any export of nuclear technology, with Jordan, Russia, South Korea, and Vietnam and is negotiating similar agreements with Brazil, India, South Africa, Turkey, and the United Arab Emirates. Hitachi has also won a tentative contract to build a nuclear power plant in Lithuania.[14]

The Fukushima-Daiichi accident has also had a dramatic effect on Germany, like Japan a highly nuclear-dependent country. Starting in the 1950s, West Germany had developed a sophisticated nuclear infrastructure originally relying on designs from Westinghouse and General Electric. In 1967, Siemens and AEG created Kraftwerk Union (KWU) to develop a German-made reactor. KWU quickly became one of the world's largest nuclear companies and concluded exports to the Netherlands, Iran, Brazil, and Argentina in the 1970s. East Germany was also actively building Soviet-designed nuclear reactors from the 1950s to the 1980s. By the time of unification in 1990, six power reactors were operating in East Germany, but after unification, the East German reactors were shut down because of safety concerns. Germany has a very strong environmental movement that, especially since Chernobyl, has sought to end the use of nuclear energy in that country. In 2000, the Social Democratic Party Chancellor, Gerhard Schröder, under great pressure from his junior coalition partner (the Green Party) decided to begin an organized and multi-year nuclear phase-out program. However, in 2010 the Christian Democratic Party chancellor Angela Merkel reversed that decision. Merkel, rare among politicians in that she has a PhD in chemistry, had wanted to do so earlier, but was bound from 2005 to 2009 in a "grand coalition" with the Social Democrats. Merkel feared that the nuclear phase-out, while popular among the German public, would mean that Germany would not be

[14] Jacques E. C. Hymans, "The Fukushima shock and Japan's nuclear future: Plus ça change?" Presented at the annual meetings of the *Association for Asian Studies*, Toronto, Ontario (18 March 2012), 9.

able to reduce its use of coal and natural gas. Her government had concluded that wind and solar power could not meet Germany's electricity demand.[15] Under a new law, the life of Germany's reactors was extended and plans to build more started to take shape.

Days after the Fukushima-Daiichi accident happened, Merkel immediately ordered the temporary shut-down of seven reactors built before 1980.[16] She went even further in May 2011 by promising to shut down all Germany's nuclear power plants by 2022.[17] Germany's seventeen nuclear power plants currently produce over 21 Gwe, representing over 26 percent of Germany's electricity generation. Merkel believes that this loss of electricity can be matched by dramatically increasing government and private sector investment in renewable energy technology. However, there are questions about whether this plan is achievable. Swedish Environment Minister Andres Carlgren called it "unrealistic," and argued that Germany will have to rely on increased coal generation or imports of nuclear energy from France and natural gas from Russia.[18] Either that or a future German government will have to backslide from Merkel's commitment.

Other European countries have followed Germany's lead. Switzerland, despite a referendum in February 2011 that supported replacing its five-reactor-strong nuclear fleet, also decided to phase out nuclear energy by 2034 (when its existing reactors end their lifetime service).[19] Italy, after a June 2011 referendum, rejected a plan to reverse its 1987 decision to phase out nuclear energy by building Areva-designed reactors. The defeat of the referendum resulted from a combination of public fears after Fukushima-Daiichi and growing

[15] For a short history of Germany nuclear power see Mez, Lutz and G. Bruce Doern, "Nuclear Energy in Germany and Canada: Divergent Regulatory Policy and Governance Paths," in Burkhard Eberlein and G. Bruce Doern, eds., *Governing the Energy Challenge: Canada and Germany in a Multi-Level Regional and Global Context* (University of Toronto Press: Toronto, 2009), 122-46.
[16] Kanter and Dempsey, "Germany Shuts 7 Plants as Europe Plans Safety Tests," *New York Times* (15 March 2011).
[17] "Last Decade of German Nuclear Power," *World Nuclear News* (31 May 2011).
[18] Quoted in Shawn McCarthy and Richard Blackwell, "Getting Nervous about Nuclear," *Globe and Mail* (31 May 2011).
[19] "Swiss Cabinet Goes for Nuclear Phase Out," *World Nuclear News* (25 May 2011).

disenchantment with the scandal-ridden Prime Minister Silvio Berlusconi (who lost three other referendums on the same day). Regardless, as Berlusconi remarked after the vote, Italy "shall have to say goodbye to nuclear."[20] A third additional Western European country, Belgium, has also recently announced a nuclear phaseout policy. Belgium has seven nuclear reactors that generate about 55% of the country's electricity. In 2009, Belgium had reversed a nuclear phaseout plan, but in December 2011, in the aftermath of the Fukushima-Daiichi accident, Belgium reversed course again and announced that it would close three reactors by 2015 and the other four by 2025. However, even in this latest decision, it issued a caveat; the new law would only be implemented if enough electricity could be secured from other sources and at a reasonable price.[21]

Maintain/Expand Countries

China, India, Russia, South Korea

There are four countries that were leading the global nuclear revival: China, India, Russia, and South Korea. These four major expanding countries have continued to pursue nuclear energy despite the Fukushima-Daiichi accident. China has 16 operating reactors, but they produce less than 2% of China's electricity.[22] However, China is currently building 26 new reactors. Pre-Fukushima-Daiichi projections were that China would have 50 GWe of new nuclear power by 2030, and possibly as much as 90 GWe.[23] Although China temporarily

[20] Quoted in Eric Reguly, "Referendum Kills Italy's Nuclear Plans," *Globe and Mail* (14 June 2011).
[21] "US, Belgium polls show different stances," *World Nuclear News* (27 February 2012).
[22] Reactors in operation was taken from IAEA, "Number of Reactors in Operation Worldwide." Reactors under construction was taken from IAEA, "Number of Reactors under construction Worldwide." Accessed on 12 January 2012 at http://www.iaea.org/cgi-bin/db.page.pl/pris.opercap.htm
[23] Zhidong Li, "The prospects for nuclear energy in the East Asian region: focusing on China," *International Journal of Global Energy Issues* 30/1–4 (2008), 264–88.

suspended new approvals for its own nuclear power plants and conducted a nationwide safety review, it has not abandoned its long-term goal of increasing nuclear energy in the country.[24] A year after the Fukushima-Daiichi accident, there are many signs that the moratorium on approving new nuclear plants is about to be lifted. These signs include important pro-nuclear speeches from Premier Wen Jiabao and other senior political figures, reactor projects being given approval to carry out site preparation work, signing of large contracts by nuclear equipment manufacturers, and feasibility studies being prepared for new reactors.[25]

India has 20 reactors that produce less than 3% of its electricity, but it is constructing another 6 reactors and has high hopes for many more.[26] Prior to the Fukushima-Daiichi accident, the low projections for India were an additional 31 GWe of new nuclear power by 2025, and the high estimate was 43 GWe.[27] India is not planning on changing their pro-nuclear policy in the aftermath of the Fukushima-Daiichi accident. Prime Minister Singh announced a strengthening of its Atomic Energy Regulatory Board to ensure the safe operation of India's nuclear reactors. However, he rejected the idea that India should abandon nuclear energy, saying that "nuclear energy has the potential of playing an increasingly important role in giving our country energy independence from traditional and polluting sources of energy."[28] A year after the Fukushima-Daiichi accident, Singh remains steadfast in his support for nuclear energy, maintaining that nuclear energy was "an essential component" of India's energy mix. While there have been

