NUCLEAR RENAISSANCE? CONTEMPORARY GEOGRAPHY OF THE U.S. NUCLEAR ENERGY INDUSTRY

Lisa Maria Marshall

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Approved by:

Scott Kirsch

John Pickles

Gabriela Valdivia

ABSTRACT

Lisa Maria Marshall: Nuclear Renaissance? Contemporary Geography of
the U.S. Nuclear Energy Industry
(Under the direction of Scott Kirsch)

The U.S. nuclear energy industry is engaged in practices and policies to invigorate the material and discursive nuclear landscape. The year 2000 marked the beginning of a contemporary resurgence with operating license renewals for Calvert Cliffs and Oconee nuclear power plants. These actions were closely followed by legislations that underwrote research and development of an improved fuel cycle (the 2003 Advanced Fuel Cycle Initiative) and new nuclear construction (the 2005 Energy Policy Act). Industrializing nations such as China moved into a rapid development phase dominated by U.S. based technologies (two EPR Areva and four Westinghouse AP 1000 designs). Domestic construction of four Westinghouse AP 1000 reactors commenced in 2012 at the Vogtle, GA and VC Summer, SC sites. Correspondingly, counter-arguments have impacted the production of nuclear space – proliferation concerns, nuclear waste management (the 2008 halt to the Yucca Mountain National Repository) along with past and recent nuclear accidents at Chernobyl (1986) and Fukushima (2011) as well as nation states phasing out of nuclear (Germany and Italy). The last decade and a half has reintroduced the question of U.S. nuclear energy industry's expansion, survival or exit. Thus in my thesis, I examine –

1. What is the geography of the contemporary U.S. nuclear energy industry?
2. What work does this industry do in the world, and how is this work reflected in current geographies of nuclear energy, real and imagined?

3. How is the industry (re)producing space for future significance? Has it been successful and why? Is the nuclear renaissance in the U.S. alive? Is the industry expanding, surviving, and/or on the way out?

Through a mapping project of the nuclear industrial enterprise – operating or under construction power plants, engineering firms, national laboratories, the regulatory agency, colleges, and professional organizations – this thesis will produce an original mapping of companies in the U.S. and their presence in key global markets. Then through a discursive analysis of governmental and industrial literature, my analysis examines how the U.S. nuclear industry has positioned itself in an appeal for efficient and effective energy systems and in arguments for national security/international influence and environmental protectionism. In depth interviews, representing various facets of industry and oppositional voices, provide an illustrative look into key current nuclear energy perspectives.

The U.S. nuclear industry is at a crossroads and the influence of government, managerial and public views will define its path moving forward. This thesis assesses some of the variables and intersections involved in the story-thus-far.

To my mentors, Winifred Sarjeant (maternal grandmother), Grace Marshall (mother), Pamela Neblett (maternal aunt), Dr. Rosina Wiltshire, Dr. Jill Vickers, Dr. John Bedward (spouse), Dr. Mohamed Bourham (faculty mentor) & Dr. Scott Kirsch (faculty adviser), I couldn’t have done this without you. Thank you for your support along the way.

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PREFACE

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1.1 – Claims About Nuclear

Nuclear power production remains a controversial energy source for the 21st century and beyond. It is part of the energy mix of the United States and 29 other nations, with 60 under constructions in 15 countries (NEI, November 2016). The top 5 nuclear generating nations include the U.S. (798.6 billion kWh), France (418 billion kWh), Russia (169.1 billion kWh), South Korea (149.2 billion kWh) and China (123.8 billion kWh) (NEI, April 2015). The energy capacity factor for nuclear (90.9%) surpasses any other fuel source, not geothermal (67.2%), coal (58.9&), combined cycle natural gas (50.3%), hydroelectric (40.5%) or wind (32.3%) compare[1] (EIA, 2014). As Figure 1 shows, in 2014, the U.S. generated approximately 4,093 billion kilowatt hours of electricity, with nuclear contributing 19% of the share. Fossil fuels generated 67% – coal [39%], natural gas [27%], and petroleum [1%]) – while hydropower stood at 6%, and other renewables at 7% (biomass 1.7%, geothermal 0.4%, solar 0.4% and wind 4.4%) (EIA, March 2015).

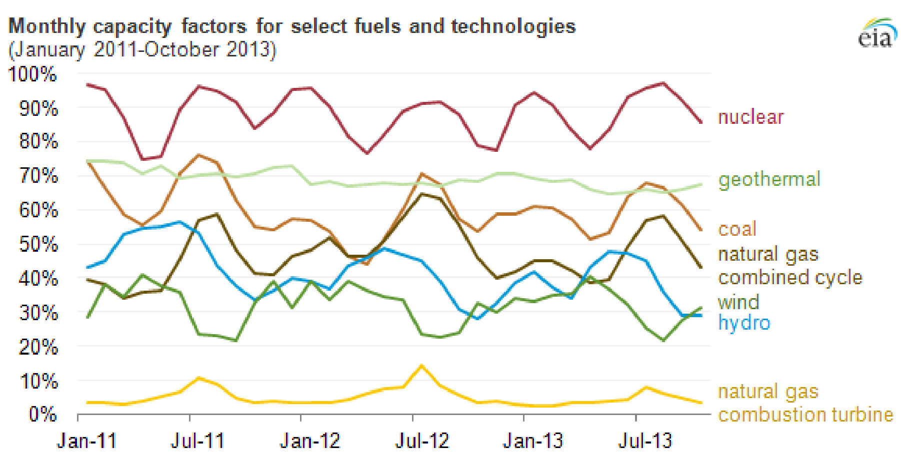

Figure 1: Capacity factor comparisons of typical energy sources (EIA, January 2014)

Amidst these noteworthy contributions of nuclear energy on the international and national stage, the U.S. stands at a crossroads and proponents of nuclear energy technology are advocating continued operation of the 104 (now 100) nuclear power plants in addition to new constructions of improved, more efficient, passively safer designs (Battelle, 2008). In 2013 the U.S. entered the domestic new nuclear build market, starting construction on four next generation reactors in the Southeast – two at the Vogtle Plant in Georgia and two at the V.C. Summer Plant in South Carolina (Williams, 2013). These designs are characterized as "simply safer, simply more advanced" and requiring no human intervention for 72 hours if a station blackout were to happen (Westinghouse, 2011). The U.S. Nuclear Regulatory Commission is reviewing an additional 8 combined operations license (COL) applications for 12 new constructions (U.S. NRC, April 2015). And internationally, there are 450 reactors in 30 nations, including Taiwan, accounting for 11% of world electricity (Nuclear Energy Institute, 2016). "Approximately 70 further nuclear power reactors are under construction, equivalent to 20% of existing capacity, while over 160 are firmly planned, equivalent to half of present capacity" (WNA, February 2015). American-based Westinghouse (AP1000 design) and Areva (EPR design) are among the signed partners; others designs include Canada's CANDU and Russia's BN 800 (World Nuclear Association, November 2012). An argument has been made that U.S. competitiveness is being compromised as other international bids go to nuclear competitors, eroding international influence (CSIS, June 2013). For example, the United Arab Emirates awarded a $20.4 billion contract to a South Korean consortium to build four APR 1400 reactors by 2020; the first is currently under construction (World Nuclear Association, November 2012).

Simultaneously nuclear energy continues to be plagued by high construction costs and delays (between $6 billion and $9 billion for each 1,100 MW plant), safety and security concerns along with issues around the non-completion of Yucca Mountain Nuclear Waste Repository and sometimes wavering public and political support (Schlissel, 2008, 2). Competing knowledges over this high risk technology have been fueled by such global factors as past and more current accidents, nuclear waste management questions, possible future disasters (human or natural), and proliferation concerns. The Union for Concerned Scientists, Sierra Club and Greenpeace have all called for a divestment in nuclear technology, suggesting renewable power sources – solar, wind, geothermal and hydroelectric – as alternatives. The 'atom in service' is seen more as an uncontrollable-destructive atom with far-reaching, long term effects – Three Mile Island (1979), Chernobyl (1986) and Fukushima Diiachi (2011) (Hibbs, 2012). Other arguments question safe operation, continued unrealistic economics, unsustainability, low uranium supply, poor mining practices, and proliferation concerns (Bulletin of the Atomic Scientists, 2008; Kessides, 2012; Hecht, 2006). Scholars have intensified their argument to problematize this high risk technology, especially concerning the lack of long term strategies for nuclear waste storage (NCWARN, 2012). For instance, the Yucca Mountain Nuclear Waste Repository was cited as the location forthe nation's high radioactive waste storage; as such the land went through physical and metaphoric transformations. The mountain was revalued – journeying from little value (seen as unclaimed or claimed by marginalized Shoshone peoples) to no value (a process needed to reclaim for the larger public good) to extreme value (as a constructed national labscape and eventual repository) (Kuletz, 1998). Nuclear waste moved from waste (holding no value) to spent fuel (holding recoverable value) as the public debate about the technology ensued and court challenges to stop construction occurred. "In August 2013, the U.S. Court of Appeals for the

District of Columbia Circuit rule[d] the UC Nuclear Regulatory Commission could resume the licensing process using currently available funding from the Nuclear Waste Fund” [2] (Dotson, April 2015). Risk associated with the nuclear fuel cycle - its production, transport, usage, spent fuel storage and overall security continues to be debated as plants are operated and new constructions are underway.

1.2 – Geography of (Nuclear) Energy

At one level my research aims to add to the description and analysis of how nuclear energy is co-produced in relation to other energy sectors, the environment and society. What place does nuclear energy occupy? What actions are taken by nuclear energy proponents as they face opposition to the technology? How do externalities become part of the co-constitutive nature of energy (e.g. air quality, climate change, globalization, capital costs, waste management, public perceptions, and proliferation concerns)? I examine the 21st century reframing of nuclear energy as a resurgent industry, through a study of the making of nuclear energy as an active material and discursive process. In providing both narrative and cartographic maps of the geography of the contemporary U.S. nuclear energy industry, I hope to provide a better understanding of how nuclear energy is remade and/or unmade in space, and through geographically specific constructions of the past, present, and future of nuclear power. The futures of energy choices have intensified in the last decade or so and my work examines one type of energy, its placement and relationship to others, our society and the implications of/to our environment. Energy resources are being taxed so how are various nuclear energy systems being (re)produced to serve as part of the energy? How is this U.S. industry responding to opponents who draw examples inside and outside national borders?

Geographies of nuclear energy can be understood in relation to the larger subfield of the geography of energy. A focus on fossil fuels, in particular coal, petroleum and natural gas have dominated in both descriptive and analytical ways. However, nuclear energy writings reached a peak in the 1990s and are now making a return in the 2000s alongside an increased focus on renewables. Energy transitions and environmental impacts are other major themes while there is a smaller body of literature on the imaginary geography of energy systems. The following timeline provides more detail as to energy resources and its topic areas and where nuclear energy has appeared.

Energy systems have evolved with scientific and technological know-how and the literature has described and increasingly analyzed a socio-technical connect. The early treatment of "how fossil fuels [energy] represents a necessary aspect of capitalist [or other political systems] production and circulation" appeared scarcely in the 1950s and 1960s (Huber, 2008, 105). The early geographies of energy literature focused more so on postwar economic growth and the need for energy. Pierre George's "Geographie de l'energie" (1950) is a classic energy geography writing where the physical as well as the social, economic, history and politics of energy consumption by different groups of humans was the focus. George wrote on the challenges of location and the costs of transportation. Quantitatively-based geographic writings on energy represented a segment of writings on production and consumption. "[G]eographers use[d] energy consumption data as key indices of economic well-being while others emphasize[d] the vital part which inanimate energy plays in permitting or attracting manufacturing industry" (Chapman, 1969, 10). Questions asked included – where could the needed deposits be found and the locations of plants that could use these fuel sources? What were the "spatial variation of energy consumption and production, the relation between the physical environment and energy supply and demand, and the regional effects of long- and short- distance transfer of energy" (Chapman, 1969)? "Causal analysis and applied studies [were] rare" (Chapman, 1969, 11). The shortage of writing on energy conflict areas would be later addressed by such writers as Le Billon (2005) on the geopolitics of resource wars, Watts (2006) on the scramble of Africa's oil and Klare (2008) on state powers and the stress on energy resources.

Four research areas Chapman identified in 1969 remain relevant – energy complex of an area, phases of the energy industry (from mining to production through to consumption), regional treatment (energy-surplus and energy-deficit) and the institutional framework (company and capital control of the energy industry) (Chapman, 1969, 11). Questions asked included what are the components of the energy industry and their spatial associations? How are institutional factors significant to the energy industry? (Chapman, 1969, 13-14) My research on nuclear energy will add to this body of energy geography literature by asking such questions as – who are the industry actors? What work do they do physically and discursively? How do past, present and future institutional factors (e.g. Atoms for Peace Program, Megatons to Megawatts, the Energy Policy Acts of 2005, Yucca Mountain Waste Nuclear Repository, to name a few), impact the boarder nexus of energy-environment-economy and play a role in the status of nuclear energy currently and into the future?

Energy-related issues remained broad in scope and effect cultural and economic activity as we move into the oil crisis period of the 1970s. Geographers examined a broad range of energy landscapes including resource location, production, consumption, imports and exports however numerical in scope. Following from such scholarship as George Manners' "The Geography of Energy" (1964), Earl Cooks' "Man, Energy and Society" (1976) spoke to the landscape of energy sources, the issues involved in energy production, the relationships between energy and society and energy decision making. We begin to see the use of data sources produced by such organizations as the Federal Energy Administration (now the Energy Information Administration) and the World Energy Outlook. My mapping project will draw on some of these data sources to provide a visual and contextual understanding of nuclear energy within the U.S. and its networks abroad. The U.S. is the largest nuclear nation in the world with 60% nuclear capacity in the Southeast, Midwest and mid-Atlantic (U.S. NRC, 2014). How has, and more importantly, does nuclear impact energy-related growth nationally and internationally? To understand this related growth, a mapped present and future will be analyzed in the context of a socio-political environment. The OPEC's 1973 oil embargo impacts, the Cold War and subsequent rising powers (China, India), and emerging nuclear energy (Middle Eastern states) have caused a focus on energy security; later works in this tradition included Plummer (1982) and Bohi (1996). The former author spoke to energy vulnerability and the later to the economics of energy security. There is continued discussion on coal in the literature – Spooner (1999) on the shaping of UK's energy supply with the decline of coal and rise in the oil and gas industry; Todd (1997) on coal transfers; and Elmes (1996) on the U.S. coal system from 1972-90, Bromley (2005) on U.S. control of world oil; Bardi (2009) on peak oil, Huber (2009) on U.S. petro- capitalism and the making of 'pain at the pump' discourse, peak oil and the making of scarcity (Bridge, 2010) and transitional power sources such as nuclear (Pasqualetti, 1984; Mounfield, 1991 on world nuclear power) are explored. My research shows that the geography of nuclear energy in the U.S. cannot be understood in isolation from global processes and events, including and the role of next generation nuclear construction in Asia, specifically China.

Core topics of resource development, power plant siting, land use, environmental impact assessment, energy distribution and the diffusion of conservation technologies dominate the literature (Solomon et al., 2003, 302). And by the 1980s and beyond work on risk perception and emergency behavior is done after Three Mile Island and Chernobyl nuclear accidents. But it is not until the 1990s do we see an increase in the nuclear power literature. For example, Mounfield (1991) gives a global review, Jacob (1990) on radioactive wastes, Gould (1990) on nuclear accidents, Pasqualetti (1990 & 1996) on plant decommissioning, Kuletz (1998) on nuclear landscapes, power and cultural politics of Yucca Mountain. Coal, petroleum, gas and nuclear energy supply 95% domestic consumption and as such themes on economics and availability along with geopolitical issues focusing on the Middle East remain prominent in the energy geography literature. Energy efficiency and conservation continue in light of literature on scarcity of the resource base. Other themes include foreign crude oil supplies (Solomon, 1989) and economic/environmental costs (Cleveland and Kaufmann, 1991). Energy policy response to global warming and climate change begin to increase at the start of the 1990s (Smil, 1990) and big dam projects and removals (Sternberg, 1996) likewise emerge in the geography of energy literature. We begin to see sustainable energy sources and their differing spatial characteristics to fossil fuels and nuclear power in the literature. My research adds to the discussion and analysis of environmental stewardship and low carbon economy – where does nuclear energy belong in the zero/low emission energy conversation? How is spent fuel revalued as a national asset that contributes to reduced environmental degradation? How are the physical and discursive environments revalued to meet these goals? A juxtaposition between nuclear energy and renewable energy emerges therefore how has proponents of nuclear energy used it in their renaissance claim?

As we move into the 2000s, research builds on the foundational work of nuclear energy in the 20th century and what some may call a renewed growth-sprit – however highly contested – that marks the beginning of the 21st century. Other continuing themes include oil, peak oil, the tar sands, environmental degradation, crises (e.g. 2006 Deepwater Horizon BP Gulf accident), and energy poverty in resource rich nations (e.g. Nigeria). Coal and oil, as well as hydroelectricity, continue to be focal points in the literature and have intensified questions around risk, environmental impact and uneven development. Issues of climate change, social/environmental justice, safety and security, and renewables role in a low carbon economy are also being researched (Pasqualetti, 2011). The question of whether fossil fuels have peaked – metaphorically and materially – has been evaluated by such scholars as Huber (2008). What does a future economic-environmental model look like? What questions need to be posed for another energy transition? Nuclear energy is part of this energy discussion and I add to an understanding of the nuclear fuel cycle in the U.S. industry; adding to recent geographical work by Eyles and Fried (2012) on rhetoric and reality of the nuclear energy sector in Ontario Canada; by Garcier (2009) on the nuclear renaissance and uranium fuel cycle supply; by Proops (2001) on the politics and language of nuclear; by Jasanoff and Kim (2009) on sociotechnical imaginaries and nuclear power in the U.S. and S. Korea; and, by Hecht (2006) on the shifting nature of the geography of nuclearity where claims of nuclear nationalism, global nuclear order and environmental stewardship are examined.

1.3 – Interrogating the Contemporary U.S. Nuclear Energy Industry

The research examines the pro-nuclear position for continuation and expansion of nuclear energy technology, investigating how their responses to the anti-nuclear position appear in their messaging and action. I suggest that a geography of nuclear necessity has evolved and is being utilized by the nuclear energy industry through reference to its essential contribution to national security, energy independence (base-load power) and environmental stewardship (carbon-free electricity) (Nuclear Energy Institute, 2003). Necessity in that nuclear energy must be a part of the energy mix if the U.S. is to meet its obligations for electrification and its contribution to the economy. Necessity has traversed several real and imaginary boundaries, (re)making nuclear energy so that it occupies a space of resiliency and relevancy – however contentious that place may be.

I interrogate the constructed place of the U.S. nuclear energy industry. More specifically, what must be done in preparation for the construction or maintenance and operation of nuclear energy technology? How is the continued use of nuclear energy justified, in light of risks witnessed by the most recent accident where there was a loss of coolant event and meltdown at Japan's Fukushima Diiachi power plant station? In addition, the mitigation of risk is considered. For example, how does the nuclear energy industry sufficiently address concerns around operation and relicensing of some plants for an additional twenty years? Lastly, I address the future of nuclear energy, questioning the work that must be done for it to flourish. I suggest there is a continual reframing of 'nuclear things' – uranium, spent fuel/nuclear waste, risk/uncertainty (natural and human-made), lessons learned – for nuclear energy production to exist. I provide a contemporary geography of the nuclear energy renaissance in the U.S. and by the U.S. that builds upon work done on various aspects of nuclear power production and the energy sector. I will provide insight into how legislation, media framing and proponents' messaging are formulated and used to advocate for continued use of nuclear energy despite it being a high risk technology.

I assess relational politics in this thesis. How do things come to matter and what are their impacts? How does the industry understand, approach and engage with society? In what ways does the technology engage with other energy technologies? And how does the nuclear space (materially and conceptually) endure? This is where Massey's propositions can assist in understanding nuclear energy's role in constructing a necessity. Massey asks that we –

1. Recognize space as the product of interrelations; as constituted through interactions, from the immensity of the global to the intimately tiny.

2. Understand space as the sphere of the possibility of the existence of multiplicity in the sense of contemporaneous plurality … If space is indeed the product of interrelations, then it must be predicted upon the existence of plurality. Multiplicity and space is co- constitutive.

3. Recognize space as always under construction … it is always in the process of being made. It is never finished; never closed. Perhaps we could imagine space as simultaneity of stories-so-far. (Massey, 2005, 9) The U.S. nuclear energy industry is indeed organized through interactions that do not hold deference to international borders, state lines or communities. For instance, the uranium fuel cycle is referenced in relation to the nuclear fuel cycle; the final product of one is the initial product of the other (Gracier, 2009). The geography of this interrelation holds much insight into the nuclear industry claim of energy independence. The two largest uranium reserves are external to the U.S. – in Canada and Australia, accounting for 32% of the market (Energy Information Administration, 2014). From the last reported figures in 2013, domestic uranium production was approximately 17% (Energy Information

Administration, 2014). The claim of nuclear energy providing energy independence is questionable even though industry officials bring both countries into the “friendly” nation category and by extension part of the U.S. space. Nuclear energy is also shaped by such non-nuclear processes as cheaper electricity from natural gas, climate change and clean water legislations. These impacts are not static and are not the only processes/’things’ that work inter-relationally to (re)make nuclear. The production and narrative that is the U.S. nuclear energy industry rests on a continuum. The spaces and places of nuclear are complex, made up of dynamic relations between multiple entities – industry (for example, utilities, researchers, suppliers, regulators, professional organizations and trade organizations) and the larger public (includes willing, non-willing and non-knowing recipients of power on the electric grid system). Associations within this space, against it and across it are important points of questioning and helps us to understand why nuclear still exists. Massey asks that we see nuclear energy as a process as much as it is product, and can help us to understand how the process of nuclear power relies on the production and reproduction of material and imaginative spaces. The process is continual and crosses several boundaries within the state, across energy mixes, and legislations. Nuclear energy is as much a thing as part of a network of sociotechnical mechanisms.

1.4 – Research Methods and Questions

I question the construction of a nuclear space and how nuclear necessity is created and recreated. The practices of the nuclear energy industry are examined – for example, reworking the image of the uranium atom from one of military to one of peaceful use. It focuses on the real and abstract work done to the atom in the production of energy and placement in society as a benefit. Following the atom’s network from fuel fabrication to usage and disposal, I will investigate the configurations in the system. This nuclear fuel cycle has many aspects to its network that must be examined – regulatory, research and development, anti-nuclear actors, the public, suppliers, utilities, and (social) media. Each human and non-human actor intersects and impacts the construction and messaging of resilience and resurgence. I aim to improve our understanding of relational space through the politics of nuclear and the impact of places – for example, national and international communities, power plants, fabrication facilities, labs, educational institutions, and waste storage locations.

