Understanding Political Pressures To Shutdown Nuclear Power Plants in the United States and South Korea

By

Nah Yoon Shin

B.S, Human Ecology, Yonsei University (2003)
M.C.P, Urban Planning, Seoul National University (2006)

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Author Signature redacted

Department of Urban Studies and Planning
December 11, 2016

Certified by Signature redacted

Professor Lawrence E. Susskind
Department of Urban Studies and Planning
Thesis Supervisor

Accepted by Signature redacted

Associate Professor P. Christopher Zegras
Committee Chair
Department of Urban Studies and Planning

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ABSTRACT

Since the mid-1990s, thirty to forty-year-old nuclear power plants have been reaching their designed lifetimes. Many operating licenses, however, are being extended after regulators review safety considerations and environmental impacts associated with each extension. These regulatory reviews have become quite controversial, not just in the United States. I analyze a number of these in the United States and South Korea—countries that are quite different in terms of their regulatory frameworks, electricity markets, safety requirements, and ways in which they engage the public in relicensing decisions. My findings are: 1) regulators, utility managers, nuclear professionals, and policy-makers in any country with ageing nuclear plants are likely to face opposition from groups that do not trust the typical risk and safety assessment studies used to justify license renewals; 2) nuclear license renewal decisions are particularly prone to conflict if stakeholders are not involved early enough, and if they perceive that their concerns are repeatedly overlooked (on the grounds that only the results of professional risk modeling are valid); and 3) the credibility of license renewal decisions will hinge on site-specific information and local knowledge, not just generic national studies. Only if there is an earnest effort to engage potentially affected stakeholders, with the assistance of a neutral facilitator, can nuclear plant relicensing facilities be avoided. Stakeholders want an opportunity to focus on issues that are most important to them, particularly site safety, given the uncertainties involved in assessing the risks with continued operation of plants that had a limited design life.

Thesis advisor: Lawrence E. Susskind
Title: Ford Professor of Urban and Environmental Planning

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LIST OF ACRONYMS

ASLB	Atomic Safety Licensing Board
CANFS	Collective Action for Nuclear-Free Society
CJTC	Comprehensive Joint Technical Committee
CRB	Citizen Review Board
DAN	Doctors Against Nuke
EPZ	Emergency Planning Zone
ETE	Evacuation time estimates
GDC	Gampo Development Council
GEIS	Generic Environmental Impact Statement
GRAMMES	Grandmothers, Mothers, and More for Energy Safety
GPM	Gaussian Plume Model
IAEA	International Atomic Energy Agency
IBEW	International Brotherhood of Electric Workers
ICRP	International Commission on Radiological Protection
JLDC	Jangahn-eup Local Development Council
KAPH	Korean Association for Physicians for Humanism
KARP	Korean Association for Radiation Protection
KEEI	Korea Energy Economics Institute
KEPCO	Korea Electric Power Corporation
KFEM	Korean Federation for Environmental Movement
KHNP	Korea Hydro & Nuclear Power
KINS	Korea Institute of Nuclear Safety
KNS	Korean Nuclear Society
KREEC	Korea Radiation Effect and Epidemiology Cohort
LOCAs	Loss-of-coolant accidents
MACCS	MELCOR Accident Consequence Code Systems
MEST	Ministry of Education, Science, and Technology (Korea)
MST	Ministry of Science and Technology
NABO	National Assembly of Budget Office
NCI	National Cancer Institute
NEI	Nuclear Energy Institute
NEMA	National Emergency Management Agency
NEPA	National Environmental Policy Act
NJDEP	New Jersey Department of Environmental Protection
NNBCCC	No Nukes Busan Citizens Countermeasure Commission
NNCR	Naa-Nasan Coalition for Relocation
NRC	Nuclear Regulatory Commission
NRDC	Natural Resource Defense Council, Inc.
NSSC	Nuclear Safety and Security Commission
NWPA	Nuclear Waste Policy Act
NYAREA	New York Affordable Reliable Electricity Alliance
PBCC	Pan-Busan Citizens Coalition For Permanent Shutdown of Kori 1
PHWR	Pressurized Heavy Water Reactor

PRA	Probabilistic Risk Assessment
PSHA	Probabilistic Seismic Hazard Assessment
PSR	Periodic Safety Report
PUCC	Pan-Ulsan Citizens Coalition to Permanently Shut Down Kori 1 and Wolsong 1
PWR	Pressurized Water Reactor
RPHP	Radiation and Public Health Project
SAMA	Severe Accident Mitigation Alternatives
SEIS	Supplemental Environmental Impact Statement
STROC	Stop the Relicensing of Oyster Creek
U.S. DOE	United States Department of Energy
U.S. EIA	United States Energy Information Administration
U.S. EPA	United States Environmental Protection Agency
VDPS	Vermont Department of Public Service
WCD	Waste Confidence Decision
YBDC	Yangbuk Development Council

1. License renewal of nuclear power plants in the United States and South Korea

1.1. Introduction

1.1.1. Extending the licenses of nuclear power plants

For more than a half century, nuclear power has been an important source of energy in many parts of the world. 450 nuclear power plants are currently supplying electric power around the world (IAEA 2016). Numerous countries rely on nuclear power as their major source of electricity. Nuclear power accounts for nearly 75 percent of electricity produced in France. In the United States, electricity generated by one hundred nuclear power plants accounts for 19 percent of the annual gross generation. In Canada and Germany, nuclear power generates approximately 16 percent of the electricity produced. And, in South Korea, it accounts for nearly 35 percent of gross annual electricity production (World Nuclear Association 2016a; World Nuclear Association 2016b; World Nuclear Association 2016c; World Nuclear Association 2016d; World Nuclear Association 2016e).

Nuclear power plants have what is called a "design lifetime." When engineers first design a reactor, they set a life expectancy, or period during which the plant can be expected to operate while maintaining adequate levels of safety. This is the original design lifetime; and, it varies depending on which nuclear regulations apply. In the

United States, for example, the Nuclear Regulatory Commission (NRC) limits design lifetime to 40 years[1], whereas in France, nuclear power plants are limited to a 30-year lifetime. In South Korea, original design lifetimes range from 30 to 60 years. Regulators and nuclear engineers claim that such variation in design lifetime does not indicate that nuclear plants are not actually safe beyond that point. For example, the U.S. NRC claims that it limited the design lifetime to 40 years not because of the limitations of nuclear technology, but because of "economic and antitrust considerations" (NRC 2015a). Indeed, regulatory agencies in most countries where nuclear power plants operate have claimed that plants can operate safely for quite a few years beyond the design lifetime, as long as they ensure that appropriate safety measures are implemented and careful monitoring is ensured.

Partly because of extended operation beyond original design lifetimes, nuclear plants around the globe are ageing. As of 2016, approximately 55 percent of all nuclear plants have operated more than 30 years (IAEA 2016) (Figure 1.1). Extending the operation of a nuclear plant beyond its design lifetime involves license extension or license renewal.[2] The terms under which licenses are renewed vary by country. In the United States, nuclear plant owners are allowed to operate for additional 20 years once they receive approval from the NRC. In France, Japan, and South Korea, plant owners

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[1] Recently, some nuclear companies are trying to extend the original design lifetime of nuclear plants from 20 years to 40 years. For example, Exelon has recently announced that it will seek for federal regulatory approval to renew the operating licenses of Peach Bottom facilities so that they can run the facilities for as

[2] Countries have named the operation of nuclear plants a few years beyond the design lifetime differently. In South Korea, it is called "continued operation" while it is called "license renewal" or "relicensing (re-licensing)" in the United States. To ensure coherence, I will use the "license renewal" and "relicensing" throughout my thesis.

can get their operating licenses renewed once every 10 year after the plants reach their initial design lifetime. In Canada, operating licenses are renewed every 5 years and plants must be refurbished. In all of these countries, regulators undertake extensive safety checks before they approve license extensions. Plant owners and/or operators must also conduct a variety of safety and environmental assessments before they can get their operating licenses renewed. The review processes may take months, even years, to complete depending on the intensity of public opposition and complexity of the safety issues that need to be addressed.

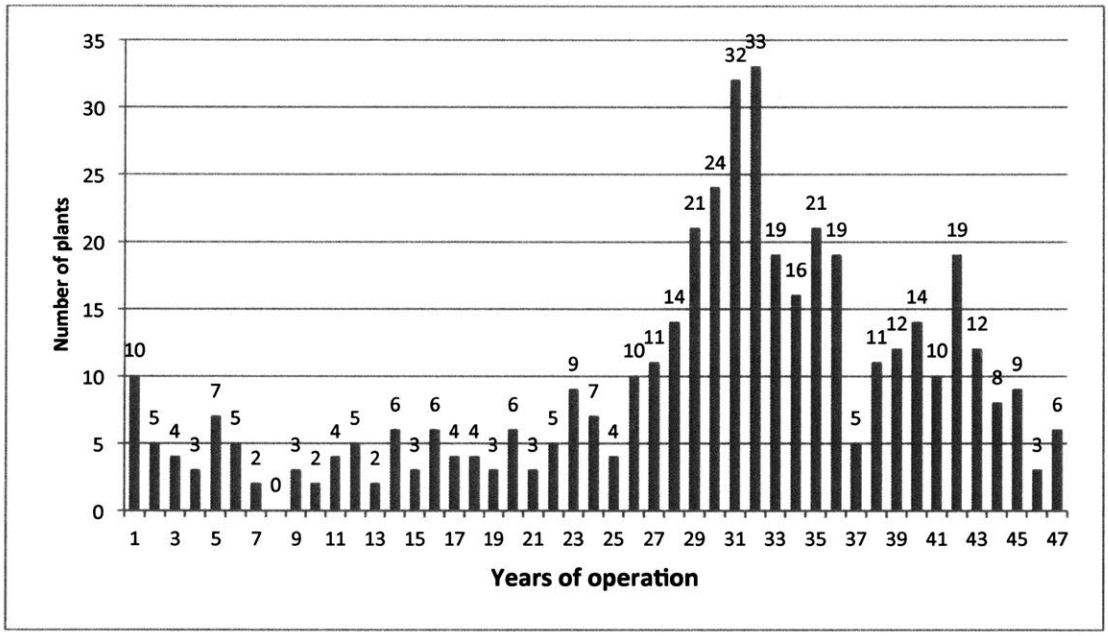

Figure 1.1 Operation period of existing nuclear power plants worldwide
Source: IAEA 2016. *Nuclear Power Reactors in the World.* p. 78

1.1.2. The need for nuclear license extensions

Why are license renewals allowed? Nuclear plants have been a primary source of stable and reliable energy supply along with coal power plants for quite a few years.

The fact that nuclear plants are on line 90 percent of each year and capable of providing electricity in a steady manner makes them a major source of base-load power.[3] Renewable energy supplies are often thought to be relatively more susceptible to weather and climate conditions (Breslow and Sailor 2002; Pryor and Barthelmie 2010; Schaeffer et al. 2012).

One essential benefit of license extension is that it may help reduce energy costs by avoiding the need to build new nuclear power plants. Nuclear license extension involves virtually no construction costs, although ongoing maintenance costs may increase. Nuclear power plants typically require large upfront construction costs and relatively long project cycles.[4] These push financial charges up. Studies show that nuclear plant construction costs in the United States escalated exponentially in the late 1970s and early 1980s primarily due to project delays.[5] The license renewal of nuclear power plants was considered as an economically efficient means of generating electricity even in countries that succeeded in reducing construction costs. For example, in South Korea, which has been able to reduce the construction cost (Lovering, Yip, and Nordhaus 2016), it was projected the license renewal would be economically beneficial. Although the interpretation of the cost-benefit analysis is still controversial,

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[3] Base load power sources refer to those facilities or plants that can generate reliable power and consistently meet the demand.

[4] Economic benefits and losses associated with the construction and operation nuclear power plants are controversial issues because these estimates vary depending on the political environment during which nuclear power plant siting takes place, as well as the methods used in cost-benefit analyses.

[5] The overnight cost of building a new nuclear power plant in the United States grew from USD 1,500 /KWe in the early 1960s to USD 5,339/KWe in 2010 (U.S. Energy Information Administration 2010). The cost increase was particularly evident after the Three Mile Island (TMI) accident that created negative image about nuclear power, suggesting that licensing and regulatory delays may have accounted for much of the increase.

Korea Hydro and Nuclear Power (KHNP) projected that the net profit associated with license renewal of Wolsong 1 would be 140 - 390 million U.S. dollars larger than the net profit associated with permanent shutdown (K. Park 2014). In sum, the extended operation of nuclear plants, which avoided the construction delays associated with building new plants, was deemed economically desirable around the world.

Nuclear power is also presumed to account for certain environmental gains, such as reductions of greenhouse gas emissions. License renewal of exiting nuclear plants is seen as one way of obtaining these benefits. The energy sector is one of the largest contributors to global greenhouse gas emissions. For instance, in 2014 and 2015, approximately 30 - 37 percent of global greenhouse gas emissions were produced from the U.S. electricity sector alone, through burning of coal, natural gas and oil (US EPA 2016; U.S. EIA 2016b). And, the greenhouse gas emissions from the global energy sector grew rapidly (around 3 percent per year) between 2000 and 2010 (IPCC 2014). Nuclear power plants, including both new and the existing ones, can reduce this growing emission level. Researchers who led a comprehensive study on the future role of nuclear power suggested that the nuclear power industry should be maintained despite large upfront costs because it is an important "carbon-free source of power" that can meet future electricity demand (MIT 2003). They calculated that1 million MWe[6] of nuclear-powered electricity could avoid approximately 1,800 million tones of carbon equivalent emitted by coal-fired plants annually. Based on these arguments about the

[6] The study assumes that this amount of nuclear power generation may be achieved by having 1,000 nuclear reactors with 1,000 MW capacity for each.

benefits of nuclear power in the U.S. electricity sector, the NRC even proposed new regulatory guidelines that would enable nuclear relicensing a second time around, and allow nuclear plants up operate up to 80 years following initial licensing (Chediak and Crawford 2016b; NRC 2015c; NRC 2016b).

1.1.3. Regulating safety and environmental impact

Nuclear license extensions could affect long-term safety and environmental quality. For these reasons, relicensing requires regulatory oversight. Safety concerns include the status of materials used to build reactor pressure vessels. They may become weakened after long exposure to excessive heat.[7] Changes in vessel conditions, however unlikely, may increase the risk of subsequent core damage (Kirk 2013). Reactor containment buildings, designed to keep radioactive materials from reaching the environment during accidents, may also develop cracks over time. Emergency diesel generators may not continue to operate when or the way they are supposed to. Typically, all of these concerns are addressed in a risk assessment that analyzes the probabilities of various events that might lead to accidents of various kinds. And, as I will show in Chapter 2 and 3, probability risk assessment (PRA) techniques were used in both the United States and South Korea for conducting the analysis. Using this technique, many threats to safety can be identified and addressed if appropriate measures are taken. Thus, it is relatively common for regulators to require nuclear plant

[7] Like coal power plants that produce power by heating coals, nuclear plants generate power by heating nuclear fuels. When nuclear fuels burn, they generate enormous amount of heat within the reactor pressure vessels.

operators to inspect all structures, components, and equipment, and to monitor the effects of aging on them.

License extensions often raise questions about potential environmental impacts, especially cumulative environmental effects since license extensions must cover an additional ten years of operation or more. The environmental issues that are often raised by environmental advocacy groups include the long-term environmental impacts of spent nuclear fuel, off-site radiological impacts of both normal operation as well as possible accidents that might occur during the renewal term, the effects of various cooling systems on endangered species, and the effects of temperature increases caused by thermal plume release to nearby water bodies (Greenpeace 2014).

In some countries, regulators conduct extensive reviews to address these concerns. In the United States, the NRC oversees all decisions about managing spent fuel on site, aiming to protect public health and safety during the renewal term. Since it involves high levels of radioactivity, spent nuclear fuel is one of the key sources of long-term environmental risk associated with nuclear relicensing. This issue has also often been at the heart of public perceptions of risk associated with nuclear power plants. Spent fuel rods can be stored safely in water pools located at the reactor site but they must cool down for at least five years before they can be packed into dry casks. Even then, they may have to sit at plant sites for decades because permanent repositories do not exist in many countries.[8] Furthermore, license extensions increase

[8] Many countries with nuclear plants, except Finland and Sweden, have not yet been able to construct permanent repositories.

the volume of spent fuel generated by each reactor. Temporary storage areas at each site may become packed with spent fuel assemblies posing greater risks than what had originally been forecasted at the time of plant construction. It was suggested that a loss of water from a high-density spent-fuel pool would likely heat up to the point where it catches fire and have serious consequences (Sandia National Laboratory 1979). It was also projected that spent fuel heat-up would be strongly affected by factors such as the availability of open spaces for air flows and building ventilation rates (Energy and Environmental Science, Inc. 2001). A 1997 study conducted for the NRC estimated that a spent-fuel fire at a pressurized water reactor (PWR) could release highly radioactive substances (Brookhaven National Laboratory 1997). Environmental groups often express fear about inadequate protection of spent fuel against external threats and hazards of various kinds, as well as potential leaks of radioactive substances caused by careless operation and inadequate maintenance during renewal term operations (Greenpeace 2014). So, the U.S. NRC examined whether the risks associated with spent fuel storage are within acceptable levels given the protective measures and actions proposed. The results of the studies on the environmental impact of storing spent fuel, as well as other impacts associated with nuclear relicensing, were documented in the Generic Environmental Impact Statement (GEIS) and used as a scientific basis of the regulatory reviews (I will explain about the conclusion that NRC made in the GEIS later in this chapter when I describe about the license renewal process in the United States).

1.1.4. Purpose of this thesis

In this thesis, I intend to examine conflicts that emerged in relicensing existing nuclear power plants in South Korea and the United States. The two countries are at different stages in the history of nuclear relicensing. In the United States, more than 80 license renewal approvals have already been granted (as of 2016), and the regulatory process has become quite standardized. In contrast, in South Korea, the regulatory framework for nuclear relicensing is still evolving, and only two license renewal approvals have been granted. The two countries have vastly different approaches to public engagement in the license renewal decisions. I examine the sources of conflicts surrounding relicensing decisions in each country and compare the responses in each case. In doing so, I intend to provide regulators, policy makers, and dispute resolutions practitioners some useful suggestions regarding possible ways of addressing future relicensing conflicts that are likely to arise.

1.1.5. Research design and method

I conducted selective comparisons of the cases that entailed public opposition to nuclear license renewal in South Korea and the United States. I conducted semi-structured interviews and collected secondary data to investigate the different types of disagreements. These data were used to examine why and how activists and local communities supported or opposed to relicensing decisions. Interviews were conducted with interested parties including those who chose to participate in federal adjudicatory proceedings, public hearings, negotiations or mediations and those who did not. In total, 56 interviews were conducted and transcribed. The interviewees include elected

politicians, local officials, and officers from regulatory and administrative agencies; workers and managers at nuclear power companies, utility companies, and interested industrial associations; representatives from environmental or anti-nuclear groups (both national and local level), regional planning commissions, town or municipality planning commissions, and local communities; and finally, academics in nuclear engineering and public health fields who themselves are either activists or engaged in crafting supporting evidence for both opponents and supporters of relicensing decisions. In the following section, I first describe the role that nuclear power has played in each country and the regulatory processes that have been put in place to regulate the relicensing of nuclear power plants.

1.2. License renewal of nuclear power plants in the United States

1.2.1. The role of nuclear power and the need for nuclear relicensing in the United States

In the United States, existing nuclear power plants have played a significant role in producing low-carbon electricity. 99 nuclear plants located in 30 different States generate up to 797 billion Kwh annually, which accounts for nearly 20 percent of all electricity generated in the United States each year (U.S. EIA 2016a). These plants have been the main sources of "clean" energy production. According to the U.S. Energy Information Administration (U.S. EIA), nuclear plants have accounted for more than 60 percent of all low-carbon electricity produced in the United States since 1980s. Advocates of nuclear power argue that the retirement of existing U.S. nuclear plants

would have significant implications for the level of greenhouse gas emissions (U.S. Energy Information Administration 2015) (see Figure 1.2). They project that "early" retirement of existing nuclear plants could contribute to annual carbon emissions increase. For instance, according to the Nuclear Energy Institute (NEI), fourteen reactors have shut down in recent years, which resulted in between 47 million tons and 64 million tons of increased carbon dioxide emissions (NEI 2016). Another five plants are likely to close within a couple of years, resulting in another 19 million tons of the increased carbon emissions (Martin 2016).

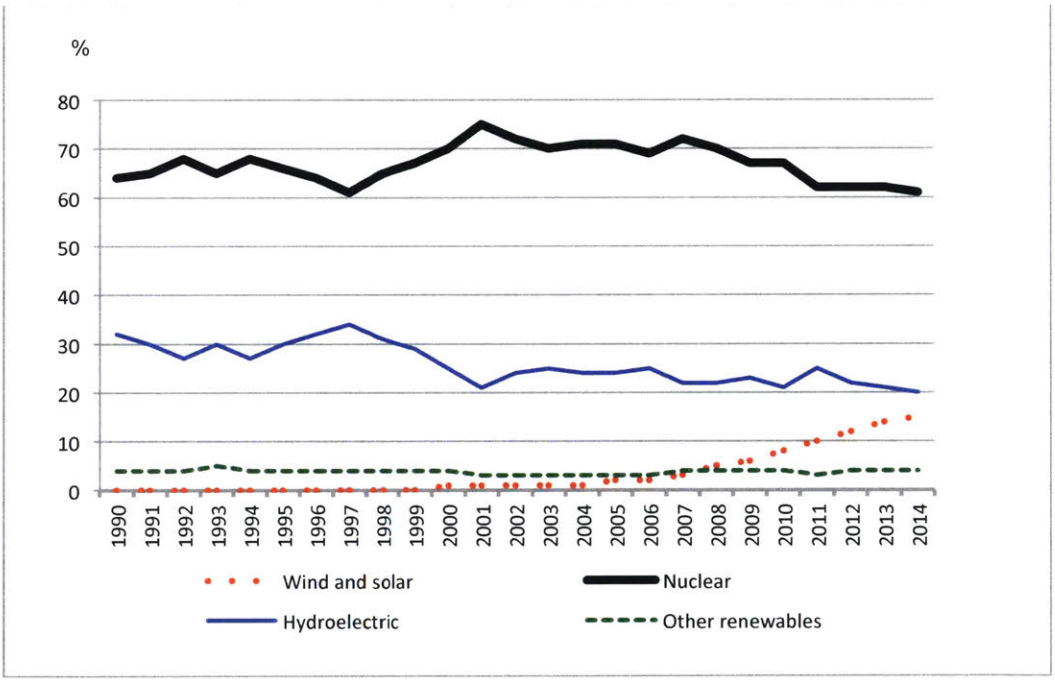

Figure 1.2 Share of non-carbon generation by source 1990-2014
Source: U.S. Energy Information Administration 2014

Recently, the U.S. Environmental Protection Agency (EPA) has highlighted the "decarbonizing effects" of nuclear power as part of the U.S. Clean Power Plan (CPP)

developed under the Clean Air Act (U.S. EPA 2015). Under the CPP, incentives are provided for construction of new nuclear plants, as well as nuclear plants that receive a capacity uprate as a result of the relicensing process. Following EPA's announcement, a number of states appear to be considering or implementing plans to provide tax credits to private nuclear companies as a means of cutting carbon emissions (and preventing plants from shutting down). For example, in 2016, the New York Department of Public Service approved a plan requiring utilities such as the New York Power Authority to purchase Zero-Emissions Credits from nuclear plant operators. Just like EPA, the State of New York also recognizes nuclear power plants as "Zero Carbon Electric Generating Facility." According to the this plan, Zero-Emission Credit is provided for the generation of a nuclear power plant of one megawatt-hour of electricity that is considered to have zero-emissions attributes. And, utilities and energy suppliers in New York would pay for the intrinsic value for carbon-free emissions from nuclear power plants by purchasing those Zero-Emission Credits (The State of New York 2016). In short, various policy mechanisms that recognize both the need and potential benefits of nuclear power have been recently introduced in the United States.

1.2.2. The regulatory process

In the United States, the license renewal process requires that both a technical review of safety issues and an environmental review be conducted as part of each application. 10 C.F.R. 54., 10 C.F.R 51. Licensees must describe aging management strategies and demonstrate that the relevant structures and components (e.g., reactor vessels, steam generators, and pipelines, etc.) can safely operate during extended

operations.[9] The NRC reviews these safety assessments to decide whether they adequately protect public safety.

NRC also examines various potential off-site environmental impacts associated with the continued operation of plants. Among these are impacts likely to be caused by refurbishment, installation of cooling tower technologies, and possible releases of radioactive materials under postulated accident conditions; impacts on water quality, human health, local land use, and socio-economic conditions; and finally, environmental impacts associated with managing spent nuclear fuel and other radioactive materials. In 1996, NRC published Generic Environmental Impact Assessment (GEIS), examining 92 possible environmental impacts that could occur as a result of nuclear plant relicensing (NRC 1996). These issues included the environmental impact of spent nuclear fuel and postulated accidents. NRC requires site-specific assessments for the issues that could not be applied to all plants due to differences in reactor designs, as well as those issues in which the benefits of plant-specific mitigation measures would be significant. Environmental issues that NRC requires site-specific assessments included the effects that cooling towers and the release of thermal plumes could have on local ecosystems, as well as the effects of measures and programs that might be used to mitigate the impacts of severe accidents. These provide information that supplements the GEIS. The NRC reviews both the existing GEIS and the site-specific environmental impact assessment to determine

[9] The NRC documented lessons learned from operating nuclear plants and compiled plant aging information in a report called the "Nuclear Power Plant Generic Aging Lessons learned (GALL)" report. In doing so, the NRC examined which generic existing programs are augmented for license renewal and which generic programs would adequately manage aging effects without change.

whether relicensing could pose new and significant impacts. It then makes preliminary judgments about whether the projected environmental impact is likely to be within acceptable levels.

It is important to note that the license renewal applicants need not examine issues that the NRC had established as generic in the GEIS. NRC had concluded that nuclear relicensing would have insignificant impact in the 68 environmental issue areas and that these findings could be applied to across all nuclear relicensing cases without additional site-specific analyses. As I will describe in Chapter 2 and 3 in detail, the NRC's conclusion about generic environmental impact became one of the main sources of conflicts in various nuclear relicensing cases in the United States.

Under the NRC regulatory framework, interested parties and individuals are given opportunities to participate in both the safety and environmental reviews. They can do so by coming to the scoping meetings, writing letters during public comment periods, speaking at public meetings, hearings or adjudicatory hearings (Figure 1.3). Concerned groups are typically invited to participate in scoping sessions held at the very beginning of each relicensing effort. At these meetings, stakeholders can ask questions about the scope of the environmental reviews the plant owner is considering. They can ask NRC staff to focus special attention on environmental issues that are particularly important to them. For example, during the EIA scoping session for the license renewal of Pilgrim Nuclear Power Plant Station, Pilgrim Watch, a local antinuclear group, demanded that the NRC carefully evaluate how the applicant planned to evacuate the public during emergency situations. After the scoping

meetings, license renewal applicants prepare and submit the Draft Supplemental Environmental Impact Statement (SEIS). NRC technical staffs conduct a thorough review of both the safety assessments and the draft SEIS. The public also reviews them and makes comments on them. In addition, the public stakeholder groups may request a formal adjudicatory hearing.