[24] Olivia Chung, "China to Maintain Nuclear Power Goal," *Asia Times* (30 March 2011).
[25] "New nuclear spring for China?" *Nuclear N-Former* (29 March 2012).
[26] Reactors in operation was taken from IAEA, "Number of Reactors in Operation Worldwide." Reactors under construction was taken from IAEA, "Number of Reactors under construction Worldwide." Accessed on 12 January 2012 at http://www.iaea.org/cgi-bin/db.page.pl/pris.opercap.htm
[27] Grover, R.B., "Prospects for nuclear energy in South Asia in the 21st century," *International Journal of Global Energy Issues* 30/1-4, 228–48. Indian Prime Minister Manmohan Singh is even more optimistic, pledging that "if we manage our program well, our three-stage strategy could yield potentially 470,000 MWe of power by the year 2050." "Think Big, India," *World Nuclear News* (29 September 2009).

[28] Quoted in "Independent Nuclear Watchdog for India?" *United Press International*, 30 March 2011.

demonstrations at the Koodankulam site, in the southern state of Tamil Nadu, where two 1, 000 MW reactors are being built, the business community, which has often suffered from electricity shortages, have welcomed the project. Singh also publicly responded to the demonstrators and other nuclear critics, by maintaining that India is "strengthening emergency preparedness and response to nuclear accidents. We are determined that our expanded nuclear power programme will follow the highest standards of nuclear safety and security. It is essential to restore public faith in nuclear energy, especially after the tragic events at Fukushima."[29]

Russia has 33 reactors producing over 17% of its electricity.[30] It is also constructing 11 new reactors. Russia seeks to double its nuclear energy output by 2020.[31] Internationally, Rosatom – Russia's state-owned nuclear company - has been building reactors and signing agreements across the globe. Rosatom is active not just in growing markets such as China and India, but in potential markets such as Bangladesh and Nigeria.[32]

South Korea has 23 reactors which produce over 30% of its electricity.[33] It is also constructing 3 new reactors which, unlike the previous ones, are designed by Koreans. President Lee Myung-bak, at a groundbreaking ceremony to mark the start of construction on the Shin Ulchin 1 and 2 reactors, called it a "huge milestone" that demonstrates that South Korea has "achieved the dream of independent nuclear technology."[34] Further testament to the increasing role of nuclear technology in South Korea is the fact that it is now an exporter. Korea Hydro &

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[29] "India needs nuclear energy, says PM Manmohan Singh," *BBC News* (27 March 2012).
[30] Reactors in operation was taken from IAEA, "Number of Reactors in Operation Worldwide." Reactors under construction was taken from IAEA, "Number of Reactors under construction Worldwide." Accessed on 12 January 2012 at http://www.iaea.org/cgi-bin/db.page.pl/pris.opercap.htm
[31] Fredrik Dahl, "Older nuclear plants pose safety challenge: IAEA," *Toronto Star* (13 March 2012).
[32] "Rosatom signs international deals," *World Nuclear News* (4 June 2012).
[33] Reactors in operation was taken from IAEA, "Number of Reactors in Operation Worldwide." Reactors under construction was taken from IAEA, "Number of Reactors under construction Worldwide." Accessed on 12 January 2012 at http://www.iaea.org/cgi-bin/db.page.pl/pris.opercap.htm
[34] "Celebrations at South Korean groundbreaking," *World Nuclear News* (8 May 2012).

Nuclear Power Co Ltd (KNHP) has already sold one research reactor to Jordan and four power reactors to the United Arab Emirates.

Developed Countries

United States has not had a new nuclear build in over 30 years. The George W. Bush Administration brought in a number of incentive programs for building new nuclear power plants: more streamlined regulatory process, reduced regulatory fees, increased nuclear research & development, loan guarantees, delay insurance, production tax credits, and limited liability. The Obama administration has continued this support of nuclear power. In President Obama's 2011 State of the Union speech he set a goal for 80 percent of the United States' electricity to come from clean energy sources, including nuclear, by 2035. "Some folks want wind and solar. Others want nuclear, clean coal and natural gas. To meet this goal, we will need them all."[35] The United States Nuclear Regulatory Commission (NRC) has already received 26 applications for new builds.[36] Nevertheless, industry insiders predict only four to eight new reactors coming online by 2015.[37]

The Fukushima-Daiichi accident is not likely to dent American government support for the maintenance and expansion of nuclear energy. Energy Secretary Steven Chu stated that "whenever there is an accident, it's very natural to have concern. We'll take this opportunity to look again at all our nuclear sites. We get 20 percent of our electricity from nuclear power, and

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[35] United States, White House, "Remarks by the President in State of the Union Address," (25 January 2011). Accessed on 3 August 2011 at http://www.whitehouse.gov/the-press-office/2011/01/25/remarks-president-state-union-address

[36] United States, Nuclear Regulatory Commission, "Combined License Applications for New Reactors," (July 2009). Accessed on 10 November 2009 at http://www.nrc.gov/reactors/new-reactors/col.htm

[37] Sharon Squassoni, "The US Nuclear Industry: Current Status and Prospects under the Obama Administration," *Nuclear Energy Futures Paper No. 7* (November 2009). Accessed on 11 November 2009 at http://www.cigionline.org/sites/default/files/Nuclear_Energy_WP07.pdf

you just don't turn that off overnight. We think nuclear power should be part of the mix."[38] In February 2012, two new reactors were approved by the NRC for construction in Georgia[39]and a few weeks later, two more reactors were approved for South Carolina.[40] Finally, the completion of the Watts Bar unit 2 reactor in Tennessee, where construction initially began in the 1970s, was given the green light. But the Nuclear Energy Institute, an American lobby group, admits that beyond these five reactors, there are no new large-scale builds on the horizon. This is due to a combination of low-cost natural gas and a stagnant demand for electricity in the United States.[41]

The Fukushima-Daiichi nuclear accident has had few effects on the Canadian nuclear sector. It did not reverse pre-existing trends towards maintaining and expanding the nuclear sector in New Brunswick, Ontario, or Saskatchewan. For example, in Ontario, the heart of Canada's nuclear sector, the refurbishment of all existing reactors is still happening and the process to build two new reactors is proceeding unabated.[42] In fact, public hearings, as part of the environmental assessment, on the new build project were held over seventeen days in March and April 2011 over the objections of many environmental groups who wanted them delayed until studies were completed assessing the impact of the Japanese disaster and the potential for something similar to occur in Ontario.[43] In August 2011, the federal Joint Review Panel (made up of officials from the Canadian Nuclear Safety Commission and the Canadian Environmental Assessment Agency) approved the project. "The Panel conclude[d] that the Project is not likely

