Abrupt Changes in Nuclear Power Development

Systemic Analysis of Impactful Policy Decisions

Carolina Mattsson

International Relations Honors Thesis

Adviser: Professor Arman Grigoryan

Lehigh University, May 2014

ABSTRACT

This thesis poses the question: Why do large nuclear accidents derail plans for nuclear power in some countries and not others? It seeks to provide answers through comparative analysis of two matched sets of cases - comparing (West) Germany to Japan and France as well as Spain to Ukraine and South Korea. Historical process tracing distills out what specific attributes of a country's reaction lead to long-term reversals in nuclear power plans. Then, armed with an understanding of how reversals come to take place, countries within the two groups of cases are compared for the underlying differences that cause variation among them. The politicization of nuclear power in national party politics stands out as a powerful mechanism determining the course of nuclear power development over decades. Inconsistency within the nuclear regulatory system serves as a secondary mechanism. Across the two groups of cases, two elements of the state appear most important in determining the prospect of long-term reversals in nuclear power plans: the vulnerability of the state to issues of energy import dependence, and the level of centralization of the government.

The history of nuclear power development is decidedly nonlinear. It is characterized by periods of rapid growth punctuated by abrupt but enduring policy reversals. In the two decades from 1965 to 1985 worldwide installed nuclear power capacity increased nearly fifty times, from around 5,000 MWe to around 240,000 MWe.[1] In the next two decades, from 1985 to 2005, worldwide installed nuclear capacity increased by only fifty percent. Tellingly, such nonlinear trends are not limited to the global scale. Individual countries show similar boom and bust patterns of nuclear power development. In such a system, *changes* are the most exciting element to study.

Large-scale nuclear accidents – such as Three Mile Island in 1979, Chernobyl in 1986 and Fukushima Diiachi in 2011 – have acted as triggers for abrupt but enduring changes in nuclear power development in many countries. Precisely how this happens (i.e. the mechanisms by which nuclear development falters) is a source of disagreement. The true puzzle, however, is why the same accidents cause flips in some countries and not others. For example, the United States entirely stopped ordering new nuclear power plants after Three Mile Island in 1979, while France had no such qualms even after Chernobyl. This thesis intends to explore two aspects of this puzzle. First, by what mechanisms do reactions to accidents cause dramatic and enduring reductions of plans for nuclear power? Secondly, which attributes of the state and government determine whether those mechanisms become activated or not, in a given country, in response to an accident?

The main portion of this thesis will comparatively analyze countries that severely curtailed their nuclear power development in response to an accident to countries that did not, under similar circumstances. Three major nuclear countries – consisting of France, Germany, and Japan – will form one comparison group. Three countries with significant but smaller nuclear programs at the time – consisting of South Korea, Spain, and Ukraine – will form a second comparison group. First, this thesis intends to shed light on the mechanism question through historical analysis of the social and political reactions that were the most relevant to nuclear power

[1] World Nuclear Association. World-nuclear.org *Nuclear Power in the World Today*

programs over the course of decades.[2] As a point of comparison, a pervasive conventional explanation for the sudden curtailment of nuclear power after accidents will be considered independently. Second, and armed with an understanding of how reversals come to take place, countries within the two groups of cases will be compared for the underlying differences that cause variation among them. Variables to be considered include: previous investment in nuclear power, economic dependence on imported fuel, degree of government centralization, degree of centralization of the nuclear industry, the mandate of the ruling government, macroeconomic variables like gross domestic product per capita, interest rates, rate of growth in electricity consumption, and level of knowledge about nuclear power.

[2] Park, Chris C. "Chapter 10: Public Confidence in Nuclear Power?" *Chernobyl: The Long Shadow*. Abingdon, Oxon: Routledge, 2011. 160-83. Print. Pg 182.

Literature review

The academic literature on nuclear power as a whole is expansive, but largely confined to case-specific, discipline-specific, and technical publications.[3] Recently, authors have contributed through quantitative analysis of nuclear power programs and policy.[4] Particularly relevant to this thesis is a small group of authors explicitly concerned with socio-political aspects of nuclear power development across large subsets of countries. Also relevant are overview publications of the energy industry as a whole, such as The Quest by Daniel Yergin, and of the nuclear industry specifically, such as the World Nuclear Industry Reports.

Technical publications about nuclear power and its prospects – from sources such as the World Nuclear Association, the International Energy Agency, and the International Atomic Energy Agency – agree on several key points. They agree that technological issues are generally settled: "Nuclear power is a mature low-carbon technology that is already available today for wider deployment."[5] This includes areas that nonetheless experience political controversy, such as the management of radioactive waste.[6] Such publications highlight issues of policy, politics, public opinion, and financing as looming large over the future of nuclear power.[7] They emphasize the importance of state participation, state support, and efficient regulatory regimes in advancing nuclear development. Furthermore, nuclear power

---

[3] Sovacool, Benjamin K., and Scott V. Valentine. *The National Politics of Nuclear Power: Economics, Security and Governance*. London: Routledge, 2012. Print. Pg 5.
[4] Csereklyei, Zsuzsanna. "Measuring the Impact of Nuclear Accidents on Energy Policy." *Ecological Economics* (2014): 121-29. *Elsevier*. Web. 10 Feb. 2014.
&
Gourley, Bernard, and Adam N. Stulberg. "Correlates of Nuclear Energy." *Nuclear Renaissance and International Security*. By Adam Stulberg. N.p.: Stanford UP, 2013. 19-49. Print.
[5] OECD. International Energy Agency. *Technology Roadmap: Nuclear Energy*. By International Energy Agency and Nuclear Energy Agency. France: Corlet, 2010. Print. Energy Technology Roadmaps. Pg 3
[6] Technology allowing for long-term storage and breeder reactors is available today and generally considered sufficient to handle current and future nuclear waste issues. Politically, the challenge is much steeper.
[7] Ibid. & Rosen, M. *Nuclear Power: Issues of Misunderstandings.* 381-388 in *Power in Developing Countries: Its Potential Role and Strategies for Its Development*. Bhabha Atomic Research Centre, Mumbai, India. Vienna: IAEA, 2000. Web. Nov. 2013.

is a global integrated industry with a relatively small number of important transnational players. A review of the risk literature on nuclear power and electricity generation follows in the "Conventional explanation" section.

Quantitative analysis has yielded some clear correlates of nuclear power development, broadly. Dependence on imported energy, gross domestic product, and a lock-in effect[8], specifically.[9] Such conclusions are supported by qualitative analysis from technical publications and overviews. Correlation with energy imports is unsurprising, as uranium is a minor part of the overall cost of nuclear power, needed infrequently in small quantities, and simple to store in reserve.[10] Nuclear power is a rather expensive endeavor, up front, and a large economy is more likely to support the necessary investment.[11] High initial construction cost limit entry into the industry, creating technological path-dependence.[12] Some have noted that the promise of cheap, consistent uranium fuel raises the attractiveness of nuclear power in times of high or volatile fossil fuel prices.[13]

While some variables correlate to development (or lack thereof) there is a group of authors explicitly concerned with socio-political aspects of nuclear power development that find quantitative and technical analysis insufficient at describing the dramatic variation seen both *over time* and *between countries*. Sovacool and Valentine utilize a systems based, inductive methodology.[14] Kolb employs

---

[8] This is the notion that "countries which have already invested in nuclear infrastructure are more likely to build nuclear power plants." [Csereklyei, 2014. Pg 127.] This variable is explainable in many ways, including that economics of scale and nuclear know-how depend on the size of the nuclear program, and that the initial investment required is large.

[9] The effects of other variables, such as regime type, economic growth, economic openness, and the presence military threats are not statistically significant. Gourley, Bernard, and Adam N. Stulberg, 2013. Pg 47-49.

[10] World Nuclear Association. World-nuclear.org. *The Economics of Nuclear Power*

[11] Gourley, Bernard, and Adam N. Stulberg, 2013. Pg 34

[12] Nikolai Sokov. Review of Stulberg, Adam N.; Fuhrmann, Matthew, eds., *The Nuclear Renaissance and International Security*. H-Diplo, H-Net Reviews. August, 2013.

[13] Lester, Richard K., and Robert Rosner. "The Growth of Nuclear Power: Drivers & Constraints." *Daedalus* 138.4 (2009): 19-30. Web. Oct. 2013.

[14] Sovacool & Valentine, 2012. Pg 6.

qualitative comparative analysis based on Boolean algebra.[15] Meanwhile, Rüdig, Yergin, and World Nuclear Industry Reports rely on descriptive historical analysis. Each of these methodologies better accommodate variation in public opinion, regulatory structures, levels of research and development, and other indirect variables that have been highlighted by technical observers for some time. However, these authors, all of whom compare nuclear power development across large subsets of countries, reach widely different conclusions. Sovacool and Valentine identify six broad drivers that act simultaneously to enable nuclear power development. Variables act through affecting these drivers.[16] Kolb analyzes the success or failure of anti-nuclear movements, finding that sustained mobilization combined with political opportunity leads to change. Political opportunity was enhanced after Chernobyl.[17] Rüdig finds important differences between market driven and government driven nuclear programs, and between centralized and decentralized political systems.[18] He is acutely aware of the time-relative nature of political decisions. Yergin provides one very clear argument: that accidents have an impact on the economics and feasibility of nuclear power by complicating regulatory processes and requirements.[19]

A crucial difference, of relevance to this thesis, emerges between these authors with respect to their explanations of the impact of nuclear accidents. Yergin, Rüdig, and Kolb seek to directly explain stagnation, or lack thereof, in nuclear power development. In contrast, Sovacol and Valentine, along with the World Nuclear Industry Reports implicitly assume that nuclear power is exceedingly dangerous and prohibitively costly. They seek to explain why some countries continue with nuclear power *in spite of* the rational drive to abandon it. Due to this bias, addressed

---

[15] Kolb, Felix. *Protest and Opportunities: The Political Outcomes of Social Movements*. Frankfurt: Campus Verlag, 2007. Print. Pg 225
[16] Sovacool & Valentine, 2012. Pg 235.
[17] Kolb, 2007. Pg 228, 234-237.
[18] Rüdig, Wolfgang. *Anti-nuclear Movements: A World Survey of Opposition to Nuclear Energy*. Harlow, Essex: Longman Current Affairs, 1990. Print. Pg 255-256.
[19] Yergin, Daniel. *The Quest: Energy, Security and the Remaking of the Modern World*. New York: Penguin, 2011. Print. Pg 418.

further in the "Conventional explanation" section, the conclusions of Rüdig, Kolb, and Yergin are of greater utility.