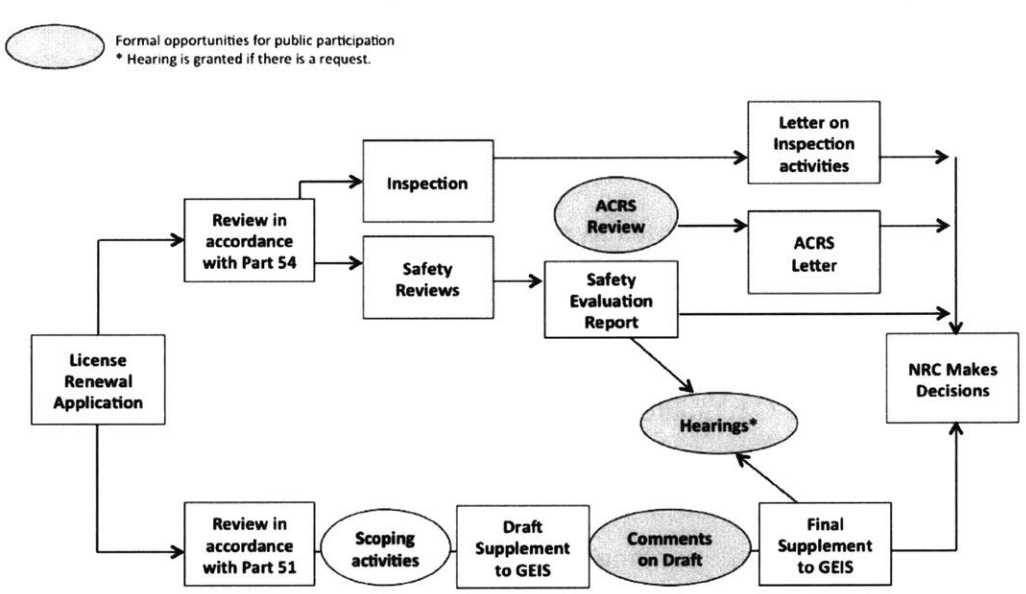

Figure 1.3. Nuclear license renewal process in the United States
Source: U.S. Nuclear Regulatory Commission

Adjudication is one of the most unique features of the U.S. license and license renewal decision-making processes. Under the Atomic Energy Act, individuals, public interest groups, state and local governments and Native American tribes can petition to intervene if they feel that their interests and rights are negatively affected by the license renewal decisions and want to contest the adequacy of the license renewal applicants' safety and environmental impact assessment reports (U.S. NRC 2013). Adjudicatory

hearing processes are established upon the request of public interveners. The adjudication processes are presided by three-member atomic safety and licensing boards (ASLB), an independent trial-level adjudicatory body of the NRC. The three administrative judges usually consist of one attorney who has skills in conducting administrative hearings and two scientific experts who have knowledge and expertise in scientific or technical areas that are relevant to the contentions.[10] Interveners file their complaints with expert testimonies that support their claims. NRC staffs and license renewal applicants refute the contentions. ALSB judges hear complaints in a way similar to ordinary district court. Scientific evidence put forth by interveners, NRC staffs and applicants are cross-examined. And, ASLB judges make decisions about whether to allow or reject certain contentions.

Public participation in relicensing proceedings may seem very open-ended; however, the concerns of some groups do not always make it to the agenda. The public stakeholders' attempts to comment or have an input in the nuclear relicensing decisions have been turned down on various procedural grounds. For example, in the Palo Verde Nuclear Generating Station Arizona case, 12 citizens who lived outside the 50-mile Emergency Planning Zone (EPZ) raised concerns about negative environmental impacts and dangers of ageing reactors but were rebutted by the NRC (Kyne and Bolin 2016). In the Diablo Canyon case, San Luis Obispo Mothers for Peace challenged that PG&E's seismic hazards analysis is conducted based on outdated methods and

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[10] NRC website: "ASLBP Responsibilities."http://www.nrc.gov/about-nrc/regulatory/adjudicatory/aslbp-respons.html

assumptions but ASLB also rejected these contentions (Mothers for Peace 2015). In still another case such as the Indian Point case, both the Village of Buchanan and the New York Affordable Reliable Electricity Alliance (NYAREA) wanted to participate in the proceeding as the supporters of relicensing, urging that the relicensing procedure should take into account the environmental, health, and economic benefits of the continued operation of Indian Point nuclear plants (O' Neil 2007). Yet, the ASLB rejected them on the grounds that these contentions were not related to plant aging issues, and thus, irrelevant to the license renewal proceeding. In short, it is up to adjudicatory judges to decide whether particular claims are within the scope of a license renewal proceeding and whether they are supported by credible evidence. As I will discuss in Chapter 2 and 3, the exercise of regulatory discretion and the pre-defined scope of he proceedings were one of the key sources of conflicts in relicensing decisions.

1.2.3. Nuclear power plants with renewed operating licenses and plants that have shut down

In the United States, many nuclear reactors reached the end of their design lifetimes in the 2000s. Calvert Cliffs Nuclear Power Plants, located in Lusby, Maryland, were the first to apply for license renewal. And, it would have been the first to go through the formal adjudicatory process. The National Whistleblower Center, a non-profit group, filed its contention arguing that the plant would not be able to safely operate for additional 20 years. But the ASLB rejected this contention (Layton 1999). Oconee plant in South Carolina owned by Duke Energy Corp. was the second to apply for the license renewal. As in the Calvert Cliffs' case, the Chattoga River Watershed

Coalition petitioned the NRC for adjudication and was denied (Layton 1999). Since then, numerous nuclear operators applied for license renewal and went through the license renewal processes. By February 2016, 83 of the 99 operating nuclear plants had been granted approval to operate for an additional 20 years. This covers 80 percent of all nuclear power plants in the United States. Currently, 12 additional plants are under review, with applications from the few remaining plants expected soon. If these applications are all approved (and the plant owners decide to continue operations), more than 90 percent of all the nuclear plants in the United States will operate for 60 years.

Some relicensed plants have shut down despite the fact that they received approval to continue operating. For example, Dominion Resources, Inc. decided to shut down its Kewaunee Power Station in 2013. Duke Energy also announced in 2013 that it would shut down its Crystal River plant located in Florida. Entergy, Inc., which has operated a number of nuclear plants in the Northeastern part of the United States, permanently closed Vermont Yankee (in Vermont) and Pilgrim Nuclear Power Plant Station (in Massachusetts) in 2014 and 2015, respectively. Exelon will close Oyster Creek Nuclear Generating Station (in New Jersey) by 2019, which would be 10 years earlier than the initial end date of its renewed term.[11] In total, 14 reactors have now

[11] Others have given up trying to get license renewal approval from the NRC, and instead chose to permanently shutdown their plants. Southern California Edison closed San Onofre Nuclear Generating Station in 2014 while they were fixing steam generators. Pacific Gas & Electric (PG&E) proposed to shutdown Diablo Canyon Power Plants (California) when it was still under the license renewal review process (Nikolewski 2016). Similarly, Exelon recently announced its intention to close Clinton and Quad Cities nuclear plants located in Illinois by 2017 and 2018, retiring the plants years before the end of their operational terms.

been shut down or their owners have announced their early retirements since 2010 (McKinzie 2016). And, 9 out of 83 nuclear plants that have been relicensed either have been retired or will be retired within a few years (NRC 2016c).

Various factors have contributed to these early retirements including technical difficulties that seemed uneconomical for the owners to retrofit, adverse economic conditions such as the sudden drop in natural gas and electricity prices, new regulatory requirements that became more stringent following the Fukushima accident in Japan, and intense local opposition. I am not able to review the extent to which local opposition was the key factor in causing the early retirement of relicensed nuclear reactors. And, I am not able to quantify the cost of these shutdowns. However, it is clear from a number of renewal controversies that local opposition significantly delayed the relicensing processes. Public interventions at Oyster Creek, Vermont Yankee Pilgrim, Indian Point, and Seabrook significantly delayed the relicensing process. The NRC initially expected reviews to take approximately 30 months if an adjudicatory hearing is required, and about 22 months if there is no hearing. On average, however, it took approximately 27 months for the NRC to complete reviews of all the license renewal applications submitted thus far (Table 1 in Appendix). Thus, it is clear that review processes have slowed in recent years. Indian Point Nuclear Power Plant Station near New York City is an extreme case. It has been under regulatory review for nearly 10 years (Entergy filed its license renewal application in 2007). The NRC has yet to approve license extensions for those two reactors. Similarly, Seabrook nuclear power plant in New Hampshire has been under the regulatory review since 2010. And, its

license renewal has not yet been approved. I will now describe several of these relicensing controversies in a bit more detail.

1.2.4. Emerging controversies surrounding license renewal of selected U.S. nuclear plants

Opponents at some of the sites listed above have raised numerous concerns regarding safety levels associated with outdated reactor designs, power cables, degradation in parts of reactor vessels, and the adequacy of the existing emergency plans. They have also focused on environmental concerns including the long-term impact of spent nuclear fuel, the effects of once-through cooling towers on local ecosystems, and the lack of radiological impact monitoring provisions. They insisted that relicensing without substantial repairs and changes in operational programs would increase environmental risks. Recently, some of these groups have added concerns about the economic feasibility of license extensions. They argue that there are new financial pressures that nuclear plant owners will face because of changing market conditions for electricity, and that these could reduce safety margins or leave insufficient decommissioning funds (Resource Insight, Inc. 2009).

There are other groups, besides the nuclear power companies themselves, who support license extensions. Some municipal agencies and resident abutters have expressed worries that "early retirement" of nuclear plants will create financial hardships for local governments and plant employees. At Oyster Creek and Indian Point Nuclear Plant Sites, IBEW, the largest workers unions in the nuclear and electricity sector, supported the license extensions. To take another example, local residents in rural Carlton, Kewaunee County, Wisconsin, were deeply concerned that the closure of

Kewaunee nuclear plant would dampen the local economy and undermine their livelihoods (Bosman 2015).

1.3. License renewal of nuclear power plants in South Korea

1.3.1. The role of nuclear power and nuclear relicensing in South Korea

In South Korea, nuclear power is a main source of domestic energy and has helped the country reduce its dependence on oil and gas imports. As of the end of 2015, there are 28 nuclear power plants in Korea: 24 are operating and 4 are under construction (Ministry of Science, ICT and Future Planning 2016). These plants generate approximately 30 percent of all the electricity produced annually, meeting a growing demand for power caused by the growth of the national economy (Table 1.1) (Korea Energy Economics Institute 2014). As in the United States, nuclear power is also the main source of low carbon energy in South Korea. In 2009 alone, Korean nuclear plants helped reduce greenhouse gas emission by the equivalent of 1.4 million ton of carbon (Cho, Kim, and Kim 2010).

Table 1.1. Energy production by source (Unit: GWh)

	Nuclear	Coal	LNG	Oil	Others	Total
2005	146,779	134,892	57,962	16, 385	8,352	364,370
	40.3%	37.0 %	15.9 %	4.5 %	2.3 %	100.0 %
2014	156, 407	203,765	111,705	7,759	41,773	521,409
	30.0 %	39.1 %	21.4 %	1.5 %	8.0 %	100.0 %

Source: Statistics of Electric Power in Korea (KEPCO 2015)

Updating foreign nuclear reactor designs, and relicensing the earliest reactors built in Korea, are indicators of the nation's technological achievements (Jasanoff and Kim 2009; S.-Y. Kim 2014). The South Korean government initially relied on nuclear scientists who had been sent to Korea from the United States, France, and Canada when it built its earliest nuclear reactors. Kori 1, the first nuclear power plant in South Korea, was constructed with technical assistance from Westinghouse engineers. Wolsong 1, the second nuclear power plant and the first Pressurized Heavy Water Reactor (PHWR), was built in collaboration with nuclear engineers from Canada. Since then, Korean nuclear engineers have been able to "catch-up" and develop their own nuclear reactor designs and export them (Jasanoff and Kim 2013; Lovering et al. 2016).[12] Relicensing the earliest reactors built with foreign nuclear technologies will require extensive safety reviews, as well as repairs to exiting structures.

1.3.2. Nuclear power plants that are relicensed and permanently shutdown

Korea is still a young country when it comes to nuclear plant relicensing. Only two out of twenty-five nuclear power plants have been allowed to operate for an additional ten years beyond their initial design lifetime. These were built between the late 1970s and early 1980s. Korea relied on assistance from abroad, then used these as

[12] Korea Electric Power Corporation (KEPCO), a state-owned power company that owns and operates all 25 Korean nuclear plants, eventually developed its own nuclear reactor designs and a series of technologies called OPR-1000 and Advanced Power Reactor-1400 (APR-1400). These were not only certified by the U.S. NRC but are also being used in building four domestic nuclear reactors and four others in United Arab Emirates (UAE) (KEPCO).

opportunities to learn how to design, build and operate different types of reactors.[13] Thirty years later, these initial facilities are serving again as opportunities to gain both technical and political experience with nuclear plant relicensing. Kori 1 was relicensed in 2007 at the end of its first 30-year design lifetime. KHNP was initially planning to get its operating license renewed for a second time; but, in June 2015, it withdrew its application and decided to permanently shut the plant down. KHNP began refurbishing Wolsong 1 in 2009, and got it relicensed in February 2015 after nearly two years of debate about seismic risk and safety systems installed at the plant.

1.3.3. The regulatory process of relicensing nuclear power plants

As in the United States, the continued operation of nuclear plants in Korea is regulated under the Atomic Energy Act. Under the Korean Atomic Energy Act, nuclear plants must receive a regulatory approval for continued operation every ten years once they reach their original design lifetimes. Enforcement Decree of the Atomic Energy Act, §42:4.[14] Initially, there had been no separate regulatory agency handling nuclear issues (at least up until the Fukushima accident). So, the Ministry of Education, Science, and Technology (MEST) and the Korea Institute of Nuclear Safety (KINS) both reviewed applications for continued operation. The Nuclear Safety and Security Commission (NSSC) was established in 2011. It now regulates nuclear safety issues, including the ones associated with the continued operation of all nuclear plants. KINS

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[13] Kori 1 is a Pressurized Water Reactor (PWR) and Wolsong 1 is a Pressurized Heavy Water Reactor (PHWR).

[14] This is not uncommon way to renew licenses of nuclear power plants. In many other countries like the UK and Japan, license renewal processes are based on the extensive periodic safety review (IAEA 2010).

still provides expertise on nuclear safety matters, helping to identify technical problems that must be addressed prior to the continued operation. After several rounds of technical feedback and discussion with KHNP, KINS drafts a review and send it to the NSSC. Based on these reports, the NSSC makes a final decision about whether to renew a license.

To get an approval for a license extension, KEPCO must conduct safety assessments called a "Periodic Safety Report" (PSR). Presidential Decree No. 19044, Sep. 14, 2005. This consists of technical assessment of the aging components of a nuclear plant and the potential radiological impacts on the environment that might result from continued operation of a reactor. In the PSR, KEPCO must address safety factors such as the actual physical condition of the plant, technical means to manage problems of aging, organizational and administration problems, emergency planning and potential impacts on environment (Jin et al. 2009). A PSR must be submitted at least two years before the end of the initial license term. Since 2013, the NSSC has required an additional safety assessment called a "Stress test" that examines whether a nuclear plant has sufficient safety margins when it comes to dealing with extreme natural hazards such as earthquakes, loss of safety systems or other severe accidents. KHNP had to meet these technical requirements when Wolsong 1 was reviewed for license renewal.

Korea is also a young country when it comes to public engagement in nuclear regulatory decisions. Regulations about nuclear license renewal, particularly regarding the engagement of concerned parties, were not fully shaped when Kori 1 neared the end

of its initial license term. Public engagement rules and norms have evolved in practice, mostly through learning-by-doing. As I illustrate in Chapters 2 and 3, they have become more open to the public discussion of safety assessment studies than they initially were. The reforms made with respect to license renewal decision-making processes in Korea provided opponents increased opportunities to present their concerns and different views about risk and benefits associated with relicensing. As a result, opponents' strategies to challenge the credibility of scientific assessments were similar to those used by activists in the United States. I will describe the format for public engagement in the first two Korean relicensing cases by briefly narrating what actually occurred.

Officially, KHNP was not required to engage the public prior to 2015 when a legal provision was changed in the Atomic Energy Act. As a result, public stakeholders in South Korea had relatively little input into regulatory review of nuclear plant relicensing during the first nuclear relicensing case. When it first applied for the continued operation of Kori 1, KHNP relied on what is called the "Decide-Announce-Defend" approach. That is, it made an internal decision to relicense; conducted safety assessments and circulated their results among nuclear experts, engineers, and regulators at KHNP, KINS, and MEST; announced its decision to the public after discussions with regulators were concluded; and tried to justify its license renewal plan to the public. The angry public who thought their concerns had been bypassed attempted to block the final approval by mobilizing street protests. Only then, were local representatives able to participate in community-corporate negotiations that subsequently produced community benefit agreements (Park 2008; Jeong 2011).

KHNP changed its approach when it came time to seek permission to re-operate Kori 1 after a station blackout (SBO) accident at the site. The public perception of risk associated with nuclear plants was particularly high at that time because the accident occurred a year after the Fukushima accident. In response to the local communities who expressed concerns about the secret way in which the Kori accident was initially handled, KHNP established an ad-hoc joint review committee so that local representatives could examine safety assessment reports and participate in their review.

In the absence of rules to guide public participation during relicensing, the ad-hoc joint review process became the basis for public engagement used in the Wolsong Case. This was the second license renewal case in Korea but the public engagement process was still not well established. There were multiple rounds of reviews, and a number of entities were in charge of those reviews. First, local representatives and environmental groups opposed to the relicensing were invited to participate in a joint review of the Stress test results (after they were submitted to the NSSC). Nineteen members convened by KINS served on Citizen Review Board (CRB).[15] The NSSC structured the joint review so that KINS and the CRB could review the results of KHNP's "Stress tests" first. When disagreements became too difficult to unravel, representatives of each CRB and KINS review team would convene and form a Comprehensive Joint Technical Committee (CJTC). Initially, KINS and CRB were

[15] On behalf of the NSSC, KINS convened stakeholder groups who might have a stake in the final license renewal decision. The members of the CRB include seven community representatives from three local municipalities near Wolsong 1, five representatives from environmental groups including KFEM, Greenpeace, and Green Korea; and professors and engineers in the fields related to the scope of the "Stress tests" including geoscience, energy, mechanical engineering, and nuclear emergency management.

going to jointly submit a report to the NSSC, identifying both points of their agreements and disagreements. Then, the NSSC Resource Panel would review these reports and provide further suggestions to the NSSC Commissioners to facilitate their judgments and decision-making. The NSSC Commissioners would review both the reports and listen to the advise of the Resource Panel and make a final license renewal decision.

In the Wolsong Case, the license renewal process did not go as it was initially planned. Through the CJTC meetings, they tried to clarify differences and identify additional scientific inquiries that they thought were necessary (NSSC 2014). However, technical disagreements between the two committees increased rather than diminished. CRB members maintained that they could not accept KINS' conclusion about the safety of the license renewal (NSSC 2015a). CRB members decided to submit their review report separately to the NSSC Commissioners. NSSC Commissioners reviewed these documents. They also heard the complaints of the CRB members, as well as the advice of the NSSC panel and KINS engineers who supported the license renewal. Some NSSC Commissioners disagreed the experts' advice. Despite the unresolved disagreements, the Chairman of the NSSC proposed to make the final decision based on the majority rule. The majority of NSSC Commissioners voted in favor of relicensing. This decision was disputed immediately, and national environmental groups and coalitions brought the case to the Supreme Court seeking nullification. In the following section, I briefly summarize the issues that were at the heart of the controversies around the license renewal decisions.

1.3.4. Controversies surrounding nuclear license renewal in South Korea

In both the Kori and Wolsong cases, KHNP and the NSSC met with strong opposition from local residents and environmental activists. There were many disagreements about the benefits and risks of relicensing. These emerged at various stages of the review processes and particularly after the station black-out accident and a nuclear that uncovered bribery and faked safety tests for critical components of nuclear plants in Korea (Sang-hun Choe 2013). In both of the Korean license renewal cases, local residents dismissed KHNP's attempts to hold public information sessions, arguing that they had been economically distressed and exposed to risk for decades. They insisted that their economic and environmental harms and feelings of deprivation must be compensated. After the station blackout accident and the nuclear scandal, a local residents' coalitions raised public health and safety concerns including worries about corrosion in the reactor vessels, the threat posed by seismic risk, and the possible link between the long-term operation of nuclear plants and elevated levels of cancer. They demanded more opportunities to present their views on the issues that concerned them.

Environmentalists were worried that the plants under review were located too close to densely populated areas. They claimed that the region would suffer huge economic and environmental harm if there were an emergency. On the heels of the Fukushima accident, environmental groups such as the Korean Federation for Environmental Movement (KFEM) insisted that the plant would be vulnerable to some postulated accident conditions including major earthquakes. They contended that KHNP had not used a sound scientific approach when its staff engineers prepared their risk assessments. The economic and environmental harms that might result from the

potential reactor failures would be too great, they argued, especially because Kori 1 was located close to a metropolitan area. These disagreements remained even though KHNP tried to defend the credibility of its risk assessment techniques and scientists from the International Atomic Energy Agency (IAEA) and the U.S. NRC verified KHNP's claims. Eventually, environmentalists joined with a local family who claimed that they were the victims of cancer caused by the nuclear plant operation, and mobilized local citizens to collect additional evidence that led to a major lawsuit against the nuclear power company (Park and Cho 2014).

In the following chapters, I examine some of these disagreements in greater depth and compare how they were handled in the U.S. and South Korea. In Chapter 2, I focus in particular on disagreements in each country on determinations of the level of acceptable risk to human health and safety, disagreements about acceptable economic losses and the distribution of economic benefits, and disagreements about the credibility of risk assessment studies and disagreements about the scope of public involvement in making final license renewal decisions. In Chapter 3, I examine these types of conflicts comparatively, exploring similarities and differences, as well as possible factors that explain the similarities and differences. Finally, in Chapter 4, I lay out policy recommendations for regulators and policy-makers involved in nuclear plant relicensing.

2. Disagreements about environmental risk and benefits associated with nuclear relicensing

Stakeholders involved in the controversies around nuclear plants' license extension debates are often polarized. In this chapter, using a number of controversial cases, I describe in detail four types of disagreements that have arisen within the license renewal process in the United States and South Korea: disagreements about acceptable levels of health and safety risk, disagreements about acceptable economic gains and losses, different views about the credibility of risk assessment studies and the appropriate role of science in license renewal decisions, and disagreements about the appropriate scope of public engagement in the license renewal process. All four types of debates have emerged in both the United States and Korea around nuclear relicensing. In the first half of this Chapter, I discuss these disagreements emerged in the license renewal processes in the United States. In the latter half of this Chapter, I examine those that have arisen in South Korea.

In my description of the controversies surrounding nuclear relicensing decisions in each country, I explain the first and second types of disagreements, exploring how opponents of relicensing highlight various risk and safety issues such as the environmental impact of the nuclear fuel cycles (particularly spent nuclear fuel), the adequacy of evacuation plans, seismic risk, cancer risk and the risk of terrorist attack on

nuclear plants.[16] I also examine the claims of many supporters of nuclear relicensing who argue that the risk associated with relicensing is often more exaggerated than the technical estimates produced by formal risk assessments. In examining the second type of disagreement, I show how the opponents of license renewal assess the economic consequences associated with possible accidents and related plant maintenance costs. I contrast these claims with supporters' concerns about job losses and the losses to both the regional and national economy (in the Korean case in particular) if plants are not relicensed.

In describing the third type of disagreement that emerged in each country, I highlight the deep-seated differences between regulators/nuclear professionals and lay activists in terms of characterizing risk and uncertainty associated with the license renewal decisions. I show that the disagreements about the acceptable level of risk, in particular, involve deep-seated knowledge claims about whose understandings about risk and uncertainty are useful and legitimate in terms of providing preventive policy actions. Then, I explore the fourth debate about the appropriate scope of public engagement in relicensing. I'm interested in what happens when the concerned public claims that a particular type or level is not acceptable. How do regulators and risk assessors take such claims into consideration? There are both similarities and differences in the way that they are handled. I explore these in my comparative analysis

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[16] There are numerous environmental and safety concerns that were raised during the license renewal disputes. For the purpose of my analysis of contentious environmental issues, I focus on the concerns related to on-site spent fuel storage, evacuation plans, seismic risk, and cancer risk. I do not discuss other contentious environmental issues such as the adverse effects of once-through cooling system on local ecosystems (i.e., impingement of fish and shellfish an thermal effects).

in Chapter 3. In Chapter 2, however, I lay the foundations for this comparative analysis by presenting the details of four controversial nuclear license extension cases – two in each country.

2.1. Conflicts around relicensing nuclear power plants in the United States

2.1.1. Disagreements about the acceptable level of risk to human health and safety

Environmental risk associated with spent nuclear fuel

In the United States, one of the major public concerns about the risk associated with nuclear relicensing involves the off-site environmental impact of spent nuclear fuel. Much of this spent fuel is stored temporarily at power plant sites while the search for a long-term repository continues.[17] Spent nuclear fuel rods, or high-level radioactive waste (HLW), are initially kept in spent fuel pools to reduce the heat they contain. Then, they are put in dry storage casks adjacent to the nuclear power plants from which they came. Spent fuel rods are considered especially hazardous because they give off high levels of radiation for a long time. Although most of the radioactivity of spent fuel rods will have

[17] Since it enacted the Nuclear Waste Policy Act in 1982, the U.S. government has been searching for a national mined geological repository for more than 30 years. The United States Congress approved a plan to site the underground repository in the land located in Nevada in 2002. But this "Yucca Mountain Nuclear Waste Repository" project was highly contested by both the public and politicians, and eventually was abandoned in 2010 during the Obama Administration. The Department of Energy (DOE) now plans to make demonstrable progress on the siting and characterization of repository sites by 2048 (DOE 2013), but the feasibility of that plan is not guaranteed. In the meantime, DOE is also planning to utilize the reactor sites that are permanently shutdown as a pilot interim storage facility by 2021 (DOE 2013).

decayed after being buried for about 1,000 years (World Nuclear Association 2016c), the radioactivity of some radioactive elements such as Plutonium-239 will stay as long as 24,000 years (NRC 2015b). According to the U.S. NRC, the surface dose rate for a spent fuel assembly exceeds 1,000 rem per hour even after it is removed from the spent fuel pool, and this is much greater than the fatal whole-body dose for humans about 500 rem received all at once. Although the Nuclear Waste Policy Act (NWPA) was established as early as 1982 for the safe and permanent disposal of highly radioactive waste, the deep geological repository planned in the Act has still not been built. As a result, spent nuclear fuel assemblies are being kept at more than 100 individual plant sites around the country.

Every time the life of a nuclear power plant is extended, the amount of waste at that site increases and the risk to the public and to the environment posed by wastes store temporarily above ground increases. In the United States, many nuclear plants built in the 1970s have been allowed to operate for 20 years beyond their original design life. Thus, the total amount of accumulated spent nuclear fuel accumulated by the end of their renewed term increases 50 percent beyond the amount accumulated at the end of the 40 years of their initial operation (Oka Ridge National Laboratory 1991).[18] In the absence of a national mined geological repository, plant operators in the United States must store spent fuel on site by adding more spent-fuel racks,

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[18] As of 2016, the U.S. nuclear reactors have generated about 76,430 metric tons of spent fuel, of which 75 percent is stored in pools, according to Nuclear Energy Institute data (Nuclear Energy Institute Nuclear Statistics: http://www.nei.org/Knowledge-Center/Nuclear-Statistics/On-Site-Storage-of-Nuclear-Waste). And, the nuclear power plants around the country generate approximately 2,000 metric tons of spent fuel every year (DOE 2013).

reconfiguring storage facilities, or building dry cask storage facilities outside the reactors. Currently it is uncertain whether the risks posed by temporary storage at multiple sites will ever be eliminated by transporting all the waste (including the shut down cores of the reactors) to a nationally-managed secure site.

Regulators and the government agencies continue to argue that temporary storage of high-level nuclear waste does not threaten public health and safety. For example, the NRC issued a "Waste Confidence Decision (WCD)." In the WCD, it states that spent fuel can be stored safely at all nuclear plant sites without significant environmental impact for at least thirty years beyond the licensed life for operation (including the renewed license term) of that reactor. 10 C.F.R. §51.23. In 2010, the NRC updated the rule and confirmed that spent fuel could be stored for sixty years beyond the licensed life of a plant.[19] And, in the prepared in 1996, the NRC determined that the on-site storage of spent nuclear fuel poses insignificant environmental risk during a 20-year long renewed term. This finding is incorporated into the safety regulations used in making the license renewal decisions.10 C.F.R. §51.23. In their view, their finding is true across all nuclear plant sites regardless of the details of their design or location.

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[19] The NRC made its first WCD in 1984 and updated it in 2010, which basically claimed that the permanent geological repository is a technically feasible option, and will be made available. In 2010, they found that "spent fuel generated in any reactor [could] be stored safely and without significant environmental impacts for at least 60 years beyond the licensed life for operation", including the term of renewed license. 10 C.F.R. §51.23 (a), 10 C.F.R. §51.95 (c)(2). The decision implied that the spent fuel could be safely stored on plant sites until the repository becomes available, whenever that was going to be. The revised rule basically extended the period, during which the spent nuclear fuel can be stored on-site, beyond the licensed (and license renewal) operating life of nuclear power plants.