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[38] Quoted in John Avlon, "Interview: Steven Chu," *Newsweek* (3 April 2011).
[39] "U.S. approves first nuclear plant in decades," *Associated Press* (9 February 2012).
[40] "Regulator OKs the Start of Summer," *World Nuclear News* (2 April 2012).
[41] David Biello, "Nuclear Reactor Approved in U.S. for First Time Since 1978," *Scientific American* (9 February 2012).
[42] For information on Ontario's electricity strategy see Ontario, *Ontario's Long-Term Energy Plan: Building our Clean Energy Future* (2010), 23-4. Accessed on 30 November 2010 from http://www.mei.gov.on.ca/en/pdf/MEI_LTEP_en.pdf
[43] Renata D'Aliesio, "Ontario asks Ottawa to consider Japan in nuclear plant expansions," *The Globe and Mail* (19 March 2011).

to cause significant adverse environmental effects, provided the mitigation measures proposed and commitments made by OPG during the review, and the Panel's recommendations are implemented."[44] Even in Alberta, the decision of Bruce Power to cancel its plans to build a nuclear power plant in Peace River was due to dropping natural gas prices, not the effects of the Fukushima-Daiichi accident.[45] Only in Quebec has there been a reversal when the Charest government decided to delay refurbishing its Gentilly-2 reactor.[46] However, Quebec is not dependent upon nuclear energy to generate electricity for the grid due to its abundant hydroelectricity supplies and there was opposition to nuclear energy in the province *before* the Fukushima-Daiichi accident. For almost a decade, public opinion polls in Quebec have shown that support for nuclear energy has fluctuated between 17-23%.[47]

France is the most nuclear dependent country in the world with 58 reactors producing over 74% of its electricity.[48] Nuclear remains the cornerstone of French energy policy. Former French president Nicolas Sarkozy had committed an additional €1 billion to future nuclear programs, including research on fourth-generation reactors. Sarkozy was critical of his European partners bringing in nuclear moratoriums, since in his view "there is no alternative to nuclear today."[49] The new French President Francois Hollande, who was elected in May 2012, has not fully released his energy strategy. However, during the campaign he initially pledged to cut the

[44] Joint Review Panel, *Darlington New Nuclear Power Plant Project* (August 2011), i.
[45] Nicki Thomas and Elise Stolte, "Bruce Power withdraws nuclear plant proposal," *Edmonton Journal* (13 December 2011).
[46] Lynn Moore, "Hydro-Québec to study nuke plant shutdown," *Montreal Gazette* (23 March 2011).
[47] Ipsos-Reid, "Issues Tracking Report, April 2010," 17 and Ipsos-Reid, "Canadian Attitudes towards Nuclear Energy: Tracking Survey Results, November 2003).
[48] Reactors in operation was taken from IAEA, "Number of Reactors in Operation Worldwide." Reactors under construction was taken from IAEA, "Number of Reactors under construction Worldwide." Accessed on 12 January 2012 at http://www.iaea.org/cgi-bin/db.page.pl/pris.opercap.htm
[49] "Sarkozy Supports Nuclear with €1 Billion Pledge," *World Nuclear News* (28 June 2011).

use of nuclear energy by 50% by 2025, but, after being pressured, revised his promise to close only the oldest reactors in France.[50]

Other European countries also remain steadfast in their support for nuclear energy. In a major address, British energy minister Charles Hendry asserted that "we must go forward with new nuclear and we would be a darker and less prosperous nation without it. After more than a decade since we built the last plant, there should be no doubt that UK wants to be a serious nuclear nation once again." Hendry added, "and that's why we don't want to see one nuclear power plant built, but we want to see a fleet."[51] Lithuania is building a new 1,300 MW reactor that will also export electricity to Estonia, Latvia, and Poland.[52] New Romanian Prime Minister Victor Ponta wants to add two more nuclear reactors to Romania's existing two operating reactors.[53] The Czech Republic will decide on the vendor to build two new reactors, adding to the six currently operating, in late 2013.[54] Finland has one reactor at the late stages of construction, and another one is planned.[55] Sweden went through a debate three decades ago which led to a 1980 referendum passing that would see Sweden phaseout nuclear energy. The results of that referendum were subsequently ignored, and eventually overturned by Parliament in 2010. This opens the door for replacing some of Sweden's aging reactors. Spain is in the process of upgrading its existing nuclear fleet.[56] Bulgaria recently dropped its plans for building

[50] "French nuclear debate ignites amidst presidential race," *Nuclear N-Former* (8 February 2012).
[51] Quoted in "Britain to Return as 'Serious Nuclear Nation,'" *World Nuclear News* (5 July 2011).
[52] "Hitachi-GE Wins Lithuanian Nuclear Tender," *World Nuclear News* (14 July 2011).
[53] "New Romanian PM supports the plan to build two more nuclear reactors," *Balkans.com* (14 May 2012).
[54] "Czech Suppliers team up with reactor vendors," *World Nuclear News* (21 March 2012).
[55] "Bidding starts for Olkiluoto 4," *World Nuclear News* (26 March 2012).
[56] "Political shift for Spanish nuclear," *World Nuclear News* (23 November 2011).

a new reactor at the last minute due to financing issues.[57] However, it is not abandoning nuclear power, and is, in fact, extending the life of two its reactors.[58]

New Entrants

If the Fukushima-Daiichi accident was going to stop nuclear energy from proceeding it needed to stop new entrants into the market. This has not been occurring. Several countries are building their first nuclear reactors. The biggest new entrant is the United Arab Emirates which is constructing four new reactors from KNHP and has plans for four more.[59] Turkey awarded a contract to Rosatom to build its first nuclear reactor in 2010 and is calling for proposals from international vendors for a second, and possibly a third, reactor.[60] Belarus has signed a contract with Rosatom for two new reactors to be completed by 2017.[61] Jordan is another country that is actively pursuing nuclear energy. In 2009 it purchased a US$183 million research reactor from South Korea.[62] Currently, it is undertaking the site selection process for its first reactor and is in the final stages of its vendor selection process.[63]

Explaining Differences

Location of Disaster

Location matters. For example, having the 1979 Three Island accident occur in the United States meant that the accident received more coverage due to the global reach of the American media and the role of the United States as a superpower. In the case of the 1986

[57] "Bulgarian government drops Belene," *World Nuclear News* (29 March 2012).
[58] "Life extension considered for Kozloduy," *World Nuclear News* (23 April 2012).
[59] "UAE Picks Korea as Nuclear Partner," *World Nuclear News*, 29 December 2009.
[60] "Candu applies to build Turkey nuclear plant," *Montreal Gazette*, 20 April 2012.
[61] "Contract signed for Belarusian reactors," *World Nuclear News* (11 October 2011).
[62] Professional Reactor Operator Society, "Korea to Build Nuclear Research Reactor in Jordan" (4 December 2009). Accessed on 12 December 2009 at http://www.nucpros.com/index.php?q=node/7519.
[63] "Jordan shortlist down to two," *World Nuclear News* (30 April 2012).