Methodology and Case Selection

This thesis acknowledges the non-linear history of nuclear power development. When it comes to nuclear power, technological, economic, social, and political variables interact so strongly that *feedback loops* dominate the overall picture.[20] To proceed despite such complexity, this thesis intends to focus later analysis by first shedding light on the mechanism question. Process tracing, to put it in methodological terms, will distill out what specific attributes of a country's reaction lead to long-term reversals in nuclear power plans.[21] As a point of comparison, the conventional mechanism used by Savacool & Valentine, among others, to explain the sudden curtailment of nuclear power after accidents will be considered independently.[22]

Second, two groups of countries will be compared across previous investment in nuclear power, economic dependence on imported fuel, degree of

---

[20] For example, building more nuclear plants of the same type make each plant cheaper, safer, and more politically feasible to construct, simultaneously. Economies of scale allow for cheaper parts. [World Nuclear Association *The Economics of Nuclear Power*] Standardized production makes for standardized safety procedures and safer operation. Massive mobilization makes it more difficult to back away from the project, politically, and raises the pressure to accomplish the expansion efficiently. Improved economics then make nuclear power more attractive, cyclically. In the opposite direction, meanwhile, social backlash affects the politics, economics, and even the technology of nuclear power negatively. Social pressure makes political decisions about siting and regulation more contested. Extending time spent in the regulatory process raises the financial cost of a plant, accentuating its high upfront capital cost. Furthermore, popular anxiety over nuclear power may limit research funding, reducing long-term technological advances that would, paradoxically, make plants both safer and cheaper.[Sovacool & Valentine, Pg 43-53]

[21] Mearsheimer, John J., and Stephen M. Walt. "The Blind Man and the Elephant in the Room: Robert Lieberman and the Israel Lobby." *Perspectives on Politics* 7.02 (2009): 259. Print.

[22] The explanation that rational decision makers are convinced to abandon nuclear will be considered, through quantitative analysis of the risks of nuclear power in terms of fatalities and economic cost, to see whether such a reaction is, in fact, purely rational.

government centralization, degree of centralization of the nuclear industry, the mandate of the ruling government, macroeconomic variables like gross domestic product per capita, interest rates, rate of growth in electricity consumption, and level of knowledge about nuclear power.[23] Because of the wealth of competing explanations, and the small number of nuclear powered countries from which to select[24], cases have been selected in such a way as to allow for the use of Mill's Method of Difference.

In the early 1980s the difference in capacity between established programs, such as in France, and emerging programs, such as in South Korea, was sizeable.

---

[23] The cost of construction of a nuclear power plant will not be considered independently, as it is sensitive to the social and political variables considered elsewhere. To justify this omission further: "Forsberg and Riech (1991) suggest that up to 60% of the capital cost of nuclear power is related to health, safety, and the environment. Because of the many systems devoted to ensuring nuclear safety, and the high proportion of safety-related costs in nuclear power plants, overall capital costs are strongly influenced by specific requirements of nuclear safety regulation." [Paffenbarger, John, and International Energy Agency. *Nuclear Power in the OECD*. Paris: IEA Publications, 2001. Print. Pg 136.]
The "cost of construction" variable will be considered thoroughly political, therefore, and not evaluated independently. The importance of political and regulatory difficulties in increasing credit risk, which is crucial because of the high upfront capital cost of nuclear power plants, is corroborated by reports from rating companies such as Standard & Poor. [Scheider, Mycle, and Antony Froggart. *The World Nuclear Industry Status Report 2004*. Rep. Brussels: Greens-EFA, 2004. Web. Jan. 2014.]
Public opinion is also seen to depend on the nuclear policy of the government, and hence is not an independent variable on its own. [Pérez-Díaz, Víctor, and Juan Carlos Rodríguez. "Nuclear Energy and Public Opinion in Spain." *ESTUDIOS DE POLÍTICA EXTERIOR* (2008): 215-25. Web.]
That 60% of the cost of a plant may come from features imposed by regulation is also a particularly interesting observation, in its own right. It helps explain the oft-repeated fact that, in contrast to other electricity generation technologies, the costs for nuclear have not gone down over time. While usually attributed to uniquely the difficult engineering challenges of nuclear power, this finding suggests instead that regulation and the political forces driving changes to regulation may be the culprit. This is yet another example of the Catch-22 that affects the social dimension of nuclear power – whereby critics end up worsening the very aspect of nuclear power that they criticize. A similar effect connecting technology and safety is detailed by Sovacool & Valentine (2012) on page 52.

[24] This precludes large-n studies.

Strong path dependence complicates comparison across such a disparity. So, this thesis will compare within two groups of similar countries. (West) Germany is compared to Japan and France, while Spain is compared to Ukraine and South Korea.

First, this thesis will analyze a group of three countries that led the world in nuclear power at that time – Japan, (West) Germany, and France. To observers in the early 1980s they were three of the largest influences on the global scene in nuclear power.[25] Their nuclear programs and populations were comparable in the decade prior to Chernobyl. All three are large, important economies. Despite their similarities in the early 80s, their nuclear programs have diverged greatly. In 2010, before Fukushima, Germany had marginally[26] more installed capacity than it did in 1986: 20,339 MWe. Meanwhile, Japan reached 50 operational reactors providing 44,396 MWe, or 30% of its electricity. France now operates 58 reactors to provide 63,130 MWe or 78% of total electricity. In short, nuclear power development languished in Germany but not in France or Japan.

Additionally, this thesis will analyze the effect of Three Mile Island and Chernobyl on a group of three countries that had smaller nuclear programs and less stable politics at the time of the accidents: Spain, South Korea, and Ukraine. Their nuclear power situations were remarkably similar in the early 1980s. They were also all engaged in a transition to democracy around the relevant time period.[27]

Since then their programs have diverged. As of 2013 Spain has 7 reactors generating only 20% of its electricity. This is barely more than in 1986 – Spain completed no new reactors since 1988. Ukraine, in contrast, has nearly doubled its

---

[25] Ha, Young-Sun. "Republic of (South) Korea." *Nuclear Power in Developing Countries*. By James E. Katz and Onkar S. Marwah. Lexington: Lexington, 1982. 221-44. Print. Pg 239

[26] Based on analysis of the tables in the German WNA country profile on the start and stop dates of individual reactors. Three plants entered into operation since 1986. About 2/3 of the capacity added, however, was offset by plant closures after 1986 but before 2010.

[27] Spain was emerging from an authoritarian dictatorship, Ukraine was gaining independence from the USSR, and South Korea was moving from beneath military rule. This complicates the policy space in which nuclear decisions were made.

operational nuclear capacity to generate 50% of its electricity from 15 reactors. It completed several reactors in the 1990s and 2000s and has plants currently under construction. South Korea has quadrupled capacity to 23 reactors and is continuing construction. Due to concurrent growth in electricity usage, nuclear provides 32% of South Korea's electricity.[28] Nuclear power development has languished in Spain, but not in South Korea or Ukraine.

While analyzed separately, these two groups of cases will complement each other in establishing the most important causal processes and differentiating variables driving abrupt and enduring changes in nuclear power development.

[28] All numbers are from the author's analysis of data from the WNA.

Conventional Explanation

Before endeavoring to find the mechanisms by which nuclear programs stagnate after an accident, it is prudent to independently analyze the most common conventional explanation. One such explanation holds that nuclear accidents expose the dangers of nuclear power. Rational decision-makers become convinced, which leads to the curtailment of programs. However, calling something "dangerous" is both obvious and unhelpful. Anything can, and is, quantifiably dangerous, and it is impossible to avoid all sources of danger. Modern societies require electricity to function, but one cannot generate electricity without risk of harm to both workers and the public. More relevant to rational decision makers is the relative risk of different sources of electricity. An objective risk assessment compares risk across electricity generating technologies. Stating the risks of nuclear power, alone, implicitly compares nuclear power generation to *infinitely perfect, risk-free* power generation. This is often misleading and irrelevant. Unsettlingly, this tactic is not uncommon, even within academia, among detractors of nuclear power.[29]

The relevant risk comparison is between nuclear power generation and alternative sources of electricity. Most important is the comparison to coal, which is

---

[29] From the World Nuclear Industry Report 2004 in regards to Chernobyl: "This brief review has explored the statistics of fact, leading to the axiom that the grand-grand-grandchildren of our children will suffer from the effects of an accident of a machine that was built to provide a service to people. That machine generated power for two years, four months, and four days but the human suffering and health detriment will go on for generation after generation. Who would dare to say it was worth the risk?" (pg 28) This simplification is particularly insidious as it denies the tens of thousands of reactor years of safe operation worldwide before and since Chernobyl.
Sovacool and Valentine likewise compare risks from nuclear power to perfect, risk-free generation. "The industry track record for safety is far from exemplary considering the inherently risky nature of the technology. Our own compilation in the Appendix shows 106 nuclear accidents responsible for 4,231 fatalities and more than $253 billion in damages from 1952 to 2011. Worryingly, our list of accidents is conservative and likely underestimates the degree to which nuclear technology is prone to failure…" (pg 243) Even more worryingly, these numbers are deliberately not compared to other sources of electricity, which, in fact, cause far more harm as counted in both lives and dollars.

the source of electricity that nuclear power actually replaces, overwhelmingly.[30] For example, in the first half of 2013 Germany's share of electricity from nuclear was 18%, down from over 25% in 2010. Meanwhile, the share of electricity from coal rose from 43% to 52%. Coal stepped in to replace nuclear. In this section, nuclear power will be compared to coal on their negative externalities in health and economics. Several authors have conducted thorough, full-cycle, risk analyses comparing across different forms of electricity generation.[31]

Severe Accident Risks

In 2010 the Nuclear Energy Agency undertook a comprehensive comparative

Table 2: Summary of severe (≥ 5 fatalities) accidents that occurred in fossil, hydro and nuclear energy chains in the period 1969-2000

	OECD			Non-OECD		
Energy chain	**Accidents**	**Fatalities**	**Fatalities/ GWey**	**Accidents**	**Fatalities**	**Fatalities/ GWey**
Coal	75	2 259	0.157	1 044	18 017	0.597
Coal (data for China 1994-1999)				819	11 334	6.169
Coal (without China)				102	4831	0.597
Oil	165	3 713	0.132	232	16 505	0.897
Natural Gas	90	1 043	0.085	45	1 000	0.111
LPG	59	1 905	1.957	46	2 016	14.896
Hydro	1	14	0.003	10	29 924	10.285
Nuclear	0	0	–	1	31*	0.048
Total	**390**	**8 934**		**1 480**	**72 324**	

Note: * These are immediate fatalities only.