My thesis also draws on the situated-ness of knowledge as it examines the (re)production of nuclear energy in the 21st century (Haraway, 1988). How has the nuclear renaissance project changed in the past 15 years? How are U.S. industry insiders making a case for nuclear energy? The work being done by proponents to advance the technology is an important question in this context. Situated-ness draws on a relational understanding and it requires that the object of knowledge be pictured as an actor and agent (Haraway, 1991: 198). Scientific knowledge production is a view from somewhere (Livingstone, 2003, 81). And so, Haraway asks that we do not engage in the 'god trick' (Haraway, 1991, 191). It is through embodiment and partiality that knowledge is acquired. There needs to be "a fundamental insistence on the contextualized nature of all forms of knowledge, meaning and behavior" (Merrifield, 1995, 50). Haraway also insists that the researcher 'reflect and analyze how one's position in relation to the processes, people, and phenomena we are researching actually affects both those phenomena and our understanding of them" (Haraway, 1991). Using a situating approach means I must, as the researcher, shed light on the research process.

This research study is from the insider's position of the nuclear industry. My association with the U.S. nuclear industry spans 15 years, working in a nuclear engineering department and contributing through their professional organization[3]. This engagement allowed me to build trust, observe and participate in the knowledge production of nuclear science and technology. I interviewed a mixture of new and experienced professionals, gender and race, as well as varying industry sector members (e.g. utility, engineering firm, national lab, regulator agency, and college). To assist with the overall research project and more specifically with an understanding of the industry's culture and before my interview selection, I employed a participation observation research approach. "Only by participating with others can [researchers] better understand lived, sensed, experienced and emotional worlds" (Crang and Cook, 2007). It allowed me to build trust, begin to learn the technical language of nuclear science and technology and provide an environment where hopefully canned responses were not given. I wanted to engage in a long standing conversation about the industry and with its proponents. A clearer understanding of the science behind nuclear fission and its application was gained through laboratory work, technical presentations and most recently technical editing and curriculum development. To also hopefully assist with the process, I volunteered within their professional organization, starting with the student chapter then the local section and then their national American Nuclear Society. My co-workers served as gate openers, introducing me to colleagues. In all instances I waited for them to ask what a geographer was doing in a nuclear engineering society. It became a conversation and longer term relationship that I hope has positively informed my situated research project.

Participant observation is a preferred method for feminist methodology (McDowell, 1993). This method assisted in increasing my understanding of the everyday experience of interviewees. It allowed me to spend time with the industry's actors and engage in their knowledge production. My concern with participant observation always remains my closeness to the subject matter and the individual interviewees themselves. For example, I observed a tendency among interviewees to assume that I knew what they meant, and hence not to fully elaborate. However, my positionality also assisted with follow-up questions to have the needed elaboration happen if not forthcoming initially. A tendency for me as a researcher to be self- selecting of materials that would shine a positive light on the industry was another concern. There was a loss of detachment that I felt at times with this approach. To attempt to reduce this likelihood I not only conducted a discursive review of industry reports but also legislative and anti-nuclear movement reports were/are being analyzed.

Overall my research methods (including interviews and discourse analysis) allow me to describe and interpret actions (textual and orally) of interviewees, industry sectors, and materials (reports, legislation, presidential directives, multimedia materials on the health of the U.S. nuclear industry. How is it reproducing itself? What challenges is it tackling? What are some of the strategies and rational behind these actions? How are discourses negotiated? The ultimate goal is to answer the question of whether the industry is in a resurgence, holding its own or in a decline from their perspective and reading of the larger society to which they belong. Interviews allow me to ask individuals their perspective on lived experiences; these responses may be biased and as such data triangulation assists in some corrective action.

My expert semi-structured interviews do come with benefits and limitations. Benefits include a deeper discussion with decision makers from various aspects of the industry. I chose a mixture of mid- and higher level professional, fairly new and more seasoned. Their intense activity directly in the industry and with the public policy arm associated with nuclear technology, gave me narratives that spanned space and time in a nuanced manner. There is always the chance that these interviewees did not deviate from the organizational messaging and that is where my extended participant observation hopefully will meditate. Also, these interviewees may be too entrenched in the nuclear industry to see the opposition to nuclear clearly. To attempt to meditate for this possibility, data triangulation was employed along with the inclusion of scholar-critiques of the technology – a radiobiologist and the literature of the Union of Concerned Scientists. Knowledge of the industry was not only gathered through interviews, it included discourse analyses.

Discourse analysis examines the geographical imaginaries of nuclear energy (Faircloth, 2006; Phillips et. al, 2002). What is the landscape it produces and reproduces? How are key messages constructed and disseminated? An analysis of scientifically cultural texts provides another insight into the industry. How does this analysis differ from/compliment the interviews? What is included, excluded or empowered? What kind of group identities does it promote? As part of my participant observation, I was engaged in some of these messaging productions and was able to speak to the discussions before the final message was prepared. This insight was discussed with interviewees as well. Materials that will be examined include industry reports, presidential directives, legislation, industry infographics, and industry mix media (e.g. social media).

Semi-structured interviewing and participatory observation coupled with discourse analysis, these methods will provide a geography (not the geography) of the contemporary nuclear industry and its efforts to produce a nuclear renaissance.

My approach adds to the literature of energy geography from somewhat of an industry insiders' perspective; provides me with an opportunity to engage and write on nuclear renaissance activities; allows me to learn their meaning and actions towards a U.S.

nuclear energy resurgence and gain a better understanding of the nuclear energy network and access its successfulness.

My key research questions are:

1. What is the contemporary geography of U.S. nuclear energy production? What spaces does it occupy, and how have they been constructed?

What abstract and material work was and is needed to create its commercial and public space? Who were and are the stakeholders (bureaucrats, experts, the public, media, and 'opponents') that actively work on or influence this space? What impact has technology had on its societal standing? How have stakeholders affected operations? How have externalities impacted the nuclear energy? To trace the historical and existing significance of the U.S. nuclear industry I will consult key industry, government, legislative and anti-nuclear documents. Multimedia pieces will also provide an understanding of the positioning of nuclear energy. Through my interview questions, representations of the work of the fuel cycle will be explored.

2. How proponents of nuclear convey meaning about the present and future of their industry?
How is the nuclear energy industry making the case for its future and garnering support from stakeholders? In what ways are expressed concerns being addressed? How is the industry mitigating risk and communicating it to officials and the public? In what ways is the construction of nuclear energy a story-so-far?

A reading of above mentioned text types will be done with these questions in mind. Through the interview process, questions will be asked about a world with and without nuclear, including the likelihood of each scenario? What sets of technologies will be appropriate for the future? In what ways will technology reduce/eliminate risk? How is risk accounted for? In what ways do energy system comparisons impact nuclear energy?

The last 15 years has been somewhat favorable to the U.S. nuclear energy industry as much as it has illuminated concerns with the technology. Japan has become the newest Achilles' heel but there have been others including near misses. The transnational nature of the nuclear power plant and its inherent risk to the U.S. and elsewhere remains prevalent. In what ways does a Fukushima-type event impact the relevance of nuclear energy?

3. Whose scientific and technical knowledge claims and by extension governance prevail and why? In other words, what must be done to the landscape – abstract and material – for the nuclear necessity narrative to persist? A reading of text and outreach material (including social media) will be used to understand the (re) framing of nuclear energy. Interviews will also be insightful.

Three primary methods will be employed for this research project – mapping, semi- structured interviews, and discourse analysis.

The aim of this mapping project is to provide readers with a visual representation of the changing U.S. nuclear energy industry. The maps of current and under construction reactors, suppliers and spent fuel sites provide an all-inclusive view of many aspects of the industry, here and abroad. "Power is the ability to do work. Which is what maps do: they work" (Woods, 1992). They work to illustrate the accounts of the past and the hopes of the future. They are representations of a particular world constructed not reproduced; all the while speaking to certain power dynamics embodied in organizations, legislation, and other stakeholders. This construction is of moments in the process of decision making. Pickles prompts us – using Gunnar Olsson's question – to think through "[w]hat is geography if it is not the drawing and interpreting of a line? And what is the drawing of a line if it is not also the creation of new objects?" The nuclear energy renaissance is such a drawing based off of physicality/elements of the nuclear fuel cycle and its oppositional forces.

The 'aim of [the] interview is not to be representative (a common but mistaken criticism of this technique) but to understand individual people experience and make sense of their own lives' (Valentine, 2005: 111). Ten, on average hour long, semi-structured interviews were done, coinciding with a nuclear energy conference and/or an energy meeting thus allowing interviewees to be in the context of the subject. The participants were purposely chosen from one of the industrial categories of supplier, utility, government (including national lab), education, trade organization and regulatory agency – soliciting perspectives on the present and future of nuclear energy in a post-Fukushima environment and recent commencement of America's new builds. What are the narratives of the industry and how do they go about the business of entrenching the story-thus-far in light of such 'unresolved' issues as spent fuel storage, the fairly recent accident and public acceptance of perceived risks were probed. In all instances, advance notice and a request to tape the interview occurred.

Discourse analysis is a useful method for the written and visual texts of the nuclear energy industry and helps to show that "our words are never neutral" (Fiske, 1994). Three levels of analysis – actual text, discursive practices and the larger social context – provide ways of knowing, valuing and experiencing the world; it illuminates power relations. Discourse is thus connected to the past and the current context, and can be interpreted differently by people. With this in mind, a correct interpretation does not exist but a plausible or adequate interpretation is likely (Fairclough, 2002). The texts analyzed include energy policy legislation, presidential directives, industry position statements and reports along with multimedia promotional materials. Their framing of details and agency will be discussed. Together these acts may convey agentless- ness, pre-suppositive statements, insinuations, connotations and modality (Huckin, 1997). In essence what is the work of the texts, and who are its audience?

1.5 – Chapters' Roadmap

In chapter 1, I set out to contextualize my overall question – are we witnessing a nuclear renaissance and how would we know either way? I provided a literature trajectory to show that nuclear energy has been incorporated into the energy geography literature in particular ways but that there are additional questions we must pose to gain a better understanding of its contemporary geography. These questions have as much to do with the industry itself as with externalities that are (re)shaping it. I propose that the industry does not get acted upon but is a (responsive) participant. I share with the reader my research methods – mapping, participant observation, semi-structured interviewing and discourse analysis – and the advantages and concerns of each. Data triangulation is employed to reduce bias.

In chapter 2, I focus on the current geography of the U.S. nuclear industry, providing a historical and technical trajectory for the commercial nuclear power industry. My focus is on the U.S. industry but I am not bounded by national borders as various international happenings impact the current and future U.S. industry. The nuclear fuel cycle is mapped as well as practices, policies and debates are examined. Case studies of General Electric-Hitachi and Yucca Mountain Nuclear Waste Repository are used to illustrate how place should be seen as a process as oppose to solely a geographical location.

In Chapter 3, I examine the future of nuclear energy. I employ discourse analysis, in light of interviews conducted, to review promotional mix media materials. How the post-Fukushima nuclear energy industry is framed is of particular interest. A U.S. nuclear necessity argument is developed and being sustained around environmental stewardship, energy/national independence and international influence. What measures are put into place and what are the opposition's responses to this messaging?

In my concluding chapter, I discuss how the historical and current socio-technical framework may shed some light on the nuclear renaissance, resilient or exiting question posed in the introductory chapter. Massey's (2005) insistence on space as a simultaneity of stories-thus-far, though not typically applied to the technological arena of power production, offers key insights for understanding the U.S. nuclear industry.

ENDNOTES

1. Capacity factor is ratio of the net electricity generated, for the time considered, to the energy that could have been generated at continuous full-power operation during the same period. (U.S. NRC, March 2015).

2. This led to the publication of Volume 3 (Repository Safety After Permanent Closure) in October 2014 …Volume 4 (Administrative and Programmatic Requirements) was published in December 2014, and Volumes 2 (Repository Safety Before Permanent Closure) and 5 (License Specifications) were published in January 2015.

3. I was hired into the created position of Director of Outreach for the purpose of education outreach and engagement. In this role I interact with pre-college, undergraduate, graduate students. Nuclear engineering education is also the focus of the American Nuclear Society where I hold several executive positions e.g. the Education, Training & Workforce Development Division, Communications Committee, Public Policy Committee, to name a few.

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CHAPTER TWO – CURRENT GEOGRAPHY OF THE U.S. NUCLEAR ENERGY INDUSTRY

2.1 – Chapter Introduction

The United States has a long tradition of grand technological challenges – completion of the Panama Canal (1904-1914); the Manhattan Project (1942-1946); Project Mercury, the early space race (1959-1963); and, the Apollo program to send humanity safely to the moon and back (1961-1972) (Constable, 2003). To this list must be added the Atoms for Peace program. President Eisenhower's 1953 United Nations speech challenged the scientific and engineering communities to tame the atom and harness it for peaceful purposes. Stakeholders were tasked with creating new nuclear innovations.

In this chapter I will examine the current geography of the US nuclear energy industry. What is its structure? How have commercial practices, legislation and societal concern influenced, and continue to affect, the industry? I assert that the recurring question of nuclear energy's relevance is linked to understanding various practices, policies and debates. And, this is where Massey's propositions can assist in understanding nuclear energy's contested role –

- [Recognizing nuclear] space as the product of interrelations; as constituted through interactions, from the immensity of the global to the intimately tiny.

- [Understanding nuclear] space as the sphere of the possibility of the existence of multiplicity in the sense of contemporaneous plurality … If space is indeed the product of interrelations, then it must be predicted upon the existence of plurality. Multiplicity and space as co-constitutive.

- [Recognizing nuclear] space as always under construction … it is always in the process of being made. It is never finished; never closed. Perhaps we

- could imagine space as a simultaneity of stories-so-far (Massey, 2005, 9).

The spaces of nuclear energy are risky junctures of dynamic relations between multiple entities – industry (for example, utilities, researchers, suppliers, regulators) and other stakeholders (for example, oppositional and watchdog groups, political figures and the larger public). Associations within this created space, against it and across it are important areas of concern and help us to understand why nuclear energy exists as part of, as addition to, or declining parts of contemporary energy portfolios.

2.2 – Physical Landscape of the U.S. Nuclear Energy Industry

The land use of an average 1000 megawatt (MW) U.S. commercial nuclear reactor is 1200 m^2/GWh/year; this figure includes the plant and cooling water (Nicholson, September 20, 2013).[1] In comparison, land use for a hydropower station would be 200,000 m^2/GWh/year, coal would be 5700 m^2/GWh/year and on-shore wind would be 1100 m^2/GWh/year ((Nicholson, September 20, 2013). Other physical indicators include fuel footprint – a light water reactor (U.S. model currently in operation) has 950,000,000 mega joules per meters cubed (MJ/m^3) in stored energy density, 80,000,000 in electrical energy density with a conversion efficiency of 30%.[2] To provide context, black coal has 24,000 MJ/m^3 in stored energy density, 2,300 MJ/m^3 in electrical energy density with a conversion efficiency of 35% whereas natural gas has 38 MJ/m^3 in stored energy density, 5 MJ/m^3 in electrical energy density with a conversion efficiency of 45% (Nicholson, September 20, 2013).

The nuclear fuel cycle starts with the acquisition of uranium that contains 0.7% uranium- 235, the needed fissile product (World Nuclear Association, 2014). Fuel fabrication facilities purchase the milled uranium and it undergoes a conversion and enrichment process to 4-5% for use in the U.S. light water reactors (LWR). Enriched uranium pellets are then positioned in fuel assemblies, Figure 2. A typical LWR utilizes 75 tons of enriched uranium to make its reactor core, Figure 3 and 4 (World Nuclear Association, 2014).

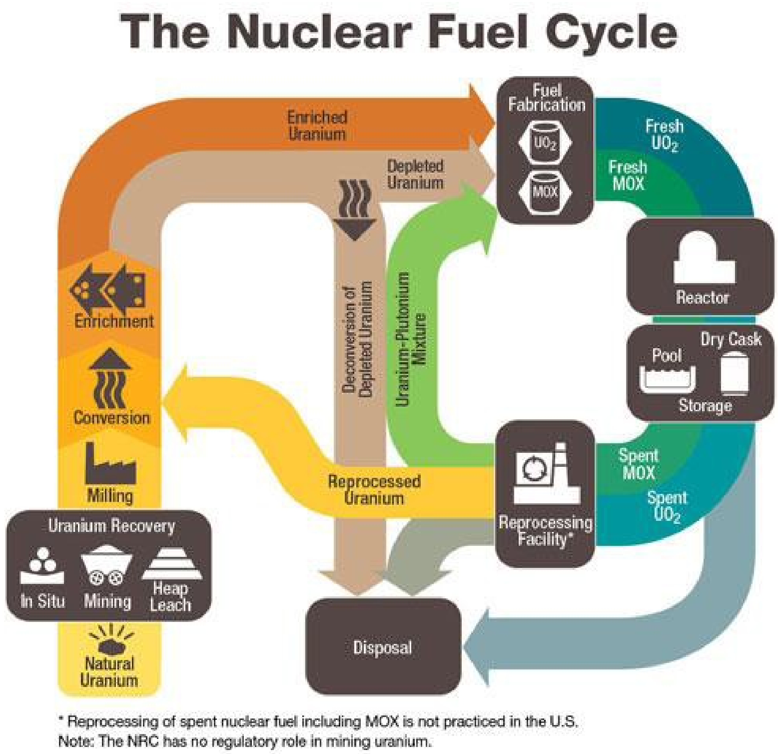

Figure 2: Nuclear Fuel Cycle from the U.S. Nuclear Regulatory Commission, http://www.nrc.gov/materials/fuel-cycle-fac/stages-fuel-cycle.html

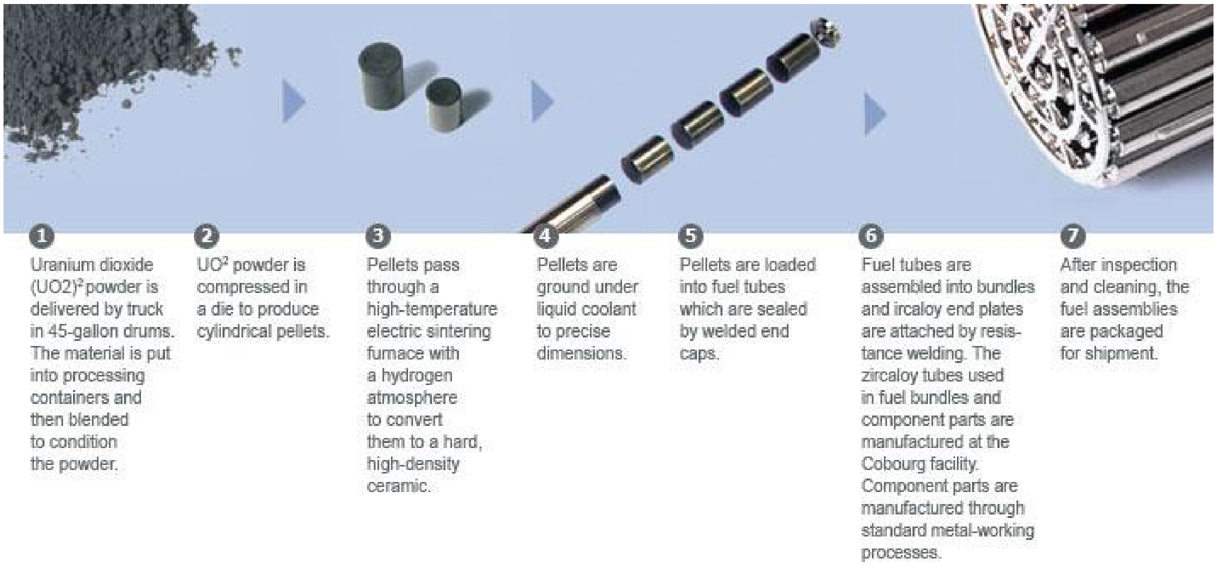

Figure 3: Uranium-235, http://www.cameco.com/fue_and_power/fuel_manufacturing/process

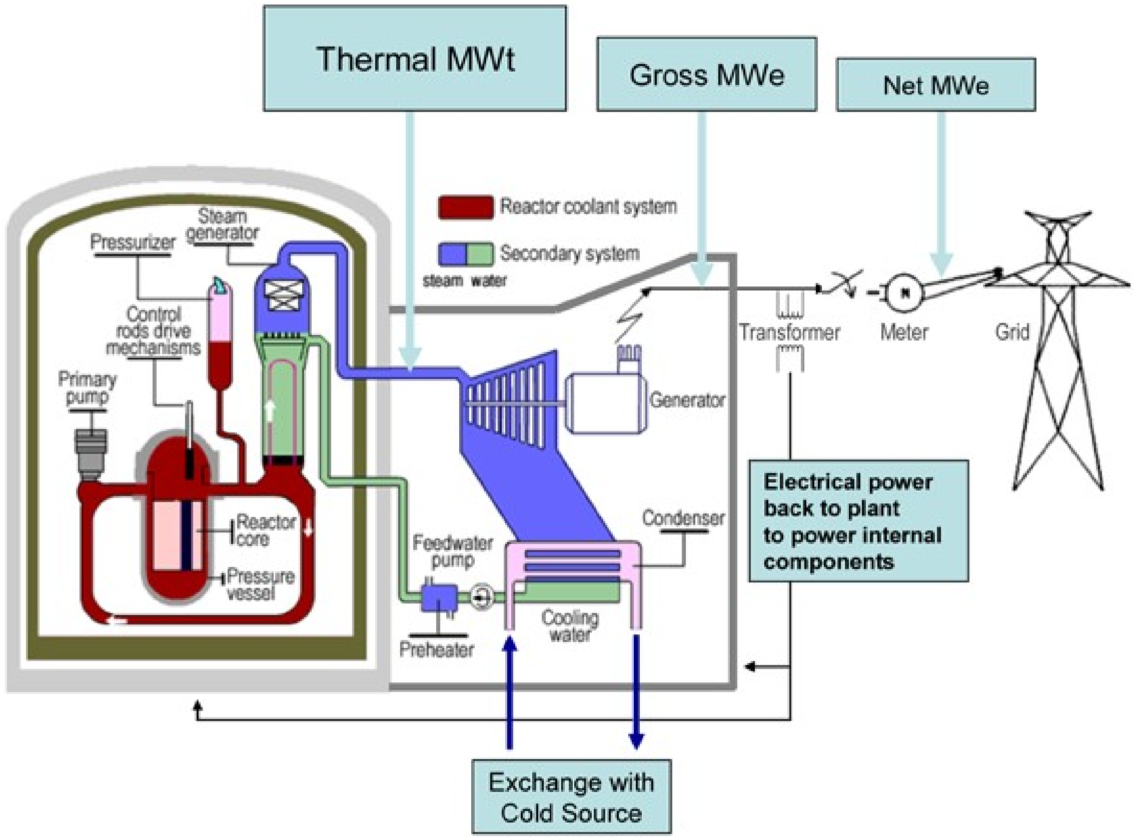

Figure 4: Typical Light Water Reactor (Pressurized Version), http://www.world-nuclear.org/info/Nuclear-Fuel-Cycle/Power-Reactors/Nuclear-Power-Reactors/

The enrichment process occurs at 14 enrichment and fuel fabrication sites throughout the U.S., figure 4. And these vendors – for example, GE Global Nuclear Fuels, Areva NP and Westinghouse, supply new fuel and service the current reactor fleet of 100.