Chernobyl accident, the effects spread throughout the European continent. This included the real threats of radiation dispersal, but also the perceived threats of the accident by bordering and regional countries. However, the Fukushima-Daiichi accident was contained on the Japanese island. This meant that it had a tremendous effect on the Japanese. Prior to the Fukushima-Daiichi accident, Japan was one of the most pro-nuclear countries in the world, and today it is one of the most anti-nuclear countries. This sudden reversal in policy and public support would not have occurred had the accident been in Europe or North America. However, it had little spillover effect on its neighbours as both China and South Korea remain committed to the pursuit of nuclear energy. In short, the location of the accident mattered a lot to Japan, but not to other countries.

Scale of Disaster

The Fukushima-Daiichi nuclear accident alarmed many anti-nuclear activists. They viewed the accident as yet another argument for phasing out nuclear energy. Those who were adamantly opposed to nuclear energy before the Fukushima-Daiichi accident are even more adamantly opposed today. They also mobilized quickly after the accident. For example, tens of thousands of Germans created a human chain around some of their nuclear power plants in the first weekend of the crisis.[64] The Fukushima-Daiichi accident easily fits into their narrative about how they have been warning for years that reactors are unsafe. They believe that the nuclear industry, utilities, regulators, and government have minimized the potential for accidents and that when things go wrong, they really go wrong. For them, Fukushima-Daiichi has proven that nuclear technology, even when operated by an experienced industrialized country such as Japan, is simply too dangerous to be handled in the long-term. As Greenpeace's Shawn-Patrick Stensil

[64] James Kanter and Judy Dempsey, "Germany Shuts 7 Plants as Europe Plans Safety Tests," *New York Times* (15 March 2011).

put it, "Fukushima is this generations' Chernobyl, and what we've seen since Fukushima is major industrial countries abandoning nuclear power and ramping up investment in green energy technology."[65]

However, one prominent environmentalist actually moved to the pro-nuclear side because of the Fukushima-Daiichi accident. George Monibot, an award-winning environmental writer from Britain, wrote in the *Guardian* that "as a result of the disaster at Fukushima, I am no longer nuclear-neutral. I now support the technology." What convinced Monibot was the fact that "a crappy old plant with inadequate safety features was hit by a monster earthquake and a vast tsunami. The electricity supply failed, knocking out the cooling system. The reactors began to explode and melt down. The disaster exposed a familiar legacy of poor design and corner-cutting. Yet, as far as we know, no one has yet received a lethal dose of radiation … Atomic energy has just been subjected to one of the harshest of possible tests, and the impact on people and the planet has been small."[66]

Monibot's comments were not isolated; they reflected the fact that while 15, 000 Japanese died as a result of the earthquake and tsunami, nobody died as a result of the Fukushima-Daiichi accident. An MIT study of the accident concluded that "the release of radioactivity from the plant has been large and some workers have received significant radiation doses, but health risks for them and the general population are expected to be negligible. In fact, no loss of life has occurred or is expected as a result of the accident. Direct damage and casualties inflected on Japan by the earthquake and tsunami far exceed any damage caused by

[65] Quoted in Jon Hembry, "Atomic Fallout: Global Chill but Nuclear Not Dead," *CBC News* (31 May 2011).
[66] George Monibot, "Going Critical: How the Fukushima Disaster Taught Me to Stop Worrying and Embrace Nuclear Power," *Guardian* (22 March 2011).

the accident at the nuclear plant."[67] The World Health Organization investigated the health effects of radiation on the Fukushima prefecture, the rest of Japan, and outside of Japan. It concluded that in the Fukushima prefecture and neighbouring prefectures "the estimated effective doses are below the internationally agreed reference level for public exposure." This was the same for the rest of Japan and outside of Japan where the dose levels are "below (and often far below) the dose levels regarded by the international radiological protection community as very small."[68] The scale of the Fukushima-Daiichi accident was not severe as media reports at the time predicated; this helps to explain why only five countries have pursued the phaseout strategy as opposed to thirty countries which have maintained/expanded their use of nuclear energy.

Public Opinion

Prior to the Fukushima-Daiichi accident, the support for nuclear energy was gradually increasing across the globe. A major twenty country multinational poll by Accenture in November 2008 showed that 74% "think that nuclear power will play an important role in meeting future electricity needs in [their] country." India (93%) and China (89%) led the way, but even the lowest surveyed country saw a majority in favour of nuclear power. European countries ranged from a high in Slovakia (88%) to a low in Greece (51%). In North America, both the United States (80%) and Canada (62%) showed clear majorities in favour of nuclear power.[69]

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[67] Buongiorna, J., R. Ballinger, M. Driscoll, B. Forget, C. Forsberg, M. Golay, M. Kazimi, N. Todreas, and J. Yanch, *Technical Lessons Learned from the Fukushima-Daichii Accident and Possible Corrective Actions for the Nuclear Industry: An Initial Evaluation* (Center for Advanced Nuclear Energy Systems, Massachusetts Institute of Technology: Cambridge, Massachusetts, 26 July 2011), 3.
[68] World Health Organization, *Preliminary Dose Estimation: from the nuclear accident after the 2011 Great East Japan Earthquake and Tsunami* (2012).
[69] Accenture, *Multinational Nuclear Power Pulse Survey 2009* (April 2009).

The Fukushima-Daiichi accident, not surprisingly, has had a dramatic downturn on global public opinion towards nuclear energy. Ipsos-Mori conducted a 24-nation survey in late May 2011 and found 62% opposition towards nuclear energy.[70] There were only three countries who supported nuclear energy: India (61%), Poland (57%), and the United States (52%). 26% of respondents said that their opinion towards nuclear energy was influenced by the accident at Fukushima-Daiichi. Interestingly, 41% of Japanese still supported nuclear energy, even though 52% were influenced by Fukushima-Daiichi accident. However, a year later attitudes towards nuclear energy in Japan have continued to plummet. In March 2012, 70% of Japanese now wanted to reduce or end nuclear energy, although 48% support restart of reactors for short-term needs.[71] Germany, the other leading nuclear phaseout country, had very low support for nuclear energy with only 19% of Germans supporting it.

Public opinion would, therefore, appear to be a key variable in explaining whether a country would phaseout nuclear energy or maintain and/or expand its use. It is assumed that the higher the public support for nuclear energy, the more likely that a country would maintain/expand its use of nuclear energy. Conversely, the lower the public support for nuclear energy, the more likely that a country would phaseout nuclear energy. The multi-country survey conducted by Ipsos-Mori in late May 2011 will be used to determine public opinion towards nuclear energy. This one survey is used because it was multi-country and asked the same questions in each country at the same time. The countries that are listed have nuclear reactors operating, under construction, or signed contracts for construction. Countries are then divided, based on the analysis in Part Two of this paper, into two categories: nuclear phaseout countries

[70] Ipsos-Mori, "Strong global opposition towards nuclear power," (23 June 2011). Accessed on 4 August 2011 at http://www.ipsos-mori.com/researchpublications/researcharchive/2817/Strong-global-opposition-towards-nuclear-power.aspx

[71] Justin McCurry, "Japan's reactors all going offline by summer," *The Globe and Mail* (10 March 2012).

and nuclear maintaining/expanding countries. Table 1 lists the percentage of people who strongly support or somewhat support nuclear power. Unfortunately, Ipsos-Mori did not survey some of the countries contained on the list of nuclear energy states. At the end of the table, a mean score is provided. The results support the assumption about the relationship between public opinion and nuclear energy policy. The phaseout countries have a higher mean score of 30.0% as compared to the expanding/ maintaining countries which have a much higher mean score of 39.4%. Thus, public opinion is a good predicator about whether a country will pursue a nuclear phaseout strategy or whether it will maintain/expand nuclear energy.