Source: Data provided to NEA by PSI.

study of severe accident risks in the production of electricity. Severe accidents are of particular interest in testing the conventional explanation for the curtailment of nuclear programs. The database catalogues 1,870 severe energy-related accidents, 1,221 of which involved coal and only one of which involved nuclear power (Chernobyl). When added together, these accidents have been responsible for over 80,000 *immediate* deaths, 31 of which occurred at Chernobyl.[32] When normalized to

---

[30] Yergin, 2011. Pg 403 & WNA *Nuclear Power in Germany*

[31] Fritzsche, Andrew F. "The Health Risks of Energy Production." *Risk Analysis* 9.4 (1989): 565-77. Web.

[32] Many would object to the use of the 31 immediate deaths resulting from Chernobyl here as opposed to the 4,056 total fatalities, as reported by the United Nations. Using latent fatality numbers for only one data point out of 1870, however,

the amount of energy produced, nuclear power is among the least dangerous sources of electricity production, from the perspective of severe accidents. Mining, extraction and transportation are less visible links in the electricity production chain, which are nonetheless more prone to severe accidents, than the operation of power plants themselves. Consequently, coal carries risks at least an order of magnitude higher than nuclear.

Routine Operating Risk

The routine operation of the electricity production fuel cycles entails quantifiable statistical risks for both workers and a subset of the public. This category of risk includes occupational hazards, both immediate and long term, and immediate risks to the public. The readily quantifiable mortality risks – for occupational risk and immediate public risk – are easily an order of magnitude higher for the coal fuel cycle than they are for the nuclear option.[33]

Latent Public Risk

Less readily quantifiable are the long-term public health risks associated with electricity production. Latent deaths following Chernobyl are included in this category, as are fatalities due to air and water pollution. 1989 estimates put nuclear power public latent risk at two or three orders of magnitude below that of coal.[34] Strikingly, the estimated number of deaths due to coal pollution in one country (Poland) in one year (2010) is larger than the entire death toll due to Chernobyl.[35]

---

is not appropriate. Accidents in coal and other fuel cycles also carry heavy latent fatality tolls, which are not as well quantified as those from Chernobyl. Accidents involving coal slurry ponds, to take one example, leak known carcinogens into local water supplies causing raised cancer risk in the local population in the same way fallout from Chernobyl did. The Center for Health and the Global Environment at Harvard Medical School estimates that carcinogens from coal use cause thousands of excess deaths per year (pg 82). Because of this data disparity, latent deaths from Chernobyl will be included in comparisons of long-term risks over generalized populations, not severe accident risks.

[33] Fritzsche, 1989.

[34] Fritzsche, 1989. Pg 572

[35] Vidal, John. "European Coal Pollution Causes 22,300 Premature Deaths a Year, Study Shows." *Theguardian.com*. Guardian News and Media, 12 June 2013. Web. 06 Feb. 2014.

In terms of public health, nuclear power must be acknowledged as undoubtedly less dangerous than coal power.

Alternative Sources

An objective risk assessment would be incomplete without also comparing nuclear power to alternatives other than coal. Comparisons to natural gas and renewables can be made with the caveat that such a replacement is less automatic and less common than replacement by coal generated electricity. However, neither natural gas nor renewable energy sources produce electricity with risks quantifiably lower than nuclear.[36][37][38]

Conclusion

In short, the conventional explanation for the curtailment of nuclear power after an accident – namely that nuclear accidents expose the dangers of nuclear power and convince rational decision-makers – is not backed by dry rationality. The mechanisms by which nuclear power programs stagnate must be found elsewhere.

---

[36] NEA, 2010. Pg 33

[37] Fritzsche, 1989.

[38] Inhaber, Herbert. "Is Solar Power More Dangerous Than Nuclear." *New Scientist* 78 (1978): 444-46. *IAEA.org*. IAEA. Web. Feb. 2014.

<u>France, Japan & Germany – Mechanisms of Change</u>

This section seeks to establish the mechanisms driving constancy or enduring change in nuclear power development by analyzing the historical progression in each country in this set. The analysis is based on multiple current and historical accounts of nuclear power development including World Nuclear Association country profiles, World Nuclear Industry Reports, publications from the International Energy Agency, articles on political history, and social scientific comparative analyses of anti-nuclear movements.

Two mechanisms stand out as having definitive long-term impact on the fortunes of German nuclear power. First, and most important, was the adoption in 1986 of an anti-nuclear platform by one of the major parties of the German Bundestag, the Social Democratic Party, in response to Chernobyl. This politicization of nuclear power ensured the longevity of anti-nuclear sentiment in the German political system. Despite losing control of the legislature in 1987, the Social Democratic Party maintained its anti-nuclear platform. Upon retaking office in 1998, a full twelve years after Chernobyl, the Social Democratic Party led Germany to officially begin its phase out of nuclear power. A second mechanism, important for its effect in the meantime, was the unwillingness of German utilities to invest in new nuclear capacity after Chernobyl. Furthermore, this reaction is understandable. In the German policy environment even fully operational nuclear plants faced ceaseless legal and regulatory challenges. The clearest example is the nuclear power plant at Mülheim Kärlich, shut down in 1988, which remains one of the only nuclear reactors ever to have been closed for political reasons after beginning operation.[39] Such a precedent undermines inspire investor confidence in German nuclear power. Local public hostility, increased costs, and other factors likely also contributed to utility unwillingness.

Neither mechanism became activated in France or Japan, nor did they curtail their nuclear programs. Historical analysis of the mechanisms that ensured the

---

[39] Paffenbarger and International Energy Agency, 2001. Pg 226. & WNA *Germany*

continuation of their nuclear development help put the German story into perspective.

France experienced just as much public protest against nuclear power as Germany in the late 1970s – both at the local level and when it came to mass mobilizations.[40] France also experienced a minor resurgence of protest after Chernobyl.[41] The French political-legal structure surrounding their nuclear power program, however, ensured that no nuclear power plants were ever successfully challenged through the legal system.[42] There is a single case of a potential site given up as a result of protests, out of political expediency, namely Polgoff.[43] Rüdig, in his thorough analysis of anti-nuclear movements, highlights two components of the French system that allowed this. First, the centralized nature of the implementation of the nuclear power program, spearheaded by the EDF and the central government, left little authority over nuclear decisions to the local authorities directly facing public opposition. Furthermore, there was a distinct lack of political opportunity to influence nuclear policy at the national level.[44] Political support by those in power never wavered.[45] [46] A streamlined regulatory system, immune to local challenge, worked hand-in-hand with consistent political support to ensure the continued development of nuclear power after Chernobyl.

Japan enthusiastically embraced nuclear power within decades of the Second World War, benefitting from the Atoms for Peace program. Nuclear power became a national strategic priority in the context of the 1973 oil shock, which left a deep impression on the country (at the time Japan relied on oil for 66% of its electricity production).[47] Although beginning its program with imported technology, the Japanese nuclear industry was largely independent by the late 1970s. Since then, Japan has consistently spent nearly twice as much on R&D for nuclear energy as any

---

[40] Rüdig, 1990. Pg 149-181 & Kolb, 2007. Pg 205.
[41] Ibid. Pg 342-3
[42] Kolb, 2007. Pg 240
[43] Rüdig, 1990. Pg 180
[44] Ibid.
[45] World Nuclear Industry Report, 1992. Pg 8
[46] Rüdig, 1990. pg 316
[47] World Nuclear Association. *Japan.*

other OECD country.[48] The political commitment to nuclear power that this reflects has been mirrored by a strong commitment on behalf of the country's electrical utilities. Ten different electrical utilities own and operate nuclear power plants in Japan.[49] The willingness of utilities to build nuclear power has not faltered, nor has government support for the industry.

Similarly to France, "In the highly 'closed' Japanese political system, any dissent was difficult to establish on the national agenda."[50] However, Japan experienced little anti-nuclear protest to begin with. At the national level, Japan had no anti-nuclear mobilization before Chernobyl, which sparked such sentiments nationally for the first time. On the first anniversary of Chernobyl, anti-nuclear rallies in Tokyo attracted 25,000 people.[51] Such uproar was emergent and short-lived, and left national politics unfazed. At the local level, the Japanese cultural practice of providing host communities with compensation, so called "strange money", and subsidies is accepted and applied widely in environmental matters. This has been an excellent diffuser of local protest.[52]

Bringing together the historical analyses results in a clearer and more nuanced picture of the mechanisms through which nuclear power programs change or remain the same. In all three cases the politicization of nuclear power, or lack thereof, stands out as a powerful mechanism determining the course of nuclear power development over decades. The experiences of France and Japan also put the German "utility unwillingness" mechanism into perspective. Local challenges to nuclear plants, both legal-wise and protest-wise, were very much present in France as well as Germany.[53] The French regulatory structure, however, effectively maintained short construction times and limited investor risk. Both France and Japan successfully used financial compensation to lessen local tension.