These views concern many local environmental groups and state governments, and they express their worries in the context of almost every proposed the license extension. The controversies around Oyster Creek, Indian Point, Vermont Yankee and Pilgrim Nuclear Power Plant Stations illustrate these concerns. In these cases, the State government agencies, attorney generals, and environmental groups claimed that license renewal applicants did not adequately examine the vulnerability of spent fuel pools to external shocks and fires in their environmental impact assessments of the specific relicensing requests. In the Pilgrim and Vermont Yankee cases, the Attorney General of the State of Massachusetts challenged the GEIS regulation and Entergy's Environmental Report, arguing that they had downplayed the risk associated with high-density storage pool fires and the increased likelihood of terrorist attacks.[20] The state claimed that the larger the quantity of spent fuel and radioactive material on the site, the higher the probability that spent fuel pools would catch fire. According to the experts the state hired, densely packed fuel can heat up to ignition temperature if the reactors suffer loss-of-coolant accidents (known as LOCAs) caused by large magnitude earthquakes or terrorist attacks (Alvarez 2003; Thompson 2007). They insisted that this logic would hold even though reactors are designed to shut down instantly in the event of an external disturbance. For environmental groups such as the Union of Concerned Scientists and Pilgrim Watch, this risk is a "real risk" (Thielman 2016) because spent fuel rods in these reactors are stored on the rooftop of reactor buildings and people

[20] Massachusetts Attorney General's Request for a Hearing and Petition to Intervene With Respect to Entergy Nuclear Operations Inc.'s Application for Renewal of the Vermont Yankee Nuclear Plant Operating License, etc. (May 26, 2006); Massachusetts Attorney General's Request for a Hearing and Petition to Intervene With Respect to Entergy Nuclear Operations Inc.'s Application for Renewal of the Pilgrim Nuclear Plant Operating License, etc. (May 26, 2006).

living nearby would be exposed to serious health risks if the reactor buildings exploded or radionuclides escaped through cracks in the buildings.

In the Vermont Yankee license renewal case, state agencies expressed concerns about the cumulative environmental impact of spent fuel stored on site. For example, Vermont Department of Public Service (VDPS) claimed that spent fuel would adversely impact both land and the rest of the natural environment since it would be on site for more than the period that the U.S. Department of Energy (DOE) had initially expected (Vermont Department of Public Service 2006). It urged that the NRC should not be overly optimistic about the availability of a national deep geological repository anytime soon. Indeed, they argued that the NRC should be planning for the possibility that a repository never becomes available, even after the plant permanently shuts down. According to the VDPS, these possibilities would impose long-term, site-specific burdens on local governments. They would have to deal with contaminated land, indefinite emergency management and permanent security, none of which were assumed in the NRC's Environmental Report (Vermont Department of Public Service 2006, 21). In the VDPS' view, NRC's generic approach to characterizing the environmental impacts and risks at each facility during periods of license renewal was inadequate. Eventually, the State Attorneys General in New Jersey, Connecticut, New York, and Vermont sued the NRC, collectively calling for site-specific re-evaluation of environmental impacts associated with on-site storage of spent fuel. In 2012, the D.C. Circuit vacated and remanded the Waste Confidence rule.[21] NRC suspended all

[21] *New York, et al. v. NRC.* 681 F.3d 471 (D.C. Cir. 2012).

relicensing processes for two years until it issued its Final Rule on Waste Confidence, addressing the concerns that had been raised (NRC 2012). Although this suspension was not applied to the Vermont Yankee case, the joint litigation that Vermont Yankee got involved in had significant long-range effects. The contention over the cumulative impacts of storing the fuel on sites continued even after the issuance of the revised rule. *Entergy Nuclear Vermont Yankee v. Shumlin*. No. 12-707 (2d. Cir. 2013).

Concerns about the environmental impacts associated with spent nuclear fuel generated multiple lawsuits that challenged the NRC's license renewal processes, particularly because the Atomic Safety Licensing Board (ASLB) and the NRC staffs viewed these concerns as unrelated to the scope of license renewal proceedings. The NRC staff and the ASLB judges claimed that terrorism concerns were security issues, which did not need to be addressed during license renewal because they were unrelated to the aging of nuclear reactors. I will expand my discussion of this issue later in this Chapter when I examine the disagreements about the scope of public engagement.

Challenging the adequacy of evacuation plans

When nuclear power plants were first sited, the NRC took various protective actions to help mitigate potential offsite consequences in the event of a severe accident. The creation of Emergency Planning Zones (EPZ) is one such protective measure. If there were a severe accident, NRC would evacuate people living within the EPZs and provides potassium iodine (KI) to all of them to help them prevent their bodies from absorbing radioactive iodine. While the radius of EPZs is normally as broad as 50 miles

from a nuclear plant,[22] not all people would be evacuated if there were an accident. Typically, emergency responders would focus on people within two miles of a plant and people living "downwind" from the projected path of a plume headed to bordering areas.[23] As a condition of their renewed license, plant operators are required to conduct Severe Accident Mitigation Alternatives (SAMA) analysis in advance. In the SAMA analysis, they forecast radioactive plume pathways or estimates of how long it will take for residents inside a 10-mile zone to evacuate under various conditions (NEI 2005).[24] Although nuclear plant operators are not required to re-examine their evacuation plans once they are approved, they must examine their SAMA analysis to receive a license renewal (NRC 1996).

Public contestation of nuclear relicensing decisions also sparked debate about the adequacy of existing emergency evacuation plans and the SAMA analysis. Environmental and local community groups have argued that existing evacuation plans are not adequate. They argue that the plans themselves and not just the analysis upon which they were originally based should be re-examined during any nuclear license renewal hearings. The claim has been stated most forcefully at plant sites located close to densely populated areas such as Pilgrim and Indian Point nuclear stations (the former

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[22] The EPZ areas consist of Plume Exposure Pathway and Ingestion Exposure Pathway EPZs Retrieved from the NRC website on Emergency Planning Zone (http://www.nrc.gov/about-nrc/emerg-preparedness/about-emerg-preparedness/planning-zones.html).

[23] NRC. 2014. "Principles of Evacuation." Retrieved from the NRC website: http://www.nrc.gov/about-nrc/emerg-preparedness/about-emerg-preparedness/protective-action/principles-evac.html).

[24] SAMA analysis is designed to assist nuclear plant operators in identifying low-cost measures that can significantly reduce off-site consequences in the event of a severe accident. The license renewal applicants must examine major undesirable events that can lead to core damage function and offsite risk, and identify measures that can reduce offsite risk significantly at a low cost. The most cost-effective measures are screened, and uncertainties associated with the SAMA analysis are examined (NEI 2005).

is located approximately 40 miles from Boston while the latter is located approximately 35 miles north of New York City). From local environmental groups' perspectives, the SAMA analysis seemed unrealistic particularly because it gave rise to evacuation plans that overlooked the importance of the unique local conditions at these sites. In the Pilgrim Case, Pilgrim Watch challenged that Entergy had not considered specific local meteorological conditions or evacuation times in forecasting dispersion of radioactive plume using an air pollution dispersion model called Gaussian Plume Model. It also failed to identify cost-effective measures that could be used to mitigate potential off-site impacts associated with license renewal using MELCOR Accident Consequence Code Systems (MACCS) code (NEI 2005).[25] Pilgrim Watch contended that the forecast of radioactive plume dispersion, which provided the basis for the evacuation plans, was inaccurate because the model input data on evacuation times and local meteorological conditions did not accurately represent the complex natural conditions in the Cape Cod area (Pilgrim Watch 2006).

In the Indian Point license renewal case, local environmental groups challenged both the evacuation plans and the SAMA analysis based on environmental justice claims. Local environmental coalitions including Hudson River Sloop Clearwater, Public Justice, Peekskill Environmental Justice Council (PEJC), physicians and environmental psychologists argued that Entergy had overlooked local socio-economic

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[25] SAMA analysis is designed to assist nuclear plant operators in identifying low-cost measures that can significantly reduce off-site consequences in the event of a severe accident. The license renewal applicants must examine major undesirable events that can lead to core damage function and offsite risk, and identify measures that can reduce offsite risk significantly at a low cost. The most cost-effective measures are screened, and uncertainties associated with the SAMA analysis are examined (NEI 2005).

conditions in its SAMA analysis. These groups claimed that Entergy had failed to account for the details of everyday living conditions such as the behaviors of public transit-dependent people, low-income ethnic groups, children housed in daycare centers and their families, and the elderly who are infirm and are unable to shelter-in-place (Clearwater 2011). To the environmental groups, the analysts' inattention to real-world conditions not only caused them to underestimate the risks to certain groups but also become a factor that disproportionally puts the most vulnerable section of the population at greater risk from radiation exposure.

A number of local residents joined this argument. They expressed disbelief about local people being able to get out in the event of an emergency. They argued that quick evacuation would be impossible due to daily traffic congestion and that the emergency bus drivers would not be responsible for evacuating schoolchildren from the emergency zone because they would be worried about their own children's' safety (acting to protect their own children first before showing up to evacuate other local children) (Claxton 2011).

Disagreement about the health impact of low-dose nuclear radiation

Stakeholders also disagreed about the cumulative environmental and health impact likely to result from the daily operation of nuclear power plants during a renewed term. The NRC's view has been that nuclear plants release only a small amount of radiation during normal operations and that there is little evidence of a link between cancer rate mortalities and proximity to nuclear plants. NRC refers to a 1991

study conducted by the National Cancer Institute (NCI)[26] to support this view. The NCI study investigated counties with commercial nuclear power plants and DOE nuclear facilities, and compared cancer mortality rates in these counties. After they examined over 900,000 cancer mortality records collected between 1950 and 1984 in the United States, the NCI researchers found no conclusive evidence of a causal link between cancer mortalities among the populations living nearby. Furthermore, they concluded that even if nuclear facilities posed a risk to neighboring populations, the risk was too small to be detected by their study. The NCI study has not been updated since it first was released[27]; nevertheless, NRC holds that the NCI conclusions are still true.

Opposition grassroots groups fear, despite the conclusion of the NCI study, that the long-term operation of nuclear plants might elevate cancer risk. The Oyster Creek Case illustrates how such concerns evolve. The story dates back to the 1980s. In 1989, a group of scientists established the Radiation and Public Health Project (RPHP) to study the relationship between low-level nuclear radiation and public health. They began a study known as "Fairy Tooth Project," during which they examined radiation levels in baby teeth samples collected from residents in New York and New Jersey. The RPHP scientists claimed that they had found high concentration of Strontium 90 –a radioactive substance known to adversely affect human health— in baby teeth collected in counties with nuclear plants (Gould et al. 2000b). RPHP researchers also insisted that

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[26] Jablon, Hrubec, and Boice. 1991. Cancer in populations living near nuclear facilities: A survey of mortality nationwide and incidence in two states. *JAMA.*

[27] More recently, the National Academy of Sciences (NAS) was planning to update research methodologies used in the initial NCI study and conduct a pilot study on a number of nuclear power plant sites (Wing, Richardson, and Hoffmann 2011). The study would have included a number of controversial license renewal cases such as Oyster Creek and San Onofre nuclear power plant stations but was dropped in 2015.

they discovered an increased incidence of cancer in children living near nuclear plants in New York and New Jersey. In sum, they concluded that children were susceptible to radiation exposure, even at relatively low doses.

Local grassroots organizations and residents living near Oyster Creek Nuclear power plant station became increasingly concerned about these findings. A group of local women found Grandmothers, Mothers, and More for Energy Safety (GRAMMES) to raise public awareness about health impacts associated with local nuclear plants (Tauro 2016). GRAMMES, Jersey Shore Nuclear Watch, New Jersey Public Interest Research Group (NJPIRG), and the Ocean County League of Women Voters joined the RPHP to organize campaigns to mobilize the public and local politicians about the health concerns during license renewal proceedings (Tauro 2016). They argued that RPHP findings, although they were preliminary and inconclusive, should be considered before approving any license renewal applications.

The fears raised by the RPHP studies also provoked criticism. NRC and the Nuclear Energy Institute (NEI) refuted local laypeople's health impact claims and criticized the RPHP findings. The NRC maintained that the methodologies used in the RPHP studies were flawed in a number of ways (NRC 2004b): the studies did not establish control populations nor isolate the effects of other risk factors. NRC claimed that the studies overgeneralized from small samples and were never subject to peer review. Both the NRC and NEI blamed nuclear weapons testing and the Chernobyl accident for the high concentrations of Strontium 90 (NEI 2014). Scientists from Westchester County, which hosted Oyster Creek nuclear plant, labeled the RPHP

studies as "junk science" (Newman 2003). The New Jersey Commission on Radiation Protection also indicated that its modeling suggested that the Sr-90 in baby teeth had not originated from Oyster Creek plant (New Jersey Commission on Radiation Protection 2006). Because of the criticism they received and the difficulties in proving the link, GRAMMES and other members of the Stop the Relicensing of Oyster Creek (STROC)[28] did not officially raise their health concerns during the license renewal proceedings (Tauro 2016; Gunter 2016).

In the U.S. license renewal cases, there are many versions of disagreements about risk that are similar to the ones I have just described. The essential nature of the debates is similar: the disagreements around the acceptable level of risk were linked to fundamental disagreements about the credibility of risk assessments and assumptions about public knowledge in the license renewal proceedings. I will illustrate these points further in my discussion about the disagreements that centered on the credibility of risk assessment studies and the scope of public engagement.

2.1.2. Disagreements about economic benefits and costs

In the United States, disagreements about economic losses and benefits stem primarily from different estimations and interpretations about the extent to which continued operation of a nuclear plant contributes to job creation, clean electricity

[28] GRAMMES, Nuclear Information Resource and Service (NIRS), New Jersey Sierra Club, New Jersey Shore Nuclear Watch, Inc., New Jersey Public Interest Research Group (NJPIRG), and New Jersey Environmental Federation formed STROC to collectively participate in the license renewal proceeding as interveners.

production, and the supply of base-load power. These disagreements were highlighted in the Indian Point Case.

Supporters of nuclear relicensing at Indian Point including Entergy, NEI, New York City and International Brotherhood of Electric Workers (IBEW) tried to explain the benefits of relicensing in terms of its contribution to local economy. They maintained that the Indian Point nuclear plants were among the highest paying employers and taxpayers in Westchester County, New York. For example, in a study prepared for New York City, it was reported that Entergy hired more than 1,000 employees and contributed approximately $30 million to state and local taxes (Charles River Associates 2011). The stakeholder groups supporting nuclear re-licensing argued that the shutdown of the plants could have a far-reaching negative impact on the electricity sector and consumers because plant operations boost the local economy. For instance, the NEI estimated that the total economic output of the Indian Point plant in Westchester, Orange, Rockland, Putnam and Dutchess counties amounted to as much as $ 763 million in 2002 alone (NEI 2004). More recently, NEI projected that the retirement of the plants would result in losses of approximately $ 2.3 billion to local counties (NEI 2015, 8). It was also found that the closure of Indian Point could make the electricity sector rely more heavily on fossil-fueled generation and increase the sensitivity of electricity prices to volatile natural gas prices (Charles River Associates 2011). In this study, it was projected that replacing Indian Point would cost roughly in between $ 11.5 billion and $ 14.3 billion, in present value dollars over a 15-year period (Charles River Associates 2011, 25-26). The study suggested that this cost could be passed on to ratepayers.

A number of local community groups living near Indian Point as well as minority groups in the State of New York emphasized the likely economic impact that closure could have on their daily lives. For example, the representatives from the African American Men of Westchester, Inc., New York State National Association for the Advancement of Colored People (NAACP), and African American Environmentalist Association (AAEA) argued that the early closure of Indian Point would lead to a substantial increase in electricity bills, affecting low income and minority populations living in New York City (Burruss 2007; Dwyer 2012). And, the increase in electricity bills would have broader repercussions on local African American businesses. It was also argued that Entergy had contributed to local infrastructure development through their donations to local municipalities, hospitals, and schools (NEI 2004). According to this argument, smaller charities and local organizations would suffer disproportionately if the plants shut down early, given their dependence on the company and plant employees for both volunteers and financial resources.

In contrast, the opposing stakeholder groups tried to highlight the potential cost associated with relicensing and downplay the cost associated with replacing the plants. In particular, citing the result of a study that they had commissioned, Natural Resource Defense Council, Inc. (NRDC) and Riverkeeper, Inc. ("Riverkeeper") contended that the Charles River Associates' study had overstated the likely cost associated with the retirement of Indian Point (Woolf, Wittenstein, and Fagan 2011). In their views, the economic impact of replacing Indian Point were contingent upon several factors including the extent to which energy efficiency programs were developed and used, the

choice of replacement resources, and availability of new transmission lines. For example, they insisted that energy efficiency programs alone could provide more than 1,500 MW of capacity savings in the region close to Indian Point (Woolf, Wittenstein, and Fagan 2011, 16). In their views, these savings could help cover the State of New York's need for additional electric resources that could be increased as a result of the permanent closure of the Indian Point plants. Similarly, the National Research Council concluded that there would be "no insurmountable barriers to the replacement of Indian Point's capacity, energy and ancillary services." (National Research Council 2006). From these perspectives, the study commissioned by New York City could well have overestimated the economic consequences of the retirement of Indian Point.

The opposing groups also insisted that potential economic losses that could result from a severe accident had been underestimated. In the SAMA analysis, Entergy used $ 2,000 per person rem to convert health consequences into monetary values and projected that an annual off-site economic risk would be roughly equivalent to $494, 000 (Entergy 2006). In environmental activists' views, Entergy had not only tried to minimize off-site consequences of severe accidents but also grossly underestimated human values. For example, on the heels of the 9.11 attack, Riverkeeper Inc. and the Union of Concerned Scientists conducted an analysis of off-site health and economic consequences of a terrorist attack at Indian Point (Lyman 2004). They maintained that the accident could result in as many as 44,000 near-term deaths from acute radiation exposure and as many as 518,000 long-term deaths (Lyman 2004). The economic damages within 100 miles could exceed $1 trillion, in part due to the need to permanently relocate local residents.

Riverkeeper also argued that the NRC had failed to consider the costs of spent fuel disposal and long-term storage in its amended "Continued Spent Fuel Storage Rule[29]." Citing their expert's study on the economics of spent fuel disposal, they claimed that the costs of managing spent nuclear fuel would be huge. According to the estimation, the spent fuel cost would be quite large in absolute value in the range of 1 cent to 2 cent per kilowatt hour (or $10 to $20 per megawatt hour), which is equivalent to nuclear electricity production cost (Cooper 2013). The expert argued that "these costs could easily could tip the balance of the analysis away from...relicensing the reactors and in favor of other alternatives or the no-action alternative" (Cooper 2014). This spent fuel cost assessment was not tailored to Indian Point; nonetheless, Riverkeeper pointed to this estimation in challenging the NRC on its inadequate reliance on the Continued Spent Fuel Storage Rule in addressing relicensing issues (Riverkeeper 2016).

2.1.3. Conflicts over the authority and credibility of risk assessment studies

In the United States, risk assessment studies used in evaluating the safety of nuclear relicensing decisions always seem to provoke controversy no matter how scientists and regulators try to persuade the public about their research findings, refine their methods or try to limit the scope of technical debate. Fundamental disagreements

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[29] NRC amended its Waste Confidence Decision as a response to the remand of the U.S. Court of Appeals in 2012. The Court of Appeals for the D.C. Circuit ruled that the NRC had violated NEPA by failing to consider the possibility that a geological repository might never become available and that the NRC had not conducted sufficient analysis of the potential leaks or fires at spent fuel pools. In response, the NRC published the Continued Spent Fuel Storage Rule in 2014. This amended rule received huge criticism from environmental groups again. These groups, most of which had joined the lawsuit against the NRC previously, sought the judicial review of the rule and GEIS by the U.S. Court of Appeals for D.C. Circuit. *Beyond Nuclear et al. v. NRC,* No. 14-1216.

continue to arise around the ways in which risks and uncertainties are characterized. In my view, it is the diverse ways of thinking about uncertainty that make the interpretations of risk assessments so politically divided. And, the negatively concerned people would likely find flaws in scientific assessment studies used to support relicensing decisions if they perceived that their particular knowledge about reality and other local conditions were overlooked in the methods used in the studies. In order to illustrate this point, I examine in-depth the controversies around the credibility of the SAMA analysis in relicensing Pilgrim Nuclear Power Plant Station. Using this case, I highlight the epistemological differences among stakeholders about risk characterization and interpretation, and contrast solutions they either use or suggest in dealing with uncertainty.

NRC conceptualizes risk in terms of the probability of an accident occurring times the consequences of that accident.[30] This concept is embedded in Probabilistic Risk Assessment (PRA). PRA is used in a wide range of NRC risk-informed safety regulations. Based on sophisticated event tree methodology, PRA identifies accident scenarios and evaluates their likelihood. A large set of accident scenarios is evaluated and complex models are employed to simulate their impacts. Nuclear engineers examine a wide range of scenarios exploring many possible ways the reactor core could be damaged. Then, they estimate the likelihood that each of these accidents might release radioactivity from nuclear power plants to the environment, and forecast off-site

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[30] NRC. 2014. "Risk Assessment in Regulation." Retrieved from NRC website: http://www.nrc.gov/about-nrc/regulatory/risk-informed.html#TheNRCsConceptofRisk.

consequences that may occur as a result of the radioactive release (Bixler and Haaker 2009; NEI 2005). In the context of the license renewal of nuclear plants, the SAMA analysis is based on this PRA approach.

Public stakeholders tend not to rely on the same probabilistic conceptualization of risk. Instead, they use common sense and tacit knowledge to estimate the magnitude of the consequences of severe accidents or to gauge the link between low-dose radiation and health impact. To these people, nuclear regulators and license applicants' approaches to risk characterization are just one of many possible ways of understanding risk and uncertainty. And, in their view, the SAMA analysis and other risk assessment studies should not be used to support license renewal decisions because they neither represent nor take into account the perspectives and knowledge of concerned publics. Therefore, they insisted that the conclusions from the formal risk assessment studies not be considered as deterministic evidence in support of licensing and relicensing decisions. In the United States, the Pilgrim Case highlights these concerns and the challenges to the scientific credibility of the SAMA analysis.

In the Pilgrim Case, the credibility of MACCS2 used in the SAMA analysis was at the center of the debate during the license renewal proceeding. Applicants are required to use MACCS2 as a tool to estimate the off-site consequences of nuclear reactor accidents at U.S. nuclear plants and facilities (Chanin et al. 1998). Modelers calculate atmospheric transport, dispersion, and deposition and collect information about wind direction, arrival and departure times. They also predict evacuation travel patterns and delay times, and calculate radioactive dose for evacuating populations.

Finally, they estimate intermediate- and long-term dose responses considering various mitigative actions that could occur following an accident. For this sequence of calculations, MACCS2 employs complex scientific models and many sources of input data such as a straight-line Gaussian Plume Model (GPM) and evacuation zone data. GPM, which characterizes atmospheric dispersion of a radioactive substance, became the focus of Pilgrim Watch's contestation because this activist group thought that GPM could not accurately predict the complex meteorological conditions near the plant site.

GPM relies on a number of assumptions about the behavior of a substance in the atmosphere. It assumes that the terrain is relatively flat, the wind speed is steady in time and in elevation, and atmospheric conditions are homogenous in the study area as well as constant throughout the period of dispersion (Zhang et al. 2001). MACCS2 employs GPM and therefore is based on similar assumptions about the atmospheric dispersion and deposition of the radioactive plume (Chanin et al. 1998) (Figure 2.1). It requires information on wind speed, wind direction, atmospheric stability, and more. In estimating radioactive plume dispersion patterns using the SAMA analysis, Entergy relied on meteorological data collected from an on-site meteorological tower (Entergy 2006).

In the eyes of Pilgrim Watch, the assumptions used in GPM were unrealistic and the meteorological data used in the model insufficient. Pilgrim Watch insisted that radioactive plume dispersion patterns are complex and unique to each site (Pilgrim Watch 2006). Pilgrim Watch argued that Entergy had only considered one year's worth of meteorological data gathered from one monitoring station (Pilgrim Watch 2006, 39-

40). They also insisted that the meteorological data Entergy used as input were not sufficient to capture the complex nature of local weather conditions, such as the direction and strength of the sea breeze. To them, these details of local conditions were crucial to assessing likely impacts in case of a severe accident. They urged NRC to install additional meteorological instrumentation along the coast and inland to better characterize the spatial variation of the wind flows and to ensure the representativeness of local meteorological data (Pilgrim Watch 2006; Lampert 2015).

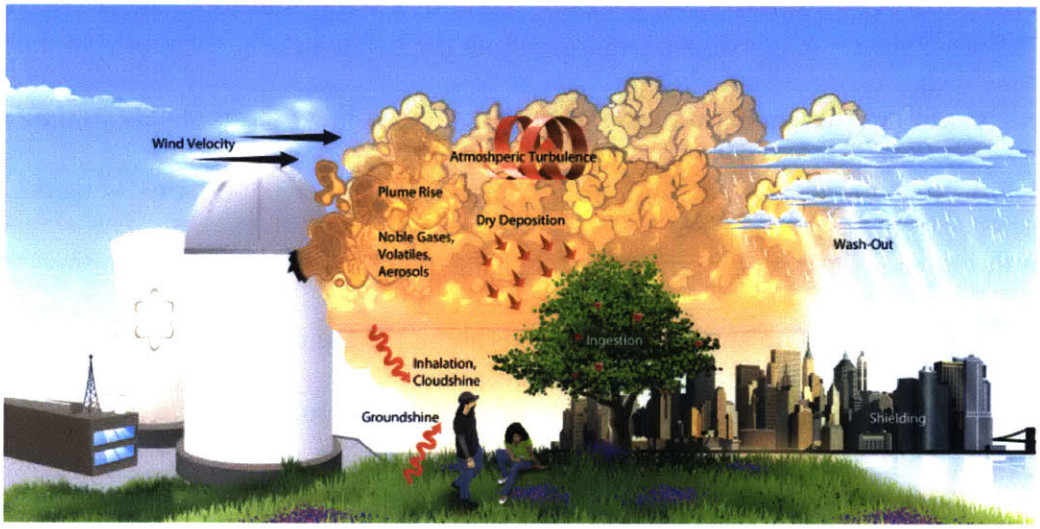

Figure 2.1 Depiction of atmospheric radioactive particle transport and deposition processes Source: Sandia National Laboratory.

NRC, Entergy, and local residents also held different views about plausible local evacuation patterns and evacuation time estimates (ETE). The SAMA analysis requires the ETE —the time needed to evacuate the public in the event of a serious accident – as an input for assessing long-term dose responses during various mitigative actions (Chanin et al. 1998). ETE is often used to inform decisions about protective action. Its acceptability is usually evaluated in light of people's intention to evacuate

and behavioral responses to severe accidents, as well as available transportation resources such as buses and ambulances (Dotson and Jones 2005; Jones et al. 2011). NRC studied communities within 10-mile EPZ, assuming that they were the main subjects of evacuation in the event of a severe accident (GAO 2013).[31] Based on this assumption, Entergy studied how long it would take for residents of that area to evacuate during an emergency. They argued that the 10-mile limit for planning was based on reliable science, although others disagreed (Cassidy 2012). They predicted that around half of the population within 2 – 5 miles would evacuate voluntarily and concluded that the time required for evacuation would range approximately between 4 and 7 hours (KLD Associates, Inc. 2004).

Local environmental groups and politicians contended that the SAMA analysis and ETE values were flawed and should not be used as a basis for granting a license renewal. First of all, Cape Downwinders, a group of local residents from the Cape Cod area, argued that Entergy inappropriately considered it unlikely that radioactive plumes could extend beyond the 10-mile EPZ in the event of a severe accident. More importantly, by limiting their analysis to the 10-mile EPZ, Entergy failed to consider the residents in Cape Cod in their evacuation plans and ETE studies (Turco 2015). Pilgrim Watch also contended that the ETE value was unrealistically low given the actual demographic and geographic conditions. All of this meant to Pilgrim Watch that the worst-case accident scenario had not been considered (Pilgrim Watch 2006). Areas

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[31] In its updated guidance on the ETE studies, NRC recommended that license and license renewal applicants consider a "shadow region", which extends five miles beyond the 10-mile EPZ areas (Jones et al. 2011).

near Pilgrim Nuclear Power Plant including Cape Cod attract many people during busy seasons. From local environmental groups' perspectives, the traffic and travel behaviors during holiday seasons and bad weather conditions could significantly increase the evacuation time. Entergy did not sufficiently consider the effects of these factors in their SAMA analysis. In short, in the local public's viewpoints, the SAMA analysis and MACCS2 modeling were both unacceptable.