Cost Issues

There has been a number of cost issues associated with the Fukushima-Daiichi accident. First, all countries immediately initiated safety reviews for all nuclear power plants. In most cases, operators have been required to add additional safety features to their plants. For example, Canadian operators have been installing new Passive Autocatalytic Recombiners to mitigate hydrogen explosions and adding more backup emergency features such as portable diesel generators and pumps.[72] However, these new safety features are going to increase the cost of building and operating nuclear power plants. As Mark Cooper has concluded, "the nuclear reactor disaster at Fukushima will increase the cost and further undermine the economic viability of nuclear power in any country that conducts such a review."[73]

A second area of cost increases is insurance. Many countries are increasing the ceiling for liability for nuclear accidents. For example, the United Kingdom has a five year plan for nuclear

[72] Canadian Nuclear Safety Commission, *CNSC Fukushima Task Force Report* (October 2011).

[73] Mark Cooper, *Nuclear Safety and Nuclear Economics: Historically, Accidents dim the Prospects for Nuclear Reactor Construction; Fukushima will have a Major Impact* (December 2011), 1. Accessed on 6 June 2012 at http://www.nirs.org/neconomics/Nuclear-Safety-and-Nuclear-Economics-Post-Fukushima.pdf

operator liability that will increase the amount from $224 million to $1.6 billion.[74] A higher liability ceiling will mean higher insurance premiums for nuclear operators. Even though this will mean higher costs for the nuclear industry, overall, the international nuclear industry supports these changes to liability. The United Kingdom's Nuclear Industry Association welcomed the fact that stated that "the government has reached a conclusion on the Paris-Brussels nuclear liabilities arrangements and fully support the decision to increase liability to €1.2 billion (US$1.6 billion). The conclusion of this consultation serves to provide further certainty to the companies involved both in new nuclear build and the existing program."[75]

However, these issues around the cost of nuclear power plants were a major challenge for the global nuclear industry *before* the Fukushima-Daiichi accident. Cost issues included the capital cost, comparisons with coal and natural gas plants, the potential for cost overruns due to construction delays, access to capital, etc. For example, the four Darlington reactors that were built in Canada in the 1980s-1990s were $10 billion over budget and five years late and the Olkiluoto reactor in Finland is 60% over budget and four years late. In Canada, the government of Ontario initially suspended the bid process for two new reactors at the Darlington site in 2009 because of a price that was "billions" too high.[76] Other provinces, such as New Brunswick, Saskatchewan, and Alberta, ran into cost issues with proposed nuclear projects. Problems related to access to capital resulting from the global economic recession have been a primary cause of the cost problem. It was for this reason that in February 2010 United States president Barrack Obama provided a US$8.3 billion federal loan guarantee to help Southern Co. build two nuclear

[74] "UK boosts nuclear liabilities," *World Nuclear News* (2 April 2012).
[75] Quoted in "UK boosts nuclear liabilities," *World Nuclear News* (2 April 2012).
[76] Quoted in Rob Ferguson, "Ontario Shelves Costly Nukes," *Toronto Star* (30 June 2009).

reactors in Georgia.[77] In March 2012, two German energy companies, who were part of a joint venture with Britain's Horizon Nuclear Power, abandoned a US$24 billion nuclear project in the United Kingdom because of financing costs.[78] Therefore, the Fukushima-Daiichi accident has increased the cost of nuclear power plants, largely due to increased safety features and higher insurance premiums, but this only exacerbated a pre-existing situation. The declining cost of natural gas[79], a major competitor to nuclear energy, combined with problems acquiring financing due to the global financial crisis have been much more important than the consequences of the Fukushima-Daiichi accident.

Energy Security

Fossil fuels will continue to be a primary source of electricity for decades to come. However, price volatility and concerns over the security of supply have been leading countries to shift towards nuclear power. In the past, the lack of domestic fossil fuels was the key driver that led countries like France and Japan to focus their electricity generation on nuclear power. Converting to nuclear meant that they did not have to rely on imports of coal, oil or natural gas. It was the 1973 oil shocks that highlighted French dependence on imported Middle Eastern oil. From that moment forward, France shifted its electricity generation from oil to nuclear. Today,

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[77] Darlene Superville, "Obama to Announce Loan Guarantee for Nuclear Plant," *Associated Press* (15 February 2010).
[78] "Britain's nuclear plans suffer setback," *Nuclear N-Former* (29 March 2012).
[79] For a general discussion about natural gas see Cleland, F. Michael. *Seismic Shifts: The Changing World of Natural Gas* (Calgary, AB: Canada West Foundation, 2011). Accessed on 7 August 2011 at http://cwf.ca/pdf-docs/publications/Seismic_Shifts_July_2011.pdf. For the impact of natural gas prices on nuclear energy see Massachusetts Institute of Technology, *The Future of Nuclear Power: An Interdisciplinary MIT Study* (MIT: Cambridge, MA, USA, 2003); Canadian Energy Research Institute, *Relative Costs of Canadian Electricity Generation Technologies* (CERI: Calgary, September 2006). Accessed on 17 August 2008 at http://www.cna.ca/english/pdf/studies/Comparative_Costs_of_Generation_Technologies_Sept-06-EN.pdf; Paul F. Joskow and John E. Parsons, "The economic future of nuclear power," *Daedalus* 138/4 (Fall 2009), 45-59; and David McLellan, "The Economics of Nuclear Power: Current Debates and Issues for Future Consideration," *Nuclear Energy Futures Paper No.1 (*February 2008).

France has the world's highest percentage of electricity produced by nuclear power (over 76%) and has become the number one electricity exporter.[80] In the case of Japan, it cannot "exchange energy with neighbouring countries through power transmission lines or pipelines" because it is an island. Japan also lacks many natural resources, meaning that it depends "on foreign countries for about 80 percent of its energy resources." This is why Japan has believed that "nuclear power generation contributes to improved energy sufficiency and to the stability of the energy supply."[81] In the absence of the approximately 28% of electricity produced by nuclear power, Japan's dependence on foreign energy sources would be even more heightened.