---

[48] Paffenbarger and International Energy Agency, 2001. Pg 232.
[49] World Nuclear Association. *Japan.*
[50] Rüdig, 1990. Pg 91.
[51] Ibid. Pg 344.
[52] Ibid. Pg 211.
[53] Kolb, 2007. Pg 241.

Inconsistency within the German regulatory system is a more refined version of the secondary mechanism causing the stagnation of nuclear power.

This is corroborated by a finer analysis of the history of German nuclear power development. German nuclear power construction went through a period of decline in the late 1970s due primarily to local public hostility and legal challenges to regulation. However, the wastefulness of a messy regulatory process sparked political action, and the process was streamlined in 1981. Three additional nuclear power plants began construction in the following year.[54] Chernobyl ensured a resurgence of regulatory and legal issues. This narrative highlights the impact of political considerations on the effectiveness of the regulatory structures. Hence, in the case of Germany[55], an inconsistent regulatory structure can be seen as a secondary, but still important, mechanism affecting nuclear power development.

The mechanisms with the most enduring effect on nuclear power stagnation are confusion within the regulatory system and the politicization of nuclear energy in national party politics. Both of these mechanisms were activated in Germany in response to Chernobyl, and neither was activated in France or Japan. Impactful variables in the subsequent analysis, then, are those that influence whether these mechanisms become activated or not after an accident. Some possible explanations of such variation include differences in historical investment in nuclear power, economic dependence on imported fuel, degree of government centralization, degree of centralization of the nuclear industry, the mandate of the ruling government, macroeconomic variables like GDP, interest rates, rate of growth in electricity consumption, and level of knowledge about nuclear power. These will be analyzed in the following section for their impact on the two mechanisms found in this section to be most relevant to long-term nuclear development in Germany, France, and Japan.

France, Japan & Germany – Distinguishing Variables

---

[54] Kolb, 2007. Pg 251.

[55] In the United States, however, this appears to have been the primary process causing nuclear stagnation.

Historical Investment in Nuclear Power

For these three high-GDP countries there are several ways to conceptualize historical investment in nuclear power. Potentially relevant, for example, is a sunk cost argument based on the extent of government investment into research and development. Such investment into the nuclear energy program is a sunk cost that amounts to little if a program is allowed to stagnate over the long term. For these three countries, however, prior research investment in nuclear power at the time of an accident does not have explanatory power over the consistency of political support for nuclear power. Quantitatively Germany and France invested similarly in nuclear power research and development in the decade before Chernobyl.[56] There is also a qualitative lack of explanatory power. The sunk cost to the government did not weigh heavily on the minds of politicians when nuclear power was taken off the table. Germany's SPD quickly terminated long running R&D efforts in North-Rhine Westphalia shortly after Chernobyl, for example.[57] Although not R&D investment, Germany has also showed ambivalence toward the availability of millions of dollars in tax revenue from nuclear power. Sunk cost, it appears, does not have explanatory power over the relevant mechanism in these three high-GDP countries.

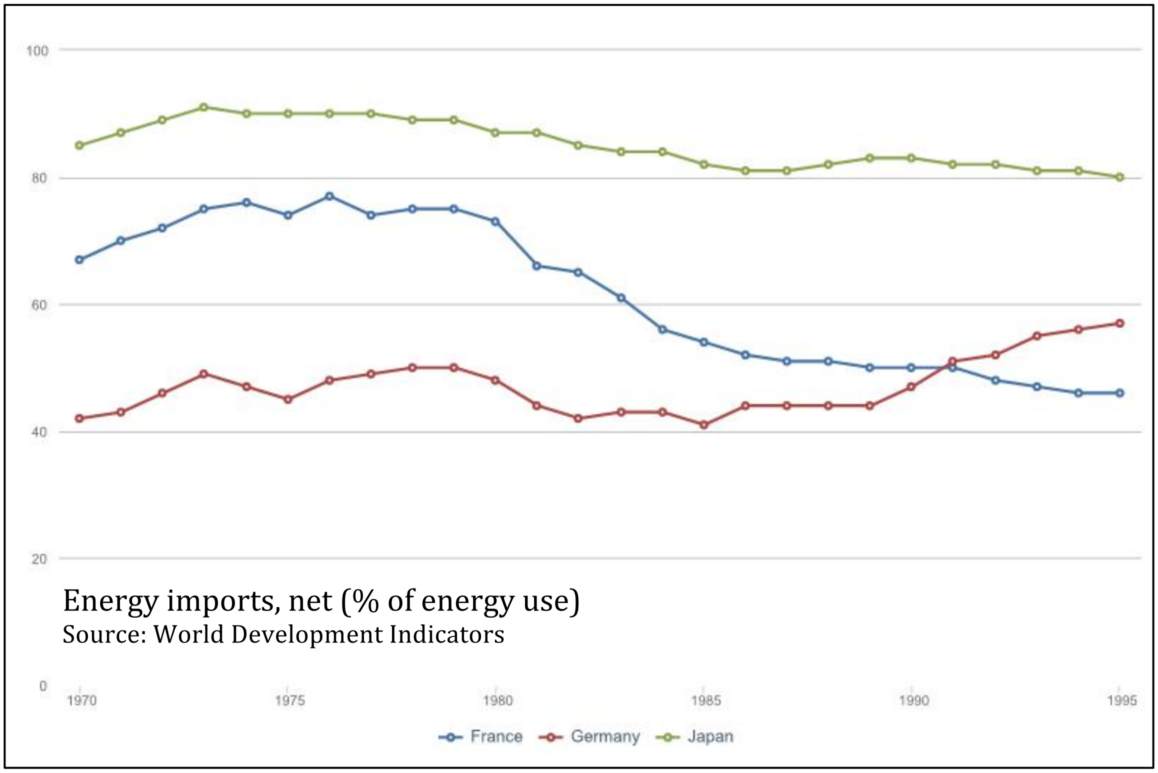
Historical investment may also lead to disparities in dependence on nuclear power that then impact the political feasibility of activation of our two mechanisms. Dependence on nuclear at the time of Chernobyl, however, does not have explanatory power even within this group of cases. Japan was less dependent on nuclear power than was Germany, on a per capita basis, while France was dramatically more dependent.[58] If one extends beyond these three cases, which were similar in both measures of prior investment to begin with, correlation falls away further. South Korea had invested very little, relatively speaking, by 1986, but has since surpassed Germany in nuclear power capacity.

Economic Dependence on Imported Fuel

---

[56] Paffenbarger and International Energy Agency, 2001. Figure 28, Pg 232.
[57] World Nuclear Association. *Germany.*
[58] Author's calculations from WNA data on capacity and historical population data. The indicator mentioned is (nuclear capacity in 1986)/(population in 1980)
The 6 year delay is due mainly to the availability of population data.

This does have explanatory power! Quantitatively, in 1986 Japan depended on energy imports for 81% of its energy, France for 52%, and Germany for 44%. The difference is even more pronounced if one takes into consideration the lag time in building reactors – in 1976 the percentages were 91%, 77%, and 48% respectively.



Energy imports, net (% of energy use)
Source: World Development Indicators

Qualitatively, a sense of dependence on energy imports is a very plausible motivation for sustained political support for nuclear power, resisting politicization. Many sources corroborate this as a motivating political factor. Import dependence does not tell the full story, however, as it has limited explanatory power over the second mechanism, the inconsistency of the regulatory system in the face of local challenge, and is unable to explain why 52% dependence is so much different from 44%. Furthermore, countries from outside this group of three hint at the incompleteness of explanation by this variable alone. Spain, for example, was more highly dependent on energy imports than France in the entire 1970s, but ended up suspending its nuclear program. Italy, at the time of the complete abandonment of its program through referendum was more highly dependent on energy imports than Japan.

<u>Regime Type</u>

All three countries were and have continued to be established democracies.

Government Structure

Japan is a parliamentary representative democracy, Germany is a federal parliamentary republic, and France is a semi-presidential representative democracy. All three have multi-party systems that accommodate small parties, but are dominated by two major parties. The structure of the central government and the legislature seems to lack explanatory power.

That Germany is a federal system, however, does carry explanatory power. The federal governmental structure influences the openness of the nuclear regulatory system greatly. The nuclear power plant at Mülheim Kärlich, again, was shut down for political reasons after beginning normal operation. Disagreement between the federal and Länder governments over the legality of the construction licenses led to the closure of the 1302MWe nuclear plant after only 2 years of operation.[59] In general, "responsibility for licensing the construction and operation of all nuclear facilities is shared between the federal and Länder governments, which confers something close to a power of veto to both."[60]

Indirectly, also, the federal nature of the German system helped facilitate the politicization of nuclear power on the national stage.[61] For example, after 1987, when the Social Democratic Party lost control over the federal government, "the SPD maintained a strict anti-nuclear stance at the state level."[62]

Centralization of the Nuclear Industry

The level of centralization of the nuclear industry has two potentially relevant components. First, the centralization of the industry itself could conceivably aid in insulating it from changes wrought by the responses to an accident. Secondly, the amount of direct state involvement in the industry at the

[59] Paffenbarger and International Energy Agency, 2001. Pg 226. & WNA *Germany*
[60] World Nuclear Association. *Germany.*
[61] Kolb, 2007. Pg 250.
[62] Rüdig, 1990. Pg 341.

time of an accident could affect the state response.[63] Both components are strongly present in France, as its nuclear power plants are operated entirely by one company – Electricité de France (EDF), a utility in which the state owns an 85% share.[64] Areva, a company that constructs nuclear power plants, is the world's largest nuclear company and over 90% French-government owned. In contrast, Germany's nuclear power plants are operated by four different utilities, all of which are privately owned.[65] Japan, however, is more similar to Germany on this count. Ten different utilities own and operate nuclear power plants in Japan, none of which are owned by the government.[66] Neither the Japanese nor the German state has stakes in their nuclear companies.