2.1.4. Disagreements about the proper scope of public involvement

In the license renewal debates, disagreements about the credibility and authority of risk assessment studies in regulatory decision-making are linked, to disagreements about the appropriate scope of public involvement. During the nuclear license renewal processes, the concerns of public interveners raise must conform to the pre-defined scope of the proceedings. The GEIS became the basic focus of the pre-defined scope of the hearings. In the following section, I examine the NRC's definition of the acceptable scope of public concerns, and highlight the stakeholders' contestation of that definition.

In an environmental policy-making context, which is inherently science-intensive, regulators and scientists may put a technical and participatory limit on the scientific issues when they engage concerned stakeholders. Gieryn (1983) and Jasanoff (1999) labeled this action a "boundary work" of science and scientists involved in policy-making processes. The boundary-making practice can become politically controversial. Jasanoff (1999), for instance, suggests that political consequences of the boundary-making practice could be quite serious:

> "The degree to which scientists' assumptions are questioned or contested depends in large part on the ability of relevant state institutions, such as courts, regulatory agencies, and expert advisory bodies, to set credible limits on the scope of technical debate. In cases where such boundary drawing proves ineffectual, experimental methods, instruments, models, interpretations, and even scientists' personal integrity may be relentlessly questioned by the media and the lay public – sometimes to the point where contested claims no longer support policy action (pp. 139-140).

In many of the U.S. license renewal disputes I examined, the negatively concerned public contested the legitimacy of the scope of technical debate and its scientific basis.

In the GEIS, NRC had identified certain environmental issues as generic while defining others as requiring site-specific responses on a plant-by-plant basis. The former were labeled as Category 1 issues while the latter were dubbed Category 2 issues. The Category 1 issues included the possible environmental impact of on-site spent nuclear fuel storage, emergency planning and public health impacts, while Category 2 issues included SAMAs and the effects of cooling tower systems on the health of water and surrounding ecosystems. In the GEIS, NRC concluded that Category 1 issues had insignificant impact and involved few if any site-specific variations across all nuclear power plants in the United States.[32] Based on this conclusion, licensees need not examine Category 1 in their license renewal applications unless NRC determined that there was new and significant information that needed to be addressed. 10 C.F.R. 51.53 (c)(3)(i) and (iv). NRC requires that applicants address Category 2 issues in their Environmental Report, and during the license renewal process, public stakeholders can raise concerns about Category 2 issues by requesting a

[32] The full the environmental impact categories and issues are listed in 10 C.F.R. 51 Part A; 10 C.F.R. 51 Appendix B to Subpart A Table B-1.

hearing. In short, the categorized environmental issues in the GEIS have been used as the basis of delimiting what can be argued.

Under the NRC Rules of Practice and Procedure, NRC clearly defined who had standing and what kinds of claims could be raised in 10 C.F.R. § 2.309 (d)(1) and (f)(1) (Table 2.1). ASLB judges rely on these rules when they decide whether to allow or reject certain contentions. Rules requiring that interveners' concerns be within the scope of the proceeding became particularly controversial during NRC adjudication.

Table 2.1 NRC criteria for judging admissible contention

10 C.F.R. § 2.309(f)(1) Admissible Contention criteria (emphasis added)
(i) Provide a specific statement of the issue of law or fact to be raised or controverted. (ii) Provide a brief explanation of the basis for the contention; *(iii) Demonstrate that the issue raised in the contention is within the scope of the proceeding;* (iv) Demonstrate that the issue raised in the contention is material to the findings the NRC must make to support the action that is involved in the proceeding; (v) Provide a concise statement of the alleged facts or expert opinions which support the requestor's/petitioner's position on the issue and on which the petitioner intends to rely at hearing, together with references to the specific sources and documents on which the requestor/petitioner intends to rely to support its position on the issue; (vi) . . . Provide sufficient information to show that a genuine dispute exists with the applicant/licensee on a material issue of law or fact. This information must include references to specific portions of the application (including the applicant's environmental report and safety report) that the petitioner disputes and the supporting reasons for each dispute, or, if the petitioner believes that the application fails to contain information on a relevant matter as required by law, the identification of each failure and the supporting reasons for the petitioner's belief.

The actual rulings of the Atomic Safety Licensing Board (ASLB) illustrate that the GEIS has been an important basis for allowing or rejecting public concerns. For example, in the Pilgrim Case, the ASLB ruled that the vulnerability and environmental impact of the spent fuel pool were "beyond the scope of... and inadmissible in, the license renewal proceeding" (NRC 2006, LBP-06-07). Similarly, in the Vermont Yankee Case, ASLB stated that the Vermont Department of Public Service (VDPS)'s

"attempts to challenge the storage of spent fuel after the license renewal term amounts to an impermissible attack on these regulations" (NRC 2006). In the Oyster Creek Case, NJDEP contended that the Environmental Report must address potential environmental impacts of terrorist attacks on Oyster Creek plant (*New Jersey Department of Environmetnal Protection v. U.S. NRC; Amergen Energy Company, LLC* 2009). However, the ASLB judges ruled that NJDEP's contention concerned a Category 1 issue, which was outside the scope of the license renewal proceeding (Smith 2010).

Public interest groups, especially those who had opposed nuclear relicensing, had different thoughts about what should count as an acceptable concern. In their view, issues about the on-site spent fuel storage, severe accident risk associated with terrorist attacks and other types of external shocks, and the adequacy of emergency plans and protective measures should all have been admissible issues. They maintained that the NRC had unfairly excluded many of their primary concerns. For example, Ms. Mary Lampert, one of the most vocal critics of Pilgrim nuclear license extension and the founder of Pilgrim Watch, challenged the NRC' pre-defined scope of the proceeding as follows:

> The idea that the spent fuel pool issue is somehow outside this analysis [Environmental Report], and that even if mitigation alternatives are readily available and cost effective the plant need not consider them, is ridiculous. The spent fuel pool is a structure that is part of the facility. Although some aspects of its environmental impacts, such as off site radiological impacts during normal operations and the prospects of long term spent fuel storage, have been taken off the table, it is still vulnerable to severe accidents and thus within the realm of a proper SAMA analysis." (Pilgrim Watch 2006, 53–54; Lampert 2012)

They contended that public stakeholders should be given a hearing based on their primary concerns, and not be restricted based on the predefined boundary of what counts as an acceptable claim.

In the controversial license renewal cases I have examined thus far, concerned stakeholders aimed their criticisms at the license renewal process itself. For instance, Mr. Edwin Lyman, a senior scientist with the Union of Concerned Scientists, singled out the license renewal process: "The process was designed to limit the scope that could be considered, specifically the ability of the public to intervene" (Thielman 2016). Similarly, in the Oyster Creek Case, Mr. Richard Webster, a lawyer from Rutgers Environmental Law Clinic who represented the local environmental coalition STROC claimed:

> "...there were a lot of things that were questionable that we never got to be able contend... It's unsatisfying that if the NRC's rules were a little looser, we would be able to look more carefully at areas where there were potential problems and improve the quality of operation. ...There were a few areas where it was pretty clear at the time, I think, that there were problems but we were closed out from litigating those problems by the rules. I think it's unfair. They hold the people challenging the relicensing to a very, very high standard. The licensee is not restricted at all, whereas the challengers are very tightly restricted." (Webster 2016)

Dissatisfaction with the regulatory process further complicated the debates over relicensing, triggering multiple rounds of litigation. In the Oyster Creek Case, New Jersey Sierra Club and New Jersey Environmental Federation appealed the NRC decision that had refused to expand the scope of its license renewal program to include such issues as the adequacy of evacuation plans and the vulnerability of spent fuel storage to terrorist attack.[33] Similarly, STROC formed temporary coalitions with anti-relicensing activists who had attempted to intervene in Vermont Yankee, Pilgrim and Indian Point license renewal proceedings. Together, they petitioned the NRC, claiming

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[33] New Jersey Sierra Club et al. v. NRC, No. 07-1267 (Second Cir., 2007)

that the license renewal review processes in these cases had not been adequate. Essentially, the petition argued that the NRC regulations had created too high a bar, preventing them from raising concerns about spent fuel and emergency planning (Lampert 2012; Webster 2016; Gunter 2016; Hoffman 2014).

The State government agencies and legislatures also got involved in some of the lawsuits between the NRC and licensees. For instance, dissatisfied with the ASLB orders, NJDEP asked the court to review the NRC's decision to deny its petition to intervene in the license renewal proceeding.[34] The court reaffirmed NRC's decision and held that that there was no "reasonably close causal relationship" between the Oyster Creek relicensing proceeding and the environmental effects of a hypothetical aircraft attack on the spent fuel pools. By the time this case was heard, the Attorney Generals of these States were convinced that the pre-defined scope of the relicensing proceedings was less than legitimate because they refused to address their collective concerns about onsite storage of spent fuel in relicensing context. They formed a coalition of Attorney generals in the Northeastern States—States of New York, Connecticut, and Vermont – to strike down the NRC's Waste Confidence Decision restricting the way state agencies could get involved in relicensing proceedings.[35] However, these litigation efforts seldom resulted in procedural reforms. Although the D.C. Circuit ruled on their requests, it did not expand the scope of public involvement during the license renewal.

Dissatisfied, environmental groups looked for other ways of getting beyond the

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[34] New Jersey Department of Environmental Protection v. NRC. No. 07-2271 (Third Cir., 2009)

[35] *New York v. NRC*. 681 F.3d 471 (D.C. Cir. 2012).

predefined scope of engagement. In the Pilgrim Case, Pilgrim Watch linked its concerns about evacuation plans with what it saw as problems with the SAMA analysis. As a result, its concerns were partially admitted as acceptable contentions (Lampert 2015). In the Indian Point Case, the Hudson Clearwater framed its criticism of existing emergency planning requirements as an environmental justice (EJ) issue (Greene 2015). In this way, the environmental groups were able to both make their claims heard and connect with local residents.

Some state legislatures were more proactive than others in attempting to go beyond the predefined scope of engagement. In the Vermont Yankee Case, the Vermont legislature and Vermont Department of Public Service sought to broaden the basis for their participation. Under the Atomic Energy Act, State agencies do not have the power to regulate nuclear safety issues, even if nuclear reactors are located within their territorial boundaries, except issues other than radiological hazards, such as water impact and the need for power. 42 U.S.C.§ 2021 (c). And, their contentions about the environmental impact of spent fuel issues were denied in the federal relicensing proceedings. Despite these limitations, the Vermont State Legislature attempted to weigh in on managing spent fuel issues by promulgating a series of state regulations and exercising its authority. The legislature enacted Acts 74 and 160 in 2005 and 2006 requiring Entergy to get an approval from the legislature when they plan to build additional spent fuel storage facilities and attempt to extend its operating license.[36]

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[36] Eventually, these regulations were invalidated in courts. Entergy Nuclear Vermont Yankee v. Shumlin 2011. No. 212-707 (2nd Cir. 2013).

Under these laws, Vermont State agencies tried to open floors for informed public deliberation and discussion about the issues that were less handled in the federal license renewal proceedings such as the states' need for power, the economics and environmental impacts of long-term storage of nuclear waste, and choice of power sources among various alternatives. According to Ms. Hoffman, the former Deputy Director of the VDPS and a General Assembly Representative, the state agencies and the legislature knew that the federal laws preempt the state regulations that were related to nuclear safety issues (Hoffman 2014; Klein 2012). They thought that they should look at the issues such as the environmental impact of on-site spent fuel storage because in their views, these issues were important in terms of the operation of the Vermont Yankee plant (Hoffman 2014).

In sum, in the United States' license renewal cases, the stakeholders supporting the license renewal highlighted the economic costs of replacing nuclear power with alternative energy sources but tried to confirm that the level of health impact or risk associated with on-site spent fuel was either negligible or inconclusive. Negatively concerned stakeholders argued, in contrast, that risk of postulated accidents and the long-term health impact of nuclear plant operation were unacceptable. They maintained that the cost of early retirement of existing nuclear plants could be offset through various energy saving programs. In short, to support their claims, stakeholders on each side of the disagreements mobilized different analytical frames and evidence. The disagreements about various types of risks, in particular, centered on the credibility of the studies that nuclear engineers and professionals submitted as part of their application. Regulators and nuclear professionals claimed that they had sufficiently

examined factors causing risk using well-established science and confirmed that the level of risk would be insignificant. But, in the activists' eyes, these studies were inadequate in terms of looking at the local factors that could affect the estimation of the level of risk. And, the environmental impact issues were categorized in terms of generic and site-specific environmental issues, and the disagreements about the scope of participation focused on the legitimacy of this categorization. In a number of cases like Indian Point and Oyster Creek cases, broad-base coalitions were created, which supported the coalitional members' attempts to transgress the predefined scope of public engagement. In the following section, I examine the ways in which the four types of disagreements unfolded in the South Korean license renewal cases.

2.2. Conflicts over relicensing nuclear power plants in South Korea

2.2.1. Disagreements about the level of acceptable risk to human health and safety

Debates about the health effects of relicensing

Both Kori and Wolsong cases entailed questions about the causal link between the location of nuclear plants and cancer risk. In South Korea, cancer risk debates got intensified nationwide when the Busan District Court erred on the side of a local resident's claim that cancer risk and proximity to nuclear plants might be positively associated. In 2012, Mr. Lee Jin Sup and his family, local residents who had lived approximately 7 km away from Kori site, filed a lawsuit against KHNP insisting that all

his family members had suffered from cancer and other serious illnesses because they had lived close to nuclear plants for decades. Mr. Lee had a colorectal cancer, his wife had thyroid cancer and his son had developmental disorder. After two years of debate, the Court ruled partially in favor of Mr. Lee's family, recognizing the possibility that the location and length of their residency near nuclear plants could have caused Mrs. Lee's thyroid cancer. Citing the result of the national epidemiological study and local medical records, the Busan District Court's judge ruled that KHNP must compensate Mrs. Lee because she had lived in areas within 10 km radius from Kori site and been exposed to radiation for a long time, even though the emitted radiation level might had been well below the regulatory limits of annual radiation release (Min 2014).

KHNP, nuclear industrial associations such as Korean Nuclear Society (KNS) and the Korean Association for Radiation Protection (KARP) disagreed with the decision. They argued that the court erred on the side of the concerned residents' anecdotal evidence and made its decision based on inconclusive findings about the health effects of nuclear power plants. KHNP appealed the decision on the grounds that the court's interpretation the national epidemiological study had been incorrect (Park 2014). KNS and KARP quickly established a research committee and examined annual radiation monitoring data. They concluded that the causal relationship between cancer risk and nuclear power plants is inconclusive because radiation concentration levels had been kept below the acceptable level (Kim et al. 2015). The researchers also pointed to an International Commission on Radiological Protection (ICRP) study that suggested that the risk of low-level exposure to radiation is uncertain. Based on all this information, KNS and KARP argued, it would be nonsensical to conclude that nuclear

plants posed significantly threats to the health of local residents even if they had operated for a long period. They concluded that more thyroid cancer incidences might have been detected not because of the actual radioactive health impact but because of the abutters' increased hospital visits and abilities to detect small cancers.[37]

In contrast, KFEM and other local environmental groups insisted that local residents had been exposed to unacceptable level of health risk. They believed that the operation of the old nuclear plants for additional ten or twenty years would further increase the residents' exposure to cancer risk. They also did not think that environmental radiation protection standards for nuclear power plant operations were not sufficiently safe because the standards were not targeted to keeping radiation levels at the lowest possible level. For example, Ms. Yang-Lee Wong-young, the director of Energy and Climate Change at KFEM collected Korean nuclear plants' radiation emission data and claimed that the nuclear plants had been releasing non-negligible amount of radioactive materials that during their normal operation (Ja-young Lee 2016). Activists and physicians who were critical of nuclear power claimed that even the low level of radiation could have a significant impact on abutters' health if the abutters had lived and been exposed to radiation for a long time (Kim 2013). After the court's decision, environmental activists began to recruit cancer survivors in places near nuclear power plants.[38] They argued that these cancer cases were "live" evidences that

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[37] KHNP has provided local residents health care benefits as a part of community benefit programs.

[38] For example, local KFEM representatives recruited local residents who were diagnosed of thyroid cancer and had lived in EPZ areas (8-10 km) for more than 5 years (Su-yeong Choe 2016). These activist groups were able to recruit nearly 250 residents in the Kori case alone out of the total 592 cancer incidences collected in all four nuclear power plant stations (Byun 2016).

strongly supported that local communities had been exposed to cancer risk (Byun 2016). The credibility of the Korea Radiation Effect and Epidemiology Cohort (KREEC) study was at the heart of all this debate about cancer risk. In Section 2.2.3, I will describe the conflicts that evolved around this issue in detail.

Debates about seismic risk

In the Wolsong Case, the local public and interest groups were concerned about seismic risk at the site. Nuclear plants are built in locations that have low seismic hazard and, at the same time, designed to withstand potential earthquakes at the sites. For the appropriate design, nuclear engineers must define what is called the "design-basis earthquake," or the level of an earthquake that nuclear power plants are built to withstand. Korean nuclear power plants, including Wolsong 1, were designed to withstand an earthquake that is approximately equivalent to a 6.5-magnitude earthquake (Im et al. 2004). Since the mid-1980s, critics have been arguing that Wolsong site is located near faults known as Yangsan and Ulsan Faults that may generate earthquakes larger than the design-basis earthquake (Figure 2.2). This criticism reemerged during the "Stress tests" reviews that took place in the aftermath of the Fukushima accident.[39]

[39] The newly elected Park Administration introduced "Stress tests" guidelines in early 2013 benchmarking post-Fukushima actions the European Union (EU) had implemented. The "Stress tests" required, though informally, that the utility company examine whether reactors could withstand extreme natural hazards such as earthquakes and flooding that may occur as rarely as one in 10,000 years but can be highly consequential. In addition, the NSSC required that the result of KHNP's "Stress tests" analysis of Wolsong 1 be "peer-reviewed" by selected members of the public and experts (NSSC 2013).

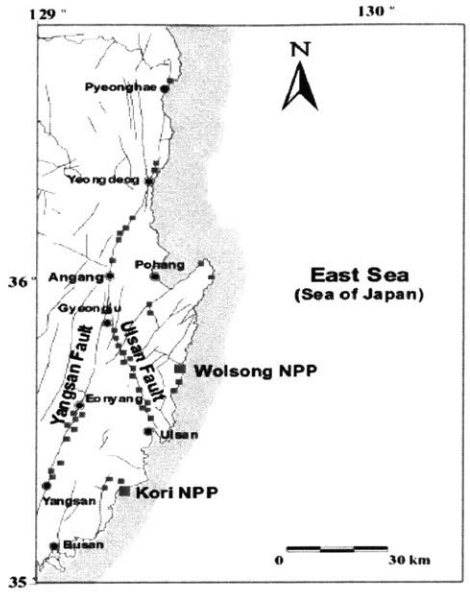

Figure 2.2 Major faults near Wolsong Nuclear Power Plant Station
Source: Seo et al. 2009. "Status of the PSHA in Korea for Nuclear Power Plants," *Nuclear Engineering and Technology* 41 (10), 1255-1262. p. 1258, under the permission of the first author

Nuclear experts at KINS and the lay members of the Citizen Review Board (CRB) had contrasting views about whether seismic risk at Wolsong nuclear plant station was within the acceptable level. KHNP claimed that Wolsong 1 reactor had a sufficient level of safety margins because earthquakes larger than a magnitude 6.5 earthquake were very unlikely to appear near the site during the renewed term (KHNP 2013). KHNP relied on the Probabilistic Seismic Hazard Assessment (PSHA) study to support its claim. PSHA estimates the likelihood that various levels of ground motion will be exceeded at a given location in a given future time period (McGuire 1995). KHNP conducted the PSHA study to estimate the maximum credible earthquake[40] that

[40] "Maximum credible earthquake" is the "largest hypothetical earthquake that may be reasonably expected to occur along a given fault or other seismic source could produce under the current tectonic setting." U.S. Department of Interior, Bureau of Reclamation. 2012. Reclamation Glossary.

could occur within the 10,000-year timeframe, and used that estimate[41] to evaluate the extent to which Wolsong 1 could deal with various plant conditions that could result from the potential earthquakes' ground motions (KHNP 2013). In the PSHA study, KHNP estimated that the maximum ground motions that could occur at the site would be approximately 0.28 *g* (KHNP 2013). Given the estimate, KHNP saw that it would be safe to assume that Wolsong 1 would not be exposed to ground shakes larger than 0.3*g* or motions equivalent to a magnitude 7 earthquake. KINS and the NSSC Resource Panel also supported that estimation after reviewing the study. They concluded that KHNP would be able to maintain its function even during the peak ground motions (NSSC 2015a; NSSC 2015b).

In contrast, the representatives of KFEM and a number of geoscientists supporting KFEM openly contested this view. They maintained that KHNP's estimate of the maximum level of earthquake was not conservative enough (NSSC 2015a; NSSC 2015b). In their views, seismic risk at the site was downsized by excluding important input data in the PSHA study (Kim 2015). And, the lack of input data made the seismic risk estimate highly uncertain (S. Kim 2015; Y. Kim 2015). KEFM further insisted that, given the high level of uncertainty associated with the study, the 10 percent safety margins that KHNP had added only a small amount of safety margin, which, in their views, was insufficient. In their view, to be conservative about seismic hazard at the site, one needs to account for *all* existing earthquake-relevant data including historical

[41] The maximum credible earthquake is expressed in terms of peak ground acceleration (PGA, *g*) or the maximum ground acceleration that could occur during earthquake shaking at a particular location.

archives and seismic data available in Japan, South Korea's neighboring country. Finally, they pointed to the discrepancy between the estimate of seismic risk in KHNP's study and the estimate in the National Seismic Hazard Map that the National Emergency Management Agency (NEMA) had published in 2012 (Expert Review Committee on the Stress Test of Wolsong 1 2015). CRB representatives called for a re-analysis of the PSHA study and demanded that the relicensing decision be postponed until the study is properly done. In short, the credibility of the PSHA study was at the heart of the public contestation about seismic risk. In Section 2.2.3, I will come back to this story to highlight disagreements about the credibility of the PSHA study in dealing with uncertainty associated with seismic risk.

Proximity of nuclear plants to cities and emergency responses

In South Korea, various plant safety and public health concerns (e.g. cancer risk, seismic risk and plant safety under pressuring conditions) often led to the discussion about the adequacy of existing evacuation plans and nuclear plant locations. This was particularly because South Korea is a country with high population density. As of 2015, approximately 520 people live per square km of land area in Korea, and Korea ranked 20th among 261 countries in terms of the population density (The World Bank 2016). Both Kori 1 and Woslong 1 are located close to Busan and Ulsan Metropolitan Cities (approximately 17 miles from each city), one of the most densely populated cities in the

already highly populated country.[42] As of 2016, 3.5 million people live in Busan Metropolitan City, 1.17 million in Ulsan Metropolitan City and 260,000 people in the City of Gyeongju. And, approximately 9,740 and 6,900 people live in Jang-ahn Eup and Yangnam-myeon, the two local villages in which Kori 1 and Wolsong 1 are located, respectively (KOSIS 2015).

Anti-nuclear/relicensing activists expressed concerns about the location of Wolsong 1 and Kori 1 and the fact that the sites are densely packed with multiple reactors. They contended that major accidents at the plant site could lead to unacceptable health consequences precisely because of the location of the plants. For example, KFEM conducted its own severe accident consequence analysis at the two sites. In its report, KFEM projected that in the Kori Case, approximately 900 people could face lethal health consequences and nearly 0.4 million people could be exposed to cancer risk if there were a major accident (Park, Yang-Lee, and Kim 2012).[43] KFEM postulated that a severe accident would result in more adverse health consequences in the Wolsong Case because a number of major industrial cities such as Ulsan and Pohang are located close to the site.[44] According to their analysis, approximately twenty thousand people will be exposed to lethal health consequences and 0.7 million

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[42] The two reactors were sited on the shores of the East Sea (or Sea of Japan) in the southeastern part of Korean peninsula—Kori 1 in Gijang County, South Gyeonsang Province, and Wolsong 1 in Yangnam-myeon, North Gyeongsang Province. Both nuclear plant stations were located in rural areas when Korea Electric Power Company (KEPCO) decided to site the nuclear plants in the 1970s.

[43] In this study, researchers assumed that the wind blows toward the City of Ulsan and people in the shadow areas do not evacuate on time.

[44] Ulsan is one of the major industrial cities in South Korea. It is home to Hyundai Motor Company and the Petrochemical Complex. Pohang is home to POSCO, a multinational steel-making company.

people could be exposed to cancer risk in case of a severe accident (Park, Yang-Lee and Kim 2012, p. 2). Similarly, Greenpeace Korea criticized that Korean government had provided insufficient amount of potassium iodine (KI) to local residents and that evacuation drills were practiced only among those who lived within 16 kilometer radius (approximately 10 miles) from the nuclear plants (Greenpeace 2013). Greenpeace held a number of eye-awakening street protests in and around Metropolitan Busan City to make a case against the continued operation of Kori 1 (Cha 2013).

Local community representatives partly supported environmental groups' claims because they were also concerned about the lack of fallout shelters and protective equipment. In one local public hearing meeting I attended in Wolsong in 2012, many residents insisted that they had not given much information about the location of fallout shelters. Community representatives of Yangbuk-myeon, the local municipality that is located only a couple of miles away from Woslong nuclear reactors, were also critical of protective measures in place:

> "Gas masks and filters that are stored here are old and outdated. Evacuation drills have not been done appropriately, either. We have our own daily work and so even if there were the drills, it would be difficult for us to participate in them." (Ihm 2012)
>
> "We have thousands of gas masks stored in Yangnam-myeon, Yangbuk-myeon and Gampo Eup. But these are all old, about 10 years old. They (government and KHNP) only care about the official records that confirm that they had provided something." (Sang-wang Kim 2012)

The NSSC contested that KFEM' study was based on unrealistic assumptions and unnecessarily amplified public perception of risk. They criticized the study on the grounds that, unlike the designs used in nuclear reactors in the Chernobyl and Fukushima cases, Korean nuclear reactors had leak-tight containment buildings that

could help prevent severe explosive accidents (NSSC 2012; Park 2012). In their views, it was also unrealistic to assume that the wind blows in one direction toward cities at a constant speed. The KHNP, KARP, and KNS also argued that the study exaggerated the health consequences of postulated accidents by inappropriately applying a linear-no-threshold (LNT) radiation-dose relationship in estimating the occurrence of cancer incidences (S.-Y. Kim 2012). While there are different perspectives about whether and how the LNT model should be used in understanding the risk of low-level radiation exposure, ICRP suggests that a "simple extrapolation from high-dose effects may not be wholly justified" (ICRP 2005, 112; ICRP 2007).[45] Based on the ICRP's suggestion, the KHNP maintained that KFEM's simulation method was not scientifically sound.

The debates about the level of acceptable risk hinged on the credibility of risk assessment studies, scientific models and input data used in the studies. I will illustrate this point in depth in Section 2.2.3 of this Chapter.

2.2.2. Disagreements about the economic benefits and losses

The perspectives about economic benefits and losses associated with nuclear relicensing were also very different among the stakeholders. KHNP insisted that, although Kori 1 has small capacity (587 MW), its continued operation would still be profitable. When it first applied for the continued operation of Kori 1 in 2007, KHNP

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[45] Because the risk of low-level exposure to radiation is highly uncertain (ICRP 2005), there are different understandings with respect to the ways in which the LNT model is applied to characterizing a radiation-dose relationship. ICRP suggests that a "simple extrapolation from high-dose effects may not be wholly justified" (ICRP 2005, 112). However, according to the U.S. NRC, LNT model suggests that any increase in dose, no matter how small, results in an incremental increase in risk (U.S. NRC 2014).

estimated that it would generate approximately between 150 and 200 million U.S. dollars worth of net benefit during the first ten years of additional operation of Kori 1 (Oh 2014; Ihm 2013).[46] And, KHNP projected that the net benefit would be more than double that estimate if the plant were allowed to operate for twenty additional years (Oh 2014). KHNP received the regulatory approval to operate for additional ten years until 2017, and provided 130 million worth of community benefit funds to Gijang County that hosted the nuclear plants (Park 2008; Jeong 2011). In 2015, the National Assembly of Budget Office (NABO) and Korea Energy Economics Institute (KEEI) reported that the KHNP would be able to generate approximately between 130 million and 190 million U.S. dollars worth of net benefit during the second license renewal term (2017-2027) (KHNP 2015).