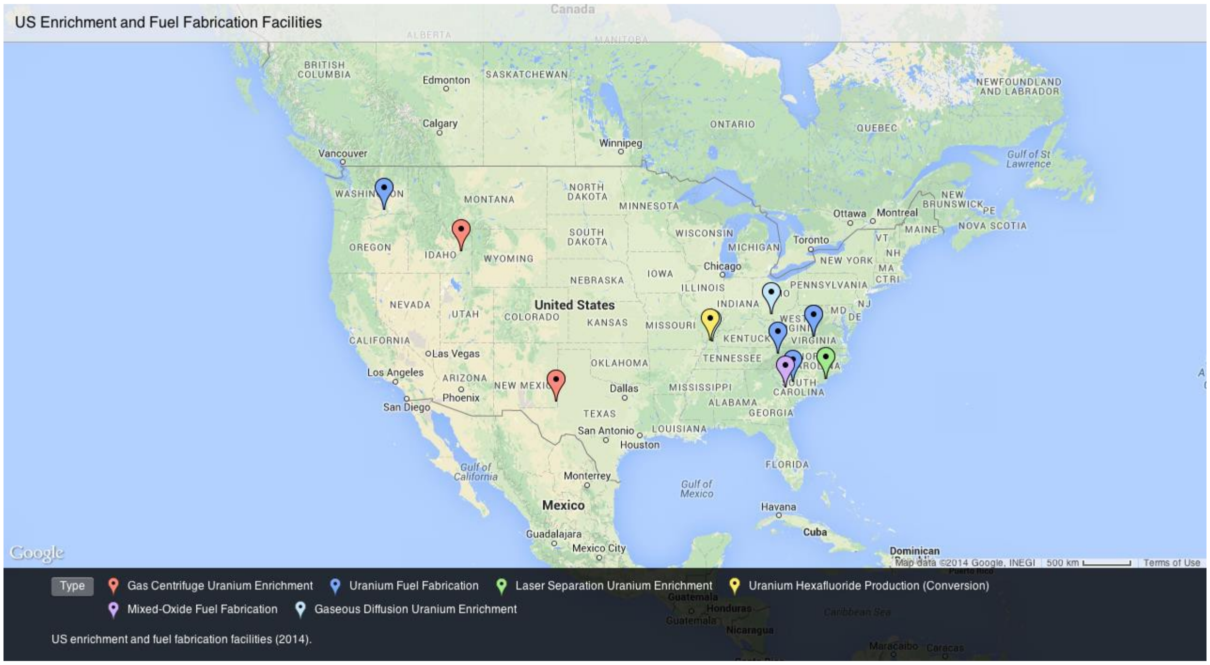

Figure 5: U.S. Enrichment and Fuel Fabrication Facilities, data from http://www.nrc.gov/info-finder/materials/fuel-cycle/

Fuel outages are scheduled every 18 or 24 months where spent fuel assemblies are removed, other assemblies are repositioned, new fuel added and any maintenance/repairs completed (NEI, 2012). The spent fuel is then stored on reactor sites in spent fuel pools or dry casks, Figures 5 and 6 respectively.

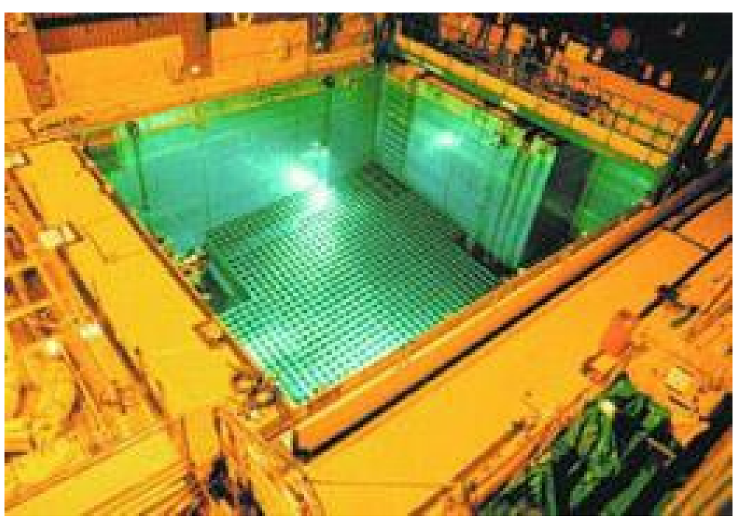

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Figure 6: Spent Fuel Pool, http://www.nrc.gov/waste/spent-fuel-storage/pools.html

Figure 7: Dry Cask Storage, http://www.nrc.gov/waste/spent-fuel-storage/faqs.html

In total there are 71,780 metric tons of spent fuel across the U.S. (figure 7) with an additional average 2000-2300 metric tons per year added (Nuclear Energy Institute, 2014). The states with the largest stored spent fuel include Illinois (9290 metric tons), Pennsylvania (6220), South Carolina (4270), New York (3790) and North Carolina (3470).

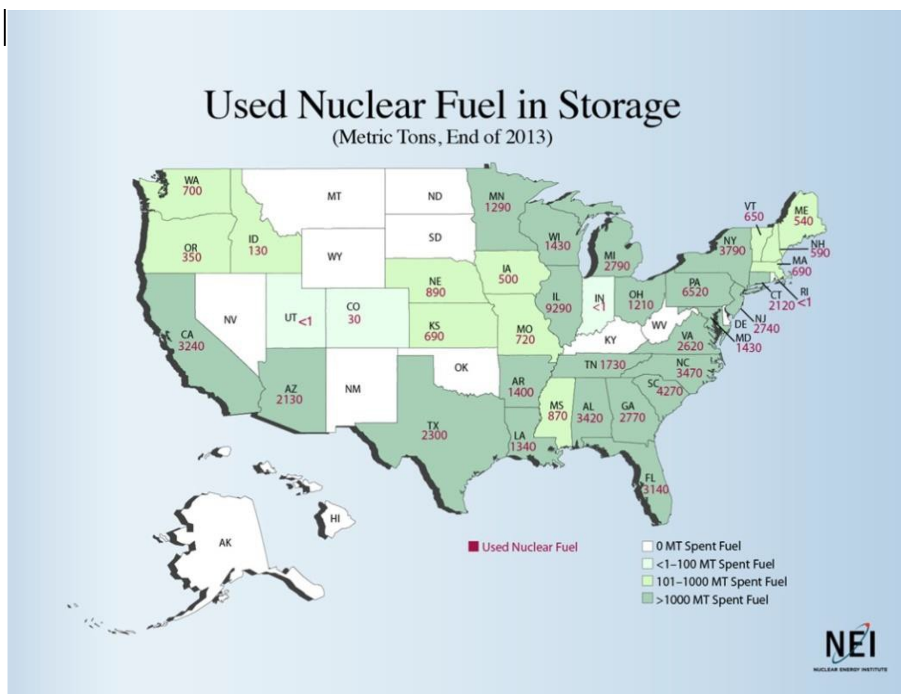

Figure 8: Spent Fuel Storage by State,
http://www.nei.org/Master-Document-Folder/Multimedia/Infographics-Database/Used-Nuclear-Fuel-Storage-Map

U.S. nuclear reactors were initially licensed for 40 years of operation. As of 2013, 73 of the 100 operating reactors have had their license extended for an additional 20 years (NEI, April 2013). Collectively, the current fleet of nuclear reactors, Figure 8, generated 713 billion kilowatt hours for 2013 accounting for 19.4% of America's electricity (NEI, 2014).

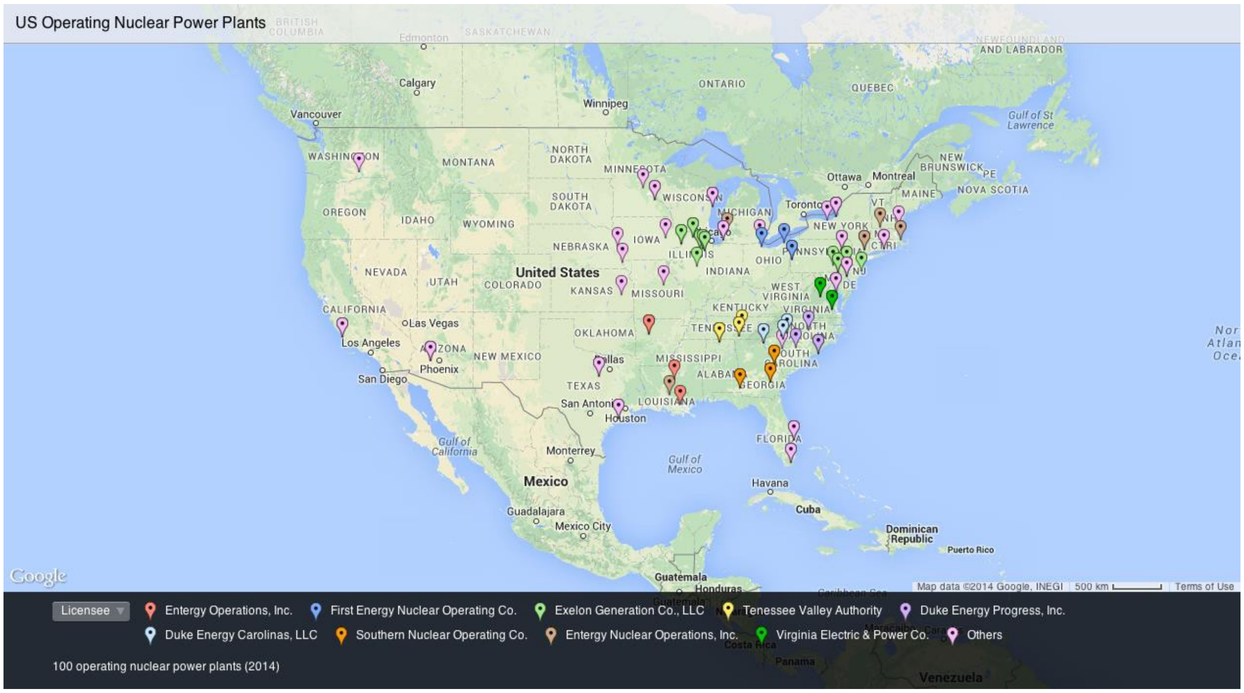

Figure 9: U.S. Operating Nuclear Reactors (with Spent Fuel),
data from http://www.nrc..gov/reactors/operating/list-power-reactor-units.html

2.3 – Major U.S. Nuclear Energy Industry Stakeholders

President's Eisenhower's UN General Assembly Speech of 1953 challenged the global community to make a reality the Atoms for Peace Program[3] –

> "It is not enough to take this [atomic] weapon out of the hands of soldiers. It must be put into the hands of those who will know how to strip its military casing and adapt it to the arts of peace" (Nuclear News, 2003, 40).

The revision of the U.S. Atomic Energy Act of 1954 followed, providing private ownership of nuclear power, and encouraging the participation of industry in the general development and use of nuclear energy. Fast forward to the 50th anniversary of Eisenhower's speech (2003) and Joe Colvin, president of the American Nuclear Society, reiterates from Eisenhower's speech –

> "The United States knows that peaceful power from atomic energy is no dream of the future. That capacity, already proved, is here – now – today. Who can doubt, if the entire body of the world's scientists and engineers had adequate amounts of fissionable material with which to test and develop ideas, that this capacity would rapidly be transformed into universal, efficient, and economic usage?" (Nuclear News, 2003, 45)

Currently, commercial nuclear power is entrenched in the energy portfolios of 29 nations with another 13 nations in the planning phase (World Nuclear Association, 2013). Four hundred and thirty seven nuclear reactors account for 13.5 percent of the world's electricity, Figure 9 (WNA, 2014).

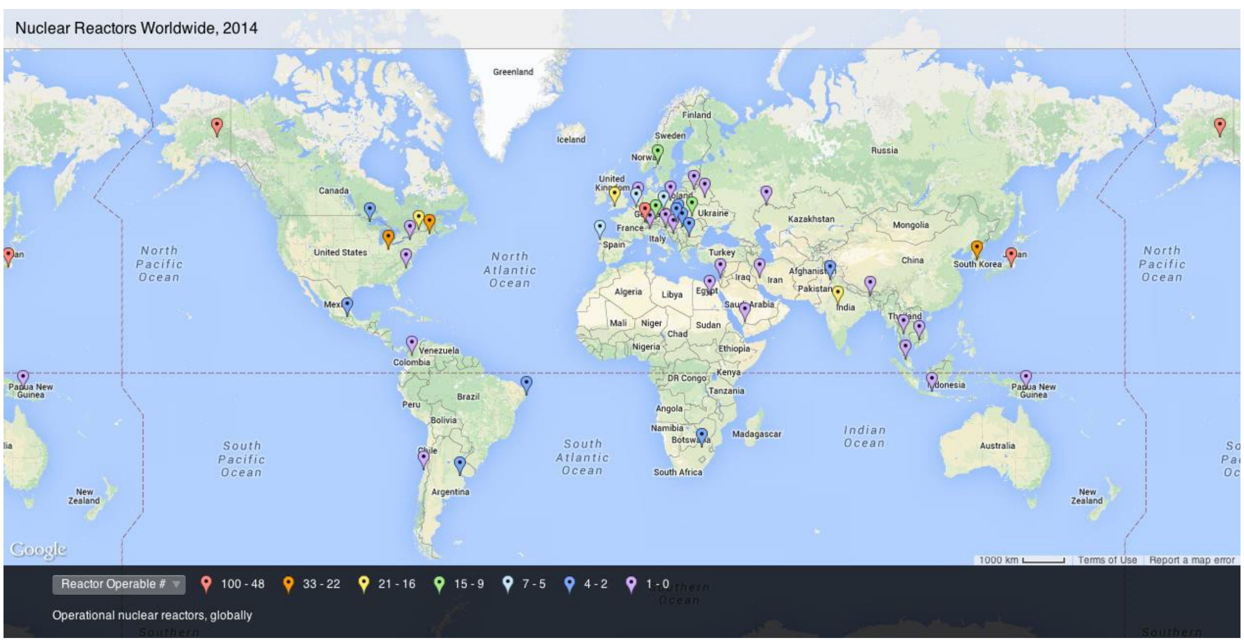

Figure 10: Nuclear Reactors Worldwide, date from http://www.world-nuclear.org/info/Facts-and-Figures/World-Nuclear-Power-Reactors-and-Uranium-Requirements/

Seventy one new reactors are under construction in 15 nations with China leading the way, Figure 10 (PRIS, 2014). They have 14 reactors in operation and 26 under construction or planned (WNA, 2014).

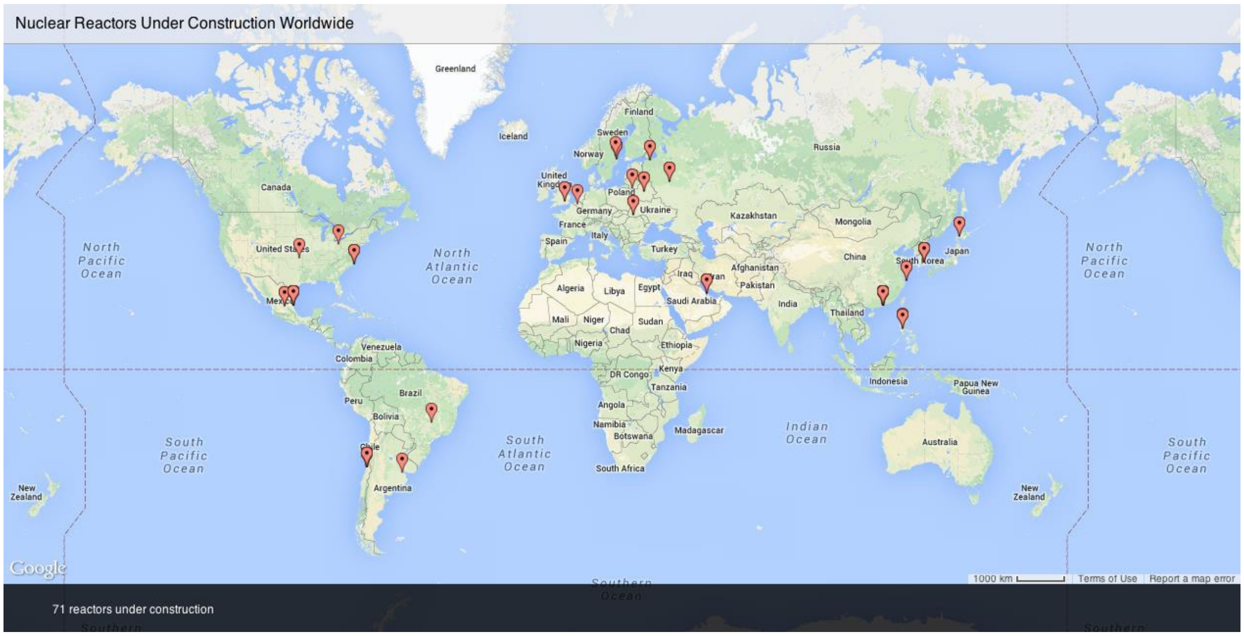

Figure 11: Nuclear Reactor Worldwide Construction, data from http://world-nuclear.org/NuclearDatabase/rdresults.apsx?id=27569&ExampleId=62

The AP 1000 Westinghouse design and the Areva EPR design are among the chosen designs; others include Canada's CANDU and Russia's BN 800 (WNA, 2012). Globally, one hundred and 167 reactors have been ordered or planned and another 317 have been proposed (WNA, 2013). In the U.S., there are currently 65 commercially operating nuclear power plants with 100 nuclear reactors in 31 states; and, they account for 20% of annual U.S. electricity since 1990 (U.S. Energy Information Administration, 2014). Thirty-six of the plants have two or more reactors. The Palo Verde plant in Arizona has three reactors and the largest combined generating capacity of 3,942 megawatts (MW) in 2010. Fort Calhoun in Nebraska has the smallest capacity with a single reactor at 478 megawatts (MW) in 2010 (U.S. EIA, 2014).

And when compared with other fuels, Table 1, the energy density of nuclear fission is greatest[4] –

Material	Energy Density (MJ/1 kg)
Solar*	0.2-1.0
Wood	10.0
Ethanol	26.8
Coal	32.5
Crude Oil	41.9
Diesel	45.8
Natural Gas	55.6
Natural Uranium	570,000
Reactor-grade Uranium	3,700,000

Table 1: Energy Densities of Fuel (NA YGN, 2009)

The top ten reactor locations and net nuclear generation are primarily in the South and Midwest.

State Ranking	Number of Plants	Number of Reactors	Reactor Owners	Share of State's Net Power, 2010
1 Illinois	6	11	Exelon Nuclear	47.8%
2 Pennsylvania	5	9	Exelon Nuclear, PPL Susquehanna & First Energy Nuclear Operating Co.	33.9%
3 South Carolina	4	7	Duke Energy & South Carolina Electric & Gas Co.	49.9%
4 New York	4	6	Entergy, Nine Mile Point Nuclear Station LLC, R.E. Ginna Nuclear Power Plant, LLC	30.6%
5 Texas	2	4	TXU Generation Co LP & STP Nuclear Operating Co	10.0%
6 North Carolina	3	5	Duke Energy	31.7%
7Alabama	2	5	Tennessee Valley Authority & Alabama Power Company	24.9%
8 Georgia	2	4	Georgia Power Company	24.6%
9 New Jersey	3	4	Exelon & PSEG Nuclear LLC	49.9%
10 California	2	4	Pacific Gas & Electric Co. & Southern California Edison Co	15.8%

Table 2: Top Ten U.S. Reactor Sites as of 2010 (compiled from U.S. EIA Data, 2014

The top utilities with reactors in their fleet include “Duke Energy who in 2011 purchased Progress Energy, making it the largest regulated nuclear fleet in the USA with 11 reactors. The $32 billion merger of Unicom and PEPCO in 2000 to form Exelon created the largest nuclear power producer in the USA, and the third largest in the world” (World Nuclear Association, 2014). The top U.S.-affiliated nuclear vendors are Westinghouse, General Electric-Hitachi and Areva. They currently service the existing civilian nuclear energy fleet and are constructing the next generation of reactors globally. As of 2014, Westinghouse operates or builds nearly 50% of the world’s nuclear power plants, with its world headquarters located in Cranberry Township, Pennsylvania (Westinghouse, 2014). Toshiba, as of 2011, owns 87% of Westinghouse, along with Ishikawajima-Harima Heavy Industries (IHHI) – an acquisition that stemmed from a 2006 sale of Westinghouse from British Nuclear Fuels (BNFL) (American Nuclear Society, 2006). Westinghouse’s AP 1000, in Figure 11, is the first Generation III+ reactor to receive design certification from the U.S. Nuclear Regulatory Commission (Westinghouse, 2014).

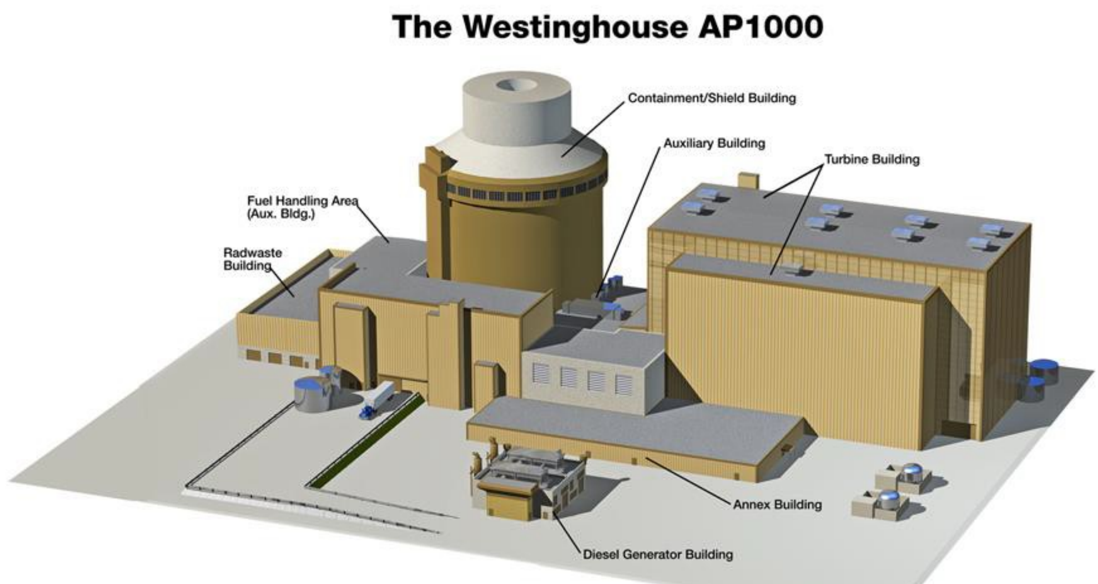

Figure 12: Westinghouse AP1000, http://westinghousenuclear.com/New-Plants/AP1000-PWR/Economic-Benefit

And it has been the most successful next generation nuclear reactor; currently being constructed by Georgia Power and Light in association with the Shaw Group. Vogtle reactors 3 and 4, in Waynesboro Georgia, are expected to be operational in 2017 and 2018 respectively, Figure 12 and 13.