The first aspect of energy security is the price of fossil fuels. Although the recession of 2008-2010 led to a temporary decline in oil and natural gas prices, the trajectory has been mostly upward (see Figure 1). These high prices provide "a strong motivation for countries with high shares of imported fuels for their electricity generation to look for substitutes."[82] A related concern is price volatility. As the IAEA has stated, "all elements of the energy supply infrastructure are long lived. Similarly, energy intensive industries base their investment decisions on cautious expectations about future energy and electricity prices. A reasonable degree of stability and predictability of resource prices is crucial for such decisions."[83] All fuel prices fluctuate. However, in the case of nuclear power, this price fluctuation has been mitigated because the cost of fuel as a percentage of production costs is only 10% for nuclear power plants, compared with 93% for natural gas plants and 77% for coal plants.[84]

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[80]International Energy Agency, *Key World Energy Statistics 2008* (Paris: IEA, 2008), 17 & 27.
[81] Japan Nuclear Power, "Japan's nuclear program," (2002). Accessed on 30 November 2009 at http://www.japannuclear.com/nuclearpower/program/
[82] Quoted in IAEA, *Climate Change and Nuclear Power 2008*, 14.
[83] Quoted in IAEA, *Climate Change and Nuclear Power 2008*, 14.
[84] John W. Rowe, "Nuclear power in a carbon-constrained world," *Daedalus* 138/4 (Fall 2009), 86.

The second aspect is security of supply. The IAEA has noted that "political conflicts in key supply regions exacerbate the price pressure and raise severe concerns over the security of supply."[85] For example, in 2006 and again in 2008 Russia shut off natural gas shipments to Ukraine because of disputes over natural gas supplies, pricing, and debts. The aftermath of Ukraine's orange revolution in 2004-5 and its impact on relations with Russia was also a factor. In the process, other EU states were also affected because about 25% of all natural gas consumed in the EU comes from Russia and 80% of it was transported through pipelines in Ukraine. This situation obviously concerned many European countries and gave them an incentive to pursue nuclear power. In 2009, Italy reversed two decades of anti-nuclear policy by declaring its intention to return to nuclear power. In explaining this decision, Claudio Scajola, Italy's Minister for Economic Development, referenced the Russian-Ukraine natural gas dispute by pointing out that it "made the Italian understand the importance of energy security [and that] we must go back to nuclear power if we want to become less dependent on others' moods."[86] Bulgaria and Slovakia also made similar comments.[87]

Energy security has often been identified in public surveys as a reason to pursue nuclear power. The Accenture poll showed that the number one reason for supporting the development/ increase in nuclear power was its role in helping their country "be less reliant on countries providing oil and gas." At 85%, energy security was seen as more important than the fact that nuclear power was a low-carbon emitter (78%).[88]

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[85] Quoted in IAEA, *Climate Change and Nuclear Power 2008*, 14.
[86] Quoted in Anna Momigliano, "Russian gas cutoff energizes nuclear comeback," *Christian Science Monitor* (16 January 2009).
[87] World Nuclear News, "Gas fires up nuclear in Europe," (7 January 2009).
[88] Accenture, *Multinational Nuclear Power Pulse Survey 2009*, 21.

Based on the above discussion, energy security would appear to be a key variable in explaining whether a country would phaseout nuclear energy or maintain and/or expand its use. There are two assumptions: the more concerned a country is about energy security, the more dependent that it would be on nuclear energy; and the more that a country was dependent upon nuclear energy, the more likely that it would resist efforts to phase it out following the Fukushima-Daiichi accident. Energy security is measured here by the percentage of electricity produced by nuclear. The countries that are listed have nuclear reactors operating, under construction, or signed contracts for construction. Countries are then divided, based on the analysis in Part Two of this paper, into two categories: nuclear phaseout countries and nuclear maintaining/expanding countries. Table 2 lists each country and the percentage of electricity generated by nuclear. At the end of the table, a mean score is provided. The results run contrary to the assumptions around energy security and nuclear dependence. The phaseout countries have a higher mean score at 26.14% as compared to the expanding/maintaining countries which have a mean score of only 20.2%. In fact, the total from the phaseout countries would have been even higher if 2010 had been used instead of 2011. This is because most of Japan's nuclear reactors were shut down immediately after the Fukushima-Daiichi accident in March 2011. This meant that the 18.1% of electricity from nuclear was generated in only three months. Normally, over 30% of Japan's electricity was generated from nuclear. A similar story occurred in Germany where its normal share of nuclear is close to 25%, in 2011 it dropped to 17.8 because it immediately shut down several of its reactors following the Fukushima-Daiichi accident.

Size of Nuclear Industry

Is the size of a country's nuclear industry a key variable in explaining whether a country responded to the Fukushima-Daiichi accident by phasing out nuclear energy or maintaining

and/or expanding its use? The assumption is that the larger the domestic nuclear industry, the more likely that it would resist efforts to phaseout nuclear energy following the Fukushima-Daiichi accident. To measure the size of a country's nuclear industry the number of reactors operating and under construction (as determined by the IAEA) is used. The countries that are listed have nuclear reactors operating, under construction, or signed contracts for construction. These countries are then divided, based on the analysis in Part Two of this paper, into two categories: nuclear phaseout countries and nuclear maintaining/ expanding countries. Table 3 lists each country and the number of reactors either operating or under construction. At the end of the table, a total and mean score is provided. The results are inconclusive. Two of the phaseout countries (Japan and Germany) have very large nuclear industries and this has meant that the mean number of reactors operating is 14.2 and the mean number of reactors under construction is 0.4. Meanwhile, the maintaining/expanding countries mean number of reactors operating is 11.9 and the mean number of reactors under construction is 1.9. Thus, the phaseout countries have a slightly higher mean score in operating reactors, and the maintaining/expanding countries have a slightly higher mean score in reactors under construction. Therefore, the size of the nuclear industry does not explain the different decisions that countries made in the aftermath of the Fukushima-Daiichi accident.

Strength of the Anti-Nuclear Coalition

The strength of a country's anti-nuclear coalition is a good predictor of its post-Fukushima-Daiichi nuclear energy policy. It is assumed that the stronger the anti-nuclear coalition the more likely a country will pursue a nuclear phaseout policy. This can be seen in the cases of the two leading phaseout countries: Germany and Japan. Germany has the world's strongest anti-nuclear coalition. The German environmental movement, which has always been

very anti-nuclear, has institutionalized itself in the Green Party. While Green parties exist in many countries, the German Greens are the largest and most powerful. The German Green Party was founded in 1980 and has been part of several coalition governments at the state level. Today, it gets between 15-20% of the popular vote in federal elections. Between 1998 and 2005, the German Greens were the junior partner in a coalition government led by the Social Democratic Party. In 2000, as condition for remaining in the coalition, the Greens convinced the German government of Chancellor Gerhard Schröder to phaseout nuclear energy. As described earlier, this policy was eventually reversed by Christian Democratic Party Chancellor Angela Merkel in 2010. But there remained a strong anti-nuclear coalition in Germany that continued to fight against nuclear energy. When the Fukushima-Daiichi accident hit, it provided the German environmental movement with another chance to phaseout nuclear energy. Public pressure, led by the anti-nuclear coalition, forced Merkel to reverse herself again and announce a nuclear phaseout plan.