These estimates became highly controversial, however. First, the Conservative politicians argued that the continued operation of Kori 1 would not be economically sensible (Kim 2015). In particular, Ha Tae-kyung and Bae Deok-gwang, the two Conservative National Assemblymen representing Gijang County contested that the cost associated with relicensing Kori 1 would have escalated if NABO and KEEI had considered the cost associated with compensating local communities and delays in regulatory processes (D. Lee 2015; S. Park 2015). The license renewal of Kori 1 became one of the major political agenda during the Mayoral Election. As a result, a number of high profile Conservative politicians in Korea soon began to think that the

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[46] The actual economic analysis report was unpublished and thus the figures varied according to different sources. These were cited in the National Assemblyman Oh Young-shik's policy report on the license renewal of nuclear reactors (Oh 2014) and a Yonhap news article.

permanent closure of Kori 1 could be more economical than relicensing Kori 1 (Unanimous High-level Manager 2016). Similarly, a Democrat National Assembly woman Shim Sang-jung criticized the study for neglecting the cost of managing spent nuclear fuel and unrealistically assuming that the net capacity factor would be 100 percent,[47] nearly 10 percent higher than the actual output during the first license renewal term (Ihm 2013). The National Assembly woman claimed that the continued operation would have shown a reversed finding if KHNP had considered the spent fuel management cost in its cost-benefit analysis.

Environmental activists had also long been arguing that the continued operation of Kori 1 and Wolsong 1 could impose unacceptable economic losses to the region if there were any severe accident. For example, in the report they published in 2012, KFEM projected that as many as 720,000 deaths and losses ranging from 12.5 billion U.S. dollars to losses as large as 860 billion U.S. dollars, depending on the degree to which evacuation becomes necessary (Park, Yang-Lee, and Kim 2012). They also estimated that in the Wolsong Case, the potential economic consequences in the event of a severe accident would be in between 362 billion U.S. dollars to 779 billion U.S. dollars, depending on the direction of the wind and the extent of evacuation. Environmental groups projected that economic damages could be even larger than these estimates, considering the nuclear reactors' proximity to Korea's major industrial cities.

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[47] The net capacity of a nuclear power plant is the ratio of its actual output (or the total amount of energy the plant actually produces) over a period of time, to its potential output if it were possible for it to operate at full capacity over the same period of time.

Abutters were concerned about their diminished property values and worried about the potential loss of economic opportunities that might result from the continued operation of the plants. They insisted that, unless it was done with any funding or development projects, relicensing would be unacceptable. A local politician representing Gijang County in Busan Metropolitan City Council claimed that property values had lowered as a result of the government's land use restrictions:

> Local residents suffered a lot because of these land use restrictions. We could neither repair our leaking roofs nor rebuild our deteriorating walls and gates. Population dropped as a result of these restrictions on development activities. Property values also plummeted. All of these undesirable consequences were caused by land use restrictions were imposed on us for the purpose of managing risk. (Ssang-woo Kim 2012)

Other local representatives insisted that they had become economically dependent on KHNP because KHNP had bought out much of their fishing rights (Seo 2012). They had to look for alternative jobs or seek for business opportunities such as opening small seafood restaurants (Seo 2012).[48] Abutters' narratives about the feelings of deprivation and economic losses were powerful. In the negotiation with KHNP, the coalition of local villagers from Gijang County was able to claim nearly 130 million dollars worth of community benefit programs.

In the following two sections, I will examine how the controversies around risk and economic impact associated with nuclear relicensing highlighted stakeholders' fundamentally different views about what count as credible risk assessments and democratic public participation.

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[48] Unlike in the United States, local people who live in the counties or towns hosting nuclear plants in Korea are not given much opportunity to work in the utility company that operates the nuclear reactors in Korea.

2.2.3. Disagreements about the credibility of risk assessment studies in making relicensing decisions

The disagreements about acceptable risk and economic impact associated nuclear relicensing highlight how the credibility of risk assessment studies was either defended or attacked in South Korea. Technical disagreements about cancer risk, as well as the debates about seismic risk in the Wolsong Case, are the cases in point. In the following section, I describe their stories in detail and show that nuclear regulatory science no longer holds a deterministic decision-making power in South Korea.

The first kind of the disagreement about the credibility of the scientific studies evolved around the national epidemiological study called the KREEC study. The KREEC study was an epidemiological study conducted for nearly twenty years from 1992 to 2011, which examined the link between cancer risk and radiation in both workers at nuclear power plants and residents living near plants (Ahn and Li 2012). KREEC researchers defined the cohort group, or the "exposed group," as those who "lived *within* 5 km radius from nuclear power plants" (Ahn and Li 2012, 1000) and the non-exposed group as those who lived *beyond* 5km radius from the plant.[49] Then, the study examined whether the cancer rates between the exposed and non-exposed groups had statistically significant differences. Researchers found that female residents living within 5 km radius from the plants might be at approximately 2.5 times higher risk of having thyroid cancer than those who live outside that boundary. Yet, the overall

[49] In this study, the non-exposed group was again divided into those who lived in between 5 and 30 km radius from plants ("inter-mediate proximate" group), and those who lived more than 30 km radius away from plants ("far-distance" group).

conclusion of the KREEC study was that there was no increased risk for all nuclear power plant areas pointing to statistically insignificant relationship.

Activists and a number of epidemiologists claimed that the assumptions and design of the KREEC study were flawed and must be revised. In particular, epidemiologists and physicians from Korean Association for Physicians for Humanism (KAPH) and Doctors Against Nuke (DAN), who eventually aligned with environmental activists, re-analyzed the KREEC study and challenged the study design with respect to the ways in which study subjects were first categorized, enrolled and traced. They first challenged the aggregation of individual cancer data collected at four different nuclear power plant sites and claimed that the study had narrowly defined the exposed group and did not properly count cancer survivors when they began their survey in 1990 (Ha et al. 2015). They argued that the duration of residence, the factor that KREEC study neglected, might be as equally important as residents' proximity to nuclear facilities in understanding dose-response relationship. On these grounds, they claimed that the national epidemiological survey must redefine the exposed group as those who had cancer and lived within 30 km radius from nuclear plants, and then test the casual relationship in terms of the duration of residence, gender, and age.

In contrast, KHNP, KNS, and KARP formed a research committee and published a report that examined the link between radiation exposure and thyroid cancer. In this report, nuclear experts argued that radiation emission levels were strictly regulated in South Korea following "As Low As Reasonably Achievable (ALARA)" principle (KNS and KARP 2015). They also estimated radiation doses in residents

living nearby Kori nuclear power plants. The researchers found that the doses were within 0.000152 – 0.0283 mSv, which was approximately only 0.2 – 2.9 percent of the regulatory limit. They claimed that the "actual" local residents would be exposed to much less radiation than these estimated doses because their research was conducted based on the conservative assumption about a dose-response relationship. Overall, these nuclear expert communities suggested that the KREEC's findings about increased thyroid cancer incidences among the female cohort groups might be based on free medical services provided to local residents KHNP had offered as a part of its community service programs and increased detections of cancer cases, but not based on the actual hazards.

Like the KREEC study, the arguments of KNS and KARP relied on a number of scientific assumptions. First, the argument was based on a scientific theory that low-dose radiation has little health impact. Second, and more importantly, following the recommendation of the ICRP, the research defined a "representative individual"—a "hypothetical individual receiving a dose that is representative of the most highly exposed individuals in the population" (KNS and KARP 2015; ICRP 2006). In their research, it was assumed that the "hypothetical" resident lives near the boundary of Kori nuclear power plant station[50], eats locally grown food and fish, and has a frequent contact with a water body located near nuclear plants. As ICRP noted, it is challenging to define the characteristics of this representative individual and estimate doses

[50] In Korea, this boundary is set approximately 700 m radius from nuclear reactors at Kori site and 914 m radius at Wolsong site (Woo et al. 2015).

especially when there is lack of knowledge or specific information about the habitual lifestyles of the population (ICRP 2006). Uncertainties may arise due to the variability of the specific information about the exposure pathways.

In response to these nuclear professionals' arguments, environmental groups and physicians consulted an expert from the European Committee on Radiation Risk (ECRR) who had insisted that low-dose radiation causes adverse health effects. To file a class action lawsuit against KHNP, these environmental activists also recruited local residents who had lived in areas located within a 10 kilometer-radius from the nuclear plants for more than 5 year (KFEM 2014). More than 500 cases were collected by March 2015, 40 percent of which were recruited at Kori site. Local residents who joined the litigation argued that they had been cancer survivors themselves or had seen their relatives or neighbors who suffered from various types of cancers. Their stories contrasted the lived experiences and hypothetical scientific models that standardized and systemized those experiences. For example, statistics showed that around 60 percent of the litigants lived on the seashore (Yong 2015), suggesting that there might be some exposure pathways that were overlooked in the nuclear expert communities' assumptions. Activists, in part, used these cancer cases and local residents' stories to challenge the credibility of the KREEC study or the study conducted by KNS and KARP.

Conflicts over the level of seismic risk and PSHA method in the Wolsong Case also highlight lay activists' attempt to challenge the credibility of the risk assessment studies used in making nuclear relicensing decisions. PSHA method is designed to

predict seismic hazard at a particular location. It is very difficult to predict when, where and how big an earthquake will strike because the movement of the earth is very complex. It is probabilistic in the sense that the analysis takes into account of uncertainties in the size and location of earthquakes and the resulting ground motions that can have an impact on a particular site. PSHA model is built by establishing a logic tree using various input parameters[51] that characterize the movement of earth (Bommer et al. 2005). Experts are called on to provide their judgments about how a model should be established and about the values that should be given on each of the parameters. Despite decades of geological surveys and active monitoring of faults, however, experts' judgments about the values for input parameters have large variations, which generates high level of uncertainty.[52] The uncertainty problem is particularly exacerbated when researchers examine areas with historically little seismic activities such as South Korea because of the limitation of available seismic data.

In the Wolsong Case, experts providing advice to each side of the seismic risk debate disagreed about the types of faults that they thought must be incorporated into the PSHA study. KHNP engineers contended that, for the purpose of nuclear relicensing, it would be safe enough if they mainly considered "capable faults"—the ones that have relatively higher chances of recurrence and thus are often considered in

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[51] The input parameters include attenuation laws, earthquake recurrence, source zonation, size and configuration of sources, and etc.

[52] In the PSHA method, these uncertainties are called "epistemic uncertainties." A PSHA study deals with the epistemic uncertainties by creating logic trees and assigning normalized weight on each of the logic branch (NSSC 2015a; NSSC 2015c).

the nuclear sector.[53] Nuclear scientists from KINS, as well as a number of geoscientists from the NSSC Resource Panel, agreed with KHNP (NSSC 2015a; NSSC 2015b) .

In contrast, from environmental activists' standpoint, the PSHA study that had only considered the capable faults would not be reliable particularly because it would not cover the worst possible seismic events. Activists and geoscientists serving the Citizen Review Board (CRB) challenged that the PSHA study was limited if not flawed because it only examined the "capable faults." Dr. Kim Sung-Wook, a geoscientist who assisted CRB members, challenged that the "capable faults" enabled KHNP to downplay seismic risk by helping to exclude a range of input data:

> If we deliberately take out all the data associated with high uncertainty in pursuit of certainty, we will end up including only the data that obviously indicate that the site is safe. I don't think that KHNP had conducted the study in a conservative manner. They deliberately chose to include only the data that had higher certainty. In the PSHA study, we have to include all the reasonably qualified data that are available out there. If the available data and the final PSHA study results are uncertain, we have to put all the related decisions on hold until uncertain things become more certain. In my view, that's more reasonable way of dealing with scientific uncertainty. Their argument that they would only consider and use what's certain seems irrational to me. (S. Kim 2015)

The CRB members and Dr. Kim insisted that the PSHA study should have relied on the pure scientific definition of "active faults"[54] and examined all kinds of information

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[53] Capable faults are defined as the faults that show evidence of movement at least once within the past 35,000 years or movement of a recurring nature within the past 500,000 years (Im et al. 2004; 10 CFR 100 Appendix III (g)).

[54] Active faults are the faults that show evidence of movement during the past 1.5 million years (Kim et al. 2011).

related to that definition, using historical earthquake catalogues[55] and seismic source maps that documented seismic activities in the East Sea (the Sea of Japan).

2.2.4. Disagreements about the scope of public involvement

In South Korea, the controversies that surrounded nuclear relicensing, in part, also reflect conflicting conceptions of the appropriate scope of public engagement. First, the nuclear regulatory agency, KHNP, local communities and environmental activists had different epistemological definitions about who counts as the affected public. KHNP and the Ministry of Science and Technology (MST) (the former nuclear regulatory agency) relied on the rules of pubic participation used in nuclear facility siting in Korea. The rules require stakeholder groups who have rights to request a public hearing during the siting process are the abutters, or those who live within and around the boundary of Emergency Planning Zone (EPZ) (MST 2005; NSSC 2014).[56] Although KHNP was not required to consult the public under the Nuclear Safety Act at that time, KHNP and MST expressed intentions to communicate exclusively with abutters (Seo 2012; Park 2012). They set up negotiations with the community representatives from small local villages located in Gijang County and Uljoo County such as Gilcheon and Wolnae Towns, Jangahn Eup, Seosaeng Myeon, all of which are located within and around 5 kilometers from Kori 1 (Figure 2.3) (Park 2012; Seo 2012;

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[55] Historical earthquake catalogues is a list of qualitative descriptions of seismic activities. In Korea, they have been collected from old Korean historical archives and records that date back to 1100 A.D.

[56] In South Korea, the EPZ includes the areas located within 8 ~10 kilometers radius from nuclear power plant stations. In 2015, geographic boundary of the EPZ expanded following the enactment of the reforms in Act on Measures for the Protection of Nuclear Facilities, etc. and Prevention of Radiation Disasters (or so-called "Emergency Planning Act").

Kim 2012; Park 2008). Following the station black out accident at Kori 1, they invited again local community representatives from Jangahn Eup (Cho 2015; Joo-hoon Kang 2012).

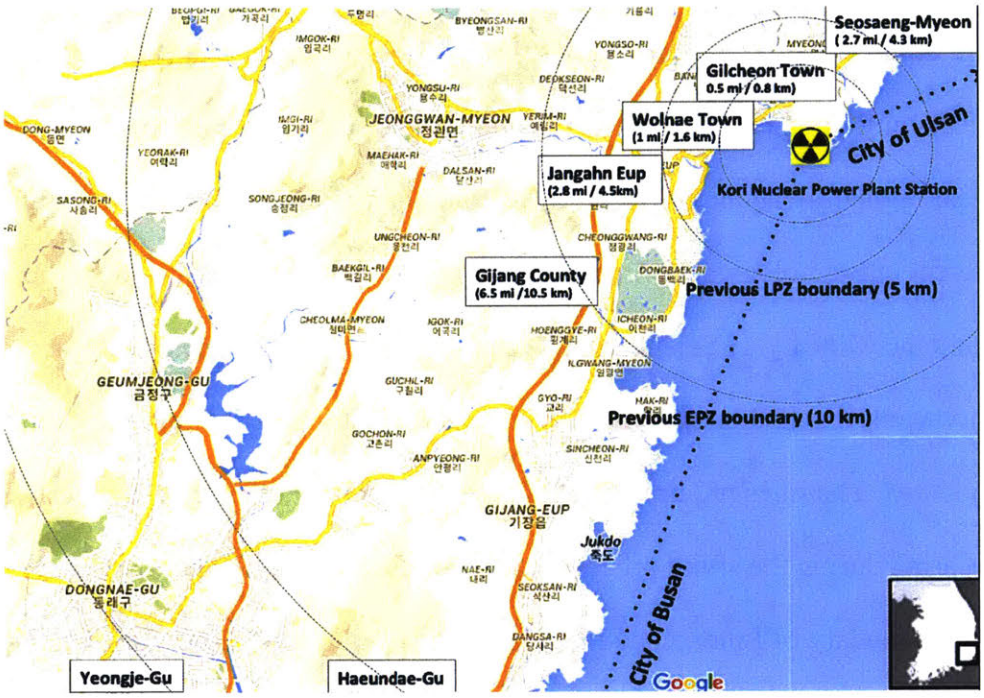

Figure 2.3 Location of Kori nuclear plant station and local communities who engaged in the license renewal process
Source: Google Map

In the eyes of the local environmental activists, KHNP and MST unfairly excluded local environmental groups and people living beyond the EPZ borders. These activists argued that KHNP had heavily relied on the "proximity presumption"—a notion that people nearest to reactor sites will be at the greatest risk in case there is a severe accident and therefore subject to public consultation or participation (Repka and Smith 2010). In the environmental groups' perspectives, it is in and of itself an exercise of power for the regulatory agency to selectively define communities at risk and

structure public engagement based on that definition (Gieryn 1983), and must be revisited. In numerous protests, press release, and a litigation filed in the local district's court, environmental activists claimed that the citizens of Busan also had rights to the safety and need be engaged in the regulatory reviews (Busan Eastern District Court. 2011. Ka-hap 211). According to Su Hui Jeong, a long-time antinuclear activist living in Busan and the Senior Director of the No Nukes Busan Citizens Countermeasure Commission (NNBCCC):

> I have thought that we must first recognize local communities as the victims of 30-year long operation of nuclear power plants. But, at the same time, we must also ask: "Are the abutters living in Gilcheon and Wolnae Towns the only ones who are affected by the continued operation of Kori 1? Are they exposed to more risks than say, people living further away from the nuclear reactor? Can we say that people in city [would] suffer less than those living closer by?"... [by] *...that's what we mean by substantive environmental justice. Viewed in this way, we will be able to expand stakeholder groups who can intervene in the issue of relicensing Kori 1. We will have to include Busan and Ulsan Metropolitan Cities.* And we need an institutional arrangement through which all these stakeholders can participate. [emphasis added]. (Jeong 2012)

The local community representatives held that they were the ones who are affected the most and had rights to participate in the license renewal decision-making. For example, in the Kori Case, abutters in Gilcheon Town, located less than one mile from Kori 1, claimed that they were the most affected people and thus reserved their rights to negotiate with KHNP Park 2012). Similarly, the representative of abutters living in Wolnae Town did not welcome the participation of people from other towns located further away from the power plant. Mr. Seo Yong-hwa, one of the community representatives who served on the negotiating committee back in 2007, insisted that

KHNP and the regulatory agency must prioritize the concerns of abutters and ensure their participation accordingly:

> Recently, Yeonje-Gu and Haeundae-Gu began to claim: "Is it only you who are at risk? If an accident like Fukushima accident occurs here at Kori, all Busan citizens will be in danger." It goes on and on like this…I think that KHNP must help the most marginalized people in small abutting towns first, and then those living elsewhere gradually if they have available resources. (Seo 2012)

In fact, abutters had different concerns among themselves. There are different sub-groups among the abutters, who often presented conflicting views among themselves about whether and how their concerns should be collectively represented during the license renewal processes. In the Wolsong Case, for example, local residents were divided into a number of different stakeholder groups: Yangnam Development Council (YNDC), Yangbuk Development Council (YBDC), Gampo Development Council (GDC), and Naa-Nasan Coalition for Relocation (NNCR). These Development Councils represented three local towns located within the EPZ boundary while the NNCR consisted of residents who lived just outside Wolsong 1(Figure 2.4). The representatives from each of the three Development Councils participated in both the Stress test reviews and negotiations with KHNP, but the NNCR did not. Although they lived in the same local municipality (Yangnam-myeon), their views and interests regarding the continued operation were quite different: YNDC representatives opposed relicensing but were willing to settle an agreement with KHNP. NNCR members also

opposed relicensing and made their relocation request.[57] An YNDC representative contended that the NNCR members were only a small number of opponents who were not supported by the rest of townspeople (anonymous community member 2016).[58] By the same token, however, the members of the NNCR contended that YNDC members were unrepresentative supporters of the extended operation of Wolsong 1 (Jeong-seop Kim 2016).

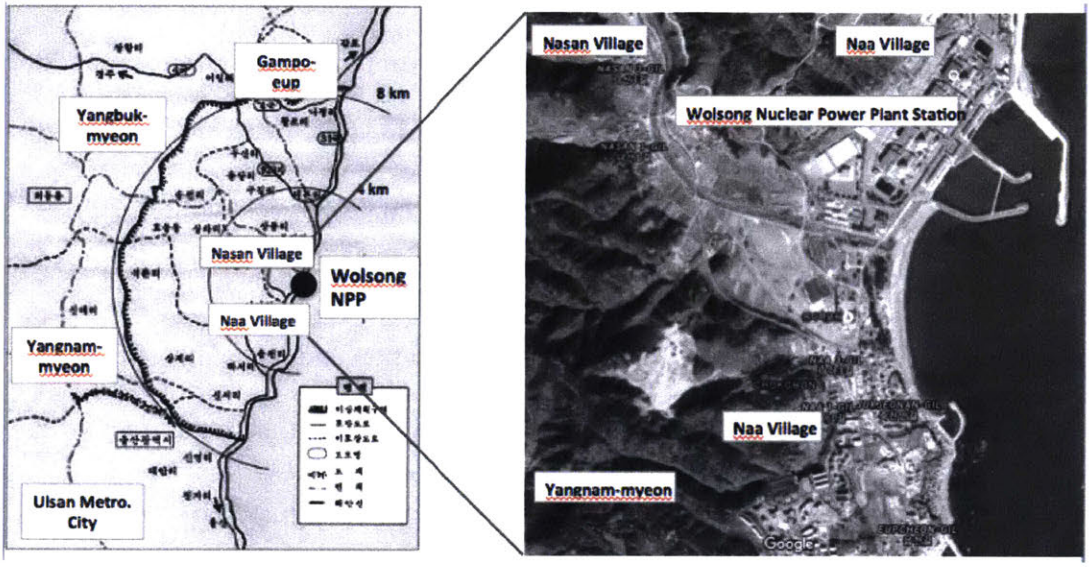

Figure 2.4. Location of Wolsong Nuclear Power Plant Station and local municipalities
Source: Website of the City of Gyeongju and Google Map

In South Korea, it seems that disagreements about the scope of technical issues examined during a number of joint review processes were much less intense than they

[57] The Nuclear Safety Act mandates that residents who inhibit within the Exclusion Areas have rights to claim for relocation and be compensated for any loss caused by relocation (The Nuclear Safety Act Article 89; The Enforcement Decree of the Nuclear Safety Act Article 129).

[58] The YNDC representative whom I interviewed wished to remain anonymous and unrecorded. My account of the interview rests on my memos and memories.

were in the United States' cases. In both Kori and Wolsong Cases, the review process focused squarely on the issues related to plant safety because KHNP is not required to address off-site environmental impact associated with nuclear relicensing except the radiological impact. As a result, numerous environmental concerns were marginalized during the review processes where the public had an opportunity to provide some input. In the Kori Case, for example, the representatives of Jangahn-eup Local Development Council (JLDC) did not address on-going neighborhood concerns such as the effects of high seawalls installed to protect the plant site from extreme natural hazards[59] and the lack of fallout shelters and protective equipment available at Kori 1 site.[60] Similarly, in the Wolsong Case, the lay reviewers of the Stress test could not deal with health concerns in depth although they were aware of the fact that local residents had been concerned about the elevated level of tritium concentration and its health effects. However, the negatively concerned stakeholders did not contest the legitimacy of the limited technical scope of participation as intensely as their U.S. counterparts.

In this chapter, I examined four different types of disagreements that I observed in the controversial nuclear plant license renewal cases in the United States and South

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[59] The seawall at Kori 1 reactor site was particularly lower than other reactor sites. In 2012, as a part of its Post-Fukushima Actions, KHNP extended the height of the existing seawalls from 7.5 m to 10 m to protect the nuclear plant station from earthquakes, high waves and flooding (https://cms.khnp.co.kr/knowledge/fukuimprove/fukuimprove2/). Some abutters expressed concerns about this effort because, in their eyes, it focused only on protecting the reactor site but was negligent of the impact on nearby neighborhood environment in the emergence of high waves (Seo 2012).

[60] In one annual public hearing meeting I attended in 2012, a number of local residents demanded that KHNP make more gas masks and clothing available to residents in Gijang County. They also questioned why many residents still did not have much information about the location of fallout shelters.

Korea. In the following chapter, I will examine what the similarities and differences are and identify factors that I think explain these similarities and differences.

3. Comparative Analysis

In the previous chapter, I examined a number of controversies surrounding nuclear re-licensing in the United States and South Korea. I looked at four kinds of disagreements that continue to arise: disputes over the acceptable level of risk, conflicts over the fair allocation of economic benefits and losses, challenges to the credibility of risk assessment studies, and confrontations over the appropriate scope of public participation in re-licensing decisions. In this chapter, I look at the similarities and differences in the way these four kinds of conflicts have been handled in the two countries.

I found the following three striking similarities – in spite of the cultural, political, historical, and legal differences – in the way these controversies have unfolded in the two countries. First, it was environmental activists and nearby residents in both countries who challenged the idea that the risks of health and severe accident were negligible, even though the relevant risk assessment studies suggested as much (albeit with high levels of uncertainty). In both countries, nuclear experts, engineers, utilities, and most regulatory agencies believed that the risks of relicensing were within acceptable levels while stakeholders tried to downplay the benefits and highlight the potential losses that could result from severe accident risks. Third, I also found that disagreements about environmental risk in both countries centered on the credibility of risk assessment studies that used to support regulatory decision-making. Specifically, the public contestation over the risk associated with nuclear re-licensing attempted to

find flaws in the design of the risk assessment studies, as well as their computer codes and input parameters.

The largest difference I found between the two countries concerned the scope of public participation that was allowed. In the United States, local activists, as well as state agencies, experts, and lawyers who supported them, contended that the rules of participation in the license renewal proceeding unfairly restricted them from raising concerns about important safety issues. In contrast, in South Korea, concerns about the limits on public participation revolved around the proximity presumption. In the following sections, I elaborate on these findings and identify the factors that might explain similarities and differences.

3.1. Similarities in license renewal conflicts

3.1.1. Similarities

Comparing the U.S. and South Korea, I found similarities in the disagreements that emerged regarding acceptable levels of risk. In the two countries, regulators and local activists differed in terms of their presumptions about the cancer risks associated with the normal operations of nuclear plants. They also disagreed about the adequacy of approved evacuation plans. In the United States, for instance, NRC concluded that the there was no definitive evidence supporting a hypothetical link between residents living in close proximity to nuclear power plants and elevated levels of cancer risk. NRC pointed to a National Cancer Institute Study that found no conclusive evidence about

such a link. Scientists working for the regulatory agency argued that cancer risk was very small and within an acceptable level. Despite this assertion, local activists and public officials were still concerned that the long-term operation of these plants might elevate cancer risk in the region. In the Oyster Creek case, in particular, independent scientists formed their own research team (called the RPHP Project) to investigate the health impacts associated with nuclear plant operation. They insisted that there is a causal link between normal plant operations and elevated cancer risk among children living nearby (Gould et al. 2000a; Mangano 2006; Mangano et al. 2003). Concerned about these findings, local women activists sought to raise public awareness about potential health impacts of living near plants (Tauro 2016). They were at the heart of a local coalition called STROC who opposed to the license extension at Oyster Creek. NRC criticized RPHP studies for the flaws in the methodology (e.g. drawing conclusions from small samples) and contended that the public did not need to worry about the "tooth fairy" findings (NRC 2004a; NRC 2004b). NEI supported NRC, finger-pointing nuclear weapons testing and the Chernobyl accident for the high concentrations of Strontium 90 (NEI 2014).

In the Korean cases, debates about the link between cancer risk and nuclear power plants were inflamed by a lawsuit (Park and Cho 2014). Environmental groups argued that even low levels of radiation could have an adverse impact on abutters' health. They insisted that cancer risk increased proportional to radiation exposure time even if exposure levels are low, particularly among young children (Kim 2013). However, KHNP, the KNS and the KARP maintained that there was no proof of

a positive relation between the operation of nuclear plans and an increase in the thyroid cancer risk found among abutters (Kim et al. 2015).