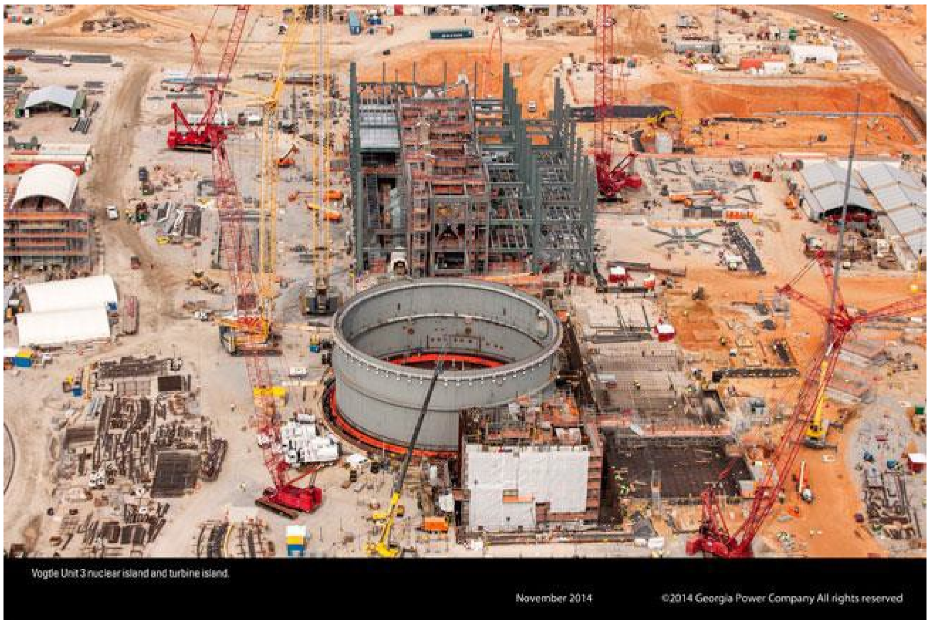

Figure 13: Westinghouse 1000 at Vogtle Site, http://www.southerncompany.com/what-doing/energy-innovation/nuclear-energy/gallery/new/

Two other U.S. nuclear reactor constructions are occurring at V.C. Summer in Jenkinsville, South Carolina. It is a co-venture by South Carolina Electric & Gas and Santee Cooper; these units are expected to be online in 2017 and 2018 respectively.

Figure 14: Westinghouse AP1000 at V.C. Summer Site, https://www.flickr.com/photos/scegnews/14756682396/in/set-72157692443419O9

The non-U.S. current AP1000 constructions are in China at the Haiyang, Figure 14, and Sanmen sites – two reactors each with a completion date of 2016 (WNA, 2012).

Figure 15: Westinghouse AP 1000 at China's Haiyang Site, http://www.westinghousenuclear.com/New-Plants/Photo-Gallery/emodule/3333/egallery1

In 2000, Global Nuclear Fuel (GNF) was formed between General Electric Energy, Hitachi and Toshiba; and, is located in Wilmington, NC (GE Hitachi Nuclear Energy, 2007). Then a global nuclear alliance was established in June 2007 – General Electric Hitachi Nuclear Energy – also with headquarters in Wilmington, NC. In 1997 their next generation reactor, the ABWR, was design certified by the U.S. Nuclear Regulatory Commission (NRC); while in 2005, their ESBWR design certification paperwork was approved this fall 2014 by the U.S. NRC (U.S. NRC, 2014). Internationally, GEH has built the first of four ABWRs in Japan (1996), and four additional units were being built, Figure 15. However, due to the Fukushima-Diiachi accident their construction has been placed on hold (WNA, 2014).

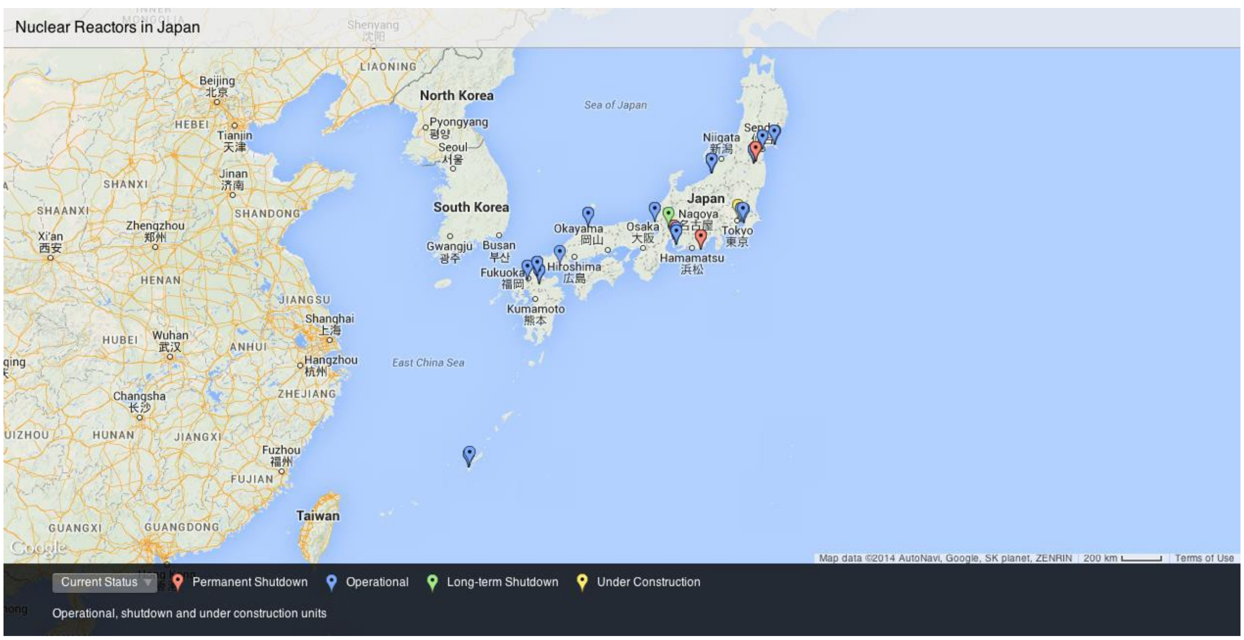

Figure 16: Nuclear Reactors in Japan, data from http://world-nuclear.org/NuclearDatabase/rdResults.aspx?id=27569

GEH is building two ABWRs in Taiwan; estimated to be connected to the electric grid in late 2014 and 2017 (WNA, 2014). And as of 2014, GEH has signed an agreement with Polska Grupa Energetyczna SA (PGE), Poland’s largest power company, to build their next two reactors (AP Newswire, 2014).

Areva is the third nuclear vendor with a presence in the United States and abroad. It operates in the U.S. as Areva Inc. North America and its headquarters is in Charlotte NC. It was established in 2001 through a merger with Framatome (formally Franco-Americaine de Constructions Atomiques, now known as Areva NP), Cogema (now Areva NC) and Technicatome (now Areva TA). Currently, Areva is a French public multinational industrial conglomerate whose headquarters is in Courbevoie, Paris; and, the French state maintains 90% ownership. Areva NP's next generation reactor, the U.S. EPR, is under design review by the U.S. NRC (U.S. NRC, 2014). International construction projects include – the first nuclear power plant ordered anywhere in Western Europe in over fifteen (15) years – at the Olkiluoto site in Finland, Framatome ANP is constructing a 1600 MWe European Pressurized Water Reactor (EPR) as the nation's fifth nuclear reactor, Figure 16. This project started in 2003 with an estimated electric grid connection of 2014 or 2015 but as of September 2014 it has a connection date in 2018 (WNN, 2014).

Figure 17: AREVA's EPR Construction in Olkiluoto 3, Finland, http://us.areva.com/EN/home-930/areva-inc-gen-iii-nuclear-reactors.html

Other Areva projects include two EPR reactors in collaboration with China Guandong Nuclear Power Group at Yangjiang, started in 2007; and, the second EPR at the Flamanville Nuclear Power Plant in France where construction started in 2009 and is expected to be complete by 2016.

The U.S. nuclear industry is multifaceted, a combination of collaborations, mergers and associations. It accounts for a substantial portion of several energy portfolios, nationally and internationally. Yet the future of nuclear energy is a work in progress, assisted by legislations especially the Energy Policy Act of 2005 (as well as beset by internal challenges and opposition).

2.4 – Legislative Writing and the U.S. Nuclear Energy Industry

In 2000, under then Vice President Dick Cheney, the national energy development group was formed. Its main tenet, safe expansion of nuclear energy by establishing the Yucca National Waste Repository, coincided with possible signs of a nuclear energy revival. For example, Calvert Cliffs nuclear power plant units 1 and 2, in Lusby MD, were the first to receive the U.S. NRC renewed operation licenses for an additional twenty years in 2000[5] (U.S. NRC, 2013). Seventy five (75) of the current 100 operating nuclear power plants have gone on to receive license renewals and an additional 18 applications are under review with a future 11 applications expected (U.S. NRC, 2014). The energy development plan became a precursor to the industry- favored 2005 Energy Policy Act (EPAct). This legislation was passed into law as the nation's first comprehensive energy legislation in thirteen years[6]. Research and development, scientific advancement for commercial application, environmental stewardship, international collaborations, and economic responsibility are key themes within the Act. An examination specifically of Title IX subtitle E – Nuclear Energy provides additional insight into the nuclear energy network.

Title IX Subtitle E is divided into seven sections and the common themes include research and development; funding allocation; collaborative efforts of researchers and officials towards efficiency of present and future nuclear systems; fuel management; joint nuclear science and engineering initiatives between universities and national laboratories; streamlining of efforts; safety and security of nuclear facilities; and, a survey of industrial applications of large radioactive sources (EPAct, 2005). Actions of the nuclear energy community are reinforced by this Act and directives are given to various stakeholders as to their role in scientific education, research, and commercial adaptation of technology. Capital, science and technology are explicitly linked in this body of law.

Section 951, entitled Nuclear Energy, speaks of a program for the development of civilian nuclear energy research, development and commercial application. Specific objectives include nuclear power viability in the nation's energy portfolio, technical support to reduce the likelihood of proliferation, maintenance of university along with national laboratories programs and infrastructure, support of researchers (individual and team based), development and acquisition of special equipment for researchers, support of technology transfer to industry and other users, and minimizing the environmental impact of nuclear energy related activities. In the pursuit of these activities, Congress authorized the Secretary of Energy to financially support these initiatives, $330,000,000 in 2007, $355,000,000 in 2008, and $495,000,000 in 2009 (EPAct, 2005). Section 952 speaks specifically to research programs, especially the Nuclear Energy Research Initiative (NERI), Nuclear Energy Systems Support Program (NESSP), Nuclear Power 2010 Program, Generation IV Nuclear Energy Systems Initiative (Gen IV), and the reactor production of hydrogen. Research and development is the key message of this section with emphasis placed on the development of advanced proliferation-resistant and passively safe reactor designs, enhancement of present nuclear reactors, and high temperature reactors capable of producing large quantities of hydrogen. There is a twinning of research and development with economically viable next generation reactors. This twinning provides for satisfaction of the Act's commercial application directive (EPAct, 2005).

Section 953 speaks to the advanced fuel cycle, allowing for proliferation resistant fuel recycling and transmutation technologies. It is in this section that care for the environment and the public is explicit. There is a concern with safety and security – safety against natural phenomena and security against man-made incidents. The financial commitment for these activities is set at $150,000,000 in 2007, $155,000,000 in 2008, and $275,000,000 in 2009. The public is situated as the benefactor within this scheme (EPAct, 2005).

Section 954 explicitly addresses the need for educational commitments in health physics, nuclear engineering and radiochemistry. It also explicitly identifies areas of human resource support. The human resource pipeline is identified and supported through undergraduate and graduate fellowships, young faculty research initiation grants, nuclear engineering research and development, collaboration amongst industry, national laboratories and universities, communication and outreach in these areas of specialties, and university-national laboratory interactions (for example, professor fellowship programs and visiting scientist programs). This section goes on to identify the need to strengthen research and training reactor programs and their infrastructure through the Innovations in Nuclear Infrastructure and Education Program (INIE). Monies associated with these activities include $43,600,000 in 2007, $50,100,000 in 2008, and $56,000,000 in 2009 (EPAct, 2005). The educational structure is valued as key to the civilian nuclear energy program – its personnel, students and infrastructure. Research from INIE feeds into the longer term work on such areas as fuel efficiency and radiation effects on nuclear materials. The educational component prepares a next generation of professionals to take the position at current facilities and those under construction.

Section 955 addresses the nuclear industry infrastructure through inventory, equipment prioritization and improvements, and streamlining. User facilities for nuclear waste research, fast neutron source, and hot cells are also to be developed. The monies associated with these tasks are $135,000,000 in 2007, $140,000,000 in 2008, and $145,000,000 in 2009 (EPAct, 2005).These areas of research speak to issues of nuclear waste management, future reprocessing and recycling to close the currently one-through fuel cycle.

Section 956 specifically requests a research and development program on cost-effective technologies to increase safety from natural phenomena and security from deliberate attacks on nuclear facilities (EPAct, 2005).

And the last section of subtitle E, 957, requires a survey of industrial applications of large radioactive sources. The scope of the survey includes nuclear well-logging, and federal departments who use radioactive sources. The objective is to analyze present disposal options and recommend legislative options to Congress (EPAct, 2005).

These seven sections provide a framework for the nuclear energy enterprise, serving an integral role in industrial development. This next section provides an example of such an expansion by General Electric-Hitachi; its relocation for national and international business interests, assisted by the U.S. EPAct of 2005 and state level incentives.

2.5 – General Electric-Hitachi and the Southern Appeal

Geography matters in economic development. In 2003, General Electric – Nuclear

Energy (GE) relocated from California to North Carolina. Following this move, the New Hanover county site was named global nuclear headquarters. Then in 2006, GE – Nuclear Energy and Hitachi (GEH – Nuclear Energy) "expand[ed] their global alliance in the nuclear power business, aiming to strengthen their position in a growing market" (New York Times, 2006). GEH's nuclear energy production site ranked, and continues to be, among the top industrial employers in New Hanover County[7] (NC Commerce, Labor and Economic Analysis Division, 2006). North Carolina has strengthened its position on the nuclear energy industry map as lucrative advancements in fuel fabrication and laser enrichment materializes on the 1,600 acre GEH campus[8]. GEH has situated itself in the expanding nuclear territory of the Carolinas – Duke Energy operates five nuclear reactors in North Carolina giving the state 6th ranking among 31 states with nuclear capacity (refer to Table 2). In addition, Charlotte North Carolina has one of the nation's highest job concentrations in the electric power and natural gas industries[9]. In a 2012-13 Carolinas' Nuclear Cluster report, the growing impact of the Carolinas was updated. "[T]he total economic impact of the nuclear industry has risen by over $19 billion over the past four years" (Mason & Ferrell, 2013). Reasons cited for this increase include "new construction, the influx of nuclear-related companies to the region, and the growth in community businesses to support the population increase associated with nuclear industry employees relocating to the Carolinas" (Mason & Ferrell). Mason and Ferrell estimate a total economic impact of $20-25 billion per year to the two-state Carolinas region (Mason & Ferrell). Although this report did not specify the number of and variety of occupations, industry representatives point to a demand in skilled trades (e.g. welders, electricians and masons), engineering and professions (e.g. civil engineers, nuclear engineers and accountants) and technicians (chemists, reactor operators and radiation protection specialists) (NEI, 2014).

State governments have also played a role in Carolinas' growth – for example, the incentives given to GEH for relocation.

> Using the JDIG [job development investment grant], we are bringing 1,580 jobs and more than $50.5 million in investment to our state, Tarheel Governor Mike Easley says… This targeted tool is proving effective in recruiting companies to North Carolina (American City Business Journals, 2003).

GEH, one of the world-leading providers of advanced reactors and nuclear services, took advantage of this JDIG and the EPAct 2005 for relocation and nuclear energy industry growth. Ninety one (91) boiling water reactors (BWRs) in eleven (11) countries have its design (GE, 2003). Its history dates back to the mid-1950s when their boiling water reactor (BWR) simplified the U.S. Navy design, known as the Pressurized Water Reactor (PWR), and opened the door to new energy solutions from nuclear technology (GE, Why Nuclear Energy?). There have been "nine evolutions in BWR technology, including the first operational light water design in the world – ABWR [advanced boiling water reactor] – and culminating in its latest generation of design – ESBWR [economic simplified boiling water reactor] (GE, Why Nuclear Energy?)." GEH has engaged in several multi-million dollar ventures as it expands its industry role. For instance, in 2006 Australian-based Silex Systems entered into an exclusive agreement with GEH to develop and commercialize an advanced, laser-based uranium enrichment technology. This agreement was the world's first, third generation process for enriching uranium that will then be used as commercial nuclear fuel (GE, 2006). In July 2007 Entergy Nuclear, the nation's second largest nuclear operating company, signed a project development agreement with GEH for a major advanced reactor components order (GE, 2007). In June 2008 Canadian-based Cameco Corporation, the world's largest uranium producer, joined GEH as owners of their laser enrichment venture (GE, 2008). GEH's Wilmington facility boosts 1,200 employees; they have "hired more than

300 people since 2003, with another 300 to 400 new hires expected in the coming years; the average salaries are reported to be $75,000 a year; and, they have undertaken a $78 million facility expansion project" to accommodate these collaborations and others to come (Cantwell, 2006).

Economic development, in the nuclear power industry, has historically occurred with government assistance, and this was and continues to be the case for nuclear energy's resurgence within the United States – a development that has benefited GEH. The U.S. Energy Policy Act of 2005 provided an encouraging environment for nuclear energy through –

2.5.1 Investment stimulus for new nuclear plant construction ($1.8 billion for core research, development, demonstration, and commercial application activities from 2007 to 2009);

2.5.2 Investment protection for first plants ($2 billion to cover cost of delays);

2.5.3 Long-term vision for nuclear energy by authorizing a robust research and development program ($580 million for the Advanced Fuel Cell Initiative, and $149.7 million for university nuclear science and engineering support); and,

2.5.4 Recognition of nuclear energy within the Department of Energy (through for example, the Nuclear 2010 Program, and the Generation IV Nuclear Energy Systems Initiative) (ICF International, 2005).

At the state level, the General Assembly of North Carolina passed Senate Bill 3 in August, 2007; an act designed to promote the development of renewable energy and energy efficiency along with new coal and nuclear generation. Within this Act, section 5

> "…permits an electric public utility that generates electric power by fossil fuel or nuclear fuel to charge increment or decrement as a rider to its rates for changes in the cost of fuel fuel-related costs used in providing its North Carolina customers with electricity from the cost of fuel and fuel-related costs established in the electric public utility's previous general rate case on the basis of cost per kilowatt hour" (NC General Assembly, 2007).

And section 7 allows for project development cost review for a nuclear facility (NC General

Assembly, 2007). It is in this favorable political environment and southeast regional energy need that GEH considered relocating.

Economic wars between regions remind us of transnational firms' fluidity (Tendler). Incentives attract firms but do not guarantee their permanence. As North Carolina courts Fortune 500 companies under such programs as the JDIG program, lessons have been learned from other states and past practices that "used public funds to subsidize land, credit, and tax exemptions, assured the recruited forms of lax reinforcement of environment and labor standards, and also promoted the state's cheap labor as their comparative advantage, along with an explicitly unfriendly environment for worker organizing" (Tendler, 10-11). Incentives that "encourage competitiveness in their own 'traditional' industries – textiles, food processing, or timber – including the introduction of new high-technology processes [are successful]; they also worked to upgrade skills in these industries … [S]tate governments institutin[g] supportive programs and targeted outside firms that would complement this effort [benefited]" (Tendler, 12-13). Looking at Mississippi's recruitment committee, they relied on "local and regional intermediaries – public utilities, railroads, banks, and local development agencies – to evaluate the soundness of prospective bidders for its recruitment subsidies" (Tendler, 14). With these lessons in mind, the documents and statements from North Carolina officials indicate they pursued their version of economic development with similar principles – building on existing infrastructure.

General Electric has had a presence in the California's San Jose area for 35 years, benefiting from the Silicon Valley community and the ranking of California amongst not only states but global nations. If California was ranked as an independent nation, it falls in the top 10 globally. In 2003 comparing gross domestic product (GDP) with gross state product (GSP) California placed 7th, just below Italy ($1,466 billion) and above China (excluding Hong Kong; $1,410 billion); its GSP was $1,446 billion (World Bank, 2005). So why did GE relocate to Wilmington, N.C.? A comparison of social indicators, reveals key variances (Table 3).

Indicator	**California**	**North Carolina**
Employment[10]	16,874,149	4,183,531
Economic Growth[11]	Ranked #16 (4.4%)	Ranked #20 (3.9%)
Gross State Product[12]	$42,727.46 per capita	$38,625.90 per capita
Cost of Living[13] - groceries - housing - utilities - transportation - health	San Jose	Wilmington 24.356% less 60.669% less 5.617% less 9.991% less 9.481% less
Cost of Living Index[14]	San Jose: 154.0	Wilmington: 102.5
Salary[15]	For $100,000 after tax in San Jose	Comparable after-tax income in Wilmington, NC - $64,335.66
Nuclear Energy (per capita) [16]	0.919 MkWh per 1,000 people	4.35 MkWh per 1,000 people
Corporate Tax Rate[17]	8.84%	6.90%

Table 3: Comparison of California and North Carolina

Not to mention, top executives have expressed difficulties in recruiting engineers to San Jose due to higher cost of living.[18] Salaries were high but expenses higher. This evolving atmosphere factored into the decision to move GEH. It did not hurt that at the North Carolina site existed GE Aircraft Engines on 1,600 acres of primarily undeveloped land. The connection to the state/region can be viewed as an expansion of a “local” company who had longstanding roots already in the community. A spokesperson for then GE – Nuclear Energy reiterated in an interview with Silicon Valley/San Jose Business Journal, that “[they] expected to create 200 jobs with an investment of about $4 million. It will be expanding its existing facility in Wilmington … estimated salary for the 200 jobs is $100,000 a year" (American City Business Journals, 2003). She went on to say that "California's business climate was not a major factor in GE's decision. San Jose has a lot of attributes that we like. We plan to maintain a presence there" (American City Business Journals, 2003). However, "nine out of ten of GE's Nuclear's customers are in the eastern U.S. The move puts the unit closer to its customers (American City Business Journals, 2003).