A centralized nuclear industry, then, may well be of supplementary relevance for France. Having a decentralized industry, however, was not a problem for Japan and likely not the main problem for Germany.

Mandate of the Ruling Government

Although also plausible, this does not appear to have explanatory power across this group of countries. Of the three, only the Japanese Liberal Democratic Party can be said to have enjoyed a strong governmental mandate at the time of Chernobyl.

Gross Domestic Product

All three have high gross domestic product and GDP per capita.

Access to Credit

Access to credit in an immediate sense, namely inflation and interest rates, can be discounted as a significant variable. Qualitatively, no case studies reviewed for this thesis made reference this as causally important in any country specifically. Quantitatively, statistical analysis finds a negative, but statistically insignificant,

[63] Beyond such quantifiable difference, efforts by the government to promote nuclear power, such as by providing subsidies or compensation (as has been the case in both France and Japan) cannot be seen as an independent variable.
[64] World Nuclear Association. *France.*
[65] World Nuclear Association. *Germany.*
[66] World Nuclear Association. *Japan.*

correlation between inflation and interest rates on nuclear reactor construction starts.[67]

Rate of Growth of Electricity Consumption

Electricity demand does not appear to be a causal variable, in relation to the continuation or lack thereof of nuclear programs. This is evidenced strongly by the case of France. France has sported a large surplus of electrical capacity for many years; they even export electricity. French nuclear power plants are the only ones in the world that load-follow (i.e. sometimes work at below full capacity), lessening their capacity factor relative to the world average. They have slowed construction of nuclear power plants as the grid reaches capacity, but that would happen with any form of power generation.[68] This does not support the hypothesis that nuclear power construction is more strongly correlated to electricity demand than other forms of power generation.

Level of knowledge of Nuclear Power

Ignorance about nuclear power has been shown to correlate with lower rates of acceptance of nuclear energy.[69] It is unfair to say that the German public was less knowledgeable about nuclear power, however. In the context of these three countries, the level of public knowledge does not appear to have much impact.

Conclusion

From this analysis, we have found the most important variables affecting enduring change in nuclear power development after an accident and the mechanisms through which they act. For established democracies with a high GDP and a large nuclear program, the most important mechanisms through which a nuclear program stagnates after an accident are confusion within the regulatory system and the consolidation of an anti-nuclear platform by a national political party. Both of these mechanisms were activated in Germany in response to Chernobyl, and neither was activated in France or Japan. Dependence on energy

[67] Csereklyei, 2014. Pg 127.
[68] World Nuclear Association. *France.*
[69] Pérez-Díaz, Víctor, and Juan Carlos Rodríguez. "Nuclear Energy and Public Opinion in Spain." *ESTUDIOS DE POLÍTICA EXTERIOR* (2008): 215-25. Web.

imports and level of federalization of the government have clear explanatory power over this difference in mechanism activation. Of supplementary relevance may be a highly centralized or state-controlled utility, in the case of France, and the mandate of the current government, in the case of Japan.

Ukraine, South Korea & Spain – Mechanisms of Change

In the previous section we analyzed the case of established democracies with high GDP. Our second group of countries introduces additional complexity, allowing us to test whether the conclusions are valid in a broader context. Spain, Ukraine, and South Korea were all moving through transitions to democracy at the time they made enduring decisions about nuclear power. In all countries, therefore, there was tremendous political opportunity and uncertainty the national level, which has been found to facilitate politicization.[70] Furthermore, all of the countries can be considered to have had "closed" regulatory systems, as they lacked the democratic infrastructure to process complaints centrally.[71] These three countries, then, offer a phenomenal comparison to the previous group.

The mechanism by which Spanish nuclear power was suspended also appears to be the politicization of nuclear power, cemented in place by the accident at Three Mile Island. Nuclear energy became a nationally politicized issue in a uniquely Spanish way, by becoming a symbol of Basque nationalism. Nuclear development began and proceeded rapidly under the Francoist regime.[72] A coalition of Spanish electrical utilities and economically powerful Spanish banks drove implementation.[73] New nuclear plants announced in 1973 and 1974 were disproportionately placed in the Basque and Catalan regions with suppressed separatist sentiments. Franco's death in 1975 prompted the democratization of the Spanish government, and unleashed previously dormant political forces. Many sites never got off the ground, so when democratization began in 1976 disagreement and political heat centered on the Lemoniz nuclear plant under construction not far from Bilbao – the largest city in Basque country. Although local opposition barely registered, regional opposition blossomed. A demonstration in Bilbao on July 14th 1977 brought somewhere between 150,000 and 200,000 protesters into the streets.

---

[70] Kolb, 2007. Pg 237.
[71] In regards to Spain, "Nuclear construction was under virtual control of the central government, and there were no realistic opportunities to have Lemoniz stopped through petitions and other legal challenges." Rüdig, 1990. Pg 138.
[72] Kolb, 2007. Pg 266.
[73] Rüdig, 1990. Pg 94.

"A closer look at the demonstration reveals that protest against nuclear energy was perhaps not the key aspect of the action, although the anti-nuclear credentials of the organizers are not in doubt… The main mobilization for the demonstration was, however, mainly carried out by far left [Basque] nationalist forces"[74] This pattern of anti-nuclear protest tied to regionalist opposition was mirrored on a smaller scale in other regions of Spain. The National Energy Plan of 1979 maintained the pro-nuclear commitment inherited from the Franco regime, drawing criticism from the main opposition parties – the Socialist Party (PSOE) and the Communist Party (PCE). These same parties officially "adopted stringent anti-nuclear positions after the 1979 accident at *Three Mile Island*."[75]

This politicization of nuclear power allowed anti-nuclear sentiments to remain in the public consciousness for years after public protests lost steam. Three years on, when the Socialist Party (PSOE) won in election of October 1982, nuclear power came under a *de facto* moratorium with the National Energy Plan of 1983 (PEN-1983). Construction stopped at five plants, including the two highly disputed units at Lemoniz.[76] This proceeded despite the cost of doing so.[77] The moratorium was confirmed eight years later and made into law in 1994. In a testament to the longevity of anti-nuclear positions once politicized, the PSOE Premier elected in 2004 and 2008 re-confirmed plans aimed at a nuclear phase-out after both elections.[78]

South Korea had a rather similar historical progression that followed a few years behind Spain. It did not, however, result in the abandonment of South Korea's similarly sized nuclear program. In 1979 President Park Chung-hee was assassinated, ending his 18 years in military-backed office. Military rule was soon re-instated, however, with a coup d'etat in December of the same year. Popular protest mobilizing tens of thousands of people emerged to oppose this development, but did not succeed, nor incorporate nuclear power in any way. This runs in contrast

---

[74] Rüdig, 1990. Pg 139.
[75] Kolb, 2007. Pg 266.
[76] World Nuclear Association. *Spain*. Pg 2.
[77] Kolb, 2007. Pg 266.
[78] World Nuclear Industry Report, 2012.

to the Basque nationalist protests in Spain, which took advantage of anti-nuclear protests, thereby amplifying them. In 1987 popular protest, with mobilization numbering in the millions, successfully brought fully democratic elections to South Korea. Again, even so soon after Chernobyl, nuclear power had no part in these mass mobilizations. This necessarily introduces additional nuance into the politicization mechanism.

Ukraine completes the comparison set. Whereas the Spanish nuclear energy program came under pressure and stagnated, the South Korean nuclear energy program did not come under pressure and did not stagnate, the Ukrainian nuclear energy program came under tremendous pressure and yet did not stagnate. This makes Ukraine particularly interesting. Chernobyl-4, the fourth of four units of the Chernobyl nuclear power complex, experienced a steam explosion and meltdown after an ill-fated test on April 26th, 1986. Thirty-one people were killed as an immediate result of the radiation released, and the detection of said radiation elsewhere set off alarm bells the world over. Within Ukraine, 45,000 people were evacuated immediately, while upwards of 300,000 people were eventually resettled due to radiological contamination of the environment.[79] A part of the Soviet Union at the time, popular concern was suppressed and nuclear power plants under construction continued unimpeded for a few years. Within a year of the disaster, a new Ukrainian nuclear power plant, Zaporozhe-3, entered commercial operation. Another plant followed suit later in 1987, two in 1988 and another in 1989. Negative opinions of nuclear power eventually made themselves known, however. In 1989, in commemoration of the third anniversary of the Chernobyl-4 explosion, 30,000 people protested in Kiev for the shutdown of the remaining Chernobyl units.[80] Keeping in mind that this was still during Soviet rule, such a showing can be considered impressive. As an indication of scale, however, participation in the anti-

---

[79] Misconceptions about the effects of radiation and stresses of relocation led to confusion and additional suffering. In many ways, such secondary effects were far more damaging than the radiological exposure itself.
"Chernobyl Accident 1986." *World-nuclear.org*. World Nuclear Association, Apr. 2014. Web. 07 Apr. 2014.

[80] Rüdig, 1990. Pg 226-227.

nuclear protests was dwarfed by protests suggesting a desire for independence, which attracted over half of a million people. In *direct* contrast to Spain such a nationalist movement did not unite with anti-nuclear forces.

In April of 1990, four years after Chernobyl, the Supreme Soviet of Ukraine halted construction on all nuclear power plants in Ukraine.[81] No move was made on closing the remaining Chernobyl plants. Ukraine declared independence in August of 1991. Shortly thereafter, a trigger for change came in the form of a destructive fire in Chernobyl unit 2 on October 11th. Chernobyl-2 was promptly shut down, and the government promised to shut down the remaining reactors by 1993. The Soviet Union officially dissolved on December 26th, 1991.