Secondly, stakeholders' disagreements about likely economic losses and benefits emerged in both countries despite the differences in the market structures of nuclear power industries. In the Indian Point case in the United States, the dispute over the economic consequences of nuclear license extension can be traced to the use of different analytical lenses. Those who supported relicensing the two nuclear reactors, such as Entergy, NEI, and New York City, believed that keeping the plants open would be more cost-effective than closing them (and having to replace them with new energy sources). They argued that the plants involved had provided high-paying jobs, substantial local tax revenues, and cost-effective base-load power, all of which would not be possible if they shutdown. In contrast, groups who opposed relicensing, such as Riverkeeper, the State of New York, and the NRDC, insisted that the economic losses associated with a potential accidents (i.e. decontamination costs) were grossly underestimated (Lyman 2007; State of New York 2014). They argued that the losses would escalate considerably if Entergy used more realistic monetary values in estimating the cost of the health effects generated by radiation exposure. However, while they also tried to downplay the costs of replacing the electricity generated by these plants with alternative energy supplies. In other words, both supporters and opponents relied on analysis and evidence that only told part of the story.

Similarly, the controversy surrounding the economic benefits and losses in the Kori case was also rooted in differences in the evidence the stakeholders used to justify

their claims. When it first filed its license renewal application, engineers from KHNP tried to explain the economic benefits of continued operation in terms of its impact on the national economy (Kim 2007; Lee 2016). They claimed that the continued operation would provide more than 30 million kW of electricity to ratepayers throughout the country (Kim 2007). They also maintained that the license extension for the second term would generate net profits that exceeded operating and maintenance costs. In contrast, environmental activists, as well as experts and politicians who supported them pointed to "hidden costs," such as the community benefit funds, decommissioning costs, and high-level nuclear waste disposal fees that they claimed outweighed the supposed economic benefits (D. Lee 2015; H. Ihm 2013). In addition, KFEM tried to highlight the potential losses associated with possible accidents, projecting losses ranging from 12.5 to 860 billion U.S. dollars, depending on the direction of wind and the extent of the evacuation (Park, Yang-Lee, and Kim 2012). They argued that these costs could easily tip the balance toward permanent closure of the plant (D. Lee 2015; S. Park 2015). KHNP immediately refuted these claims, running simulations of their own. They argued that KFEM's estimates did not take into account of the fact that reactor buildings were designed to limit the amount of radioactive released into the environment (K. Park 2012). Finally, they also contended that KFEM was ignorant of the international guidelines for conducting a severe accident impact analysis and that they had falsely applied the concept of population dose (Ki-jean Park 2012).

It is difficult to pinpoint the risk perceptions behind all of these charges and counter-charges. Interviews with agency staffs, elected officials, environmental activists, local residents, and experts who had supported either the regulators or the

activist groups, were inconclusive. Their political strategies may not have accurately reflected their perceptions of risks and benefits associated with nuclear relicensing. Instead, they might reflect nothing more than their thoughts about various risk assessment studies being discussed. I can only assume that stakeholders on the opposing and supporting sides in both countries used similar strategies because it served their interests to do so.

In both the United States and South Korea, disagreements about environmental risk centered on the credibility of the risk assessment studies used to support regulatory decision-making. By comparing the claims of environmental activists in the two countries, I found that those opposed to relicensing employed similar strategies—attempting to find flaws in the design of risk assessment studies, computer codes, input data and interpretation. They questioned the reliability and the appropriateness of the scientific studies that were used to support relicensing decisions. Given the stark differences in regulatory decision-making and the safety assessment studies used in each country, the similarity in tactics is quite interesting.

In both the United States and South Korean, environmental groups, as well as stakeholders and experts supporting their claims, often fused their political values with their arguments that they had sufficient knowledge to challenge the scientific studies put forward by experts advocating renewal. Their questions almost always targeted the moral and normative aspects of scientific assessment: Are probabilistic assessment and sensitivity analysis the most credible ways of characterizing the uncertainties surrounding the public health risk of nuclear power? Do nuclear experts and researchers

adequately take into account of the daily lives of local citizens and their first-hand knowledge (e.g. the activist contestation about the insufficient inclusion of local meteorological data in the Pilgrim Case)? Was the monetary value attached to a human life appropriate (e.g. the contestation over the Indian Point SAMA analysis)? Who are "communities at risk" and how should they be included or represented in environmental/health impact studies (e.g. the contestation about the omission of an Environmental Justice population analysis in the Indian Point Case, and challenges to the design of the national epidemiological study in the Korean cases)? All of these questions were used to challenge the scientific credibility of the risk assessments on normative ground.

Most importantly, in both countries, opposing stakeholder called attention to site-specific characteristics in raising doubts about the credibility of probabilistic risk assessments. The calculations involved in all of these studies (i.e., PRA) are quite complex. They hinge on a great many "non-objective" assumptions. And, the analysts must input hundreds of parameters, many of which involve large amounts of uncertainty. Thus, the results can vary greatly depending on the choice of parameters and the way the input data are organized. Environmental groups and their like-minded experts strongly opposed relying just on low probability events, averaging techniques or sensitivity analyses, all of which require standardized methods and aggregation of data points to some extent. They argued that utilities failed to consider uncertainties associated with variations in input data by neglecting individual information but instead using aggregated data. One impetus was their notion that the inclusion of site-specific data or collection of more information would clarify the uncertainty problem and help

prevent the worst-case scenario from occurring. In the end, these disagreements about the PRA's ability to capture reality and predict future events often converged on the normative discussion about what counts as qualified input data.

In the Pilgrim Case, for instance, Pilgrim Watch questioned the credibility of the SAMA analysis. They argued that Entergy had used averaged meteorological data that did not provide a true representation of the site-specific characteristics. Similarly, in the Indian Point Case, the New York State Attorney General, International Safety Research Inc. who provided expert advice to the State agencies of New York, and the Union of Concerned Scientists argued that the inputs to the MACCS2 code should have reflected the characteristics of each nuclear reactor location. They claimed that the costs and methods of cleaning up after a severe accident would be very different depending on whether a reactor is surrounded by farmland, forests, suburban areas, urban areas, or hyper-urban areas (Lemay 2011). In their view, the Indian Point SAMA analysis paid insufficient attention to the physical conditions surrounding Indian Point – which consisted of high-rise buildings, and mixed commercial and residential suburbs – and the ways these conditions could shape the consequences of a severe accident.

In the Wolsong Case, KFEM and a number of geologists and geophysicists questioned the credibility of the PSHA study. They raised questions about the omission of data they thought were relevant to determining seismic characteristics of the site. They emphasized that the Korean peninsula has relatively long inter-seismic intervals (in other words, low frequency) and little seismic activity, which renders seismic risk estimation quite difficult. They noted that the Wolsong site had relatively more seismic

activity in the past. They also insisted that researchers who conducted the PSHA study should have considered as much site-relevant data as possible, including historical earthquake data and seismic data available in Japan. In their views, the PSHA study would have produced a different result if the modelers had considered appropriate and all the available seismic data and given more weights to expert opinion suggesting a larger value for the maximum credible earthquakes—in other words, the worst-case earthquake scenario. However, KHNP and experts at KINS and the NSSC Resource Panel did not agree. This debate raised the question of what counts as qualified input data and how uncertainties should be characterized.

Arguments about the importance of taking site-specific characteristics into account in nuclear relicensing decisions helped them establish themselves and other underrepresented groups as important stakeholders. They maintained that they had been underrepresented in various risk assessment studies and their interests had received inadequate protective measures. The underlying claim was that the particular experiences of those who are affected by the license renewal decisions must be recognized and incorporated into scientific studies if they were to perceive these scientific studies credible.

For example, in the Indian Point Case, Riverkeeper, Chapter of Citizens for Equal Environmental Protection (CEEP), and the City of Peekskill Council (located 1.5 miles from the plant) questioned the validity of existing evacuation plans. They said that the possible impact on an "environmental justice population" living in the City of Peekskill and the village of Ossining had been overlooked. These groups conducted

research on their own in which they demonstrated that minorities and low-income families near Indian Point would definitely be affected by air pollution from the plant (Raimundi, Wilson, and Greene 2010). They also showed that the population in the City of Peekskill relied heavily on public transportation and therefore might be exposed to higher environmental risk in the event of severe accidents (Clearwater 2012; Claxton 2011). Based on this information, local activist groups and the experts they hired demanded that regulators acknowledge the disproportionate impact a serious accident at the plant site would have on these groups and called for new emergency evacuation and protection plans.

Similarly, in the South Korean Cases, environmental groups challenged the definition of exposed groups in the national epidemiological study. This helped them connect with local residents and collect anecdotal evidence from cancer survivors in the local areas. In particular, in the Kori Case, environmental groups and experts such as Busan Chapter of KFEM and KAPH challenged the design of the study for the way it categorized exposed and non-exposed groups. They maintained that the national study had defined "community at risk" too narrowly, and incorrectly assumed that only abutters living within a 5 km radius of nuclear plants would be exposed. In this way, environmental activists tried to mobilize local residents who lived beyond the 5km-bundary but fairly close to nuclear plants.

In several of the renewal cases I examined, regulators called for additional research particularly when environmental activists challenged the credibility of risk assessment studies by noting the insufficient analysis of the site-specific conditions. In

the Indian Point Case, for instance, NRC reversed its previous decision and required Entergy to conduct an additional sensitivity analysis to address the uncertainty surrounding the input data it used in its SAMA analysis (NRC 2016a). And, earlier, the Appeals Court remanded NRC to redo its analysis of the environmental impacts of storing spent fuel on site for the long term. *New York et al. v. NRC (2012)*. Similarly, in the Wolsong Case, the NSSC Resource Panel suggested that the NSSC require KHNP to re-examine its PSHA study and conduct a new study of the seismic sources at the site. In light of the debate about the link between proximity to nuclear plants and thyroid cancer rates, the NSSC called for a follow-up epidemiological survey of workers and residents living near nuclear plants (Jinjoo Lee 2015). In both countries, regulators called for additional long-term studies that halted, albeit, only temporarily, scientific disagreements about how to estimate risk and deal with uncertainty in nuclear plant relicensing.

3.1.2. Why similar?

Why do the stakeholder groups in the two countries divide in similar fashion with regard to their interpretation of risk assessment studies conducted for making nuclear license extension decisions despite significant cultural, historical, economical, and legal differences between the two countries? Or, put another way, why are the strategies used to defend or attack the scientific credibility of quantitative risk assessments similar in the two countries?

I think there are three reasons for the surprising similarities. First, in my view, the similarities partly stem from the fact that the safety guidelines and regulations used

in the license renewal decisions in both countries build on the same technical discourse – PRA – that characterizes risk in a very particular way. PRA postulates the probability of an accident then calculates the consequences of that accident (Keller and Modarres 2005). It uses event trees to determine both the probabilities and the consequences of an accident. Event trees help identify failures in major systems, such as the engineered safety systems of a reactor, as well as the ability of a nuclear power plant's containment system to prevent the release of radiation. In both the United States and South Korea, PRA is the primary method of formulating safety regulations that support license renewal decision-making.[61]

In the United States, nuclear experts relied on PRA in drafting NRC risk-informed safety regulations and communicating risk to the public (Apostolakis 2004; Keller and Modarres 2005). It was the basis for developing guidelines for risk-informed licensing, emphasizing the assessment of risk associated with dry storage of spent nuclear fuel and justifying the revision of the Pressurized Thermal Shock screening criteria (Keller and Modarres 2005).

When it first drafted the GEIS in 1996, NRC used PRA to figure the potential impacts of severe accidents during the renewed term. It concluded that environmental consequences from severe accidents would be small for all U.S. nuclear plants because the probability of accidents was so low (10 C.F. R. 51 Subpart A, Appendix B, Table

[61] In South Korea, Probabilistic Safety Assessment (PSA) is more frequently used than the PRA. They refer to the same methods.

B-1).[62] At the same time, the GEIS required utilities to identify cost-effective alternatives to mitigate the severity of accidents at individual plant sites. This was based on SAMA analysis, which also employs various PRAs. Nuclear engineers are required to examine a wide range of accident scenarios that can lead to core damage function, estimate the frequency of accidents that may release radioactivity, identify the types of accidents with relatively high frequencies, examine off-site risks, tease out the most cost-effective risk mitigation measures and examine uncertainties associated cost-benefit analysis (Bixler and Haaker 2009; NEI 2005). In short, PRA has become a dominant technical and "cultural practice" within the U.S. nuclear regulatory sector (Kadak and Matsuo 2007), including the relicensing decision-making processes.

In South Korea, probabilistic risk assessments have been used increasingly to support nuclear licensing and relicensing decisions (Kim et al. 2003). PRA was officially introduced in the Korean nuclear regulatory system in 1994 when the Ministry of Science and Technology published its Nuclear Safety Policy Statement. By 2014, the NSSC required KHNP to conduct a PRA for all existing nuclear power plants (NSSC No. 2014-10). PRA was also used in a number of safety regulations formulated for making nuclear relicensing decisions, which Korean nuclear experts and regulators had learned from the experiences of nuclear industry in the United States. For instance, PRA was incorporated into a method called Master Curve method that was used in evaluating the integrity of a nuclear reactor pressure vessel during Pressurized Thermal

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[62] According to this rule, "probability weighted consequences of atmospheric releases, fallout onto open bodies of water, releases to groundwater, and societal and economic impacts from severe accidents are small for all plants." (10 C.F. R. 51 Subpart A, Appendix B, Table B-1, Issue 76)

Shock conditions. PRA was also incorporated into the PSHA studies that were used to estimate the likelihood of earthquake events occurring at the site and their magnitudes.

It is difficult to say that the use of PRA in risk-informed safety regulations was the cause of disagreements. Rather, stakeholders who were opposed to license extensions realized the key role PRA played, and chose to focus on it. Comparing the public disagreements in the two countries, it seems that that key stakeholders in both countries are disinclined to accept the probabilistic conceptualization of risk. Instead, they prefer to focus on worst-case scenarios. They want to be assured of the feasibility of preventive measures. Although they learned and used technical language to articulate their opposition, activists and local community groups also relied on common sense, anecdotal evidence, or tacit knowledge gathered through their daily lives during which they estimate the magnitude of consequences associated with potential severe accidents and notice what appears to be a link between low-dose radiation and health impact. To the lay activists, nuclear regulators and license applicants' probabilistic approach to risk characterization was just one of various possible ways of thinking about risk and uncertainty. Risk assessment studies were not perceived as legitimate because, in the eyes of those who contested them, they neither represented the worries of the concerned public nor took into account site-specific conditions. As a result, the activists insisted that the conclusions drawn from risk assessment studies should not be considered deterministic in making licensing and relicensing decisions.

Finally, an increase in public participation in nuclear licensing and relicensing decision-making processes in South Korea may have also contributed to the use of the

"credibility challenges" that emerged in the United States. Under the initial Korean regulatory framework, KHNP had not been required to consult public interest groups during the license renewal process until 2014 (Figure 3.1). In the absence of explicit rules about public engagement, KHNP initially took the standard "Decide-Announce-Defend" approach when it applied for license renewal of Kori 1 in 2006 (T. Park 2008; Jeong 2011). Safety assessment documents were not released to the public before hearings and the company-local community negotiations began. And, public interest groups were poorly organized about the technical aspects of risk associated with nuclear relicensing. As a result, there was little scientific contestation about the ways in which the utilities and regulators analyzed risks, benefits and uncertainties. However, as we can see in Figure 3.1, the Korean government introduced new rules in 2012 regarding how the public was to be engaged in license renewals. These changes were applied in the Wolsong Case, in which the CRB and ad-hoc joint technical committee meetings were introduced. Stakeholders were invited to review the Stress test evaluation submitted as part of the license renewal application. It was mainly at these junctures that the public stakeholders including KFEM and local communities challenged the lack of input data and tried to undermine the credibility of the PSHA study (Y. Kim 2015; S. Kim 2015; Sang-wang Kim 2016). In short, in both the United States and South Korea, public stakeholders challenged the way in which utilities, experts and regulators were characterizing the risks and uncertainties associated with nuclear relicensing.

Figure 3.1 Regulatory reforms regarding public engagement methods used in a license renewal process in South Korea

3.2. Differences in the sources of license renewal conflicts

3.2.1. Differences

The controversies around nuclear re-licensing in the two countries were different in terms of how public participation requirements were challenged. The representatives of the opposing groups, whom I interviewed, expressed strong dissatisfaction with the public participation methods used in each country. Their specific challenges, however, were somewhat different. In the United States, disgruntled groups disagreed with NRC about *what kinds of concerns could be raised at a hearing*. In South Korea the battle was much more about *who accounts as the affected public*. In the following sections, I examine this difference in depth and describe how and why these differences probably emerged.

In the United States, disagreements about the scope of public involvement were rooted in contrasting judgments about what counted as admissible contentions rather than who could participate in the proceedings. Rules requiring that interveners' concerns be within the scope of the proceeding became particularly controversial during NRC adjudication. As I illustrated in Chapter 2, the concerns were not permitted if they were deemed beyond the scope of the license renewal proceeding. Environmental issues raised by the GEIS were defined as admissible. Concerns related to Category 2 issues such as the environmental impact of cooling towers and SAMA were acceptable. Those related to Category 1 issues such as evacuation plans and the environmental impact of spent fuel storage were considered to be outside of the scope of the proceedings. There are numerous license renewal case examples in which ASLB

made its decisions about acceptable contentions along this line. In the Oyster Creek Case, to name one case example, the ASLB judges ruled that contentions about the vulnerability and environmental impact of the spent fuel pool were "*beyond the scope of... and inadmissible* in, the license renewal proceeding." LBP-06-07, 63 NRC 188 (2006). Similarly, in the Indian Point Case, ASLB judges stated that State of New York and Clearwater's attempt to challenge the storage of spent nuclear fuel during the renewed term was an "impermissible challenge" on the NRC conclusion that spent fuel storage issues do not need a site-specific environmental report or discussion. LBP-08-13, 68 NRC 43, 217 (2008).

The representatives of environmental groups and State agencies who participated in the federal relicensing processes as interveners insisted that they had been unfairly constrained by the pre-defined list of what was permissible (Webster 2016; Lampert 2012; Gunter 2016; Tauro 2016). They maintained that a number of Category 1 safety and environmental issues needed to be addressed during the adjudication because they had important site-specific impacts. Again, in the Oyster Creek Case, the New Jersey Sierra Club and the New Jersey Environmental Federation challenged the NRC decision that refused their effort to focus on the adequacy of the evacuation plans and the vulnerability of spent fuel storage systems to terrorist attack. *New Jersey Sierra Club et al. v. NRC, 2007* (Second Cir. No. 07-1267). The New Jersey Department of Environmental Protection asked the court to review the NRC decision to deny its petition to intervene in the license renewal proceeding. *New Jersey Department of Environmental Protection v. NRC, 2009* (2009). In the Pilgrim Case, Ms. Lampert, the representative of Pilgrim Watch, complained that key public concerns

such as emergency planning, spent fuel storage, health impacts and leaks of radioactive liquids offsite from buried components" were "deliberately taken off the table for petitioners to litigate" (Lampert 2012).

In South Korea, in contrast, the technical scope of the review processes was relatively less contentious. Central to public dissatisfaction was the question of "who should participate" and "who should be counted as the communities at risk." Conventionally, under Korean nuclear safety regulation, "abutters" were defined as those who live in "neighboring areas" located within a 5-kilometer radius from nuclear facilities. (The MST 1990 No. 4134; The MOTIE 2015 No. 13151) and those who lived within EPZ boundaries (NSSC No. 2011-4). According to the Nuclear Safety Act, KHNP must consult with local communities and the NSSC has the authority to decide the geographic scope of the public allowed to participate in the consultation (The Nuclear Safety Act (Act No. 13078) Article 103 Paragraph 1, subparagraph 2). In the Kori Case, although they tried to communicate with the public, KHNP and the Ministry of Knowledge and Economy sought to build a consensus with local communities or abutters living near the nuclear plant (Park 2008). In the Wolsong Case, representatives from both local communities and environmental groups were invited to participate in reviewing the Stress-test; however, only community representatives from the three neighboring areas were invited.

In both cases, public groups disagreed about the ways in which the utility company, the Korean government and the NSSC relied on the "proximity presumption" in engaging the public—an assumption that a stakeholder has standing to intervene or

request a hearing if he or she lives within, or otherwise has frequent contacts with, the zone of possible harm from the nuclear reactor (Repka and Smith 2010). Regulatory entities, policy makers, and facility operators often rely on this proximity hypothesis in engaging the public (Benford, Moore, and Williams 1993; Hunter and Leyden 1995; Lowry 1998; Aldrich 2008). Disputes around facility siting or relicensing may involve the question of which community boundaries matter and why because different stakeholders may hold on to their own notions of a community (Lesbirel 2011). In the Kori Case, in particular, local environmental groups contested the utilities and regulators' use of the existing EPZ boundary to identify legitimate public participants. In the eyes of these groups, "communities at risk" were too narrowly defined – in their view stakeholders other than abutters had a right to participate (Jeong 2012; Jeong 2015). Similarly, in the Wolsong Case, Collective Action for Nuclear-Free Society (CAFNS) filed a citizen suit challenging what they saw as procedural deficits. These included the absence of consent from all local communities and underrepresentation of citizens who lived beyond the EPZ areas (Kang 2015).

The representatives of some communities stepped forward to claim their right to participate in the joint review process, not by rejecting the proximity presumption, but by supporting it and mobilizing their collective identity as abutters (Seo 2012; Joo-hoon Kang 2012; Jeong-seop Kim 2016). The underlying logic of their claim was that the residents living closer to the nuclear power plants had been and would be more adversely affected than those who lived farther away. In their minds, environmental groups and residents who lived farther away from the nuclear reactor did not really share the same lived experiences about the impact of plant operation (Seo 2012).

In the Wolsong Case community members expressed concern about the link between the relatively high levels of tritium concentration in the local areas and cumulative health impacts. Yet, the purpose and scope joint review process in which they participated were to evaluate the plant's capacity to withstand emergent situations. Therefore, their health impact concerns were downplayed while concerns about the credibility of the plant-level risk assessment studies such as the PSHA got almost all the attention. Opposing stakeholders did not contest the scope of Stress-test reviews once they earned a seat in the review processes. For example, the Chairman of the CRB said that it would be difficult to bring up issues like cancer risk associated with high level of tritium. The "stress-test" had its own scope and boundary that they must take into account (Y. Kim 2015).

3.2.2. Why were they different in the way they were?

Why was public contestation regarding the scope of engagement different in the two countries? Why was the geographic scope of public involvement more controversial in the South Korean cases than in the United States' cases? And why was the acceptable scope of technical disagreements more highly contested in the United States than it was in Korea? In my view, the difference might have resulted from the different levels of regulatory discretion that stakeholders thought were used as a means to limit their involvement.

The proximity presumption could have been less contentious in the United States than in South Korea because activists did not think that NRC used the proximity presumption as a way to limit their expression of concerns. The opposing stakeholders

rarely challenged the geographic scope of public engagement, but this was not because the proximity presumption was not used. NRC assumes that, in general, petitioners residing within 50 miles of a reactor can de-facto be recognized as stakeholders, and this was considered to be the "rule of thumb" in reactor licensing proceedings. Sequoyah Fuels Corp. & Gen. Atomic (Gore, Oklahoma Site), CLI-94-12, 40 NRC 64, 75 n. 22 (1994). The proximity assumption was also used in the context of license renewal decision-making because the "radioactive source posing the danger in a reactor license renewal case is identical to the source" that gave rise to the rule used in licensing proceedings. Amergen Energy Co. LLC (Oyster Creek Nuclear Generating Station), Docket No. 50-0219-LR (ASLBP No. 06-884-91-LR) (2006). However, in granting standing, ASLB also considers a number of other factors including the extent to which a nuclear license renewal decision could have an impact on the interests of the petitioners, such as their property, financial, and other interests. 10 C.F.R. §2.309(d)(1)(2).

In the Korean cases, it seems that the long-standing public engagement procedures were no longer compatible with growing public concerns about nuclear re-licensing. The fact that large anti-relicensing coalitions emerged in both Busan and Ulsan Metropolitan Cities (Shin 2015; K. Kim 2015) seeking to shutdown the two aging nuclear plants supports this hypothesis. In the Kori Case, a bipartisan coalition was formed prior to KHNP's application for license renewal of Kori 1 for the second time. In February 2015, more than 120 local and regional grassroots organizations from Busan and Ulsan Metropolitan Cities formed an anti-relicensing coalition called Pan-Busan Citizens Coalition For Permanent Shutdown of Kori 1 (the Pan-Busan Citizens

Coalition, PBCC) (Su-yeong Choe 2016; K. Kim 2015). Similarly, in April 2015, more than 40 interest groups in Ulsan Metropolitan City established Pan-Ulsan Citizens Coalition to Permanently Shut Down Kori 1 and Wolsong 1 (PUCC). They emphasized that people residing in certain districts of Busan and Ulsan Metropolitan Cities lived close to both Kori and Wolsong nuclear plants and would be affected by a license renewal decision (Ulsan KFEM 2015).

These interest groups were not considered to be conventional "communities at risk." Thus, they were not granted legal standing when they tried to raise concerns. They were not given an opportunity to provide a meaningful input. On the heels of the Fukushima accident, a group of citizens in Busan filed a preliminary injunction aimed at shutting down Kori 1. The Busan District Court ruled that this group could not be granted legal standing unless they could provide concrete scientific evidence showing a high probability of postulated accidents and proving that they would also be affected. *Busan Eastern District Court Ka-Hap 2011.* In the eyes of the activists who opposed relicensing but lived far from the plants, the proximity presumption might have been the primary mechanism used to limit their involvement.

In the United States, the limited technical scope of the license renewal proceedings is no longer compatible with growing concerns about the impact of license extension on spent nuclear fuel storage. A series of lawsuits in which state agencies sought to repeal ASLB's decisions along these lines illustrate this point. In *NJDEP v. NRC* (2009), the NJDEP asked the court to review the NRC's decision to deny its petition to intervene. They questioned the idea that the environmental risk associated

with continuous storage of spent fuel on site is only a *generic* problem and not a *site-specific* problem.

In the two South Korean cases, opposing stakeholders seldom challenged the scope of technical disagreements because the review processes in which they were involved were informal ad-hoc forums. In addition, public participants were concerned about ensuring the authority, legitimacy and credibility of their advice once they were given opportunities to participate.

Based on these findings, I suggest that those who were either excluded or underrepresented might well have perceived regulators' categorization of public concerns and standardization of their involvement as illegitimate, and even a deliberate attempt to marginalize particular concerns or groups of stakeholders. In the Kori, Wolsong, Indian Point, and Pilgrim cases, these perceptions about the license renewal processes shaped a policy discourse and gained political salience. Activists may be able to broaden their coalitions building upon claims that challenge the procedural deficits of relicensing decision-making. And, the presence of large coalitions may have an impact on public perceptions about the risks and benefits associated with nuclear license extension.

Nonetheless, it is still challenging to prove a direct causal relationship between dissatisfaction with the limited scope of participation during the facility-siting process and widespread opposition. This is one of the underdeveloped areas within the literature on Not-In-My-Backyard (NIMBY) and facility-siting disputes, which requires additional research (Schively 2007; McAdam et al. 2010).

Absent definitive proof about the factors leading to widespread opposition, it could be tempting to state that growing political opposition to risky facility siting, licensing and relicensing is mostly an overreaction to risk. Utilities and the nuclear regulatory agencies must resist this temptation if they want to (re)build public trust. Instead, they should focus on new ways to respond to such risk perceptions and find ways to convince stakeholders that they are actually doing something to reduce risk. Activists must also contemplate what the best ways are of ensuring meaningful public input. Local residents must think of ways to ensure that their interests are met even in the midst of many other strong voices for and against facility-siting and relicensing the nuclear plants. In the following chapter, I will offer some recommendations along these lines.

4. Conclusion and policy recommendations

4.1. Summary of findings

In this thesis, I examined political pressures to shut down existing nuclear power plants. In particular, I examined and compared controversies surrounding the license renewal of existing nuclear plants in South Korea and the United States – two countries that are vastly different in terms of regulatory framework, safety requirements, approaches to public engagement, and the number of plants that are allowed to operate a few years beyond their design lifetimes. I chose to compare these countries because I wanted to understand the underlying sources of conflicts, the extent to which they were the same or different, and why and how they were similar or different. I examined four types of disagreements in each country: disagreements over the determination of the level of acceptable risk to human health and safety, disagreements concerning acceptable economic losses and the distribution of economic benefits, disagreements regarding the credibility of risk assessment studies, and disagreements about the scope of public involvement in making final license renewal decisions.