In the case of Japan, there had been an anti-nuclear coalition prior to Fukushima-Daiichi accident, but the accident has sparked the mobilization of a much larger movement. Demonstrations of tens of thousands of Japanese opposing nuclear energy have been common since March 2011.[89] The sudden shift in public opinion is also reflected in this strengthening anti-nuclear coalition. While the elites of government and industry may still support nuclear energy, there is a large and growing segment of the population which is not.[90] The leading maintaining/expanding nuclear energy countries (China, India, Russia, South Korea) all lack significant anti-nuclear coalitions.

[89] Yuri Kageyama, "Thousands march in Japan against nuclear power as final reactor switches off," *Toronto Star* (5 May 2012).
[90] Hymans, "The Fukushima shock and Japan's nuclear future."

Democracy

Is democracy a key variable in explaining whether a country is phasing out nuclear energy or maintaining and/or expanding its use? The assumption is that the more democratic the country, the more likely that it would decide to phaseout nuclear energy following the Fukushima-Daiichi accident. The assumption is based on the fact that key phaseout countries are Japan and Germany, and key maintaining/expanding countries are Russia and China. To determine the effect of democracy, Freedom House's *2012 Freedom in the World* survey is used. The scores for civil liberties and political rights are combined into one total out of seven, with one being the best and seven being the worst. The countries that are listed have nuclear reactors operating, under construction, or signed contracts for construction. These countries are then divided, based on the analysis in Part Two of this paper, into two categories: nuclear phaseout countries and nuclear maintaining/expanding countries. Table 4 lists each country and their Freedom House rating. At the end of the table, a mean score is given. At initial glance it appears that there is a significant difference between the two types of countries. The nuclear phaseout mean is 1.1 and the nuclear maintaining/expanding mean is 2.7. However, some caveats are in order. First, even 2.7 is considered Free under Freedom House's methodology. Second, the n for the phaseout countries is only 5, but the maintaining/expanding countries is 30. This means that there is a wider range of countries – free, partly free, and not free – in the maintaining/expanding list. Third, there are 11countries at the highest level of the Freedom House ratings among the maintaining/expanding list – more than those phasing out nuclear energy. In short, all nuclear phaseout countries are democratic, but not all democratic countries are phasing out nuclear energy. This means that the level of democracy is not a good predictor for whether a country phaseout or maintained/expanded nuclear energy post-Fukushima-Daiichi.

Conclusion

This paper has clearly identified the countries that are either phasing out nuclear energy (ie., Japan and Germany) or maintaining/expanding it (ie., China, India, Russia, and South Korea). However, it went beyond description to try to explain these differences. It tested several possible explanations for why a country would choose one path over the other. It determined that energy security, the size of its nuclear industry, and the level of democracy had little to no impact on a county's decision surrounding nuclear energy. In contrast, the location of the accident, the scale of the accident, public opinion, cost issues, and the strength of a country's anti-nuclear coalition were much more influential. Future work will be needed to assess the relative weight of these variables.

It has also been argued that the Fukushima-Daiichi accident, unlike the one in Chernobyl, did not have a long-term and transformative effect on the international nuclear sector. It did cause a major policy shift in Japan as that country went from being one of the world's most pro-nuclear countries to one of the most anti-nuclear countries within days. Whether it is a long-term shift will depend upon whether Japan can sustain the double whammy of lower electricity supply and the multi-billion dollar annual cost of importing higher amounts of fossil fuels. If it can find a way out, such as through greater use wind and solar power or through greater electricity conservation, than the policy reversal will be permanent. If it cannot, then you will likely see a gradual movement back to nuclear energy.

In the rest of the world, the Fukushima-Daiichi accident has simply accentuated pre-existing political and economic conditions. The other phaseout countries, led by Germany, were responding to a growing environmental movement combined with public reaction to the Fukushima-Daiichi accident. However, it remains an open question whether Germany, in

particular, will be able to wean itself off of nuclear energy through an expansion of renewal energy sources, or whether it will have to rely upon imports of French and Czech nuclear or natural gas from Russia. For the vast majority of the other countries in the world, the decision-making calculus for pursuing nuclear energy was the same post-Fukushima-Daiichi that it was pre-Fukushima-Daiichi. That is the interplay between the drivers for nuclear energy (electricity demand, energy security, and concerns over climate change) and its constraints (safety concerns, cost, and links to weapons proliferation).