Despite facing what observers at the time called "enormous public opposition"[82] toward nuclear projects the newly independent government of Ukraine voted in 1993 to both lift the nuclear power moratorium and to delay the closure of the remaining two Chernobyl units.[83] The sixth unit of the Zaporozhe power plant was promptly completed and was connected to the grid in October of 1995.[84] The government and the national nuclear utility, furthermore, were enthusiastic to complete two large units left near 80% completion in 1990 – Khmelnitski-2 and Rovno-4.[85] The negotiation of international loans specific to this purpose carried the requirement of closing the remaining Chernobyl units. Chernobyl-1 was closed in 1996, Chernobyl-3 was closed in 2000, while both Khmelnitski-2 and Rovno-4 came online first in 2005. In the end, Ukraine funded most of the completion costs with local financing and bonds.[86] Since the completion of these plants, Ukraine has commissioned two more. Again, it appears that solid political support for nuclear, even in the face of protest and change, is the main mechanism that kept nuclear power development going.

---

[81] WNIR, 1992. Pg 12.
[82] WNIR, 1992. Pg 13.
[83] WNIR, 2004. Pg 25.
[84] World Nuclear Association. *Reactor database.* Zaporozhe-6
[85] World Nuclear Association. *Ukraine.*
[86] Ibid.

Comparing across the three cases, it becomes clear that raw political opportunity is not enough to politicize nuclear power. This mechanism for long-term nuclear power stagnation – politicization – is more complex, but no less vital, in the context of these three countries as it is in the context of established democracies.

Ukraine, South Korea & Spain – Distinguishing Variables

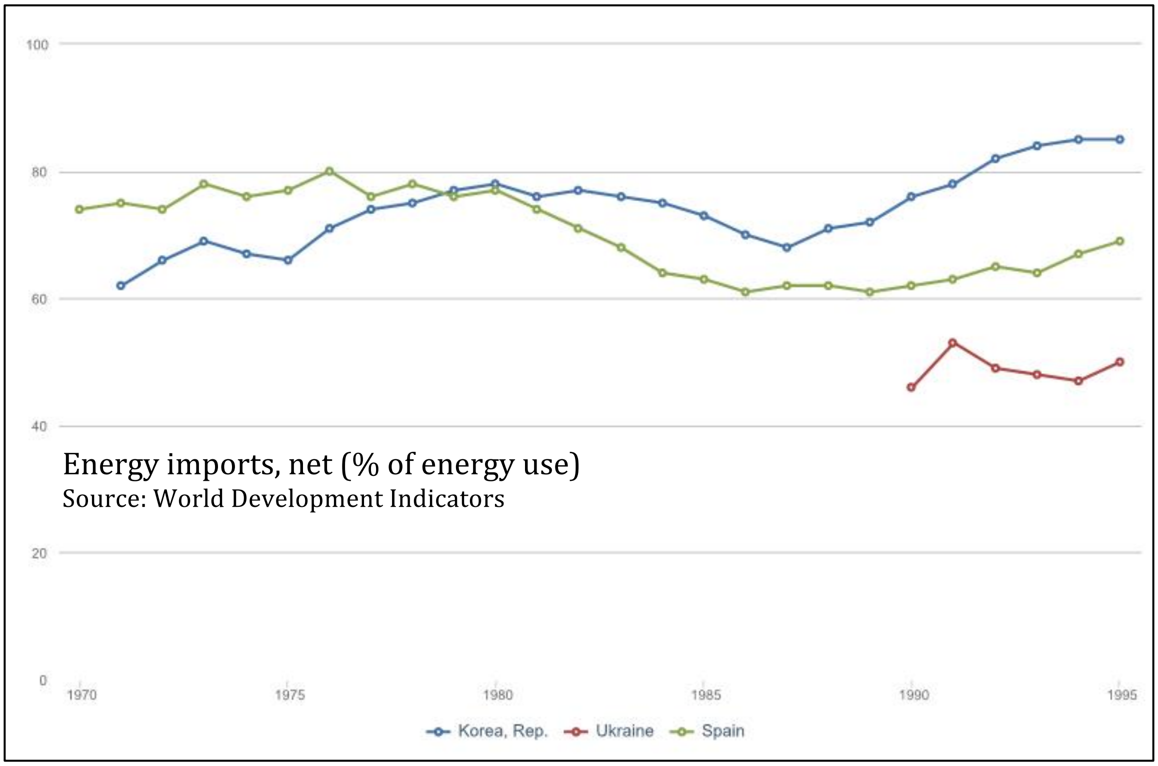
Historical Investment in Nuclear Power

Previous investment in nuclear power plants does not have explanatory power independently of other variables. In this group of cases the R&D funding at the time of the accidents in question was minimal – none of these countries began their programs with indigenous capacity. Rather, they imported reactors. The three countries also had remarkably similar capacity per capita in the early 1980s. Looking from the sunk-cost angle, however, interesting differences emerge between the countries in this group. The weight of previous investment on government decisions appears to have varied. Spain abandoned several nearly-constructed nuclear plants in 1982, which represented a significant portion of government investment,[87] while South Korea did not come to consider abandoning plants and Ukraine campaigned hard against international pressure to maintain the Chernobyl plant operational for as long as possible.[88]

Economic Dependence on Imported Fuel

In contrast to our earlier group of countries, economic dependence on imported fuel does not have independent explanatory. Ukraine, of the three, is least dependent on imports as a fraction of total primary energy consumption by quite a large margin.

[87] Paffenbarger and IEA, 2001. Pg 226. & Kolb, 2007. Pg 266.
[88] World Nuclear Association. *Ukraine.* K2-R4 Appendix



At the time of the relevant decisions, Spain had similar dependence to South Korea. Observes noted in 1992 that "Instead of nuclear energy, the country plans to build a natural gas pipeline across the Straight of Gibraltar to bring Algerian gas to the Iberian Peninsula."[89] The pipeline was subsequently built and began operating in 1996.[90] The choice between importing fossil fuels and maintaining nuclear sources was clear.

Dependence on energy imports is of supplementary explanatory value for the case of South Korea, which imported 70% of its primary energy at the time of Chernobyl.[91]

<u>Gross Domestic Product</u>

Ukraine and South Korea had far lower GDP that Spain in the early 1980s, and this has explanatory power. Although neither historical investment in nuclear power nor economic dependence on imported fuel had independent explanatory

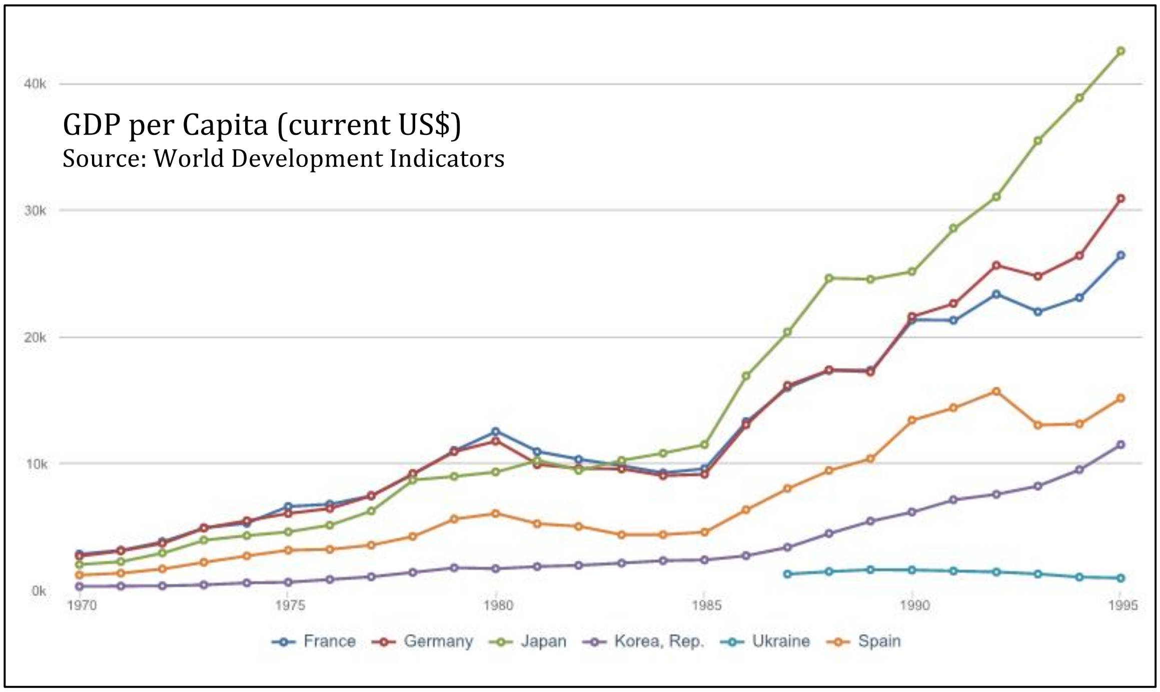
---

[89] WNIR, 1992. Pg 8.

[90] Khan, Edward. *The Electricity Industry in Spain*. Working paper no. PWP-032. Berkley: University of California Energy Institute, 1995. Program on Workable Energy Regulation.

[91] World Bank DataBank – Net Energy Imports as % of energy use

power, they gain importance as variables through their interaction with GDP and GDP per capita[92].



Having a lower GDP makes investments in nuclear energy larger relative to the economy as a whole, and may explain why Ukraine and South Korea were less receptive to the idea of abandoning nuclear plants. In these countries, the plants represented a larger investment on behalf of the state. Similarly, wealth may influence the perception of energy import dependence of a country. A richer country, in term of higher GDP per capita, will have more resources available with which to import energy. Energy dependence, therefore, may be less salient of an issue.