The North Carolina job development investment grant [JDIG], worth $5.9 million over nine years, granted to GEH also factored into the decision (American City Business Journals, 2003). North Carolina Department of Commerce, the Wilmington Industrial Development Committee, New Hanover Commissioners, and then Progress Energy worked together to develop the recruitment package. They relied on data from local companies and institutions to make a case for GEH's recruitment. For example, Progress Energy was one of two utilities in the state, ranked first as the largest taxpayer in New Hanover County ($1,671,254 tax levy) (Wilmington Industrial Development Committee of 100). Its Brunswick Nuclear Power Plant employs 1,200 in Southport, NC – making then Progress Energy one of the larger companies in the region of Brunswick and New Hanover Counties. North Carolina marketed as its distinctive advantages–

1. Skilled, productive workers and a friendly labor environment;
2. Comprehensive workforce development network;
3. Exceptional educational opportunities (nationally recognized pre-schools to universities);
4. Proximity to major markets (a central east coast location and extensive transportation infrastructure within a 700-mile radius of more than 170 million U.S. and Canadian consumers with global connections via deep water ports and international flights. [GEH's campus in New Hanover is less than 30 minutes from the sea port; NC provides tax

credits towards income taxes paid by businesses or individuals using ports' facilities…];

5. Global connectivity [especially with major firms as Cisco, Nortel and IBM in the Research Triangle Park (RTP).];

6. Competitive operating cost structure … overall taxes and cost of living indices all below the national average [NC's per capita state and local tax rates are low; ranking 36th among the 50 states];

7. A great place to live – [amenities include, for example, a thriving Wilmington arts community; strong school system; and, the Wilmington beaches];

8. A government that works for business - … strategic investments in education, infrastructure and technology;

9. Performance-based, targeted incentive programs;

10. Professional economic development assistance (NC Department of Commerce, 2008).

North Carolina offered tax credits and cost-saving programs as well –

1. Article 3J tax credits/William S. Lee (Article 3A) tax credits;

2. Foreign Trade Zones - …defer, reduce and/or eliminate import duties [GEH uses as it exports fuel assemblies to Asian markets];

3. Industrial Revenue Bonds – provides tax-exempt financing for eligible new or expanded manufacturing facilities; and,

4. Road access and rail access programs – provides funds for the construction of roads and rail access to new or expanded industrial facilities NC Department of Commerce, 2008).

GEH received –

1. A $900,000 grant from the state's One North Carolina Fund [that was contingent on a local match];

2. A JDIG award that spans 12 years. NC Department of Commerce estimates the project will generate a cumulative gross product value of $3.07 billion; produce a positive cumulative net state revenue impact of $62.2 million; contribute up to $8.57 million to the state's Industrial Development Fund for infrastructure improvements; and,

3. Each of the 12 years the company meets performance targets, NC will provide a

grant equal to 75% of the state's personal income withholding taxes derived from the creation of new jobs … yield[ing] as much as $25.7 million in maximum benefits to GE Hitachi; and,

4. The Department of Energy subsidized GE's $450 million investment in the advanced reactor program [part of the 2005 U.S. Energy Policy Act initiative].[19]

North Carolina capitalized on GEH's ties to the state and successfully offered performance-based incentives.

> "… [T]axes are dwarfed by other costs and place-based assets (e.g. universities, etc.) and therefore exert minimal influence on investments and location decisions…Other indicators taken into consideration include location, population size, quality of the physical infrastructure and workforce" (Schweke, 3).

Place-based assets – the 1600-acre GE owned property, collaborations with the University of North Carolina system, along with the 'new' Duke Power as utility clients – played a key role in GEH's decision to move and expand its campus[20]. The proximity to regulatory bodies such as the U.S. Nuclear Regulatory Commission (NRC) in Washington, D.C. was also instrumental; GEH's next generation reactor design is being reviewed for issuance of a construction and operating license (COL).

State governments also fear company recruitment loss if their demands are too great; indicating a lack of local research use to aid in the package offer (Tendler). This was not been the case for North Carolina. The Kerr-Tar Region Implementation Plan and the Economic Impact Study of Duke Energy's Brunswick Facility relied on such institutions as the Office of Economic Development at UNC-Chapel Hill and the University of North Carolina at Wilmington for analyses of regional impact (Stewart, 2004). Both reports showed linkages and potential growth patterns for establishing a mini-hub near RTP and Brunswick's Nuclear Facility impact on Southport, NC. Mini-hubs provide the manufactured materials and labor expertise for larger corporate regions.

Another concern suggested that state and local economic development may not be as lucrative for locals as first indicated (Markusen, 2007). Skilled labor would be transferred and/or migrate to North Carolina for said open positions. Several authors asked for a compromise – not banning incentives and certainly not continuing the status quo – but a middle ground “to produce good, long-term jobs and improve efficiency and equity in the process (Markusen, 2007)”. This concern was heeded by North Carolina. The then Governor Easley reported on new job development through the JDIG – so in addition to the initial influx of employees from San Jose and the newly graduated engineers from such schools as NC State University in Raleigh, NC, Georgia Institute of Technology and Penn State University – the $5.9 million program rewards GEH for local educational development. Employee focused training programs and community college partnership play a role in refocusing regional economic development (Bartik, 2005, 139- 166). GEH now funds a Nuclear Maintenance Program at Cape Fear Community College requiring graduates to make a two year commitment to the organization thereafter. Additionally, GEH’s Edison Engineering Development Program (EEDP) prepares employees for management positions; these employees can choose from NC State’s engineering master degrees to meet the educational requirements. There are 15 online masters’ engineering programs. In particular, the Master of Nuclear Engineering (MNE) and the Master of Science in mechanical engineering provide power related courses suited to complement employment in the nuclear energy industry. Online MNE students are increasingly employed by Duke Energy, Areva and General Electric-Hitachi, for example (Marshall, 2014). In addition GEH EEDP employees must obtain a masters’ degree in engineering. The parameters for employment fall within a broad array of power generation, energy delivery, and water process technologies. EEDP employees work in several areas of the energy industry, including renewable resources, biogas and alternative fuels, and coal, oil, natural gas, and nuclear energy[21].

Place as a process as oppose to solely a geographical location worked in favor of Wilmington. Industry clusters and inter-firm networks drew on the strengths and fortunes in numbers, improvements in technology, growth of economy as a whole, cooperation and competition co-existing, [along with] knowledge spillovers (Malizia, 2000). Investigating the industrial landscape of North Carolina and surrounding states, one finds a developing nuclear energy cluster. The Carolinas Nuclear Cluster was formed in 2007 by New Carolina to work on these key areas – economic development (defining supply chains and business development); workforce development (improving professional and craft education in the nuclear energy talent pipeline); technology development (unifying the region's research and development resources); public policy (analyzing public issues to move the industry forward); and, communications (media relations, presentations, messaging and outreach) (New Carolina, 2013).

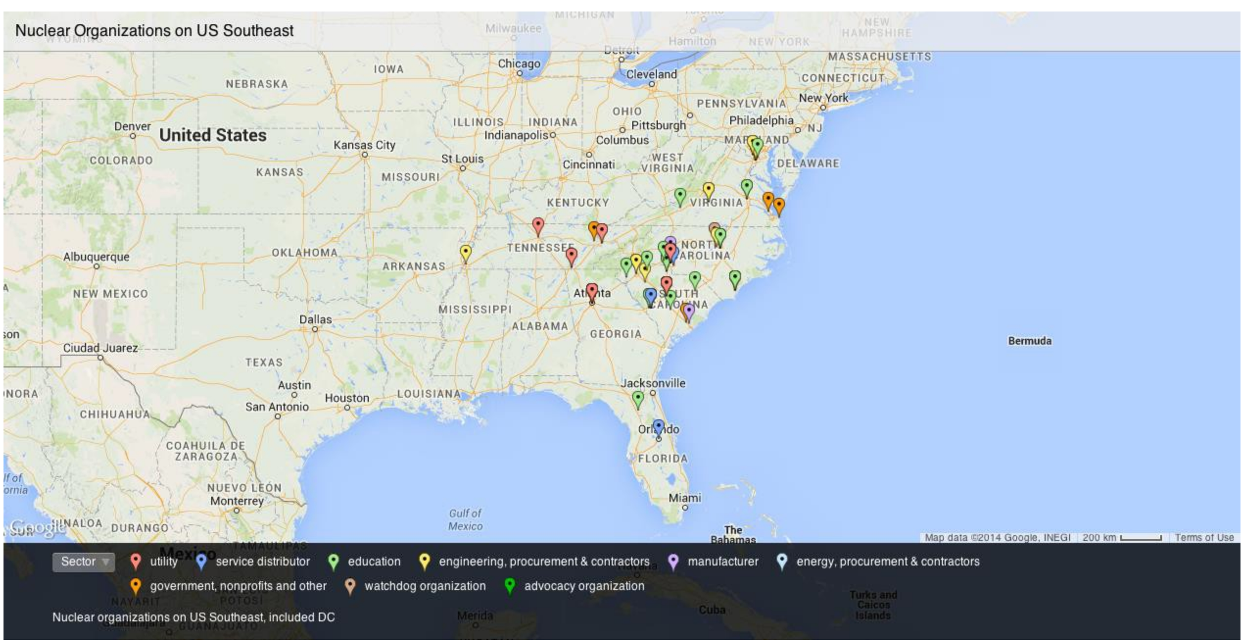

Figure 18: Nuclear Organizations in the Southeast U.S., compiled from the Carolina Nuclear Cluster, U.S. Department of Energy Office of Nuclear Energy, and the Nuclear Engineering Sourcebook

Regulatory along with research and development bodies are located in Washington, DC – the U.S. Nuclear Regulatory Commission (NRC) and the Department of Energy (DOE). Educational institutions with engineering and business & management programs are nearby – NC State's Department of Nuclear Engineering, Cape Fear Community College (started the Nuclear Maintenance Technology Program), and similar programs in Virginia, South Carolina, Tennessee and Georgia. NuStart Energy Development, a ten member coalition with two reactor vendors – GEH and Westinghouse – formed to advance the licensing process for the advanced nuclear power plant, and complete the design engineering for the two selected reactor technologies (ESBWR and AP1000).[22] Potential clients of Westinghouse and GEH, Detroit Energy, Duke Energy, EDF International, and Entergy Firms are not seeking every opportunity to outcompete each other, there was an emphasis on collective risk and growth such was the case of NuStart (Senbenberger, 1992, 19). Collective learning as a means of moving away from competitiveness based on lower wages toward competitiveness based on productive capacities was another factor.

GE and Hitachi may seem to have forged an alliance in the 21st century around the production of nuclear fuel marketing, design, development and manufacturing functions, but in fact a "comprehensive, tripartite licensing agreement for boiling water reactor [BWR] plants was signed in 1967. GE, Hitachi and Toshiba have been working together in the building and maintenance of BWR plants in Japan and overseas…the three companies established JNF [Japan Nuclear Fuel] in 1967, through which they have since delivered some 60,000 nuclear fuel units to Japanese power companies" (GE, 2000). A 47-year old business relationship "work[ed] to provide highly competitive nuclear fuel, services and technology and ensure even higher degrees of customer satisfaction" (GE, 2000). Today, GEH uses these and subsequent innovations and human relationships.

With the restructuring of nuclear energy companies to take advantage of the aligning economic and legislative initiatives, there remains a key area of concern – nuclear waste management. Industry action regarding a long term storage facility, Yucca Mountain National Nuclear Waste Repository, is next provided.

2.6 – Nuclear Waste Management in the U.S.

The U.S. Department of Energy estimates that by 2020, the nation will need 44% more electricity than it did in 2005[23]. This projected need has consequently been translated into conservation measures, higher energy efficiency, and the search for diversification of energy production. Global climate change discussions around carbon dioxide production and the effects of greenhouse gases have also been of concern. It is in this type of environment that the nuclear energy industry has positioned itself. Bodansky points to the future scenarios for choosing nuclear–

- "The gradual replacement of present coal-fired power plants by nuclear plants. Both coal and nuclear plants are used primarily for baseload[24] generation; their roles are interchangeable.
- The use of nuclear power rather than natural gas when new capacity is needed. This would free natural gas to replace oil or coal in heating and other applications.
- The replacement of petroleum in transportation … Looking ahead several decades, nuclear energy could contribute by providing power for electric vehicles, hydrogen production, and electrified mass transportation ...
- The replacement of fossil fuels by electricity for heating" (Bodansky, 2003, 17).

One of the key concerns associated with expansion opportunities of nuclear energy, however, resides with its spent fuel.[25] The United States currently has more than 65,000 tons of spent nuclear fuel stored at about 75 operating and shutdown reactor sites around the country. More than 2,000 tons are being produced each year (refer to Figure 7). The DOE also is storing an additional 2,500 tons of spent fuel and large volumes of high-level nuclear waste, mostly from past weapons programs, at a handful of government-owned sites (U.S. NRC, 2012). By 2035, approximately 105,000 metric tons of radioactive waste will need to be secured (from OCRWM)[26]. As such, "Yucca Mountain [was considered] the cornerstone of our nation's spent fuel strategy"; it [was] a key instrument in the nuclear industry's resurgence (Nuclear News, 2006, 64-66). The solution of a deep geologic disposal site is one that has been forged over time by scientific claims and politics, evolving into the external labscape/underground laboratory[27]. Through an examination of some of the key elements of commercial nuclear power production and its relatedness to nuclear waste management, the Yucca Mountain development project unfolded and, to many industry actors, remain unsolved.

The U.S. Atomic Energy Act of 1954 provided for private ownership of nuclear power, and encouraged the participation of industry in the general development and use of nuclear energy. It provided for both the development and the regulation of the uses of nuclear materials and facilities in the United States. The Act expressed parameters for the conducting, assisting, and fostering of research and development in order to encourage maximum scientific and industrial progress. It spoke to the dissemination of unclassified scientific and technical information and for the control, dissemination, and declassification of Restricted Data, subject to appropriate safeguards. And a program for international cooperation to promote common defense and security, for which cooperating nations would benefit from the technological advances[28]. This same Act provided that the disposal of highly radioactive waste would be the responsibility of the federal government. Then in 1957, the National Academy of Sciences

(NAS) recommended deep geologic disposal for radioactive waste, suggesting salt deposits and other rock types be investigated.[29] It was a recommendation "reconfirmed in a 1970 NAS study that spelled out the advantages of salt, although it also suggested further studies" (Bodansky, 2003, 292). The 1970 repository site named was located near Lyons, Kansas. Interestingly enough, "prior commercial activity had created cavities and boreholes in the salt that comprised the site's safety… physical collapse and the intrusion of water" became a concern (Bodansky, 2003, 293). As such, further investigations into this possible site were abandoned.

It would take until the early 1980s, under President Reagan, for a nuclear policy statement to substantively revisit the repository issue. Meanwhile, nuclear research, power production, and weaponry continued to increase the amount of spent fuel and high level radioactive waste (HLRW) that would have to eventually be safely stored.

> "The Nuclear Waste Policy Act of 1982, which I'm signing today, provides the long overdue assurance that we now have a safe and effective solution to the nuclear waste problem. It's an important step in the pursuit of the peaceful uses of atomic energy …This administration is committed to the use of nuclear energy as a crucial element in the enormous task of supplying America's energy needs …This Act -- the culmination of 25 years of legislative effort -- clears the barrier that has stood in the way of development of this vital energy resource. It allows the Federal Government to fulfil its responsibilities concerning nuclear waste in a timely and responsible manner" (Reagan, 1983).

Reagan's statement emphasized the importance of nuclear power as a possible solution to the nation's energy needs, and the issue of nuclear waste management was addressed with the signing of this Act. Specifically, the Nuclear Waste Policy Act (NWPA) developed a program for the disposal of spent fuel and high-level radioactive waste (HLRW). Initially, two repositories were to be named to ensure regional equity; also, the Act set forth a 1998 timeframe for federal waste acceptance and, started the Nuclear Waste Fund.[30] Nine sites in six states were under consideration by the U.S. Department of Energy (U.S. DOE). Reagan approved three of the nine for extensive scientific study: Hanford, WA, Deaf Smith County, TX and Yucca Mountain, NV (Michal, 2009, 68).

By 1984 the Office for Civilian Radioactive Waste Management (OCRWM) was established to further the development of a radioactive waste disposal plan. By 1986 DOE postponed the second repository-siting program, and in 1987 Congress amended the NWPA to designate Yucca Mountain the sole repository site to be studied. Investigations moved quickly as public hearings began in 1988 and surface studies began three years later. A consortium of government contractors, Bechtel Corporation and Science Applications International Corporation (SAIC), were awarded the $1 billion contract to develop a system to transport and store radioactive waste at Yucca Mountain. In 1993 the first phase of the Exploratory Studies Facility (ESF) began. The U.S. DOE set 1998 as the date it would begin to accept interim waste storage and by 2010 acceptance of nuclear waste would occur. Lawsuits were filed, by states and the nuclear industry, as the 1998 deadline passed. In 1999 the environmental impact statement for Yucca Mountain was released for public comment but by 2000, due to concerns that the Environmental Protection Agency's (EPA) role in setting radiation standards would be too limited, President Clinton vetoed the nuclear waste legislation passed by Congress. Then in 2002, with the change in political will from democratic to republican control, Energy Secretary Abraham recommended Yucca Mountain as a suitable site to President George W. Bush. Nevada Governor Guinn disapproved but both the Congress and Senate overturned his veto. The DOE began work for site licensing but the Nuclear Regulatory Commission (NRC) identified technical issues that had to be resolved. In addition, the State of Nevada filed suits against the DOE, NRC, Bush, and Abraham. Whilst the lawsuits progressed, the OCRWM continued their research initiatives: surface-based testing and investment; underground geologic mapping and testing; and, laboratory material testing and modeling[31]. Federal agencies were created or tasked to move the project forward, in spite of resistance. In 2004, the Court of Appeals in the District of Columbia dismissed the EPA's 10,000-year radiation standard for Yucca along with other Nevada suits. Subsequent lawsuits followed with relation to the Caliente Rail Line for shipping waste to Nevada. As DOE, the NRC, OCRWM and other key players answered objections to Yucca through legal channels, the DOE scheduled to submit the license application in 2005-06; application hearings were scheduled for 2006-07; the DOE were expected to start construction in 2008; the first shipment was estimated to arrive in 2010; and, waste emplacement completed by 2033 (Blomley, 2003). Despite the delay, certain interests appeared to be prevailing as evidenced by the continued funding and experimentation at the underground lab. "Edward F. Sproat, III, director of the OCRWM, on April 10, 2008, made a statement at the fiscal year 2009 appropriations hearing in Washington, D.C. The requested funding level in 2008 amounted to

$494.5 million and will be used for the following purposes:

- [To] submit of a License Application for a Construction Authorization for a geologic repository for disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain to the Nuclear Regulatory Commission (NRC) by June 30, 2008;

- [To] certify DOE's Licensing Support Network collection in accordance with NRC requirements and regulations by December 21, 2007;

- [To] complete the Supplemental Environmental Impact Statement (EIS) for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain;

- [To] perform the analysis and deliver the report to Congress required by the NWPA on the need for a second repository; and,

- To [c]omplete the final EIS for a Rail Alignment for the Construction and

Operation of a Railroad in Nevada to a Geologic Repository at Yucca Mountain (Sproat, 2009)”.[32]

Sproat also reported that Congress’ reduction in funding from the supported $494.5 million to $386.4 million, along with the fiscal year 2007 reduction by $100 million, would cause a reduction in personnel by 900; OCRWM could not meet the scheduled opening date in March 2017 (Sproat, 2005). With the requested funding, the 2009 objectives would be to –

- “Defend the License Application for the repository before the NRC;
- Begin detailed design for the facilities required for receipt of spent nuclear fuel and high-level radioactive waste at the repository;
- Continue essential interactions with State, local, and Tribal governments needed to support national transportation planning;
- Complete efforts to finalize the contour mapping and the layout of the rail line to support land acquisition and complete a right-of-way application for the Nevada rail line;
- Continue design and licensing work on the Transportation, Aging and Disposal (TAD) canister system;
- Continue staffing and training the OCRWM organization so that it has the stills and culture needed to design, license, and manage the construction and operation of the Yucca Mountain project with safety, quality, and cost effectiveness; and,
- Continue planning and design compliant and well-integrated safeguards and security, safety, and emergency management program”.[33]

As Wainwright reminds us, “scientific practices may make the territory of the state appear stable, uncontested and complete “(Wainwright, 2003, 201). Yucca Mountain explained politically follows this course of action — a relatively synchronized move towards a national repository.

However, the scientific community was not without reservations about Yucca Mountain’s suitability as a long-term repository. It was minimized within the documentation or in the interpretation of documents. For example, the NAS study of 1957 recommended deep geologic disposal for radioactive waste, suggesting salt deposits and other rock types is investigated (U.S. DOE, 33). This investigation was narrowed to geologic rock formation. The cited science behind the decision has been repeatedly framed as follows,

> "In 1976, the director of the USGS [U.S. Geological Survey] identified a number of positive attributes in and around the Nevada Test Site that would make positive contributions to geologic disposal, including multiple natural barriers, remoteness, and an arid climate. [Then] in 1981, a USGS scientist documented that the water tables in the desert Southwest are among the deepest in the world, and the geologic setting includes multiple natural barriers that could isolate wastes for 'tens of thousands to perhaps hundreds of thousands of years'" (US DOE, 2001, 1-14).

A suggestion to study geological formations was taken as a mandate for its sole study. Subsequently, some of the qualifying attributes of Yucca Mountain were been challenged, for instance the arid nature of the location. The DOE scientists assumed that due to the low precipitation rate (15 cm/year) and the high evapotransportation rate (95% of precipitation evaporates or is taken up by plants), water moves slowly (Echhardt, 2000, 464-89). In the 1990s however, there was a discovery of the isotope chlorine-36 in rocks at the repository level (1000 feet below ground). Chlorine-36 in groundwater is said to be primarily the occurrence of 1950s atmospheric tests in the Pacific; an implication that in less than 50 years the isotope had used water as a medium (MacFarlane, 2003, 789). The claims of aridity and natural barriers were questioned. What we see next is the reliance on alloy-22 as the engineered material to contain radioactive waste and shield it from water. Claims of impermeability based on natural barriers were amended to figure more predominantly in technological knowledge. We also had advisory boards expressing their doubts on technical assessments of Yucca Mountain. For instance, in 2002 the U.S. Nuclear Waste Technical Review Board[34] (NWTRB) stated,

> "When the DOE's technical and scientific work is taken as a whole, the Board's view is that the technical basis for the DOE's repository performance estimates is weak to moderate at this time…Gaps in the data and basic understanding cause uncertainties in the concepts and assumptions on which the DOE's performance estimates are now based" (Bodansky, 2004, 327).

It would appear that convenience and lack of strong opposition played a role in the selection as well. A U.S. Geologic Survey scientist interviewed by Kuletz, stated "DOE has all its eggs in one basket, and that basket is Yucca Mountain…And they did that for almost purely economic reasons (Kuletz, 1998, 271-2). Not to mention the junior status of the Nevada Congressional senators – a small state population wise – when the NWPA Act was enacted.