I found a number of similarities, contrary to my expectations. First, in both the United State and South Korea, supporters and opponents of nuclear relicensing had different conclusions about whether the risk of possible accidents and their health-

related impacts would be within acceptable levels. Nuclear professionals (i.e., utilities, nuclear engineers, and nuclear industrial associations) who supported license renewals in both countries characterized risk in terms of the probability of an accident times its consequences using probabilistic risk assessment methods. They maintained that the probability of a severe accident in which the public would be exposed to excessive radiation is sufficiently low during a renewed term, and therefore, the risk is acceptable despite the potential consequences. Although they did not support all license renewals, regulators also relied on the probabilistic characterization of risk associated with postulated accidents along with possible public health and environmental impacts. In contrast, environmental activists and local residents in both countries emphasized the "consequences" of possible accidents. They thought traditional probabilistic assessments of accident risk were unrealistic because, according to them, they either downplayed the full scope of the risk or relied on general evacuation plans (that overlooked the importance of site-specific characteristics) to reduce risks to acceptable levels.

With respect to possible impacts, license renewal proponents in both countries maintained that radiation released from daily operation of nuclear plants is sufficiently regulated and its concentration in the environment is generally too small even to be detected. They argued that health risks would be sufficiently low even if they considered cumulative impacts and not one-time events. They pointed to national epidemiological studies that found no relationship between the normal operation of nuclear plants and the health of nearby residents. In contrast, renewal opponents, including a number of medical experts and groups of abutters, believed that residents—

particularly children—could have been exposed to possible cancer risks if they lived near nuclear plants for long periods. To support their claims, local residents, activists, and epidemiologists collect both anecdotal evidence such as the medical histories of nearby families and neighbors, as well as non-conventional data such as baby teeth with high levels of strontium.

The American and Korean cases were also similar in terms of the disagreements that emerged between supporters and opponents regarding the likely level of economic losses and benefits associated with license renewals. In both countries, environmental groups highlighted what they thought were underestimated costs, including the loss of human life in the event of severe accidents, and claimed that these costs would be unacceptable if they were measured properly. In contrast, supporters of nuclear relicensing emphasized the benefits of license renewals, including the creation of high-paying jobs and increased tax revenues. They criticized opponents for downplaying the likely impact of permanent shutdowns on the electricity sector and the cost of replacing existing nuclear plants with other energy producing facilities.

Third, and most interestingly, I found that community activists in the United States and South Korea used similar tactics to publicize their concerns about public health risks and the economic consequences: they tried to undermine the credibility of published risk assessment studies and cost-benefit analyses. These attacks were performed in a similar fashion in both countries. Environmental activists worked with experts who supported their positions to criticize that the sensitivity analyses and data used in most of the technical studies submitted in support of relicensing requests. Most

importantly, they used their attacks on the scientific credibility of the technical studies to mobilize local knowledge about site-specific conditions (e.g., local meteorological conditions) and life experiences (e.g., traffic patterns) to challenge decision-making that relied too heavily on aggregation, standardization. They demanded that non-traditional data sources (e.g., historical archival data on seismic events and anecdotes about the health impact of nuclear plant operation) be given weight in license renewal decisions as a way of reducing analytic uncertainties. I argue that the surprising similarities in the concerned activists' strategies are caused, in part, by the use of the same professional scientific tools used in both countries to analyze and characterize risk. The claims that community activists made may not always be correct, but it is clear from my research that, if regulators and nuclear professionals do not make an effort to take site-specific local knowledge into account, their decisions will lose political credibility in the society at-large.

Finally, conflicts over nuclear relicensing in the two countries were different in some respects. I found that assumptions about and methods of public engagement diverge. In the United States, regulators, utilities, activists and state agencies had very different views about what counted as acceptable issues to raise at a hearing. This shaped the debate over the appropriate role of the public. In South Korea, stakeholders disagreed about who counted as the affected groups and should be given a chance to speak at a hearing. In the United States, the NRC identified certain environmental issues as generic, removing the need to examine these on a plant-by-plant basis. In the controversies I examined, environmental activists and state agencies questioned the legitimacy of regulators' categorization of these concerns. They felt that labeling these

concerns as "generic" unfairly closed the door on public discussion of these issues at the outset of license renewal proceedings. In South Korea (especially during the first license renewal review process that took place in the Kori Case), both the regulator and utility company limited their definition of communities-at-risk to people living within the boundary of the EPZ, and communicated with and made compensatory offers to these groups alone. Korean environmental activists criticized regulators for their narrow definition of communities-at- risk.

4.2. Limitation of the study and areas for future research

My study was conducted based on my interviews with agency staffs, elected officials, environmental activists, local residents, and experts who had supported either the regulators or the activist groups, which have a number of limitations. First, political strategies and stories revealed during the interviews may not accurately reflect their perceptions of risks and benefits associated with nuclear relicensing. Instead, they might just reflect their thoughts about various risk assessment studies being discussed. Therefore, I could only assume that stakeholders on the opposing and supporting sides in both countries used similar strategies because it served their interests to do so.

Second, although I have selected the representatives of major stakeholder groups to conduct the interviews, the data I collected cannot fully reflect the diversity of public opinion with respect to the benefits, risks, and costs associated with nuclear license

renewal decisions. To address this limitation, structured surveys or analyses of social media accounts around this issue may be useful.

Third, from my findings, it can be inferred that stakeholders' perceptions about public engagement rules may shape their perception of whether the risks associated with nuclear relicensing are being adequately managed. However, I was not able to produce definitive evidence of the impact of negative perceptions on the perceived legitimacy of the relicensing processes or on the decisions to form coalitions during or after the relicensing processes. Recent studies have shown that coalitions and their expansion have become a critical political force in provoking facility-siting disputes (Devlin and Yap 2008; M. Kang and Jang 2013; Gupta 2013; McAdam and Boudet 2012; Boudet 2011; Sherman 2011). These studies examine the effectiveness of a range of tactics used to bridge oppositional frames (Sherman 2011; Boudet 2011; Kang and Jang 2013). They also examine the impact of (1) the strength of the social networks built among existing local civic associations (Aldrich 2008; Boudet and Ortolano 2010; Walsh, Warland, and Smith 1997), (2) support from political allies (Boudet and Ortolano 2010; Lesbirel 1998), and (3) intergovernmental conflicts generated by site-specific fights (Sherman 2011). Unfortunately, these studies provide little insight into whether public groups dissatisfied with facility-siting decision-making were able to mobilize still larger anti-facility coalitions. Does the lack of diverse stakeholder involvement result in the formation of broader oppositional coalition? How and why do certain public engagement practices lead to broadened opposition that can have a decisive impact on siting or license renewal decisions? Future studies should address these questions, which remain underdeveloped in the (nuclear) facility-siting literature.

4.3. Policy implications

My findings raise a number of challenging questions for regulators and policymakers in each country to consider. First, the convergence of oppositional strategies by community activists raises questions about the credibility of quantitative risk assessment studies that rely only on probabilistic and other quantitative risk assessment methods to assess "actual risk." In this approach, laypeople's knowledge is seen as a distorted version of the actual risk facing the public, shaped by ignorance, prior beliefs and subjective personal experiences (Jasanoff 1998). However, according to Young (1996), relying more on local (or indigenous) knowledge can help reveal "particular experiences"— experiences that are often overlooked by outsiders like regulators, utility managers, and scientists, who are "situated differently." In science-intensive environmental disputes, claims that mobilize local knowledge often show how and why risk professionals rely on unacceptable level of simplification or aggregation. They also help to generate important information that is often ruled out by professionals as irrelevant because it is either too individual or contextual. Finally, they reveal differences within what is presumed to be the same population that makes certain groups more susceptible to hazards (Corburn 2005, 72–75). For example, in the Indian Point Case, Clearwater tried to demonstrate that the existing SAMA analysis overlooked the situation facing low income and minorities living near the plant sites because they relied on public transportation in their daily lives. This would clearly make them more vulnerable in the event of various postulated accidents.

Policymakers and regulators must recognize that when community activists claim that important local information is being overlooked, they are trying to shift the focus, and in the process modify control or power over the framing of problems and possible solutions. They should be aware that repeatedly overlooking such claims may result in broad-based political backlash. On the other hand, policymakers who rely to heavily on the claims of local activists must be aware that they risk overlooking important parts of the whole story. In the Indian Point Case, contrary to Clearwater's claims about the likelihood of negative impacts on low income and minority groups during emergency situations, the representatives of the African American Environmentalist Association New York Office (AAEA-NY) contended that the environmental report had sufficiently explored the likely impact on that group, but did not adequately examine the environmental benefits that Indian Point relicensing might offer this same group. Decision-makers and regulators must realize that the same kinds of assessments are likely to be interpreted, politicized and used in different ways by different stakeholders. It would, therefore, be useful to have an ad-hoc, informal forum during which both scientific and non-scientific information about the positive and negative impacts of relicensing could be discussed and synthesized before final decisions are made about how to frame risk assessments or other benefit-cost analyses. Assistance from neutral facilitators may be helpful in enabling such groups to reach consensus (Susskind, McKearnen, and Thomas-Lamar 1999). By relying on information and knowledge that both supporters and opponents think are important in terms of addressing their concerns, policymakers may be able to help stakeholders

jointly produce "usable knowledge" to support license renewal decision-making in a constructive manner (Lindblom and Cohen 1979; Ozawa and Susskind 1985).

Secondly, my findings suggest that regulators and policymakers should be cautious when they draw arbitrary boundaries around problem areas or identify relevant stakeholders at the outset of a nuclear relicensing process. In the United States, substantive categorization in the GEIS was one of the most important factors that gave the public and state agencies the impression that NRC was unfairly blocking their attempts to raise important environmental and safety concerns. In South Korea, particularly in the Kori Case, the choice of engaging a narrow set of local communities was the major procedural factor that made environmental activists and other interest groups feel they were excluded. If regulators are serious about meeting their obligation to ensure public input and wish to prevent growing public distrust, they should think hard about excluding stakeholder groups and their primary concerns. They should also provide informal policy forums where the scope of technical disagreements can be discussed without reference to legal precedents or generic conclusions. Finally, in my view, both decisions about the designation of appropriate stakeholder groups and final choices about the methods of public engagement should be made on a site-by-site basis.

It is challenging to ensure that all relevant stakeholders are represented in license renewal decision. New information may emerge during a debate around possible impacts associated with nuclear relicensing, which causes new groups of stakeholders to emerge. Because public engagement practices are consequential choices that can shape the politics of policy-making processes (Quick and Feldman 2011),

agencies should be open to the idea of including new groups in the process as unexpected issues emerge. Hunold and Young (1998) suggest that decisions concerning hazardous facility-siting should be made on the basis of a fairly "large unit of review," so that more stakeholder groups from a broader territorial boundary can get involved. From this theoretical viewpoint, an emphasis on the "inclusiveness" in the management of decision-making processes seems most appropriate. However, some time ago, Schattschneider (1960) suggested that political interest groups will attempt to enlarge the scope of conflict by engaging more individuals and potential stakeholders. In recent studies about the facility-siting disputes, it was found that local contention in some cases spread to larger geographical areas, especially when state regulators were able to help connect disparate opposition groups by engaging these oppositional groups in various policy forums and developing broader oppositional claims (Boudet 2011; Sherman 2011). So, both over- and under- representation of stakeholders may become a growing source of conflict. Policymakers must identify and convene stakeholders carefully and on a site-by-site basis so that interests and concerns are balanced.

An effort to build a consensus around planning the future energy policy in Vermont may be a good example that illustrates how my suggestions can be implemented in practice. In around 2005, state agencies and the legislature in Vermont faced major challenge in terms of their energy policy. Nearly two-thirds of Vermont's electricity that came from two large power generation contracts with Vermont Yankee (nuclear power) and Hydro-Quebec (hydropower) were due to expire in between 2012 and 2016. Vermont Department of Public Service asked Consensus Building Institute to assist them in navigating this policy challenge. The result that came out of this

consensus-building effort was not directly incorporated into actions that affected the state's energy policy or the nuclear relicensing decision. However, it is still an important example that shows how neutral facilitators can help identify stakeholders, assist them in jointly developing the scope of inquiries, and help review information in a manner that balances various interests and concerns about relying on a particular energy source.

First, important stakeholders representing the energy supply sectors such as Entergy (the nuclear plant operator), local industries such as IBM, local antinuclear groups and the representative of local community hosting Vermont Yankee plant were identified and invited to serve on the Advisory Committee and Resource Panel. With assistance from a neutral facilitator, the Panel members synthesized available information that examined environmental impact, costs and benefits associated with each energy source. They collaboratively developed background educational materials and survey questions that were used as the basis for steering discussion among citizens who participated in policy workshops. The technical document described 1) the energy supply gap that Vermont faced at that time, 2) information about the real benefits of reliable base load power at stable prices, 3) the extent to which existing power purchase from Vermont Yankee could be replaced, and 4) the possibility that spent nuclear fuel could be stored in Vermont for a long time. When the stakeholders prepared this document, they did not rely on the findings generated from technically complex models. Instead, they chose to present simple diagrams that synthesized information about relative costs and benefits associated with each energy source including nuclear power. These diagrams served as a "single text" and were used effectively in assisting a

statewide public dialogue on the State's future energy plans. Under the current regulatory framework, neither the state nor its citizens had final say in relicensing decisions. And, this policy dialogue focused on broader scope of issues related to the state's energy plan. So, the outcome of the consensus-building effort did not affect the nuclear relicensing decision. Nevertheless, it helped both the stakeholders and the public learn important information about the "ultimate risk and benefit calculation" that they had to make in choosing a particular energy source over another (Raab Associates, LTD. and Consensus Building Institute 2007, 26-29).

The third and final implication of my findings is that stakeholders should focus on cost-effective precautionary measures that can be implemented in the face of incomplete information or substantial uncertainty. Conflicts lingered nearly ten years in some of the cases I examined. In the United States, regulators faced multiple lawsuits during that time, while courts pressed them to redress findings about the long-term environmental impact of spent fuel. This took years to complete. In the Wolsong Case (South Korea), the utility company was asked by the regulator to develop a long-term research plan to investigate seismic risk at the site. However, the site experienced a magnitude 5.8 earthquake in September 2016, even before the result came out (Ryall 2016). Instead of merely finding flaws in risk assessment studies or waiting for a definitive proof of safety, I suggest that states, counties and local communities seek to develop contingent actions and precautionary measures while they wait for more definitive sources of information. For example, in the Indian Point and Kori cases, environmental activists and local community members worried that local infrastructure, as well as a subgroup of local population housed in a number of community centers

such as children in daycare centers and seniors, might be particularly vulnerable if evacuation became necessary. Although national agencies have final say over evacuation plans, interim evacuation plans developed by both supporters and the concerned groups of laypeople, drawing on knowledge about particular local conditions, could be adopted temporarily. For instance, local women with children have know-how about what it takes to prepare infants and toddlers for quick evacuation. They could require all daycare centers to ask parents to bring extra water, juice, formula, diapers, food, and clothing at the beginning of each registration period. Parents and teachers at daycare centers and schools could work together to develop realistic plans about what they would do and how they would do it if evacuation became necessary due to unexpected radiation exposure. In this way, temporary evacuation plans could be tailored to each situation. Attempts to value the knowledge and information of concerned stakeholders informally might allay feelings of powerlessness and build trust that will make it easier to implement formal evacuation plans.

Bibliography

Ahn, Yoon-Ok, and Zhong Min Li. 2012. "Cancer Risk in Adult Residents near Nuclear Power Plants in Korea - A Cohort Study of 1992-2010." *Journal of Korean Medical Science* 27 (9): 999–1008.

Aldrich, Daniel P. 2008. *Site Fights: Divisive Facilities and Civil Society in Japan and the West*. Cornell University Press. http://works.bepress.com/daniel_aldrich/4.

Anonymous community member. 2016. Interview with anonymous community member of East Gyeongju Residents' Coalition.

Apostolakis, George E. 2004. "How Useful Is Quantitative Risk Assessment?" *Risk Analysis* 24 (3): 515–20.

Benford, Robert, Helen Moore, and J. Allen Williams. 1993. "In Whose Backyard?: Concern About Siting a Nuclear Waste Facility." *Sociological Inquiry* 63 (1): 30–48.

Bixler, Nathan, and Rick Haaker. 2009. "Accident Consequence Analysis P-301." presented at the NRC Professional Development Center, Bethesda, MD. http://pbadupws.nrc.gov/docs/ML1204/ML12044A217.pdf.

Bommer, Julian J., Frank Scherbaum, Hilmar Bungum, Fabrice Cotton, Fabio Sabetta, and Norman A. Abrahamson. 2005. "On the Use of Logic Trees for Ground-Motion Prediction Equations in Seismic-Hazard Analysis." *Bulletin of the Seismological Society of America* 95 (April): 377–89.

Bosman, Julie. 2015. "Rural Wisconsin Community Laments Nuclear Power Plant's Closure." *The New York Times*, August 11. http://www.nytimes.com/2015/08/12/us/rural-wisconsin-community-laments-nuclear-power-plants-closure.html.

Boudet, Hilary Schaffer. 2011. "From NIMBY to NIABY: Regional Mobilization against Liquefied Natural Gas in the United States." *Environmental Politics* 20 (6): 786–806.

Boudet, Hilary Schaffer, and Leonard Ortolano. 2010. "A Tale of Two Sitings: Contentious Politics in Liquefied Natural Gas Facility Siting in California." *Journal of Planning Education and Research*, July.

Breslow, Paul B., and David J. Sailor. 2002. "Vulnerability of Wind Power Resources to Climate Change in the Continental United States." *Renewable Energy* 27 (4): 585–98.

Brookhaven National Laboratory. 1997. "A Safety and Regulatory Assessment of Generic BWR and PWR Permanently Shutdown Nuclear Power Plants." NUREG/CR-6451. U.S. Nuclear Regulatory Commission.

Burruss, Melvin. 2007. "Re: Relicensing of Indian Point," September 19. http://pbadupws.nrc.gov/docs/ML0727/ML072700561.pdf.

Busan Eastern District Court. 2011. Ka-hap 2011. Busan Eastern District Court.

Byun, Young-cheol. 2016. Personal interview with Byun, Y-C.

Cassidy, patrick. 2012. "Official: Cape Lacks Nuke Evacuation Plan." *Cape Cod Times*, October 4.

Cha, Geun-ho. 2013. "Greenpeace, Dismissing 'Gwangahn Bridge Protest' in 52 Hours." *Yonhap News*, July 11.

Chanin, D., M.L. Young, J. Randall, and K. Jamali. 1998. "Code Manual for MACCS2: Volume 1, User's Guide."

Charles River Associates. 2011. "Indian Point Energy Center Retirement Analysis (Prepared for: New York City Department of Environmental Protection)."

Chediak, Mark, and Jonathan Crawford. 2016a. "Exelon Will Seek License to Run Nuclear Plant for 80 Years." *Bloomberg*, June 6.

———. 2016b. "Exelon Will Seek License to Run Nuclear Plant for 80 Years." *Bloomberg.com*, June 7.

Cho, Byung-Oke, Shin-Jong Kim, and Jum-Su Kim. 2010. "An analysis on Korean nuclear power's contribution to the GHG emission reduction and the economic effect." *Journal of Energy Engineering* 19 (4): 203–14.

Cho, Chang-guk. 2015. Personal interview.

Choe, Sang-hun. 2013. "Scandal in South Korea over Nuclear Revelations." *The New York Times*, August 3.

Choe, Su-yeong. 2016. Personal interview.

Claxton, Drew. 2011. "Declaration of Drew Claxton Regarding Hudson River Sloop Clearwater, Inc.'s Combined Reply to NRC Staff and Entergy's Answer to Environmental Justice Contention." NRC. http://pbadupws.nrc.gov/docs/ML1233/ML12335A557.pdf.

Clearwater. 2011. "Initial Prefiled Written Testimony of Manna Jo Greene Regarding ClearWater's Environmental Justice Contention EC-3A." NRC. http://www.nrc.gov/docs/ML1135/ML11356A508.pdf.

———. 2012. "Summary of Clearwater's Environmental Justice Contention Testimony at Indian Point Relicensing Hearings in Front of Atomic Safety Licensing Board." Clearwater.

Cooper, Mark. 2013. "In the Matter of Proposed Rule: Waste Confidence- Continued Storage of Spent Nuclear Fuel 10 C.F.R. Part 51 Draft Waste Confidence Generic Environmental Impact Statement." NRC.

———. 2014. "Declaration of Mark Cooper In Support of Motions to Reopen the Record of NRC Reactor Licensing and Re-Licensing Proceedings." NRC. http://pbadupws.nrc.gov/docs/ML1427/ML14272A611.pdf.

Corburn, J. 2005. *Street Science: Community Knowledge and Environmental Health Justice*. Cambridge, MA: The MIT Press.

Devlin, John F., and Nonita T. Yap. 2008. "Contentious Politics in Environmental Assessment: Blocked Projects and Winning Coalitions." *Impact Assessment and Project Appraisal* 26 (1): 17–27.

DOE. 2013. "Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Radioactive Waste." U.S. Department of Energy.

Dotson, L. J., and J. Jones. 2005. "Development of Evacuation Time Estimate Studies for Nuclear Power Plants." NUREG/CR-6863, SAND 2004-5900. Sandia National Laboratories.

Dwyer, Jim. 2012. "Vision for Cheap Power Even If Indian Point Nuclear Plant Is Closed." *The New York Times*, January 12.

Energy and Environmental Science, Inc. 2001. "Analysis of Spent Fuel Heatup Following Loss of Water in a Spent Fuel Pool: A Users' Manual for the Computer Code SHARP." NUREG/CR-6441. U.S. NRC. http://www.nrc.gov/docs/ML0210/ML021050336.pdf.

Entergy. 2006. "Pilgrim Nuclear Power Station: Applicant's Environmental Report Operating License Renewal Stage." http://www.nrc.gov/reactors/operating/licensing/renewal/applications/pilgrim/environ-report.pdf.

Expert Review Committee on the Stress Test of Wolsong 1. 2015. "Wolsong 1 Nuclear Reactor Stress Test Performance Review Report." The Nuclear Security and Safety Commission.

GAO. 2013. "Emergency Preparedness: NRC Needs to Better Understand Likely Public Response to Radiological Incidents at Nuclear Power Plants." GAO-13-243. Washington, DC.

Gieryn, T. 1983. "Boundary-Work and the Demarcation of Science from on-Science: Strains and Interests in Professional Ideologies of Scientists." *American Sociological Review* 48 (6): 781–95.

Gould, J. M., E. J. Sternglass, J. D. Sherman, J. Brown, W. McDonnell, and J. J. Mangano. 2000a. "Strontium-90 in Deciduous Teeth as a Factor in Early Childhood Cancer." *International Journal of Health Services: Planning, Administration, Evaluation* 30 (3): 515–39.

Gould, J.M, E. J. Sternglass, J. D. Sherman, J. Brown, W. McDonnell, and Joseph J. Mangano. 2000b. "Strontium-90 in Deciduous Teeth as a Factor in Early Childhood Cancer." *International Journal of Health Services* 30 (3).

Greene, Manna Jo. 2015. Personal interview.

Greenpeace. 2013. "Nuclear Emergency Planning 2013: Korea Is Not Ready." Greenpeace. http://www.greenpeace.org/korea/Global/korea/publications/reports/climate-energy/2013/jul-2013-nuke-emergency-plan-kor.pdf.

———. 2014. "Lifetime Extension of Ageing Nuclear Power Plants: Entering a New Era of Risk."

Gunter, Paul. 2016. Personal interview.

Gupta. 2013. "Order in a Chaotic Subsystem: A Comparative Analysis of Nuclear Facility Siting Using Coalition Opportunity Structures and the Advocacy Coalition Framework." Norman, Oklahoma: University of Oklahoma.

Ha, Mina, Jeong-Min Kim, Young-soo Joo, Kim Myoung-Hee Kim, and Domyung Paek. 2015. "A follow-up epidemiological survey of residents living near nuclear power plants in Korea (Prepared for discussion." Seoul National University Department of Public Health.

Hoffman. 2014. Personal interview.

Hunold, C., and Iris Marion Young. 1998. "Justice, Democracy, and Hazardous Siting." *Political Studies*, 82–95.

Hunter, Susan, and Kevin Leyden. 1995. "Beyond NIMBY: Explaining Opposition to Hazardous Waste Facilities." *Policy Studies Journal* 23 (4): 601–19.

IAEA. 2010. "Periodic Safety Review of Nuclear Power Plants: Experience of Member States." IAEA-TECDOC-1643. Vienna, Austria: International Atomic Energy Agency (IAEA). http://www-pub.iaea.org/.

———. 2016. "Nuclear Power Reactors in the World." IAEA-RDS-2/36. Vienna, Austria: International Atomic Energy Agency (IAEA).

ICRP. 2005. "Low-Dose Extrapolation of Radiation-Related Cancer Risk. ICRP Publication 99." *Annals of the ICRP* 35 (4): 1–142.

———. 2006. "Assessing Dose of the Representative Person for the Purpose of the Radiation Protection of the Public. ICRP Publication 101a." Annals of the ICRP 36 (3).

———. 2007. "The 2007 Recommendations of the International Commission on Radiological Protection. ICRP Publication 103." *Annals of the ICRP* 37 (2-4).

Ihm, Byung-shik. 2012. Personal interview.

Ihm, Hyung-sup. 2013. "The National Assemblywoman Shim Sang-Jung Argues, 'The Economic Analysis of the Continued Operation of Kori 1 Was Flawed.'" *Yonhap News*, December 8.

Im, C.B., M. Noh, H.S. Choi, and H.J. Kim. 2004. "Capable Fault Criteria Applied to Nuclear Power Plant Sites, and Their Technical Background." *Journal of the Geological Society of Korea* 40 (2): 279–84.

IPCC. 2014. *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press.

Jasanoff, S. 1999. "The Songlines of Risk." *Environmental Values* 8 (2): 135–52.

Jasanoff, Sheila. 1998. "The Political Science of Risk Perception." *Reliability Engineering & System Safety* 59 (1): 91–99.

Jasanoff, S., and S. H. Kim. 2009. "Containing the Atom: Sociotechnical Imaginaries and Nuclear Power in the United States and South Korea." *Minerva* 47: 119–46.

Jeong, Su Hui. 2011. "Nuclear Industry and Local Resident Movements." Master Thesis, Pusan National University.

———. 2012. Personal interview.

———. 2015. Personal interview.

Jin, T-E, H-Y Roh, T-R Kim, and Y-S Park. 2009. "Current Status and Prospect for Periodic Safety Review of Aging Nuclear Power Plants in Korea." *Nuclear Engineering and Technology* 41 (4- Special issue in celebration of the 40th anniversary of the Korean Nuclear Society): 545–48.

Jones, J., F. Walton, B. Wolshon, and J. Laughlin. 2011. "Criteria for Development of Evacuation Time Estimate Studies." NUREG/CR-7002, SAND 2010-0016P. Sandia National Laboratories and Nuclear Regulatory Commission.

Kadak, Andrew C., and Toshihiro Matsuo. 2007. "The Nuclear Industry's Transition to Risk-Informed Regulation and Operation in the United States." *Reliability Engineering & System Safety*, Recent Advances in Theory & Applications of Stochastic Point Process Models in Reliability Engineering, 92 (5): 609–18.

Kang, Jae-gyu. 2015. "Society without Nuclear: The Problems of the Nuclear Safety Regulations." *Ulsan Journal*, July 9. http://www.usjournal.kr/News/74514.

Kang, Joo-hoon. 2012. Personal interview.

Kang, Minah, and Jiho Jang. 2013. "NIMBY or NIABY? Who Defines a Policy Problem and Why: Analysis of Framing in Radioactive Waste Disposal Facility Placement in South Korea." *Asia Pacific Viewpoint* 54 (1): 49–60.

Keller, William, and Mohammad Modarres. 2005. "A Historical Overview of Probabilistic Risk Assessment Development and Its Use in the Nuclear Power Industry: A Tribute to the Late Professor Norman Carl Rasmussen." *Reliability Engineering & System Safety* 89: 271–85.

KFEM. 2014. "Recruiting Thyroid Cancer Victims in the Areas Near Nuclear Power Plants for Class Action Lawsuit." December 18. http://kfem.or.kr/?p=145592.

KHNP. 2013. "Wolsong Reactor 1 Stress Test Performance Report." Korea Hydro and Nuclear Power Co. Ltd.

———. 2015. "KHNP Finally Decides Not to Apply for the Second License Renewal of Kori 1." June 16. http://blog.khnp.co.kr/blog/archives/18500.

Kim, Changbae. 2015. "Continued operation of Kori 1 may result in the loss of 340 billion won." *Hankook Ilbo*, May 19. http://www.hankookilbo.com/v/3e27849e9acc4b98aa004965b6de4deb.