Table 1

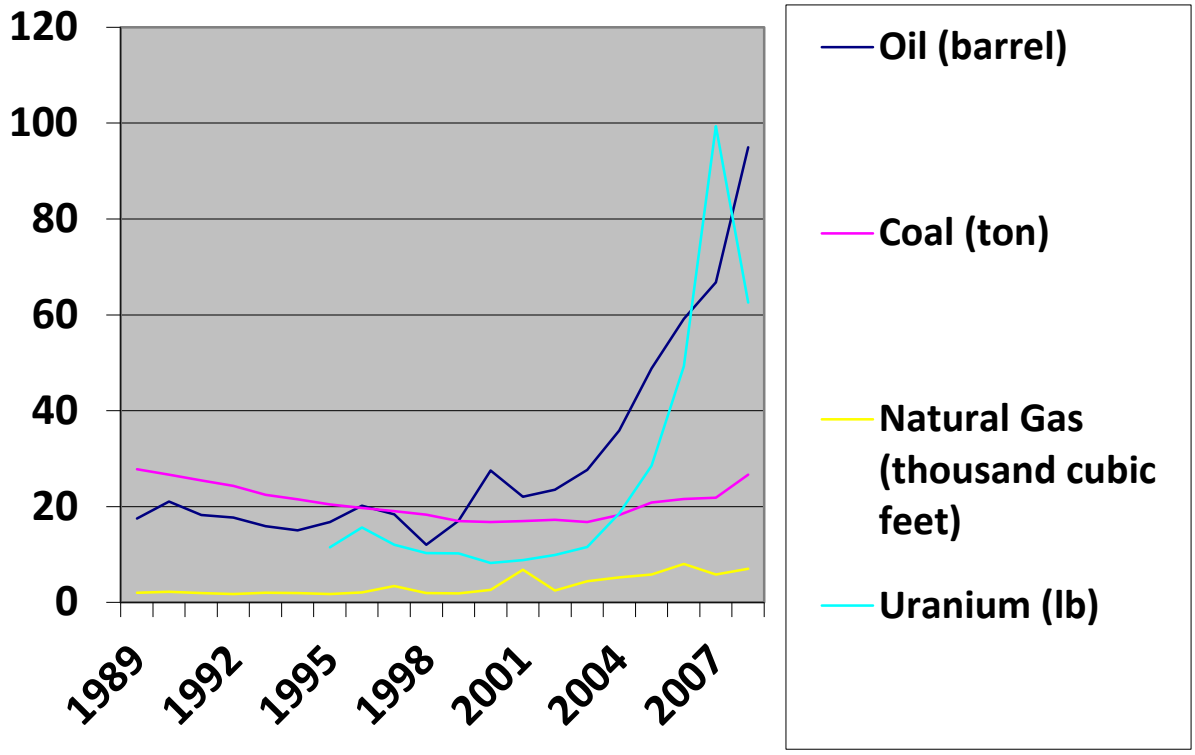
Public Opinion and Nuclear Energy

Nuclear Phaseout Countries		Nuclear Maintain/Expand Countries	
Country	**Strongly Support/Somewhat Support Nuclear Power**	**Country**	**Strongly Support/Somewhat Support Nuclear Power**
Japan	41%	United States	52%
Germany	21%	France	34%
Switzerland	n/a	Russia	39%
Italy	19%	South Korea	40%
Belgium	39%	India	61%
		United Kingdom	48%
		Canada	36%
		China	42%
		Ukraine	n/a
		Sweden	50%
		Spain	40%
		Czech Republic	n/a
		Finland	n/a
		Hungary	41%
		Slovakia	n/a
		Pakistan	n/a
		Argentina	28%
		Brazil	32%
		Bulgaria	n/a
		Mexico	18%
		Romania	n/a
		South Africa	40%
		Armenia	n/a
		Iran	n/a
		Netherlands	n/a
		Slovenia	n/a
		United Arab Emirates	n/a
		Turkey	29%
		Belarus	n/a
		Jordan	n/a
Mean	**30.0**	**Mean**	**39.4**

Source: Ipsos-Mori, "Strong global opposition towards nuclear power," (23 June 2011). Accessed on 4 August 2011 at http://www.ipsos-mori.com/researchpublications/researcharchive/2817/Strong-global-opposition-towards-nuclear-power.aspx. The list of nuclear phaseout and maintaining/expanding nuclear energy countries determined by the author.

Figure 1

Historical Prices for Electricity Fuels (US$)



Source: Oil prices were obtained from http://www.iea.org/stats/surveys/mps.pdf Coal prices were obtained from http://www.eia.doe.gov/emeu/aer/pdf/pages/sec7_19.pdf Uranium prices were obtained from http://www.firsturanium.com Natural gas prices were obtained from http://tonto.eia.doe.gov/dnav/ng/hist/n9190us3m.htm

Table 2

Percentage of Electricity from Nuclear Energy

Nuclear Phaseout Countries		Nuclear Maintain/Expand Countries	
Country	**Percentage of Electricity from Nuclear**	**Country**	**Percentage of Electricity from Nuclear**
Japan	18.1	United States	77.7
Germany	17.8	France	19.2
Switzerland	40.8	Russia	17.6
Italy	0	South Korea	34.6
Belgium	54	India	3.7
		United Kingdom	17.8
		Canada	15.3
		China	1.8
		Ukraine	47.2
		Sweden	39.6
		Spain	19.5
		Czech Republic	33
		Finland	31.6
		Hungary	43.2
		Slovakia	54
		Pakistan	3.8
		Argentina	5.0
		Brazil	3.2
		Bulgaria	32.6
		Mexico	3.6
		Romania	19
		South Africa	5.2
		Armenia	33.2
		Iran	0
		Netherlands	3.6
		Slovenia	41.7
		United Arab Emirates	0
		Turkey	0
		Belarus	0
		Jordan	0
Mean	**26.14**	**Mean**	**20.2**

Source: The percentage of electricity from nuclear is from IAEA, "Nuclear Share of Electricity Generation in 2011," Accessed on 5 June 2012 at http://pris.iaea.org/PRIS/WorldStatistics/NuclearShareofElectricityGeneration.aspx. The list of nuclear phaseout and maintaining/expanding nuclear energy countries determined by the author.

Table 3

Size of Nuclear Industry and Nuclear Energy Decision

Nuclear Phaseout Countries			Nuclear Maintain/Expand Countries		
Country	**Operating Reactors**	**Reactors Under Construction**	**Country**	**Operating Reactors**	**Reactors Under Construction**
Japan	50	2	United States	104	1
Germany	9	0	France	58	1
Switzerland	5	0	Russia	33	11
Italy	0	0	South Korea	23	3
Belgium	7	0	India	20	7
			United Kingdom	16	0
			Canada	18	0
			China	16	26
			Ukraine	15	2
			Sweden	10	0
			Spain	8	0
			Czech Republic	6	0
			Finland	4	1
			Hungary	4	0
			Slovakia	4	2
			Pakistan	3	2
			Argentina	2	1
			Brazil	2	1
			Bulgaria	2	0
			Mexico	2	0
			Romania	2	0
			South Africa	2	0
			Armenia	1	0
			Iran	1	0
			Netherlands	1	0
			Slovenia	1	0
			United Arab Emirates	0	0
			Turkey	0	0
			Belarus	0	0
			Jordan	0	0
Total	**71**	**2**	**Total**	**358**	**58**
Mean	**14.2**	**0.4**	**Mean**	**11.9**	**1.9**

Source: Operating reactors from IAEA, "Operational and Long-Term Shutdown Reactors." Accessed on 5 June 2012 at http://pris.iaea.org/PRIS/WorldStatistics/OperationalReactorsByCountry.aspx. Reactors under construction from IAEA, "Under Construction Reactors." Accessed on 5 June 2012 at

http://pris.iaea.org/PRIS/WorldStatistics/UnderConstructionReactorsByCountry.aspx. The list of nuclear phaseout and maintaining/expanding nuclear energy countries determined by the author.

Table 4

Nuclear Energy and Democracy

Nuclear Phaseout Countries		Nuclear Maintain/Expand Countries	
Country	**Freedom House Score**	**Country**	**Freedom House Score**
Japan	1.5	United States	1
Germany	1	France	1
Switzerland	1	Russia	5.5
Italy	1	South Korea	1.5
Belgium	1	India	2.5
		United Kingdom	1
		Canada	1
		China	6.5
		Ukraine	3.5
		Sweden	1
		Spain	1
		Czech Republic	1
		Finland	1
		Hungary	1.5
		Slovakia	1
		Pakistan	4.5
		Argentina	2
		Brazil	2
		Bulgaria	2
		Mexico	3
		Romania	2
		South Africa	2
		Armenia	5
		Iran	6
		Netherlands	1
		Slovenia	1
		United Arab Emirates	6
		Turkey	3
		Belarus	6.5
		Jordan	5.5
Mean	**1.1**	**Mean**	**2.7**

Source: Freedom House score from Freedom House, *2012 Freedom in the World.* Accessed on 5 June 2012 at http://www.freedomhouse.org/report-types/freedom-world. Operating reactors from IAEA, "Operational and Long-Term Shutdown Reactors." Accessed on 5 June 2012 at http://pris.iaea.org/PRIS/WorldStatistics/OperationalReactorsByCountry.aspx. Reactors under construction from IAEA, "Under Construction Reactors." Accessed on 5 June 2012 at http://pris.iaea.org/PRIS/WorldStatistics/UnderConstructionReactorsByCountry.aspx. The list of nuclear phaseout and maintaining/expanding nuclear energy countries determined by the author.