Examples of differing scientific claims were witnessed in the analysis of the engineered casks. The use of titanium drip shield and the nickel-based alloy (Alloy-22) for the outer barrier of the waste package were expected to have very long lifetimes, according to OCRWM. "In the repository environment, Alloy 22 is very corrosion-resistant, with general corrosion penetrating only about 0.03 inches in 10,000 years. The Titanium Grade 7 is also corrosion-resistant, with general corrosion penetrating only about 0.08 inches in 10,000 years. Only about 1 percent of the waste packages are projected to lose some of their integrity during the first 80,000 years."[35] The expected warm temperature would result in water evaporation before the radionuclides could dissolve in the water and make their way out of the engineered region. Shoesmith however pointed to uncertainties in the package design. He spoke to the performance of the final closure welds on the waste package lids. Unlike other welds on empty canisters, a final one to close the canister was not feasible. The temperature needed was 1,150 degrees Celsius; this heat level would threaten the integrity of the waste (Shoesmith, 2006, 290). Engineers envisioned a high- power laser beam to introduce shock waves into the weld surface. There was also de-alloying, especially of chromium, and aging concerns resulting in corrosion (Shoesmith, 2006, 298).

Uncertainty in cool or warm design to retard corrosion was yet another issue; and the introduction of external material through the water medium may have also resulted in speeding up the corrosion process (Shoesmith, 2006, 291). Further modeling was needed while appropriation of funds and excavation of the site continued.

It is important to note that the data collected was based partly on modeling and/or experiments in a laboratory – on- and off-site. Both Shoesmith and Stahl consulted with laboratory scientists and engineers at Lawrence Livermore National Laboratory, Framatome Advanced Nuclear Power and General Electric Corporate Research and Development (Shoesmith, 2006, 299). There was a certain level of confidence lacking in these analyses as all variables cannot be taken into account – minimizing unknowns in a controlled environment is very different from actual repository operation, tens of thousands of years in the future. What science is reliant upon is the advancement of their know-how to tackle issues as they arise, as a matter of growth within the scientific disciplines. It is worth mentioning again that the underground labscape continued research while litigation continued.

Yucca Mountain National Nuclear Waste Repository was/is situated through owning.

> "Yucca Mountain is located in a desert, isolated from populations, in a region where the land is controlled by the federal government, including the U.S. military. Most of the land is under federally restricted access."[36]

This is the continued position of the federal government as it moved forward with the repository. However, there were objections to this claim by the indigenous populations that still reside in the region – namely the Western Shoshone people (the Southern Paiute and Owens Valley Paiute are the other two major indigenous populations). Western Shoshone view the mountain as sacred –

> "Our history is not what has been written in books. Our history is in the Creator's belongings: the rocks and the mountains, the springs and in all living things … They're determined to put it [nuclear waste] there" (Kuletz, 1998, 240).

They also continue to contest the state's ownership of the land. A Shoshone elder recalled,

> "We used to live in that area [Nevada Test Site] in the 40s. But then we had to be moved out of it. See, when they made this test range and such, that's when we had to move off the land. The land's ours yet" (Kuletz, 1998, 240).

Figure 19: Proposed Yucca Mountain Nuclear Repository, http:www.mrc.gov/waste/hlw-disposal/photo-loc.html

In spite of these objections, the Bureau of Land Management, on behest of the Native American people, sold the land.

> "In spite of heavy opposition from the Western Shoshone Nation, [July, 2004], the Western Shoshone Distribution Bill was signed into 'law' by George W. Bush, President of the United States. The bill would authorize an alleged payoff of approximately 15 cents an acre for millions of acres of disputed lands in Nevada, Idaho, Utah and California. A majority of tribal councils, representing approximately 80% of the population, the Western Shoshone National Council and all the traditional people strongly oppose the bill…"[37]

> "The Western Shoshone has been litigating the territorial integrity of their homeland since at least 1951, when a claim was filed, purportedly in their behalf, before the Indian Claims Commission. A full statement of this history is in Elmer R. Rusco, "Historic Change in Western Shoshone Country: The Establishment of the Western Shoshone National Council and Traditionalist Land Claims" (*American Indian*

Quarterly, 337 1992).

> Suffice it to say that the United States government has endeavored for years to extinguish the territorial integrity of the Western Shoshone Nation. The U.S. offered money in exchange for land and, when the Shoshone refused to accept, presumed to accept on their behalf. This is an example of so-called "federal trusteeship" and "plenary power" over Indian affairs, which the U.S. Supreme Court upheld in *United States v. Dann*, 470 U.S. 39 (1985), stating that "the Shoshone's aboriginal title has been extinguished" because the U.S. accepted the money from itself on behalf of the Western Shoshone."[38]

Indigenous land rights and voice were and continue to be marginalized and silenced. "A property regime is never complete and self-evident but requires continual doing. The doing of real property happens not only in courtrooms and the law schools. Property must also be put to work on material spaces and real people, including owners and those who are to be excluded from that which is owned (Blomley, 2002, 557). The Western Shoshone were stripped of their land ownership rights based on several years of "familial" representation by the Bureau of Land Management. This action was crucial for the land to have become available. Yucca Mountain was rendered unused despite a different sort of usage or legal title. "The Western Shoshone land base includes the Nevada Test Site, Yucca Mountain, and beyond (actually 24 million acres). The 'legal' claim to the Nevada Test Site stems from the 1863 Treaty of Ruby Valley, which was a peace and friendship treaty allowing settlers to travel through Shoshone territory, not to withdraw it from Indian use (Kuletz, 1998, 148). Access to the land became restricted based on its re-titling as federally restricted. There was a hierarchy of land rights and claims imposed – one that gave primacy to the federal government over local indigenous peoples. Kuletz reminds us that the "geographies of sacrifice are socially constructed, and they hold different consequences for groups that are situated differently within late modern societies (Kuletz, 1998, 94).

Pickles prompts us – using Gunnar Olsson's question – to think through "[w]hat is geography if it is not the drawing and interpreting of a line? And what is the drawing of a line if It is not also the creation of new objects? (Pickles, 2004, 3) Yucca Mountain exemplified this process of being transformed from a natural habitat and range to isolated land to underground laboratory. Simultaneously, the engineered Yucca Mountain was created within a denatured Yucca Mountain allowing the nuclear waste repository to exist. Timelines for acceptance of spent fuel can only exist if, to some, the underground laboratory was on the continuum for establishment. Yucca Mountain served as a testing environment where geological and seismic testing were underway. Data that then would support the likely suitability for nuclear waste storage.

The land remains detached from local users (e.g. the Western Shoshone) through devaluation of existing use as non-use. The federal government, on behalf of the American population, reclaimed the mountain. Territory was marked and the stage set for transformation from less to better value. Yucca Mountain was described as "a desert, isolated from population centers, in a region where the land is controlled by the federal government, including the U.S. military".[39] "Barren, remote and of limited intellectual appeal, Yucca Mountain in far southern Nevada is fast becoming the world's most intensely studies piece of real estate" (Science, 256, 1992). Through the establishment of the Exploratory Studies Facility, Yucca Mountain was transformed abstractly and physically into an underground laboratory, occupied by international scientists who were investigating the viability of deep geological disposal. "The power to define a place can often mean the power to decide its destiny (Blomley, 2002, 574). The federal government did just that by claiming national interests and supporting its actions with scientific statements – even as these claims were questioned. For example, a 1990 report of the National Research Council stated,

> “There is a worldwide scientific consensus that deep geological disposal, the approach being followed in the United States, is the best option for disposing of high-level radioactive waste (HLW). There is no scientific or technical reason to think that a satisfactory geological repository cannot be built (Carbon, 1997, 54-5).

Of course, counter-statements within the scientific community were rarely, if at all, cited. More times than not, “[o]nce scientific claims are disseminated, they carry the weight of authority; contesting them [becomes] expensive and difficult” (Wainwright, 2003, 201).

The Yucca Mountain Nuclear Waste Repository was eventually halted when Senator Obama became president. “President Obama quickly set his administration into action, employing both of the two powerful levers that the NWPA had given the executive branch: the Department of Energy and the Nuclear Regulatory Commission. The administration used both fiscal starvation and regulations to shut down the Yucca Mountain project. Most prominently, President Obama promoted Commissioner Jaczko to the status of NRC chairman in May 2009, placing a firm anti- Yucca hands on the wheel” (White, 2012, 11). The administration instructed DOE to withdraw the license review application from the NRC. It also eliminated all funding with the exception of funds to end the project. Then in 2010 President Obama issued a Presidential Memorandum ordering Energy Secretary Steven Chu to convene a Blue Ribbon Commission on America’s Nuclear Future (BRC), which would review “all alternatives for the storage, processing, and disposal of” nuclear waste. The memorandum, made no mention of the Yucca Mountain project, tacitly signal[ing] its demise and the further delay by untold years of a permanent nuclear-waste solution” (White, 2012). The final report recommended:

1. A new, consent-based approach to siting future nuclear waste management facilities.
2. A new organization dedicated solely to implementing the waste management program and empowered with the authority and resources to succeed.

3. Access to the funds nuclear utility ratepayers are providing for the purpose of nuclear waste management.

4. Prompt efforts to develop one or more geologic disposal facilities.

5. Prompt efforts to develop one or more consolidated storage facilities.

6. Prompt efforts to prepare for the eventual large-scale transport of spent nuclear fuel and high-level waste to consolidated storage and disposal facilities when such facilities become available.

7. Support for continued U.S. innovation in nuclear energy technology and for workforce development.

8. Active U.S. leadership in international efforts to address safety, waste management, non-proliferation, and security concerns (BRC, 2012).

The BRC statement that "America's nuclear waste management program is at an impasse" stood. Meanwhile, a series of court challenges ensued, they included –

- "In May 2012, the U.S. Court of Appeals for the Federal Circuit affirmed a lower court's decision that nuclear utilities were entitled to nearly $160 million in damages for the government's failure to accept their spent nuclear fuel and nuclear waste under the NWPA.

- In June 2012, the U.S. Court of Appeals for the D.C. Circuit held that the Department of Energy had violated the NWPA by failing to consider whether to adjust the fees nuclear facilities paid to the DOE in light of the fact that the government would no longer be providing a waste repository. The court declared DOE's actions "legally defective" and ordered the secretary to respond within six months as to the agency's plan of action going forward.

- Finally, just a week later, the same court issued another decision holding that the NRC's environmental review of proposed rules for the temporary storage of nuclear waste and spent nuclear fuel was legally insufficient without a full consideration of the consequences of the absence of a long-term government storage facility" (White, 2012).

NRC Chairperson Alison McFarlane was appointed to the position in July 2012. Her opposition to Yucca Mountain National Nuclear Waste Repository is well known; the move was seen as another attempt by the Obama administration to keep it a non-starter. However, the "U.S. Court of Appeals for the DC Circuit held the case in abeyance for more than a year to give Congress an opportunity to clarify its intent. Seeing no action, the court on August 2013 ordered the NRC to complete its evaluation of the application and issue a final decision granting or denying the license. In its ruling the court said the NRC is "under a legal obligation to continue the licensing process' and identified the agency as having 'at least $11.1 million in appropriated funds' to do so" (NEI, 2013).

This chapter discussed some prevailing features of the U.S. nuclear energy industry – its dynamic structure highlighting key actors, legislations and issues. There are particular geographies of production (e.g. physical, economic and legislative), consumption (energy, education and economic demands and supplies) and modes of disposal (local spent fuel storage and the national repository arguments) that construct/challenge the nuclear energy enterprise. It explored what Doreen Massey refers to as, the event of place; the challenge to examine processes, not as settled and pre-given (Massey, 2005). Continuing in this vein, my next chapter will investigate the imagined geography of nuclear energy, its discursive entanglements through key reports, interviews, and internal multimedia productions in light of the 2000s as the so-called renaissance years and the industry's subsequent direction after the Fukushima-Diiachi earthquake and tsunami and continued/renewed opposition.

ENDNOTES

1. There are currently 100 nuclear reactors operating in the U.S., http://www.nrc.gov/ reactors/operating.html.

2. Energy density is the amount of energy stored in a given volume or mass of a certain substance or material. Conversion efficiency refers to useable energy rates.

3. President Truman signed the U.S. Atomic Energy Act of 1946, establishing the Atomic Energy Commission (AEC). The objective of AEC was to control nuclear weapons and energy development along with the exploration of peaceful uses for atomic energy. "Eight years later, Congress replaced that law with the Atomic Energy Act of 1954, which for the first time made the development of commercial nuclear power possible. The act assigned the AEC the functions of both encouraging the use of nuclear power and regulating its safety…The Energy Reorganization Act of 1974 created the Nuclear Regulatory Commission [and separated the research and development arm of the former AEC to the U.S. Department of Energy" (U.S. NRC, 2014).

4. Energy density is the amount of energy stored in a given volume or mass of a certain substance or material. If an energy source has a high energy density, then you'll need less material or resources to create the same, if not more, amounts of power than energy sources with lower energy densities. (NA GYN, 2009).

5. Four of the 75 renewed licenses will not be acted upon - Kewaunee, San Onofre, Crystal River and Vermont Yankee are offline and scheduled to be decommissioned. The former for economic reasons, the later for political reasons and the other two based on structural damage that the licensees have decided not to repair.

6. The Energy Policy Act of 1992 did not directly address nuclear science and technology. It did clarify the licensing and standards setting responsibilities of the Nuclear Regulatory Commission and the Environmental Protection Agency (EPA). It also called for the National Academy of Sciences to make recommendations that would serve as the basis for the EPA's radiation protection standard.

7. GEH has remained among the top industrial employers in New Hanover County from 2006 to 2013.

8. General Electric (GE) currently plans to use the Australian laser enrichment technology known as Separation of Isotopes by Laser Excitation (SILEX) to enrich natural UF6 gas in the uranium-235 isotope. GE is planning to conduct the project in two phases, a test phase and a commercial-scale enrichment plant phase. The Test Loop, which is being built at GE's nuclear fuel fabrication facility in Wilmington, North Carolina, USA, will verify performance and reliability data for full scale (commercial-like) facilities. This engineering demonstration program is currently under construction. For the commercial-scale plant phase, GE submitted a license application in June 2009. On September 25, 2012, NRC staff issued a construction and operating license for the facility (U.S. NRC,

2013).

9. The Carolinas are a hub of nuclear expertise, supplying more than 11% of the nation's nuclear power production (CNC, 2014). The Carolinas' Nuclear Cluster (CNC) is a 50-member organization that was founded in 2009 under the New Carolina - a non-profit working to increase South Carolina's economic competitiveness through a cluster development strategy. It is now part of E4 Carolinas - a not-for-profit corporation that convenes industry, research and educational institutions, innovators, economic development organizations, and public leaders to coordinate the energy cluster in the Carolinas. (E4, 2014).

10. Bureau of Labor Statistics. March 2006 via StateMaster.

11. Bureau of Economic Analysis via StateMaster. Percent change in GSP from 2004 to 2005.

12. U.S. Census Bureau, 2004. via StateMaster.

13. Cost of Living Index Calculator Result. http://wilmingtonchamber.org/newmlsfinder.html.

14. Cost of Living Index Calculator Result. http://wilmingtonchamber.org/newmlsfinder.html.

15. North Carolina Department of Commerce. Quality of Life. www.nccommerce.com.

16. National Priorities Project Database, 2001 via StateMaster. Numbers indicate how much nuclear energy was consumed in terms of millions of kilowatt hours (MkWh).

17. Refer to http://www.taxadmin.org/fta/rate/corp_inc.html.

18. As a Nuclear Outreach Director, I have had opportunities to discuss recruitment needs with top GEH executives. This statement occurred in 2007 as a reflection on the difficulty in closing hires when located in San Jose.

18 "Gov. Easley Announces 900 Jobs in New Hanover County" press release, 04/30/2008.

19 "GE Expanding Nuclear Site – Wilmington Facility to Consolidate Engineers, Technicians" in News & Observer, May 17, 2006.

20 GEH has been an educational partner to the department (through for example, the traineeship program for NC State's Master of Nuclear Engineering degree, as one of the top employers for graduating students; and, as a funding source for K-12 Science, Technology, Engineering and Mathematics initiatives). In fall 2008 the online Master of Nuclear Engineering saw its first students from GEH – Wilmington; students' tuition is covered by the company.

The Nuclear Maintenance Technology Program between GEH and Cape Fear Community College has enrolled 65 students and hired 11 graduates. The company pays tuition and a stipend in return for a two-year commitment to work for GEH. Press release “Gov. Easley Announces 900 Jobs in New Hanover County” 04/30/2008.

21 GEH (2014). Early Career and Experienced Program: Edison Engineering Development Program (EEDP), United States, http://www.ge.com/careers/culture/university-students/edison-engineering-development- program/united-states.

22 Refer to www.nustartenergy.com.

23 U.S. Department of Energy. Office of Nuclear Energy, Science, and Technology. www.doe.gov.

24 Baseload generation refers to the operation of coal and nuclear power plants at 100% capacity. Their energy production is the base of the power used while other energy sources (hydroelectric, solar, geothermal, etc.) are fluctuated to meet demands.

25 Spent nuclear fuel is used fuel from nuclear reactors at commercial power plants, research reactors, government facilities, and from Navy vessels. High-level wastes are those resulting from reprocessing spent fuel or are the spent fuel itself, either of defense or commercial origin. From Murray, 2003: 70.

26 Office of the Civilian Radioactive Waste Management. How much nuclear waste is in the United States? http://www.ocrwm.doe.gov/ymp/about/howmuch.shtml.

27 Yucca Mountain Nuclear Waste Repository.

28 U.S. Nuclear Regulatory Commission (2014). Governing Legislation, http://www.nrc.gov/about-nrc/governing- laws.html#atomic.

29 U.S. Department of Energy. Office of Public Affairs. Why Yucca Mountain? p. 33 www.energy.gov.

30 The Nuclear Waste Fund gets 0.1 cents per kilowatt-hour on electricity generated at nuclear plants from consumers. It is used to cover the expenses of waste disposal, including the construction of a repository.

31 US Department of Energy, Office of the Civilian Radioactive Waste Management. How much nuclear waste is in the United States? http://www.ocrwm.doe.gov/ymp/about/howmuch.shtml

32 Statement of Edward F. Sproat, III, Director, Office of Civilian Radioactive Waste Management, U.S. Department of Energy. FY2009 Appropriations Hearing, Washington, D.C. http://www.ocrwm.doe.gov.

33 Statement of Edward F. Sproat, III, Director, Office of Civilian Radioactive Waste Management, U.S. Department of Energy. FY2009 Appropriations Hearing, Washington, D.C. http://www.ocrwm.doe.gov.

34 The U.S. Nuclear Waste Technical Review Board Is (NWTRB) is an independent agency of the U.S. Federal Government. Its sole purpose is to perform independent scientific and technical peer review of the Department of Energy's program for managing and disposing of high-level radioactive waste and spent nuclear fuel and provide findings & recommendations to Congress, the Secretary of Energy, & the interested public. http://www.nwtrb.gov/.

35 U.S. Department of Energy. Office of Public Affairs. Why Yucca Mountain? www.energy.gov.

36 U.S. Department of Energy. Office of Public Affairs. Why is the DOE studying only Yucca Mountain? p. 6-7. www.energy.gov.

37 Refer to www.wsdp.org.

38 Western Shoshone Intervention in U.S. v. Nye County and Western Shoshone v. the United States and Oro Nevada Resources, Inc. and Complaints of Judicial Misconduct. www.wsdp.org.

39 39 U.S. Department of Energy. Office of Public Affairs. Why Yucca Mountain? p. 33 www.energy.gov.

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CHAPTER THREE – THE FUTURE OF NUCLEAR

3.1 – Chapter Introduction

New nuclear is clean, safe and affordable (CASEnergy, 2014). It is indispensable and should be an important component of environmental stewardship, energy independence and national security (MIT Study, 2003). President Obama, as presidents before him, has defined the U.S. as an innovation leader where nuclear science and technology is one such advance that should be highlighted as a national asset. He stated in 2010,

> "[w]hether its nuclear energy, or solar or wind energy, if we fail to invest in the technologies of tomorrow, then we're going to be importing those technologies instead of exporting them. We will fall behind. Jobs will be produced overseas, instead of here in the United States of America. And that's not a future that I accept." (Obama, 2010)

Nuclear energy is actively being produced and reproduced – materially and discursively – and this chapter will examine the mechanisms and messaging that are put forth to counter arguments of risk, costliness and being environmentally unsound (Union of Concerned Scientists, 2009). The nuclear energy enterprise is using policies (for example, around climate change), 'improved' technology (for example, modular reactor designs) and national security and innovativeness to propel the argument for the continued use and expansion of its technology. A nuclear necessity argument, where nuclear energy must be part of the U.S. energy production sources, is being put forth by proponents and this chapter will unpack these claims through an examination of their strategies and communication. Interviews with various nuclear energy professionals will also illustrate major themes and actions underway to build a new nuclear. This chapter will examine how the U.S. nuclear energy industry is framing its future, who are involved and what impact do their policies and reports, mix media campaigns and advocate work contribute to the staying power, resurgence, or demise of nuclear energy. Where does this framing lead us?

The early 2000s ushered in an increased level of engagement from nuclear energy corporations, professional organizations, and advocates in the framing of their identity through their engagement with energy production, policies, economics, and public opinion/imagery. President George W. Bush with the establishment of the 2001 National Energy Policy Development Group (NEPDG) gave attention and support to the role of new nuclear. By the time the NEPDG plan became the U.S. Energy Act of 2005, the nuclear energy enterprise was referencing a nuclear resurgence in such monthly publications as the American Nuclear Society's Nuclear News periodical, in their "Renaissance Watch" column, Figure 1 (Nuclear News, August 2014). A monthly update on new construction, regulations and policies nationally and internationally.