Kim, Gyo-yoon, Yoo-yoon Park, Gun-wook Kang, Dong-kwon Geum, Bong-hwan Kim, Gwang-pyo Kim, Byung-il Kim, et al. 2015. "Scientific Assessment of the Relationship Between the Exposure of Residents Living Nearby Nuclear Power

Plants to Radiation And Thyroid Cancer." Korean Nuclear Society and the Korean Association for Radioactive Protection.

Kim, Ick-Joong. 2013. *Korea: Exiting Nuclear Era*. Hantijae.

Kim, Jeong-seop. 2016. Personal Interview.

Kim, Jong-mahn. 2007. "Op-Ed: Let's Contribute to National Economic Development by Extending the Operation of Kori 1." *Ulsan Kwang-Yeok Maeil*, October 1.

Kim, Kwang-soo. 2015. "Joining to Shutdown Kori 1." *The Hankyoreh*, February 10. http://www.hani.co.kr/arti/society/environment/677823.html.

Kim, S. 2015. Personal interview.

Kim, Sang-wang. 2012. Personal interview.

———. 2016. Personal interview.

Kim, Soh-Yeon. 2012. "[Issue] A conflict over the simulation of postulated accidnet at nuclear power plants." *Korea Nuclear Power*, December 22.

———. 2014. "Continued operation of Wolsong 1 reactor faces a major watershed: The history of excellent performance for 30 years and improved safety features that were recognized by the IAEA." *Korea Nuclear Power*, October 13.

Kim, Ssang-woo. 2012. Personal interview.

Kim, Wong-sik, G-y. Seong, Changjoo Lee, Young-hwan Choi, Yong-suk Choi, and Hyo-jung Kim. 2003. "Direction to Adopting Risk-Informed and Performance-based Regulation."

Kim, Yeon-min. 2015. Personal interview.

Kirk, Mark. 2013. "Development of the Alternate Pressurized Thermal Shock Rule (10 CFR 50.61 A) In the United States." *Nuclear Engineering and Technology* 45 (3): 277–94.

KLD Associates, Inc. 2004. "Pilgrim Nuclear Power Station Development of Evacuation Time Estimates (prepared for Entergy Nuclear Northeast Emergency Preparedness Division)." KLD TR-382. http://www.nrc.gov/docs/ML0714/ML071440332.pdf.

Klein, Tony. 2012. Personal interview.

KNS, and KARP. 2015. "A Scientific Analysis of the Link Between Local Residents Living Nearby Nuclear Power Plants and the Occurrence of Thyroid Cancer." Korean Nuclear Society and the Korean Association for Radioactive Protection.

Korea Electric Power Corporation (KEPCO). 2015. "Statistics of Electric Power in Korea 2014."

Korea Energy Economics Institute. 2014. "Yearbook of Energy Statistics."

KOSIS. 2015. "Household and Population by Eup, Myeon, Li." Korean Statistical Information Service.

Kyne, Dean, and Bob Bolin. 2016. "Emerging Environmental Justice Issues in Nuclear Power and Radioactive Contamination." *International Journal of Environmental Research and Public Health* 13 (7).

Lampert, Mary. 2012. Email interview.

———. 2015. Personal interview.

Layton, Lyndsey. 1999. "Nuclear Industry Watching Calvert Cliffs." *Washington Post*, April. http://www.washingtonpost.com/wp-srv/local/daily/april99/nuclear1.htm.

Lee, Dong-hyuk. 2015. "Saenuri Party, now shifting its policy to call for the permanent shutdown of Kori 1." *Hankook Ilbo*, February 26.

Lee, Ja-young. 2016. "1993, Radiation Emission Levels at Kori Site Had Been 13 Million Times More than the Level L in the Advanced Countries." *Busan Ilbo*, June 13.

Lee, Jinjoo. 2015. "Endless Debate on the Link between Nuclear Power Plants and Thyroid Cancer." *The Elect Times*, October 16.

Lee, Suk-woo. 2016. "40 Years of Korean Nuclear History: Homage to Kori 1." *Korea Nuclear Power*, August 17.

Lemay, Francois. 2011. "Pre-Field Written Testimony of Dr. Francois J. Lemay Regarding Consolidated NYS-12-C." http://www.nrc.gov/docs/ML1234/ML12340A608.pdf.

Lesbirel, Hayden. 1998. *NIMBY Politics in Japan: Energy Siting and the Management of Environmental Conflict*. Ithaca: Cornell University Press.

———. 2011. "Project Siting and the Concept of Community." *Environmental Politics* 20 (6): 826–42.

Lindblom, C., and D. Cohen. 1979. *Usable Knowledge: Social Science and Social Problem-Solving*. New Haven: Yale University Press.

Lovering, Jessica R., Arthur Yip, and Ted Nordhaus. 2016. "Historical Construction Costs of Global Nuclear Power Reactors." *Energy Policy* 91 (April): 371–82.

Lowry, Robert C. 1998. "All Hazardous Waste Politics Is Local: Grass-Roots Advocacy and Public Participation in Siting and Cleanup Decisions." *Policy Studies Journal* 26 (4): 748–59.

Lyman, Edwin. 2004. "Chernobyl on the Hudson?: The Health and Economic Impacts of a Terrorist Attack at the Indian Point Nuclear Plant." Union of Concerned Scientists.

Lyman, Edwin S. 2007. "A Critique of the Radiological Consequence Assessment Conducted in Support of the Indian Point Severe Accident Mitigation Alternatives Analysis." NRC. http://www.nrc.gov/docs/ML1100/ML110030945.pdf.

Mangano, Joseph J. 2006. "A Short Latency between Radiation Exposure from Nuclear Plants and Cancer in Young Children." *International Journal of Health Services: Planning, Administration, Evaluation* 36 (1): 113–35.

Mangano, Joseph J., Jay M. Gould, Ernest J. Sternglass, Janette D. Sherman, and William McDonnell. 2003. "An Unexpected Rise in Strontium-90 in US Deciduous Teeth in the 1990s." *The Science of the Total Environment* 317 (1-3): 37–51.

Martin, Richard. 2016. "Nuclear Shutdowns Could Ramp Up U.S. Carbon Emissions." *MIT Technology Review*. May 20. https://www.technologyreview.com/s/601533/nuclear-shutdowns-could-ramp-up-us-carbon-emissions/.

McAdam, Doug, Hilary Schaffer Boudet, Jennifer Davis, Ryan J. Orr, W. Richard Scott, and Raymond E. Levitt. 2010. "'Site Fights': Explaining Opposition to Pipeline Projects in the Developing World." *Sociological Forum* 25 (3): 401–27.

McAdam, Professor Doug, and Hilary Boudet. 2012. *Putting Social Movements in Their Place: Explaining Opposition to Energy Projects in the United States, 2000-2005*. 1st ed. Cambridge University Press.

McGuire, R. K. 1995. "Probabilistic Seismic Hazard Analysis and Design Earthquakes: Closing the Loop." *Bulletin of the Seismological Society of America* 85 (5): 1275–84.

McKinzie, Matthew. 2016. "Diablo Canyon Nuclear Closure Plan: An Important Model." June 22. https://www.nrdc.org/experts/matthew-mckinzie/diablo-canyon-nuclear-closure-plan-important-model.

Ministry of Science, ICT and Future Planning. 2016. "A White Paper on Nuclear Power 2016." Ministry of Science, ICT and Future Planning. http://www.msip.go.kr/.

Min, Young-kyu. 2014. "The Busan District Court Ruled, 'KHNP Is Liable for the Occurrence of Thyroid Cancer in Residents Living near Nuclear Power Plants.'" *Yonhap News*, October 17.

MIT. 2003. *The Future of Nuclear Fuel Cycle: An Interdisciplinary MIT Study*.

Mothers for Peace. 2015. "ASLB Rejection of Mothers for Peace Contentions Is Not the End of the Story." August 9. https://mothersforpeace.org/2015-08-09-aslb-rejection-of-mothers-for-peace-contentions-is-not-the-end-of-the-story.

National Research Council. 2006. *Alternatives to the Indian Point Energy Center for Meeting New York Electric Power Needs*. National Academies Press.

NEI. 2004. "Economic Benefits of Indian Point Energy Center." Nuclear Energy Institute.

———. 2005. "Severe Accident Mitigation Alternatives (SAMA) Analysis: Guidance Document." Nuclear Energy Institute.

———. 2014. "Peer-Reviewed Science on Radiation Health Effects Dispels 'Tooth Fairy Project.'" Nuclear Energy Institute. Available at: http://www.nei.org/CorporateSite/media/filefolder/Backgrounders/Fact-Sheets/Tooth-Fairy-Project_March-2014.pdf?ext=.pdf.

———. 2016. "The Nuclear Energy Agenda for DOE's Quadrennial Energy Review." July 7. http://www.nei.org/News-Media/News/News-Archives/The-Nuclear-Energy-Agenda-for-DOE-s-Quadrennial-En.

New Jersey Commission on Radiation Protection. 2006. "Recommendation Against Further State Funding of the Radiation and Public Health Project for Analysis of Radioactive Strontium-90 in Baby Teeth." http://www.nrc.gov/docs/ML0721/ML072150436.pdf.

New Jersey Department of Environmental Protection v. U.S. NRC; Amergen Energy Company, LLC. 2009. United States Court of Appeals, 3rd Circuit.

Newman, Andy. 2003. "In Baby Teeth, a Test of Fallout; A Long-Shot Search for Nuclear Peril in Molars and Cupids." *The New York Times*, November 11.

Nikolewski, Rob. 2016. "PG&E Files Plan to Shut down Diablo Canyon Nuclear Power Plant." *Los Angeles Times*, August 11.

NRC. 1996. "Generic Environmental Impact Statement for Nuclear Power Plant Operating Licenses Renewal: Environmental Impact Statement." NUREG-1437.

———. 2004a. "The Technical Basis for the NRC's Guidelines for External Risk Communication." NUREG/CR-6840. http://www.nrc.gov/reading-rm/doc-collections/nuregs/contract/cr6840/cr6840.pdf.

———. 2004b. "Backgrounder on Radiation Protection and the 'Tooth Fairy' Issue." U.S. Nuclear Regulatory Commission.

———. 2006. *Nuclear Regulatory Commission Issuances: Opinions of the Nuclear Regulatory Commission with Selected Orders*. Vol. 64. The U.S. Nuclear Regulatory Commission. http://www.nrc.gov/docs/ML0903/ML090360507.pdf.

———. 2012. "Memorandum and Order, CLI-12-16." U.S. Nuclear Regulatory Commission.

———. 2015a. "Reactor License Renewal Overview." March 9. http://www.nrc.gov/reactors/operating/licensing/renewal/overview.html.

———. 2015b. "Backgrounder on Radioactive Waste." http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/radwaste.html.

———. 2015c. "Standard Review Plan for Review of Subsequent License Renewal Applications for Nuclear Power Plants (Draft Report for Comment)." U.S. Nuclear Regulatory Commission.

———. 2016a. "Memorandum and Order (CLI-16-07)." U.S. Nuclear Regulatory Commission. http://www.nrc.gov/docs/ML1612/ML16125A150.pdf.

———. 2016b. "Subsequent License Renewal." August 4. http://www.nrc.gov/reactors/operating/licensing/renewal/subsequent-license-renewal.html.

———. 2016c. "Status of License Renewal Applications and Industry Activities." December 2.

NSSC. 2012. "Explaining the Press Release about Health Risk Impact from a Postulated Accident at Kori Nuclear Plant." Nuclear Safety and Security Commission. Available at: http://www.nssc.go.kr/nssc/notice/report.jsp?mode=view&article_no=3529.

———. 2013. "The Plan for Implementing Stress-test for Aging Nuclear Power Plants." The Nuclear Security and Safety Commission.

———. 2014. "The Status of the Stress Test Review of Wolsong 1." Nuclear Safety and Security Commission. www.nssc.go.kr.

———. 2015a. "The 33th Nuclear Safety and Security Commission Meeting." Meeting Minutes. NSSC.

———. 2015b. "The 34th Nuclear Safety and Security Commission Meeting." Meeting Minutes. NSSC.

———. 2015c. "The 35th Nuclear Safety and Security Commission Meeting." Meeting Minutes. NSSC.

Oh, Young-shik. 2014. "A Policy Report: Problems associated with the cost-benefit analysis of the continued operation of ageing nuclear power plants."

Oka Ridge National Laboratory. 1991. "Integrated Data Base for 1991: U.S. Spent Fuel and Radioactive Waste Inventories, Projections and Characteristics." DOE/RW-0006. Department of Energy. http://www.nrc.gov/docs/ML0401/ML040150679.pdf.

Ozawa, C., and L. Susskind. 1985. "Mediating Science-Intensive Policy Disputes." *Journal of Policy Analysis and Management* 5 (1): 23–39.

Park, Byung-hoon. 2014. "KHNP Appealed the Court's Decision That Nuclear Plant Emissions Caused on the Thyroid Cancer." *JoongAng Daily*, October 22.

Park, Gab-yong. 2012. Personal interview.

Park, J-G. 2012. "The NSSC, 'KFEM's Simulation Exaggerated Impact of Severe Accidents.'" *Korea Nuclear Power*, May 23.

Park, J-M, and Meeyoung Cho. 2014. "South Korea Cancer Victims Bring Class Action against Nuclear Operator." *Reuters*, December 16.

Park, K. 2014. "Controversies around the economic impact analysis conducted by National Assembly Budget Office." *The Korea Electric Power News*, August 21.

Park, Ki-jean. 2012. "Conflicts over the logic of Wolsong and Kori 1 Severe Accident Simulation." *The Korean Electric Power News*, December.

Park, Saehee. 2015. "Bae Duk-Kwang and Ha Tae-kyung call for the permanent shutdown of Kori 1." *JoongAng Daily*, February 27.

Park, S. J., W-Y Yang-Lee, and I. J. Kim. 2012. "Simulation of Impacts of Severe Accidents at Wolsong and Kori 1 - Applying Japanese SEO Code In the Analyses of Korean Nuclear Power Plants (2nd version)." Friends of the Earth-Korea.

Park, Taesoon. 2008. "Resolving Public Dispute Around Kori 1 Through Consensus-Building." Seoul, Korea: Institute of Social Conflict.

Pilgrim Watch. 2006. *Entergy Corporation Pilgrim Nuclear Power Station License Renewal Application*. U.S. Nuclear Regulatory Commission.

Pryor, S. C., and R. J. Barthelmie. 2010. "Climate Change Impacts on Wind Energy: A Review." *Renewable and Sustainable Energy Reviews* 14 (1): 430–37.

Quick, Kathryn S., and Martha S. Feldman. 2011. "Distinguishing Participation and Inclusion." *Journal of Planning Education and Research* 31 (3): 272–90.

Raab Associates, LTD., and Consensus Building Institute. 2007. "Vermont's Energy Future Regional Workshops: Final Report." http://www.cbuilding.org/sites/default/files/CBI_VT_Energy_Workshops_Report.pdf.

Raimundi, Karla C., MJ Wilson, and Mana Jo Greene. 2010. "Community-Based Environmental Justice Inventory for the City of Peekskill." Peekskill Environmental Justice Council, Hudson River Sloop Clearwater, Inc., Citizens for Equal Environmental Protection (CEEP). http://www.clearwater.org/wp-content/uploads/2011/03/CBEJI_FINAL-_DRAFT-1-30-11-for-printing.pdf.

Repka, David A., and Tyson R. Smith. 2010. "Proximity, Presumptions, and Public Participation: Reforming Standing at the Nuclear Regulatory Commission." *Administrative Law Review* 62 (2): 583–601.

Resource Insight, Inc. 2009. "Direct Testimony of Paul Chernick on Behalf of Conservation Law Foundation and Vermont Public Interest Research Group." http://psb.vermont.gov/sites/psb/files/docket/7440VT_Yankee_Relicensing/Supplemental/CLF_VPIRG_chernick_pf.pdf.

Riverkeeper. 2016. "In the Matter of Energy Nuclear Operations, Inc. (Indian Point Nuclear Generating Units 2 and 3): 'Riverkeeper's Request for Admission of New Environmental Contention.'" http://www.nrc.gov/docs/ML1606/ML16068A441.pdf.

Ryall, Julian. 2016. "Warning That Korean Peninsula Could Become New Quake Zone after Series of Tremors in the South." *The Telegraph*, September 13. http://www.telegraph.co.uk/news/2016/09/13/warning-that-korean-peninsula-could-become-new-quake-zone-after/.

Sandia National Laboratory. 1979. "Spent Fuel Heatup Following Loss of Water During Storage." NUREG/CR-0649. U.S. Nuclear Regulatory Commission.

Schaeffer, Roberto, Alexandre Salem Szklo, André Frossard Pereira de Lucena, Bruno Soares Moreira Cesar Borba, Larissa Pinheiro Pupo Nogueira, Fernanda Pereira Fleming, Alberto Troccoli, Mike Harrison, and Mohammed Sadeck Boulahya. 2012. "Energy Sector Vulnerability to Climate Change: A Review." *Energy* 38 (1): 1–12.

Schattschneider, E. E. 1960. *The Semisovereign People*. New York: Holt, Reinhart, and Winston.

Schively, Carissa. 2007. "Understanding the NIMBY and LULU Phenomena: Reassessing Our Knowledge Base and Informing Future Research." *Journal of Planning Literature* 21 (3): 255–66.

Seo, Yong-hwa. 2012. Personal interview.

Sherman, Daniel J. 2011. *Not Here, Not There, Not Anywhere: Politics, Social Movements, and the Disposal of Low-Level Radioactive Waste*. RFF Press.

Shin, Dong-myeong. 2015. "Establishing Ulsan Coalition to Shutdown Aging Nuclear Plants." *The Hankyoreh*, April 30.

Smith, Thomas. 2010. "Terrorist Attacks & NEPA: The Third Circuit Creates a Split in Authority. New Jersey Department of Environmental Protection v. NRC." *Journal of Environmental and Sustainability Law* 17 (2).

State of New York. 2014. "State of New York Petition for Review of Atomic Safety and Licensing Board Decision LBP-13-13 with Respect to Consolidated Contention (NYS-12C)." NRC.

Susskind, Lawrence E., Sarah McKearnen, and Jennifer Thomas-Lamar. 1999. *The Consensus Building Handbook: A Comprehensive Guide to Reaching Agreement*. SAGE.

Susskind, Lawrence, and Connie Ozawa. 1984. "Mediated Negotiation in the Public Sector: The Planner as Mediator." *Journal of Planning Education and Research* 4 (1): 5–15.

Tauro, Janet. 2016. Personal interview.

The MOTIE. 2015. *Act on Assistance to Electric Power Plants-Neighboring Areas*. https://elaw.klri.re.kr/kor_service/lawView.do?hseq=24950&lang=ENG.

The MST. 1989. *Act on Assistance to Electric Power Plants-Neighboring Areas*. https://elaw.klri.re.kr/kor_service/lawView.do?hseq=24950&lang=ENG.

———. 2005. *Guidelines for Drafting Radiological Environmental Impact Assessment Studies of Nuclear Facilities. Ministry of Science and Technology Enforcement Rule*. Vol. 2005–19.

The NSSC. 2014. *Guidelines for Drafting Radiological Environmental Impact Assessment Studies of Nuclear Facilities. Enforcement Rule*. Vol. 2014–11.

The State of New York. 2016. "Governor Cuomo Announces Establishment of Clean Energy Standard That Mandates 50 Percent Renewables by 2030." August 1.

https://www.governor.ny.gov/news/governor-cuomo-announces-establishment-clean-energy-standard-mandates-50-percent-renewables.

The World Bank. 2016. "World Development Indicators." The World Bank. http://databank.worldbank.org/data/reports.aspx?source=2&series=EN.POP.DNST&country=KOR.

Thielman, Sam. 2016. "Indian Point Nuclear Plant Reeks of Troubled History." *The Guardian*, March 28, sec. US news.

Turco, Diane. 2015. Personal interview.

Ulsan KFEM. 2015. "[Press Release] Establishing Pan-Ulsan Citizens Coalition to Permanently Shut Down Kori 1 and Wolsong 1." http://www.ulsankfem.or.kr/.

Unanimous High-level Manager. 2016. Personal interview.

U.S. EIA. 2016a. "Energy Information Administration's Monthly Energy Review and Electric Power Annual."

———. 2016b. "How Much of U.S. Carbon Dioxide Emissions Are Associated with Electricity Generation?" April. http://www.eia.gov/tools

U.S. Energy Information Administration. 2010. "Updated Capital Cost Estimates for Electricity Generation Plants." Washington, DC: U.S. Energy Information Administration.

———. 2015. "U.S. Energy-Related Carbon Dioxide Emissions, 2014." U.S. Department of Energy.

U.S. EPA. 2015. *Clean Power Plan Final Rule*. Vol. 40 C.F.R. Part 60. https://www.epa.gov/cleanpowerplan/clean-power-plan-existing-power-plants.

US EPA. 2016. "Sources of Greenhouse Gas Emissions." Overviews and Factsheets. Accessed December 10. https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions.

U.S. NRC. 2013. "The Atomic Safety and Licensing Board Panel." NUREG/BR-0249, Revision 4. U.S. Nuclear Regulatory Commission. http://www.nrc.gov/reading-rm/doc-collections/nuregs/brochures/br0249/r4/.

———. 2014. "Radiation Exposure and Cancer." NRC. http://www.nrc.gov/about-nrc/radiation/health-effects/rad-exposure-cancer.html.

Vermont Department of Public Service. 2006. "Vermont Department of Public Service Notice of Intention to Participate and Petition to Intervene." U.S. NRC.

Walsh, Edward J., Rex H. Warland, and Doug Smith. 1997. *Don't Burn It Here: Grassroots Challenges to Trash Incinerators*. The Pennsylvania State University Press.

Webster, Richard. 2016. Personal interview.

Wing, Steve, David Richardson, and Wolfgang Hoffmann. 2011. "Cancer Risks near Nuclear Facilities: The Importance of Research Design and Explicit Study Hypotheses." *Environmental Health Perspectives* 119: 417–21.

Woolf, Tim, Matt Wittenstein, and Bob Fagan. 2011. "Indian Point Energy Center Nuclear Plant Retirement Analysis: Replacement Options, Reliability Issues and Economic Effects." Synapse Energy Economics, Inc.

Woo, S. Y., C. S. Yang, G. Kim, and Kim. 2015. "Examination of Regulation Requirements on Exclusion Areas for Advanced Countries." KINS/RR-1289. Korea Institute of Nuclear Safety.

World Nuclear Association. 2016a. "Nuclear Power in Germany." October. http://www.world-nuclear.org/information-library/country-profiles/countries-g-n/germany.aspx.

———. 2016b. "Nuclear Power in South Korea." October. http://www.world-nuclear.org/information-library/country-profiles/countries-o-s/south-korea.aspx.

———. 2016c. "Radioactive Waste Management." October. http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/radwaste.html.

———. 2016d. "Nuclear Power in Canada." November. http://www.world-nuclear.org/information-library/country-profiles/countries-a-f/canada-nuclear-power.aspx.

———. 2016e. "Nuclear Power in France." November. http://www.world-nuclear.org/information-library/country-profiles/countries-a-f/france.aspx.

———. 2016f. "Nuclear Power in the United States." December. http://www.world-nuclear.org/information-library/country-profiles/countries-a-f/canada-nuclear-power.aspx.

Yong, S. 2015. "63.5% of thyroid cancer victims are seashore dwellers." Ulsan Journal, March 18. http://www.usjournal.kr/News/69843

Appendix I. List of nuclear power plants with approvals for license renewal in the United States

Plants Operating with Renewed Licenses	State	License renewal application	Regulatory approvals	Duration of relicensing process (days)	Permanent shutdown
Arkansas Nuclear One, Unit 1	AR	2/1/00	6/22/01	507	X
Arkansas Nuclear One, Unit 2	AR	10/15/03	6/30/05	624	X
Beaver Valley	PA	8/27/07	11/5/09	801	X
Browns Ferry	AL	1/6/04	5/5/06	850	X
Brunswick	NC	10/25/04	6/25/06	608	X
Calvert Cliffs	MD	4/28/98	3/23/00	695	X
Columbia Generating Station	WA	1/19/10	6/1/12	864	X
Cooper	NE	9/24/08	7/15/11	1,024	X
Crystal River Unit 3	FL	12/18/08	2/6/13	1,511	Shutdown in 2013
D.C. Cook	MI	11/3/03	8/30/05	666	X
Dresden and Quad Cities	IL	1/3/03	10/28/04	664	X
Duane Arnold Energy Center	IA	10/1/08	12/16/10	806	X
Edwin I. Hatch	GA	3/1/00	1/7/02	677	X
Farley	AL	9/15/03	5/12/05	605	X
FitzPatrick	NY	8/1/06	9/8/08	769	Will be closed Jan. 2017
Fort Calhoun	NE	1/11/02	11/4/03	662	X
Ginna	NY	8/1/02	5/19/04	657	X

Harris	NC	11/16/06	12/17/08	762	X
Hope Creek	NJ	8/18/09	7/20/11	701	X
Kewaunee	WI	8/14/08	2/24/2011 (application withdrawn)	924	Shutdown in 2013
McGuire and Catawba	NC	6/14/01	12/3/03	902	X
Millstone *	CT	1/22/04	11/28/05	676	X
Monticello	MS	3/24/05	11/8/06	594	X
Nine Mile Point, Units 1 and 2	NY	5/27/04	10/31/06	887	X
North Anna and Surry	VA	5/29/01	3/20/03	660	X
Oconee	SC	7/7/98	5/23/00	686	X
Oyster Creek	NJ	7/22/05	4/8/09	1,356	Will be closed in 2019
Palisades	MI	3/31/05	1/17/07	657	X
Palo Verde	AZ	12/15/08	4/21/11	857	X
Peach Bottom	PA	7/2/01	5/7/03	674	X
Pilgrim	MA	1/27/06	5/29/12	2,314	Will be closed in 2019
Point Beach	WI	2/26/04	12/22/05	665	X
Prairie Island, Units 1 and 2	MN	4/15/08	6/27/11	1,168	X
Robinson	SC	6/17/02	4/19/04	672	X
Salem	DE	8/18/09	6/30/11	681	X
St. Lucie	FL	11/30/01	10/2/03	671	X
Summer	SC	8/6/02	4/23/04	626	X
Susquehanna	PA	9/13/06	11/24/09	1,168	X

Three Mile Island, Unit 1	PA	1/8/08	10/22/09	653	X
Turkey Point	FL	9/11/00	7/17/02	674	X
Vermont Yankee	VA	1/27/06	3/21/11	1,879	Shutdown in 2014
Vogtle	GA	6/29/07	6/3/09	705	X
Wolf Creek	KS	10/4/06	11/20/08	778	X

Appendix II. List of nuclear power plants operating in South Korea

Reactor	Net capacity	Commercial operation	License renewal application	Planned close
Kori 1	576 MWe	4/78	Yes	6/2017
Kori 2	640 MWe	7/83	No	2023
Kori 3	1011 MWe	9/85	Yes	2025
Kori 4	1010 MWe	4/86	No	
Shin Kori 1	999 MWe	2/11	No	
Shin Kori 2	1000 MWe	7/12	No	
Shin Kori 3	1340 MWe	(9/16)	No	
Hanbit 1, Yonggwang	961 MWe	8/86	No	
Hanbit 2, Yonggwang	977 MWe	6/87	No	
Hanbit 3, Yonggwang	1000 MWe	12/95	No	
Hanbit 4, Yonggwang	998 MWe	3/96	No	
Hanbit 5, Yonggwang	994 MWe	5/02	No	
Hanbit 6, Yonggwang	993 MWe	12/02	No	
Wolsong 1	657 MWe	4/83	No	Relicensed in 2015; current license will expire in 2022
Wolsong 2	650 MWe	7/97	No	
Wolsong 3	665 MWe	7/98	No	
Wolsong 4	669 MWe	10/99	No	
Shin Wolsong 1	998 MWe	7/12	No	
Shin Wolsong 2	10000 MWe	7/15	No	
Hanul 1, Ulchin	963 MWe	9/88	No	
Hanul 2, Ulchin	965 MWe	9/89	No	
Hanul 3, Ulchin	997 MWe	8/98	No	
Hanul 4, Ulchin	999 MWe	12/99	No	
Hanul 5, Ulchin	998 MWe	7/04	No	
Hanul 6, Ulchin	997 MWe	4/05	No	