Spain and Ukraine are directly comparable in their reaction to temporary moratoriums and the decisions made to keep or lift them. Spain imposed a moratorium on five plants as a part of the PEN-1983. These five plants, moreover, were abandoned at an uncommonly advanced stage of construction (92% and 50% completed in some cases)[93] thereby representing a sizeable investment on the part

---

92 The populations of the three countries are very similar. GDP and GDP per capita are equivalent indicators for the purposes of this analysis.
93 Paffenbarger and International Energy Agency, 2001. Pg 226.

of the Spanish state – 18.5% of their nuclear investment in 1982. This appreciably changed energy investment patterns.[94] In Ukraine's case, the Supreme Soviet placed all nuclear plants under construction at the time under moratorium in April of 1990, notably before the collapse of the Soviet Union.[95] Similarly to Spain, construction stopped at an advanced stage, and represented a large investment. In Spain, the moratorium persisted until it became permanent law twelve years later. Ukraine's moratorium, however, was lifted after only three years by the newly independent government - even though Chernobyl-2 had caught fire, closing in 1991, and the paused plants "faced enormous public opposition".[96] The different economic situations have explanatory power over the difference in response. Ukraine began the transition to democracy at a lower starting point, relatively, in terms of GDP per capita, and "NPPs were the most modern power sources".[97] Ukraine's economy collapsed almost entirely with the fall of the communist economic system, rendering organic fuel "scarce".[98] Spain's economy survived transition to democracy relatively unscathed. New independence brought economic problems to the fore, exacerbating the issue of foreign import dependence while enhancing the value to the state of previous investments in nuclear power. This combination of factors also helps explain why nuclear power received so little challenge on the larger political scene in South Korea. There, low GDP and high energy import dependence combined to insulate nuclear at the level of the central government.[99]

---

[94] Kolb, 2007. Pg 266.
[95] WNIR, 1992. Pg 13.
[96] WNIR, 1992. Pg 8. & Rüdig, 1990. Pg 226-227.
[97] Ibid. Pg 285.
[98] Kokhan, I.V., and V.J Zeniuk "Current Status and Perspctives of Atomic Energy Development in Ukraine". *Power in Developing Countries: Its Potential Role and Strategies for Its Development*. Bhabha Atomic Research Centre, Mumbai, India. Vienna: IAEA, 2000. 285-290 Web. Nov. 2013. Pg 285.
[99] There were several local demonstrations between 1988 and 1990, at the Kori facility and new potential nuclear waste disposal sites. The potential for political impact was there, but these protests remained entirely local in character. [WNIR, 1992. & Paffenbarger and IEA, 2001. Pg 256.] The combination of low GDP and high energy import dependence apparently made opposing nuclear power an unappealing option for the government, even given the opportunity for political gains.

When allowed to interact with GDP both historical investment in nuclear power and economic dependence on imported fuel have explanatory power.

Regime Type

All three of the countries in this set of cases went through a period of transition to democracy during the time where the most lasting decisions regarding nuclear power were made. The type of regime from which the transition occurred does not have explanatory power. Spain and South Korea were the most similar in that a military-backed strongman had held power for more than a decade before the transition took place. No country had a transition remarkably more tumultuous than the others.

There exists a time-relative difference that one cannot rule out as important, however. In Spain, the transition to democracy definitively began before any of the major nuclear accidents. Massive anti-nuclear protests rocked Bilbao as early as 1977. The success of the Basque nationalists at promoting the anti-nuclear cause, even in its infancy when the movement was emerging and based on largely theoretical dangers of nuclear power, ensured that it was a national political issue *before* Three Mile Island. In the other two countries the transition to democracy truly took hold after Chernobyl, but was underway in one form or another before 1986. In the case of Ukraine, while still a part of the USSR, the liberalizing reforms of Gorbachev were begun before Chernobyl. In the case of South Korea, political turmoil, including pro-democratic protests, followed the assassination Park Chung-hee and the establishment of a new military government in 1979. In neither case was this political opportunity early enough in history to parallel the Spanish case. It is possible, given the salience of the politicization mechanism in making permanent anti-nuclear decisions, that transitions to democracy have greater potential to impact nuclear development when they occur before large-scale accidents, rather than during or after. Particularly, political parties who are official at the time of an accident might face more pressure to adopt and keep anti-nuclear party platforms than parties emerging in the years following one. In South Korea and Ukraine political parties competitive to the regime emerged at a later time.

While possible, several elements make the argument supporting this variable less than fully convincing. Specifically, in Spain the anti-nuclear movement first allied with regionalist factions, not legitimate political parties – the politicization as a result of this. Particularly in the case of Ukraine, there would seem to be some similar overlap between the goals of independence activists and anti-nuclear activists. If such an alliance did not emerge right after Chernobyl while anti-nuclear opinions were intense, it seems less likely – not more – that such an alliance would have formed in the largely ambivalent atmosphere beforehand, as it did in Spain. This reasoning applies equally well to other potential political alliances and to the case of South Korea. We may also be running up against a selection bias, as it is unclear whether such alliances were attempted in Ukraine but unsuccessful for other reasons.

Regime type does not have explanatory power, and the timing of the transition to democracy (as it applies to the level of establishment of political parties) at the time of the accident may or may not be relevant. More convincing, in any case, are variables that offer an explanation as to why the political alliance occurred in Spain or why it was so successful at affecting national politics.

Government Structure

From the previous group of cases, the federal nature of the German government carries explanatory power, as compared to the unitary states France and Japan. Spain, Ukraine, and South Korea are all unitary states. However, Spain has an established regionalist history and is significantly less centralized. Although not a federal state, the Spanish constitution (1978) gives substantial governing leeway to its seventeen "autonomous communities".[100] Ukraine and South Korea have one small region each with greater autonomy. Spanish regionalism, then, is similar in some respects to German federalism. We have seen, however, that the regulatory mechanism was not relevant to the three cases considered here, as none of the countries had regulatory systems that responded to public pressure. Instead,

[100] They are the corresponding Spanish structure to a region or state. Central Intelligence Agency. "Spain." cia.gov. Central Intelligence Agency, n.d. Web. 13 Apr. 2014.

Spanish regionalism led directly to activating the politicization mechanism by helping the nuclear issue echo onto the national stage. This lends strong support to the idea that decentralized government (i.e. federalism or regionalism) has an indirect influence on the politicization mechanism. Earlier, this was considered of potential relevance in Germany. This group of case studies, then, reiterates the advantage of a centralized unitary state – as opposed to a federal or highly decentralized state – in maintaining nuclear development in the shadow of a large-scale accident.

Centralization of the Nuclear Industry

The nuclear industry was centralized, to a great extent, in all three countries. Regional electricity companies in South Korea consolidated together into one company as early as 1961. Nuclear research and development efforts were also highly centralized, under the Office of Atomic Energy.[101] Ukraine has a designated and state-owned nuclear power utility, Energoatom.[102] In Spain, a state-owned company, ENUSA, has run all nuclear front-end activities since 1972. Ownership and operation of nuclear power was carried out mainly by the state-owned *Empresa Nacional de Electricidad S.A* (later renamed Endesa) and Iberduero (later Iberdrola).[103] Spain's licensing system was also highly centralized, offering "no practical chances of challenging these decisions effectively within licensing procedures or courts."[104]

Mandate of the Ruling Government

As these three countries transitioned toward democracy they experienced tumultuous political changes. In Spain, the ruling political party in 1980 existed only between 1977 and 1983. In South Korea, the first democratic elections were very close. In Ukraine, the political scene was rapidly shifting as political parties formed and political structures evolved. In no case was there a clear mandate for the ruling government during the relevant time period.

---

101 Sovacool & Valentine, Pg 159.
102 World Nuclear Association. *Ukraine*.
103 World Nuclear Association. *Spain.* & Endesa.com
104 Rüdig, 1990. Pg 311.

Access to Credit

Access to credit in an immediate sense, namely inflation and interest rates, was earlier discounted as a significant variable among our stable democracies.[105] Transitions to democracy and the accompanying political instability might well add impediments to finding financing, and variation therein. This does not appear to have causal relevance, however. Ukraine illustrates this point nicely, in that it faced large challenges in finding the financing to complete Khmelnitski-2 and Ronvo-4 in the 1990s but managed to do so, anyway. Ukraine sought loans from both the EU (specifically the European Bank for Reconstruction & Development and the European Commission) and Russia. These loans came with such restrictions, however, that Ukraine proceeded "with local finance and a bond issue".[106] Scaled-down loans from the international players eventually played a role, as well. Despite the financing difficulties of transitioning to a market economy, and the outright refusal of large international loans, Ukraine was able to finance the completion of these two units. As the other two countries faced far less intense financial challenges, the success of Ukraine shows that access to credit may be discounted as a relevant variable in this group of cases.

Rate of Growth of Electricity Consumption

The case of Ukraine is a direct refutation of this variable. Concerning the two nuclear power plants that have entered operation in Ukraine since Chernobyl: "Khmelnitsky-2 and Rovno-4 reactors… began operating in the summer of 2004 and were said to be the replacement reactors for the remaining Chernobyl units closed by 2000. However, due to the economic decline in the country during the early 1990s Ukraine's peak demand, when construction was restarted in 1995, was around 30,000 MW, with an installed capacity of around 54,000 MW and thus there is substantial reserve capacity, about 80%, or over twenty times the operational capacity of Chernobyl." Ukraine's electricity consumption had gone down significantly in recent years, yet they still built nuclear capacity soon after Chernobyl.

[105] Csereklyei, 2014. Pg 127.
[106] World Nuclear Association. *Ukraine*. Appendix

High rates of electricity growth may be of supplementary importance, however. There is some evidence that Spain explicitly considered its 1984 electricity growth in the context of nuclear power, and found it not rapid enough to warrant licensing new nuclear power pants.[107] Electricity growth rebounded in the 1990s, however, with no impact on nuclear policy. Spain was willing to build coal plants, combined cycle plants and a natural gas pipeline to Algeria to meet the growth in electricity demand.

A high rate of growth in electricity consumption could be a supplementary variable for South Korea, although it is unclear how electricity consumption would have an effect isolated to nuclear power.

<u>Level of knowledge of Nuclear Power</u>

Ignorance about nuclear power has been shown to correlate with lower rates of acceptance of nuclear energy.[108] In the context of these three countries the causal relevance of this observation appear limited. The populations of South Korea and Ukraine likely knew less technical details about nuclear power, and direct public influence on policy was limited, anyway.