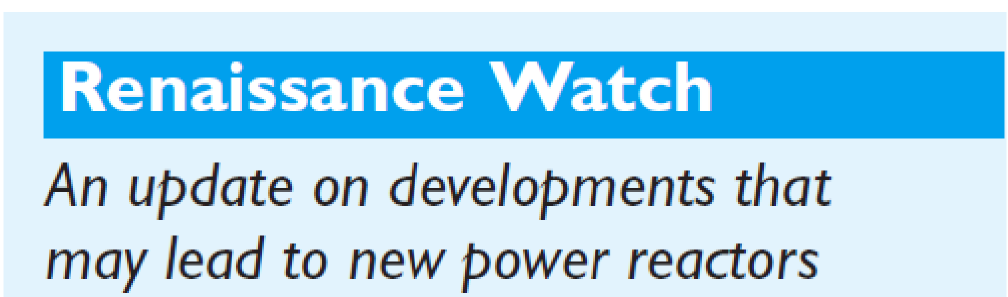

Figure 20: Renaissance Watch column is a roundup of domestic and international progress around nuclear energy (ANS, July 2007, 14-15)

The politics and economics of nuclear energy heightened with Nuclear Power 2010, a 2002 to 2010 government-industry, cost-shared partnership to spur new construction of advanced generation plants – the Generation III+ (World Nuclear Association, 2014). The 2003 and then updated 2009 MIT Future of Nuclear Power studies analyzed what would be required to retain nuclear power as a significant option for reducing greenhouse gas emissions and meeting growing needs for electricity supply (MIT, 2003). A $4.75 million commissioned MIT Study of the Nuclear Fuel Cycle was funded by an industry consortium and arranged by the Nuclear Energy Institute along with the Electric Power Research Institute (NEI, 2010). It included Idaho National Laboratory (INL), AREVA, GE-Hitachi (GEH), Westinghouse, NAC International, and Energy Solutions (NEI, 2010). This report recommended that "the U.S. move toward centralized spent nuclear fuel storage sites . . . in support of a long-term used nuclear fuel management strategy... It also recommended research, development and demonstration of advanced technologies to improve the benefits from recycling" (MIT, 2007). The 2005 Advanced Fuel Cycle Initiative, a component of an earlier 1999 Nuclear Energy Research Initiative by the U.S. Department of Energy, sought to "enable the safe, secure, economic and sustainable expansion of nuclear energy by conducting research, development, and demonstration focused on nuclear fuel recycling and waste management" (INL, 2014). The 2007 Energy Independence and Security Act sought, among other initiatives, to move the United States toward greater energy independence and security (H.R. 6, 2007). Specifically and by legislative tone, title III, subtitle D on industrial energy efficiency, title VII on carbon capture and sequestration, and title IX on international energy programs that assist and deploy energy technologies and investment in global energy markets, implicate nuclear energy in energy independence, security and economics (H.R. 6, 2007). The International Framework for Nuclear Energy Cooperation/IFNEC, formally the 2006 Global Nuclear Energy Partnership (GNEP), works on the advancement of proliferation-resistant recycling technologies along with the supply of nuclear fuel to developing countries that promise not to engage in enrichment and reprocessing activities (WNN, 2014).

Then in March 2011 the Fukushima-Diiachi nuclear accident occurred. A 9.0 magnitude earthquake and tsunami made landfall off the northeast coast of Honshu Island (the main part of island; Figure 21); reactors lost diesel backup power, subsequently they could not be cooled and core meltdown occurred (WNA, 2014). Units 1, 3 and 4 experienced hydrogen explosions on the service floor above reactor containment, hydrogen mixed with air and ignited, blowing off the roofs and cladding on the top part of the buildings (Figures 2, 3, 4 5 & 6). Major releases of radionuclides, including long-lived cesium, were detected in the

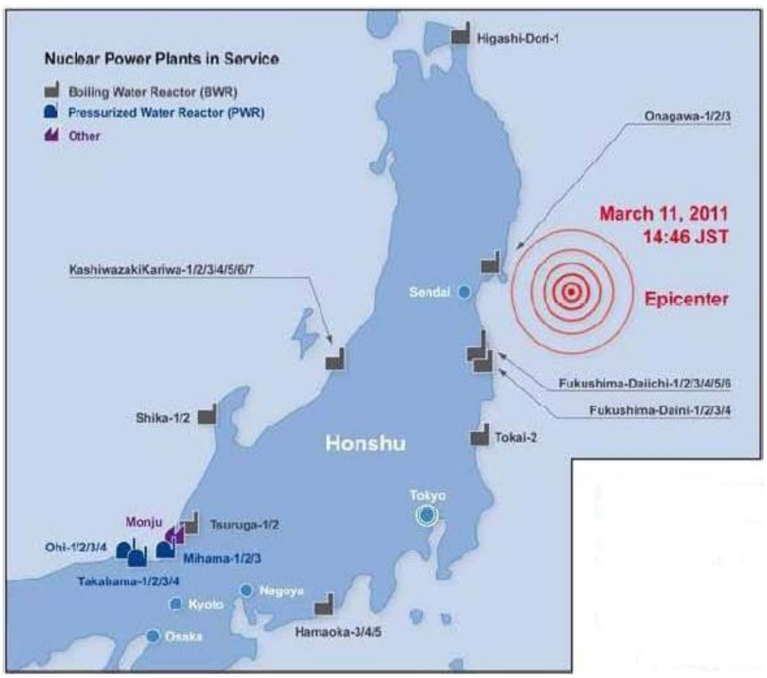

Figure 21: Fukushima Diiachi Nuclear Power Plants and Epicenter of Earthquake (U.S. NRC 2011)

air, in mid-March 2011 (WNA, 2014). Area evacuation of 20 kilometers occurred for some 160,000 people and 81,000 evacuees remain displaced due to government concern regarding radiological effects (WNA, 2014).

Figure 22: Fukushima Diiacho Multi-Unit Reactor Site (U.S. NRC 2011)

Figure 23: Fukushima Diiachi Multi-Unity Reactor Site After Explosions (U.S. NRC 2011)

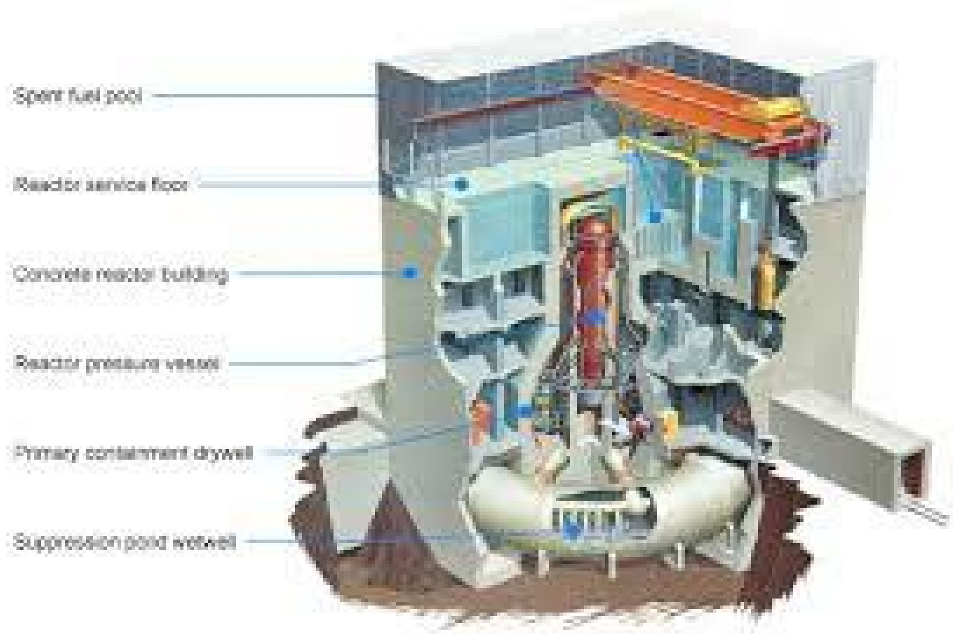

Figure 24: Fukushima Daiichi reactors are GE boiling water reactors (BWR) of an early (1960s) design supplied by GE, Toshiba and Hitachi (WNA, 2014)

Figure 25: The hydrogen explosion at Fukushima Unit 1 Reactor (WNA, 2014)

Tokyo Electric Power Company (TEPCO) has been able to keep temperatures in the reactor pressure vessels below boiling and transfer heat to external heat sinks (WNA 2014). Access has been gained to reactor buildings but the radiation dose rate was still too high. It was not until December 2011 that they declared 'cold shutdown condition' when radiation levels became minimal (WNA 2014). The spent fuel pools are also of concern on unit 1, 2, 3 and 4. TEPCO is in the process of removing the fuel assemblies from unit 4, and removing salt from the cooling water to reduce corrosion. Nations around the world ordered a review of nuclear safety protocols especially for beyond-design events similar to occurrences at the Fukushima Diiachi nuclear power plants. The U.S. Nuclear Regulatory Commission near term report, Recommendations for Enhancing Reactor Safety in the 21st Century, acknowledged the requirements for design-basis events where protection and mitigation features were covered by specific regulations or the general design criteria by 10 CFR Part 50 'Domestic Licensing of Production and Utilization Facilities', Appendix A, 'General Design Criteria for Nuclear Power Plants' (U.S. NRC, 2011, vii). The Commission also recognized "requirements for some 'beyond-design-basis' events through specific regulations (e.g. station blackout, large fires and explosions); along with, voluntary industry initiatives to address severe accident features, strategies and guidelines for operating reactors (U.S NRC, 2011, vii). The Commission recommended a move away from a 'patchwork of regulatory requirements and other safety initiatives'. Overall the defense in depth and probabilistic risk assessment would strengthen the beyond design basis approach to future events[1] (U.S. NRC 2011). In essence, the industry is relying more heavily on redundancy of equipment and/or practices and prediction of the foreseen and unforeseen accident scenarios.

Two nations that halted their route with nuclear energy include Japan and Germany. In July 2011 an Energy & Environment Council (Enecan or EEC) was set up by the Democratic

Party of Japan (DPJ) cabinet office as part of the National Policy Unit to recommend on Japan's energy future to 2050. Enecan's 2012 release of the "Innovative Energy and Environment Strategy" recommended a phase-out of nuclear power by 2040; they would not go beyond a 40 year operating limit (WNA, 2014). This report was eventually identified as a reference document only; Japan d flexibility around energy issues (WNA, 2014). Japan is energy resource poor and its economy relies on such powerhouses as Hitachi and Toshiba, two companies heavily into nuclear product and services. Germany has reduced its reliance on nuclear energy from 25%, prior to 2011, to 18% in 2014 (WNA, 2014). After the 1998 federal elections, a coalition government of the Social Democratic Party and the Green Party held a phase out of nuclear energy in its policy. However, the 2009 new coalition government, the Christian Democrat and Liberal Democrat coalition government cancelled the phase-out. It was reintroduced in 2011 under Chancellor Merkel, resulting in the immediate shut down of eight plants (WNA, 2014).

The U.S., as other nations, debated the continued use but in the end appeared not to be deterred. They conducted reviews of operating plants, incorporated and are still incorporating lessons learned and seemingly moving forward. Nuclear energy as part of the energy mix portfolio, in markets here and abroad, continue to exist.

In 2012 the Small Modular Nuclear Reactors (SMRs) program obtained design certification and construction-operation license (COLs) for two light-water SMRs on a cost-share basis with industry, accelerating its commercial deployment (WNN, 2014). Babcock & Wilcox's 125 MWe mPower design, supported by Bechtel, is one such design. The Megatons to Megawatts program, started in 1993, converted 500 tons of high-enriched uranium (HEU) from dismantled Russian warheads into low-enriched uranium (LEU); and, the U.S. received one half of their 2013 fuel from this source (WNN, 2014). The 123 Agreement, from the U.S. Atomic Energy Act 1954, is a bilateral nuclear cooperation agreement with various countries (e.g. India, China, United Arab Emirates); these nations would not develop enrichment technologies instead purchase fuel (WNN, 2014). And on January 25, 2015, during a visit by President Obama to India, President Modi confirmed a civilian nuclear deal. At a press conference, President Modi stated that,

> [t]he civil nuclear agreement was the centerpiece of our transformed relationship, which demonstrated new trust. It also created new economic opportunities and expanded our option for clean energy. In the course of the past four months, we have worked with a sense of purpose to move it forward. I am pleased that six years after we signed our bilateral agreement, we are moving towards commercial cooperation, consistent with our law, our international legal obligations, and technical and commercial viability. (Modi, 2015)

Although comprehensive details have not been announced, the U.S. nuclear industry looks forward to the agreement,

> Christopher White, a spokesman for nuclear construction firm GE Hitachi Nuclear Energy, said in a statement that the company "applauds the efforts of the U.S. and Indian governments" and that "we look forward to reviewing the governmental agreement." White said GE Hitachi wants an agreement that "brings India into compliance with the International Convention on Supplementary Compensation," which would cap liability in case of a disaster. (Zezima, 2015)

Concerns around end use monitoring and non-civilian use of material have evidently been resolved (still to be shared). At present the economics of U.S. nuclear energy corporations has heightened through expansion into the Indian market. It should be noted that Presidents Modi and Putin signed agreements to strengthen their nuclear cooperation in December 2014. Their bilateral cooperation in the nuclear power sector is globally one of the largest between any two countries – "construction of additional Russian-designed nuclear power units in India, cooperation in research and development of innovative nuclear power plants, and localization of manufacturing of equipment and fuel assemblies in India are the goals of their future collaboration" (Modi, 2015). Not less than 12 nuclear reactors in the next two decades were agreed upon (Modi, 2015). Other policy frameworks such as the 2012 Blue Ribbon Commission on Americas' Nuclear Future (BRC) was tasked by President Obama to recommend improvements to the nuclear waste program, the Nuclear Waste Policy Act (NWPA), and to make general recommendations on the path forward. Nuclear waste management is a major criticism to the various policies mentioned above. How can the U.S. continue to work in and expand nuclear energy in light of no clear strategy for highly radioactive by-products? Key recommendations of the Commission echoed this concern and included,

- A repository or long-term storage facility sited using a "consent-based" approach
- Responsibility for siting, licensing, building, and operating repositories and/or centralized storage facilities should be shifted from the Department of Energy to a new, independent single-purpose organization
- Full access to the nuclear waste fund that has been paid for by the 0.1 cent/kW-hr fee levied on nuclear-generated electricity
- Develop a geologic disposal facility

- Develop one or more consolidated used fuel storage facilities
- Preparation for the eventual shipment of large amounts of used fuel should begin soon.
- Support research and development as it relates to advanced reactors and fuel cycles, as well as nuclear workforce development programs.
- Provide aid, advice, and technical and regulatory assistance to other countries, particularly those who are starting new nuclear programs (BRC, 2012).

It is important to note that the nuclear energy industry continues without the implementation of a precise nuclear waste plan as required by the NWPA – its spent fuel is currently stored in place at nuclear power facilities until the federal government takes possession.

The 2012 All-the-Above Energy Strategy supports economic growth and jobs, enhances energy security and deploys low-carbon energy technologies and lays the foundation for a clean energy future (White House, May 2014). Specific nuclear energy content includes financial support for research, development and deployment of small modular and advanced large scale reactors. The nuclear energy enterprise has benefited from abovementioned reports, legislations, public polices and emerging economic partnerships. It is in this environment that various organizations have developed strategies to frame nuclear energy's presence. Next I will examine organizations, pro-nuclear professionals and strategies that embody nuclear energy as it frames its future.

3.2 - Organizational Messaging

In tangent with policies, legislation and economic initiatives, nuclear energy organizations make themselves relevant through various initiatives targeted at policy makers, their districts and the larger public. I examine select organizations to demonstrate their objectives and messaging. Industry constituents are actively framing nuclear energy and attempting to universalize their worldview, not solely on technical terms but more specifically around the benefits the technology affords the individual, the community and the nation. Boundaries are actively set and patrolled so that a discourse of a national necessity for safe, reliable electricity that will power our economy and save our environment can be propagated. This review of nuclear discourse is accomplished through position statements, infographics, press releases and frequent interaction with legislative stakeholders at the federal and state levels. Members of scientific and trade organizations are crucial advocates in this interaction. The discourse also extends to the international scale in which the national necessity universalizes global issues around climate change, energy security and the impact of electrification on standard of living. The nuclear energy enterprise is asking their (non)constituents to get involved in the energy conversation – a conversation that extends beyond nuclear but for the benefit of nuclear. For example, alliances with pro-nuclear environmentalists are seen.

3.3 – CASEnergy

CASEnergy describes itself as a national networked organization that "supports the increased use of nuclear energy to ensure an affordable, environmentally clean, reliable and safe supply of electricity. The Coalition believes that nuclear energy is a vital part of America's energy portfolio (CASEnergy, 2014). Their key initiatives include a clean air policy, job creation and economic growth, energy diversification and minority involvement. Founded in 2006, its current chairs are Governor Christine Todd Whitman, former Governor of New Jersey and EPA Administrator, and former United States Trade Representative and mayor of Dallas, Ambassador Ron Kirk (CASEnergy, 2014). Dr. Patrick Moore was a co-founder and former Greenpeace leader[2]. As he reflects back to the 1970s, Moore states that they got it wrong by lumping nuclear weapons in with nuclear energy. In the context of the Vietnam War and the Cold War, Dr. Moore explains that Greenpeace was against everything radiation (CASEnergy, 2014). If that connection was not made then, he argues that less fossil fuel and more nuclear energy could have been manufactured … he goes on to state in the You Tube organizational video that "from an environmental point of view, nuclear energy is number one" (CASEnergy, 2014). This pronouncement is recreated in the coalition's outreach initiatives, for example their speeches and infographics. Their 'ten top facts about nuclear energy' infographics echoes my interviewees and are also produced by other nuclear science and engineering organizations such as the American Nuclear Society (ANS). CASEnergy's top ten facts include a pronouncement of low carbon electricity, affordability, reliability (operational efficiency of 80% in 2012), uranium fuel efficiency in comparison to other fuel sources, clean energy from carbon free power, safe and secure, revenue generated annually ($16 million in state and local tax, $470 million economic input), job creation (1400-3500 construction jobs and 40-700 permanent jobs), higher salaries (with 36-44% above average salary), and public support (81% near plants versus 57% general public is in favor of nuclear energy) (CASEnergy, 2014). An interviewed independent consultant & former executive at a major nuclear engineering vendor (interviewee A) echoed Dr. Moore's statements, she states that there is an "unreasonable fear of radiation". She goes on to speak about the essentialness of nuclear energy in terms of base load power, clean air, low carbon footprint, and job creation; "the climate may change/trump the nuclear issue and as such nuclear energy will be essential to the discussion”.

3.4 – The American Nuclear Society (ANS)

The American Nuclear Society, one of the oldest professional nuclear science and technology organizations in the nation, founded in 1954, intensified its public outreach approach in the 2000s. Their Top Ten Myths of Nuclear Energy, http://www.nuclearconnect.org/know-nuclear/talking-nuclear/top-10-myths-about-nuclear-energy, challenged these statements and complimented CASEnergy Coalition – “Americans get most of their yearly radiation dose from nuclear power plants; a nuclear reactor can explode like a nuclear bomb; nuclear energy is bad for the environment; nuclear energy is not safe; there is no solution for huge amounts of nuclear waste being generated; most Americans don’t support nuclear power; an American ‘Chernobyl’ would kill thousands of people; nuclear waste cannot be safely transported; used nuclear fuel is deadly for 10,000 years; and, nuclear energy can’t reduce our dependence on foreign oil (Nuclear Connect, 2014). These myths are corrected with “facts” about nuclear energy being safe, reliable and secure (Appendix 1). This list of myths also appears on Nuclear Connect, http://www.nuclearconnect.org/, an educational and public outreach website of the American Nuclear Society (ANS). The ANS’ Center for Nuclear Science and Technology Information has a specific mandate to inform on the contributions of nuclear science and technology, engaging the public and media and inspiring an understanding of nuclear by educators, students and policymakers. Nuclear Connect was launched in 2013 and its goal is to address various concepts and foster a knowledge of nuclear – its science, technology, applications and concept discussion. This approach is echoed by my interviewees. For example, a regulatory official (interviewee B) spoke to the non-polluting nature of nuclear in comparison with coal fired power plants. He goes on to say that "clear air is needed. Nuclear is not to be a replacement to fossil or renewables we need them all". The messaging on how you may know nuclear is also relayed in images used. For instance, the photograph below appears in the Top Ten Myths of Nuclear Energy. The power plant is integrated in the landscape, everyday activities occur – walking, crops growing in the field and a mailbox representing household happenings nearby (Figure 7).

Figure 26: Nuclear Connect, Know Nuclear, http://www.nuclearconnect.org/know-nuclear/talking-nuclear/top-10-myths-about-nuclear-energy

The infographic also makes connections with other technologies and industries – an electric car is charging and the text speaks to nuclear-generated electricity powering past and present trains and subways, present and increasing hybrid cars and in the future nuclear energy may power smaller communities that are dependent on oil or even participate in the hydrogen economy of fuel cells and synthetic liquid fuels (ANS, 2014). The message is cross platform and relational – Southern Company asks us to "chew on that, gumballs that is". Gumballs are the size of a uranium pellet, the energy source for nuclear power and through their "86 Seconds on Nuclear Energy and Gumballs" video, they make comparisons with other fuel sources based on amount needed[3]. The power in one uranium pellet requires 125 barrels of oil, 17,000 cubic meters of coal or 1 ton of oil; they go onto highlight the 24/7 reliability of nuclear energy, low cost, no greenhouse gases, new nuclear investment and to conclude that nuclear needs to be a piece of the puzzle (Southern Company, June 2013). The delivery of the message is as important as the message and another Southern Company You Tube "91 Seconds on Scrambled Eggs and Energy Policy" video asks that we do not put all our eggs into one basket when it comes to a U.S. energy policy[4]. Eggs are representative of various energy sources – solar, wind, 21st century coal, natural gas, renewables and energy efficiency – in a basket. If one solar egg does not shine, the wind doesn't blow or the cost of one energy supply rises too high it will be "pretty bad" (Southern, June 2013). Instead Southern Company is echoing what CASEnergy, ANS and others have been saying, 'when we diversify our energy sources we can weather the unexpected' (Southern, June 2013).

3.5 – Georgia Power and Light – AP 100 at Vogtle Power Plant

Georgia Power and Light, a Southern Company, is completing the two next generation reactors, Westinghouse AP 1000, at the Vogtle power plant site. The construction of Vogtle 3 & 4 represents a $10 billion capital investment in Georgia (Southern Company, 2014). "Georgia Power's share of the project (45.7 percent) represents a construction and capital cost forecast of $4.799 billion" (Southern Company, 2014). As one of the largest job-producing project in the state, it employs over 5,000 people during peak construction and will be creating 800 permanent jobs when in operation (Southern, 2014). "The Company's economic analysis is that completing the project will provide more benefits than the next best option (combined cycle natural gas)" (Southern Company, 2014). As in many factsheets or company web pages, benefits are touted, Southern stresses that "customers will receive approximately $2.3 billion in benefits from the project, including approximately $250 million as a result of federal loan guarantees" (Southern Company, 2013, 1). "[T]he Vogtle site will be the first 4 unit site in the U.S. that will produce enough safe, reliable, affordable electricity to power 1,000,000 Georgia homes and businesses. The maximum rate impact is expected to be between 6 and 8 percent. With 4 percent already in rates, the remaining additional rate impact for customers is between 2 and 4 percent" (Southern Company, 2014, 1-2). The complexity of the construction project can be followed on vendor and utility media libraries. For instance, the Vogtle project has stills and video of its progress.