<u>Conclusion</u>

From this analysis, we have found the most important variables affecting enduring change in nuclear power development after an accident, and the mechanisms through which they act, for less politically stable countries with an emerging nuclear program. The most important mechanism through which a nuclear program stagnates was, again, found to be the politicization of nuclear power on the national stage, specifically through the adoption of anti-nuclear views in national party platforms. This mechanism was activated in Spain in response to Three Mile Island, but was not activated in South Korea or Ukraine. Combinations of variables played a large role in this group of cases. Low GDP has clear explanatory power over the difference in mechanism activation, particularly through interaction

---

[107] Rüdig, 1990. Pg 339.

[108] Public opinion is also seen to depend on the nuclear policy of the government, and hence is not an independent variable on its own.
Pérez-Díaz & Rodríguez, 2008. Pg 215-225.

with significant investment in nuclear power and dependence on energy imports. In echo of our findings for the previous group of cases, a decentralized government structure also has clear explanatory power. Of supplementary relevance may be a high rate of growth in electricity consumption in the case of South Korea, and a relatively early start to the transition to democracy in the case of Spain.

Conclusion

This thesis posed the question: Why do large nuclear accidents derail plans for nuclear power in some countries and not others? It has provided answers through comparative analysis of two matched sets of cases. Three major nuclear countries – consisting of France, Germany, and Japan – formed one comparison set as nuclear power development stagnated in Germany, but not in France or Japan. Three countries with significant but smaller nuclear programs at the time – consisting of South Korea, Spain, and Ukraine – formed a second comparison set as nuclear power development stagnated in Spain, but not in South Korea or Ukraine.

Crucial to understanding differences between the countries was to first isolate the mechanisms by which reactions to accidents cause dramatic and enduring reductions of plans for nuclear power. More specifically, what mechanisms caused flips from positive feedback to negative feedback situations in the nuclear programs of Spain and Germany? A pervasive conventional explanation holds that nuclear accidents expose the dangers of nuclear power and convince rational decision-makers and publics. This explanation was considered independently, through quantitative analysis of the risks of nuclear power in terms of fatalities and economic cost. We found that dry rationality about risk on the part of decision-makers cannot explain curtailment of nuclear programs because the vast majority of nuclear power generation that goes offline or remains unconstructed is replaced by coal. Risk from nuclear and coal power are directly comparable across severe accident risk, routine operating risk, latent public risk, and economic cost. Nuclear power is considerably less dangerous on every count. Additionally, neither natural gas nor renewable energy sources produce electricity with risks quantifiably lower than nuclear.

More fruitful was to analyze through process tracing what specific attributes of a country's reaction to accidents lead to long-term reversals in nuclear power plans. Bringing together the historical analysis of France, Germany and Japan resulted in a clear yet nuanced picture for established democracies with large nuclear programs. The politicization of nuclear power in national party politics stood out as a powerful mechanism determining the course of nuclear power development over decades. Inconsistency within the nuclear regulatory system was a secondary mechanism. Both of these mechanisms were activated in Germany in response to Chernobyl, and neither was activated in France or Japan. Spain, Ukraine, and South Korea were all engaged in a transition to democracy around the relevant time period, which complicated the policy space in which decisions were made. The most important mechanism was, again, found to be the politicization of nuclear power on the national stage, specifically through the adoption of anti-nuclear views in national party platforms. This mechanism was activated in Spain in response to Three Mile Island, but was not activated in South Korea or Ukraine.

Armed with an understanding of how reversals came to take place, countries within the two groups of cases were be compared for the underlying differences that cause variation among them. Specifically, which attributes of the state and government determine whether the above mechanisms become activated in a given country, in response to an accident? For established democracies with large nuclear programs dependence on energy imports and level of federalization of the government have clear explanatory power. Of supplementary relevance may be a highly centralized or state-controlled utility, in the case of France, and the mandate of the current government, in the case of Japan. For less politically stable countries with an emerging nuclear program combinations of variables played a larger role. Low GDP has clear explanatory power over the difference in mechanism activation, particularly through interaction with prior investment in nuclear power and dependence on energy imports. In echo of our findings for the previous group of cases, a decentralized government structure has clear explanatory power. Of supplementary relevance may be a high rate of growth in electricity consumption in the case of South Korea, and a relatively early start to the transition to democracy in the case of Spain.

Across the two groups of cases, two elements of the state appear most important in determining the prospect of long-term reversals in nuclear power plans: the vulnerability of the state to issues of energy import dependence, and the level of centralization of the state government. Vulnerability to issues of energy import dependence, exacerbated by a low GDP, lessen the possibility of activating the politicization mechanism. A federal or highly decentralized state heightens the possibility of activating the politicization mechanism and also makes an inconsistent regulatory system (the second mechanism discouraging nuclear power development) more likely. On a case-by-case basis, other variables that directly impact these mechanisms are supplementary, but still relevant.

Bibliography

Paffenbarger, John, and International Energy Agency. *Nuclear Power in the OECD*. Paris: IEA Publications, 2001. Print. Pg 136.

Kolb, Felix. *Protest and Opportunities: The Political Outcomes of Social Movements*. Frankfurt: Campus Verlag, 2007. Print. Pg 225

Rüdig, Wolfgang. *Anti-nuclear Movements: A World Survey of Opposition to Nuclear Energy*. Harlow, Essex: Longman Current Affairs, 1990. Print. Pg 255-256.

Sovacool, Benjamin K., and Scott V. Valentine. *The National Politics of Nuclear Power: Economics, Security and Governance*. London: Routledge, 2012. Print. Pg 5.

Yergin, Daniel. *The Quest: Energy, Security and the Remaking of the Modern World*. New York: Penguin, 2011. Print.

"Information Library." *World Nuclear Association*. <http://world-nuclear.org/Information-Library/>.

Flavin, Christopher, et. al. *The World Nuclear Industry Status Report 1992*. Rep. London: Greenpeace International, 1992. Web. Jan. 2014.

Scheider, Mycle, and Antony Froggart. *The World Nuclear Industry Status Report 2004*. Rep. Brussels: Greens-EFA, 2004. Web. Jan. 2014.

Scheider, Mycle, et. al. *The World Nuclear Industry Status Report 2009*. Rep. Brussels: Greens-EFA, 2009. Web. Jan. 2014.

Gourley, Bernard, and Adam N. Stulberg. "Correlates of Nuclear Energy." *Nuclear Renaissance and International Security*. By Adam Stulberg. N.p.: Stanford UP, 2013. 19-49. Print.

Nikolai Sokov. Review of Stulberg, Adam N.; Fuhrmann, Matthew, eds., *The Nuclear Renaissance and International Security*. H-Diplo, H-Net Reviews. August, 2013.

Lester, Richard K., and Robert Rosner. "The Growth of Nuclear Power: Drivers & Constraints." *Daedalus* 138.4 (2009): 19-30. Web. Oct. 2013.

Csereklyei, Zsuzsanna. "Measuring the Impact of Nuclear Accidents on Energy Policy." *Ecological Economics* (2014): 121-29. *Elsevier*. Web. 10 Feb. 2014.

OECD. International Energy Agency. *Technology Roadmap: Nuclear Energy*. By International Energy Agency and Nuclear Energy Agency. France: Corlet, 2010. Print. Energy Technology Roadmaps. Pg 3

Fritzsche, Andrew F. "The Health Risks of Energy Production." *Risk Analysis* 9.4 (1989): 565-77. Web.

Comparing Nuclear Accident Risks with Those from Other Energy Sources. Issy-les-

Moulineaux: Nuclear Energy Agency, Organization for Economic Co-operation and Development, 2010. Print.

Epstein, Paul R., Jonathan J. Buonocore, Kevin Eckerle, Michael Hendryx, Benjamin M. Stout III, Richard Heinberg, Richard W. Clapp, Beverly May, Nancy L. Reinhart, Melissa M. Ahern, Samir K. Doshi, and Leslie Glustrom. "Full Cost Accounting for the Life Cycle of Coal." *Annals of the New York Academy of Sciences* 1219.1 (2011): 73-98. Web.

Vidal, John. "European Coal Pollution Causes 22,300 Premature Deaths a Year, Study Shows." *Theguardian.com*. Guardian News and Media, 12 June 2013. Web. 06 Feb. 2014.

Inhaber, Herbert. "Is Solar Power More Dangerous Than Nuclear." *New Scientist* 78 (1978): 444-46. *IAEA.org*. IAEA. Web. Feb. 2014.

Pérez-Díaz, Víctor, and Juan Carlos Rodríguez. "Nuclear Energy and Public Opinion in Spain." *ESTUDIOS DE POLÍTICA EXTERIOR* (2008): 215-25. Web.

Ha, Young-Sun. "Republic of (South) Korea." *Nuclear Power in Developing Countries*. By James E. Katz and Onkar S. Marwah. Lexington: Lexington, 1982. 221-44. Print.

Park, Chris C. "Chapter 10: Public Confidence in Nuclear Power?" *Chernobyl: The Long Shadow*. Abingdon, Oxon: Routledge, 2011. 160-83. Print. Pg 182.

Rosen, M. *Nuclear Power: Issues of Misunderstandings.* Pg 381-388 in *Power in Developing Countries: Its Potential Role and Strategies for Its Development*. Bhabha Atomic Research Centre, Mumbai, India. Vienna: IAEA, 2000. Web. Nov. 2013.

Mearsheimer, John J., and Stephen M. Walt. "The Blind Man and the Elephant in the Room: Robert Lieberman and the Israel Lobby." *Perspectives on Politics* 7.02 (2009): 259. Print.

Khan, Edward. *The Electricity Industry in Spain*. Working paper no. PWP-032. Berkley: University of California Energy Institute, 1995. Program on Workable Energy Regulation.

Central Intelligence Agency. "Spain." cia.gov. Central Intelligence Agency, n.d. Web. 13 Apr. 2014.