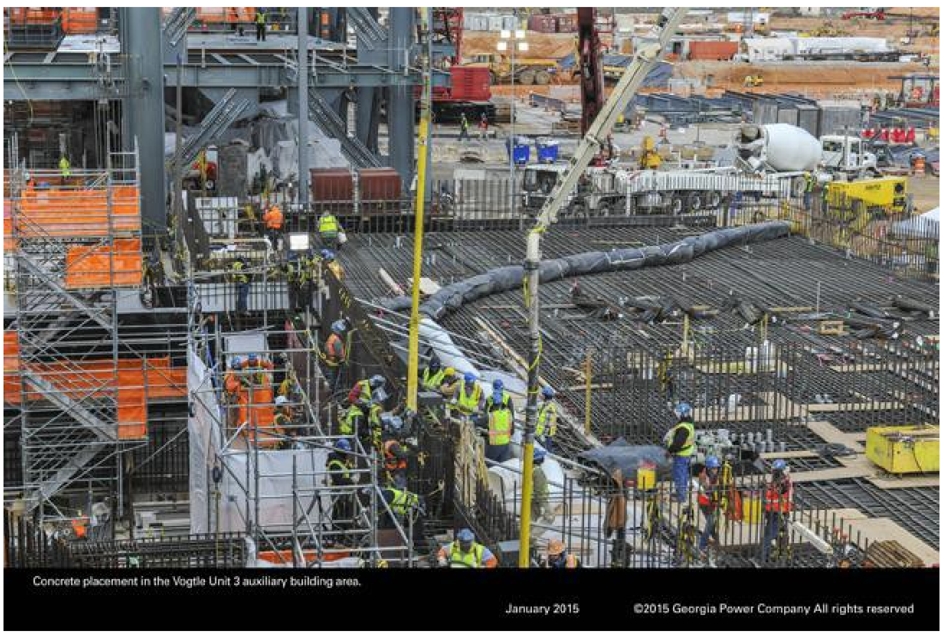

Figure 27: Concrete placement in the auxiliary building and Vogtle 3 cooling tower construction, http://www.southerncompany.com/what-doing/energy-innovation/nuclear-energy/photos.cshtml (Southern Company, 2015)

There are time lapse accounts of projects and videos that explain the benefits of the nuclear construction project. The complexity of the project is mega projects is coupled with "Why Nuclear" videos to create a narrative of reliable, cost competitive electricity that makes a state/nation economically viable. Videos are short and directed, for example the 7:32 minute "Why Nuclear" video for Vogtle contextualizes nuclear energy in the following manner –

- Electricity affords comfort, security and is the backbone of the economy
- Southern (as other utilities) must think ahead and provide a balanced mix from electric power resources. Power when one needs it and where nuclear fits as a base load supply.
- Interestingly, the video juxtapositions nuclear with natural gas and coal. The cost of constructing natural gas plants is low but Georgia Power admits that the cost of operation is more expensive. “Natural gas prices have been increasing by as much as 475% from 2002-07 … coal by as much as 50% from 2002-07 … transportation cost for coal from mines to plants has increased by 50%.
- Environmental costs are quantified to be $7 billion from 1990-2018. Other costs of mercury nitrogen oxides and sulfur dioxide reduction by 75-93% of 1990 levels are noted”.
- Growth in population size and the need for 35% more generating capacity over the next ten years with increased carbon emission regulation brings Georgia Power to ‘Why Nuclear’.
- Nuclear benefits are reiterated: fuel diversity, the nation’s largest source of emission free energy, operated safely and securely in Georgia for decades
- Nuclear challenges are also addressed: overruns in past construction costs have been addressed through a streamline process of construction and operating licenses (COLs); although nuclear power plants are expensive to build their fuel is less expensive than fossil fuel
- The high cost of construction is tackled by passing rate increases onto consumers as construction occurs instead of upon completion. Georgia Power shares that they

> estimate a $300 million saving on interest. Utility credit ratings are favorably impacted by this phased-in approach resulting in lower financing cost. (Southern Company, 2014)

There is also a distinction made between pre-21st century coal, natural gas and renewables – technological improvements are what utilities are investing in moving forward. Interviewee D from an engineering firm and member of various professional nuclear organizations reminds us that "we can't do it alone, need fossil and renewables". Interviewee B from the regulatory agency reminds us "there is better efficiency (in nuclear), 90% capacity[y] factors versus 50% in the 1980s". In how the industry needs to frame the politics of nuclear he speaks of "nuclear [as] not [being] a replacement to fossil, renewables…we need them all". These recommendations are also in line with the strategic communications plan developed by the ANS Public Information Committee in 2012. The key focused messages are radiation and radioactivity are a natural part of our world, nuclear technology works and, nuclear technology enhances our quality of life (Pointer, 2012).

Engineering vendors are also speaking to the benefits of the technology. For instance, Westinghouse's AP 1000 is the lead U.S. Nuclear Regulatory Commission (NRC) approved design. They also speak to the mega construction projects nationally (Vogtle in Georgia and VC Summer in South Carolina) as well as international projects (Haiyang China) (Figure 9).

Figure 28: AP1000 construction at Haiyang, China site (May 2014), http://www.westinghousenuclear.com/New-Plants/Photo-Galery/emodule/333/egallery/1

Westinghouse AP 1000 information pieces are more detailed and focus on the benefits of the technology. The AP 1000 was the first generation III+ reactor design to be certified by the U.S. NRC and built within the U.S. or globally. It is described as simple, safe and innovative and meeting the needs of a growing world's population for electricity (Westinghouse, 2010). The social benefits narrative is similar: soaring energy demands due to new technologies, electrification in industrializing nations, dwindling fossil fuels, increase in pollution and global warming due to carbon emissions (Westinghouse, 2010). Characteristics of the AP1000 include,

- Simplified plant design in safety systems, normal operating systems, control room, construction techniques, fewer cables, components and seismic building volume.
- Design improvements based on 50 years of operations and improvements to its currently operating pressurized water reactors.
- Licensed passive safety systems using natural circulation, gravity, convection

and compressed gas to operate in the evident of an accident (Figure 10). The AP1000 passive cooling system cools the outer surface of the steel containment shell using natural circulation of air and water evaporation. Its ultimate heat sink is the atmosphere.

- Large safety margins meet the U.S. NRC deterministic safety and probabilistic-risk criteria with large margins. Mean of risk metrics are 5x10-7 per year CDF (core damage frequency and $6x10^{-8}$ per year LRF (large release frequency). Three orders of magnitude from NRC CDF requirements.
- NRC reactor design certified with COL license in place (Westinghouse, 2010).

The AP1000 has been physically modified and the language to describe its features is equally so – less fuel, smaller land footprint and a passive design in case of a Fukushima type accident (Figure 10) (Westinghouse, 2010). For example, "by placing the reactor core at the lowest elevation in the plant, the cooling water can drain into the core through gravity alone. Typically, emergency core cooling water for flooding the core is pumped in. In passive safety designs the core is instead first rapidly vented to atmospheric pressure and flooded via gravity by water in large reservoirs above the core" (Forsberg, 1990, 133). The laws of physics are utilized to assist reactor personnel in responding to accident scenarios.

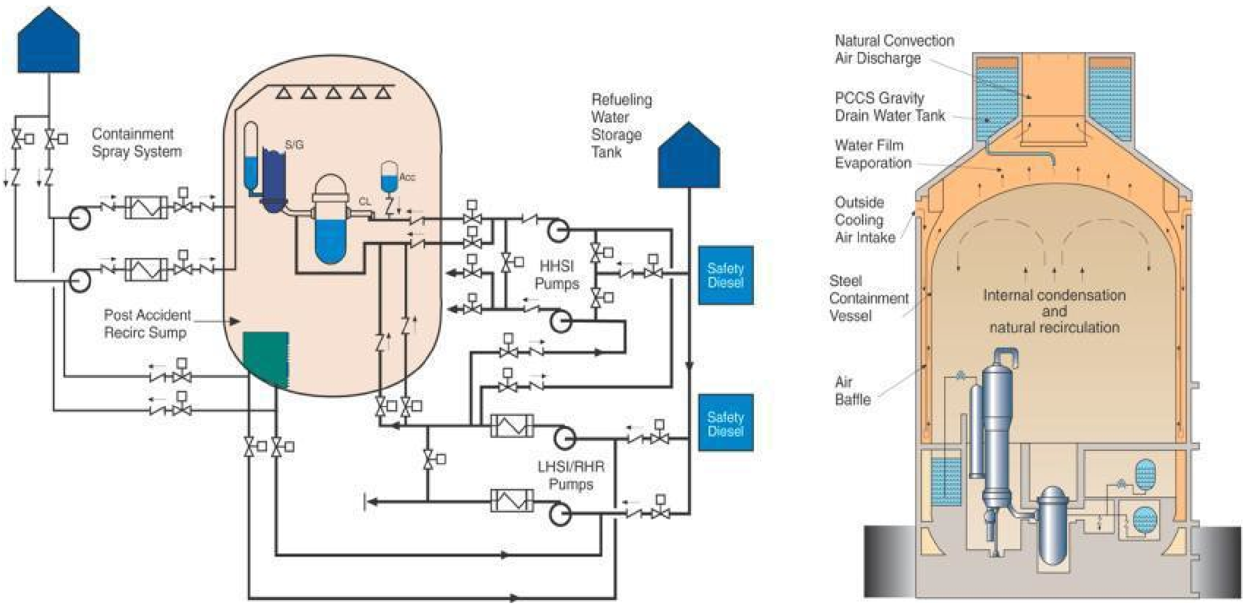

Figure 29: Standard Pressurized Water Reactor (left) and AP1000 (right). Simplification of safety systems dramatically reduces building volumes. (Westinghouse, 2011)

The emphasis on no-operator accident shutdown takes what is deemed human error out of the equation. The reactor decay heat generation would decline for 72 hours before operator action was needed for core and containment cooling (Figure 11; Westinghouse, 2011).

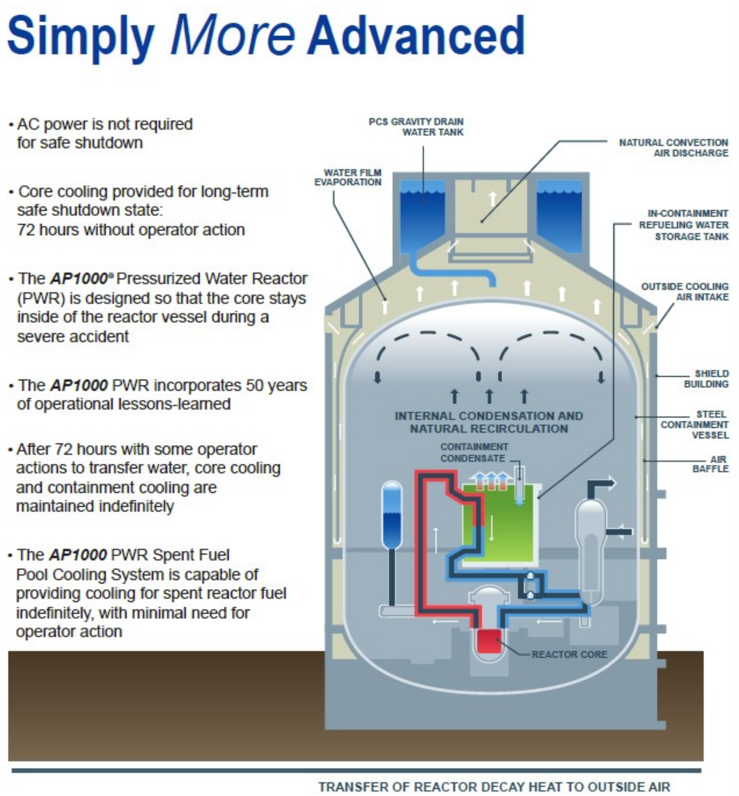

Figure 30: AP1000 Simply Electric (Westinghouse, 2011)

Position statements assist in framing politics and the ANS' Public Policy Committee has produced them with this in mind. These statements are then used by nuclear professionals, media, congressional staffers and lobbyist when issues need elaboration. These statements are "prepared by key members whose relevant experience or publications inform the documents and then the documents are reviewed by ANS committees and divisions. The final position statements are approved by the Board of Directors" (ANS, 2014). The scope of the statements include nuclear energy, regulations and safety, nuclear fuel cycle and waste management, non- proliferation and international cooperation, other uses of nuclear technology, environment and health, nuclear engineering education, knowledge transfer and workforce development. My research interviewees identified key challenges that are addressed by many of these position statements or public outreach done by nuclear professionals at the national or local level. Organizations like the ANS has worked diligently to have its representatives speak to the talking points published. This linking allows for a consistent message about nuclear energy and its role in society. For example, there is a Capitol Hill Day at each Washington DC ANS Winter Meeting where a cross section of ANS professionals visit with congressional staff members on nuclear issues ranging from a need for a comprehensive energy plan, a national nuclear waste repository and/or funding educational nuclear science and technology programs. Other ANS initiatives include a permanent Washington DC representative, who works on organizational name recognition and provides an ANS voice on important policy debates that shape the nuclear industry (ANS, 2013). In an ANS conference session during the 2013 Winter Meeting, Mr. Piercy outlined the political climate of Washington and where nuclear lay. His perspective was that the nuclear energy industry had to stay in the game by exporting U.S. nuclear technology to maintain U.S. nuclear safety and security leadership around the globe (Piercy, 2013). He described U.S. nuclear safety and regulatory system is the "gold standard" and any contract would require the U.S. to maintain control over the nuclear fuel, creating disincentives for enrichment and reprocessing activities, greater overall U.S. influence in global nonproliferation policies (Piercy, 2013). While in the U.S. the nuclear energy industry must maintain high paying jobs (to attract young professionals) and the protection of U.S. nuclear investment (e.g. the Price Anderson Act[5]). There is overlap with the ANS Strategic Plan and its call for "professional development [to] support the ongoing education and development of the nuclear science and technology workforce on best-in-class scientific and engineering techniques that promote the safe, efficient and effective application of nuclear science and technology; sharing information and advancement in nuclear technology by having ANS and its members be the leading source of nuclear science and technology information within the international science and technology community; engaging the public to Increase awareness of the safe, effective and efficient applications and contributions of nuclear science and technology and the contributions of individuals working in nuclear science and technology attracting individuals into nuclear careers; and, engaging policy makers to obtain policy makers' support for the application of nuclear science and technology to meet societal needs (ANS, 2012). Piercy also calls on the Federal government to act on multiple fronts to maintain and renew U.S. nuclear leadership - be timely and flexible negotiating 123 agreements[5], improve the 810 process[6], forge international partnerships, be aggressive with export financing, support advanced nuclear technology development, be an eager lead customer of new technology, invest in the human element and develop a nuclear waste plan (Piercy, 2013). Interviewees from the nuclear energy industry also framed the challenges of nuclear as political. For instance, young professionals in a Southeast utility say the Yucca National Nuclear Waste Repository[7] as having political not technical hurdles, it was the juncture of where politics meets technology and more so a not in my backyard (NIMBY) concern. The nuclear energy consultant interviewee saw "waste [as] a political and technical problem, it was a waste of good fuel [used fuel can be reprocessed for another reactor type not in use here in the U.S.], and that the Blue Ribbon Commission on America's Nuclear Future is a political game to end run Yucca" (Interviewee A Transcript). Another interviewee who is a radiobiologist brought attention to the spent fuels being considered safe in pools, "although the real reason appear[ed] to be the absence of suitable alternative storage sites in most countries. [He goes on to remark that] there is a non-negligible risk associated with having spent fuel onsite as this increases the risk of additional problems in the case of a nuclear accident especially if, as in the case of the GE-designed

Fukushima reactors, the spent fuel pools are located high above the ground, making delivery of cooling water extremely difficult in the case of a station blackout". Nuclear waste management is technical and political after all.

3.6 – Nuclear Energy Institute

The Nuclear Energy Institute (NEI) is a nuclear energy industry trade organization established in 1994 with the merger of the Nuclear Utility Management and Resources Council (NUMARC), which addressed generic regulatory and technical issues, the U.S. Council for Energy Awareness (USCEA), which conducted a national communications program, the American Nuclear Energy Council (ANEC), which handled governmental affairs, the nuclear division of the Edison Electric Institute, which handled issues involving used nuclear fuel management, nuclear fuel supply and the economics of nuclear energy (NEI, 2014). The earliest trade organization to today's NEI was the 1953 Atomic Industrial Forum (AIF). NEI's current direction includes "foster and encourage the continued safe utilization and development of nuclear energy and technologies … by providing policy direction in the areas of regulation, legislation, congressional support, assessments/taxes, waste, transportation, security and other critical activities; a unified nuclear industry approach to address … regulatory issues and related technical matters; advocacy and representation before the Congress, Executive Branch agencies, federal regulatory bodies, state policy forums and other public policy groups; accurate and timely information to policy makers, the public and other external constituencies; and, support to workforce development and training." (NEI, 2014) There are 350 members in 17 nations working towards "safe, secure, dependable, environmentally sound and economic electric energy" (NEI, 2014). Their scope ranges from the uranium fuel cycle to the nuclear fuel cycle, nuclear medicine to agriculture and issues of transportation and waste management (NEI, 2014). Where NEI differs from CASEnergy Coalition (a spin-off of NEI) and ANS is that it is more so in the public policy realm. They focus on nuclear energy support through favorable legislation, regulation and coordinate members towards this end. The NEI Presidents' Report provides insight into its focus and initiatives. Prior to the Fukushima Diiachi accident, NEI's achievements were in the political, regulatory and public areas. Dating back to 2003, they focused on materials management (generic plant materials), nuclear facility security, a comprehensive energy policy push, funding and licensing of Yucca Mountain National Waste Repository, emergency planning, new plant development, increased public support, increased plant performance and a branding campaign (e.g. op eds, media outreach and the use of opinion polls[9]) to further their directives (NEI, 2014). Then in 2011 the messaging enhanced safety, "making safe nuclear energy even safer) through lessons learned and restoring public and political confidence in nuclear energy. Bisconti Research charted a decline at the time of the accident but the 2014 results show a recovery 65% in favor of nuclear energy as one of the ways to provide electricity in the United States (Bisconti, 2014).

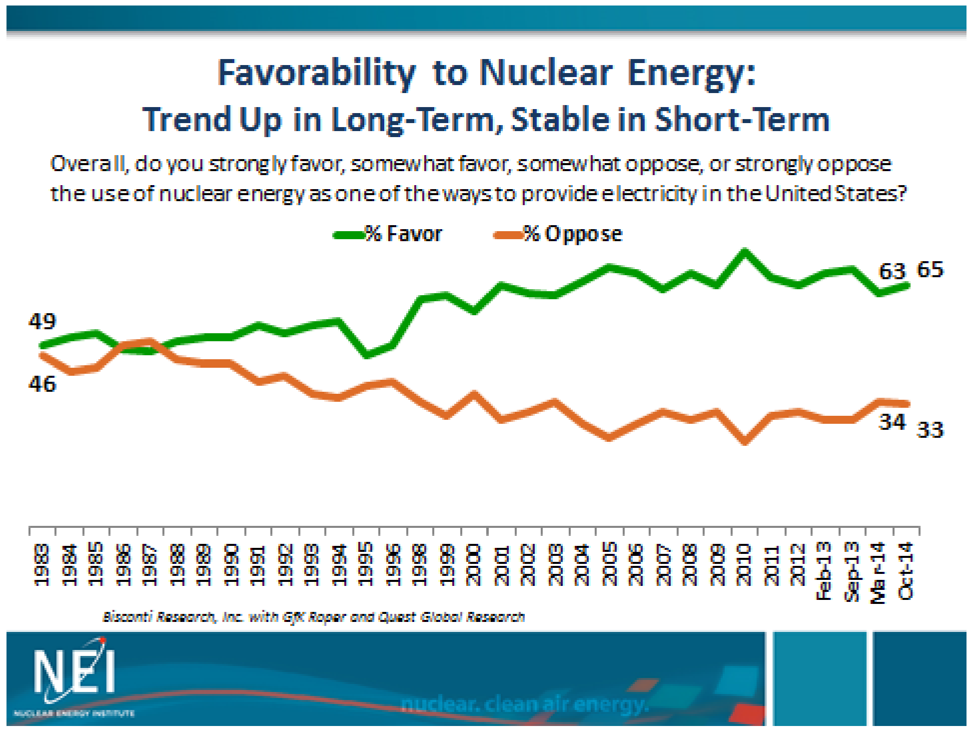

Figure 31: Bisconti (2014).
http://www.nei.org/Master-Document-Folder/Backgrounders/Presentations/Public-Opinion-Presentation,-Oct-2014

In 2013 an important U.S. Court of Appeal in Washington DC case was won. NEI and the National Association of Regulatory Utility Commissioners received a verdict that amounts to $750 million in savings annually in nuclear waste fund fees in that U.S. Department of Energy submitted to the U.S. Congress a proposal to suspend 1 million-per-kilowatt fee until a national used fuel management and disposal program is implemented; it is estimated to save industry $4-7 billion over 5 to 10 years. (NEI, 2013) Additionally the Appeals Court directed the U.S. Nuclear Regulatory Commission (NRC) to ‘promptly continue’ with the licensing process of Yucca Mountain as the national nuclear waste repository, pending appropriations (NEI, 2013).

NEI has embarked on a benefits-focused nuclear energy branding campaign. It is in line with utilities, their members, and interviewees’ responses to their role as nuclear energy professionals. Whether you asked the female engineering consultant or the engineering firm professional, they viewed themselves as advocates, they “needed to be advocates outside the job in a non-nerd way”. Interviewee G, the national laboratory scientists, saw himself as “an advocate for his own profession” and this was exemplified by interviewees E and I who both worked for the largest utility with a nuclear fleet. Both persons where attending the North American Young Generation Nuclear Conference (NA YGN) that had organized with NEI to have a Capitol Hill Day, where professional engaged with congressional staffers. Interviewee B explicitly mentioned advocacy at an elevated/high level; they understood that if the “best U.S. nuclear plant and [associated] technology would be shared with other nations”, the role of the nuclear professional had to be impeccable. Interviewee I reflected on “the nuclear engineering professor as educator, there to explain while the ANS pulls professionals together [to] promote policy issues, NEI seen as having impact on government, promot[ing] policy, and NA YGN as being a space for young professional perspectives on industry, public outreach and Capitol Hill Day around legislation”.

My interviewees identified challenges to nuclear energy as an unreasonable fear of radiation/public perception not technical, proliferation concerns, the need for increased education, an understanding of accidents (e.g. Fukushima, Chernobyl and Three Mile Island) a waste storage plan and implementation, nuclear materials issues for an aging fleet, complexity of nuclear structures, water consumption at plants, fast reactors, perceived risk of this high technology, the power-weapons link and the difference between a reactor and bomb. The ANS strategic plan calls upon its divisions and committees to address many of these same issues.

Professional outreach organizations such as the North American Young Generation Nuclear, NA YGN and U.S. Women in Nuclear (WIN) specialize in engaging young professionals in the future of nuclear. NA YGN was established in 1999 by young professionals who “wanted to create an organization that provided professional development, public information, knowledge transfer, recruiting and networking opportunities for the next generation of nuclear leaders” (NA YGN, 2014). Their primary members are newly graduated students and early career professionals. The U.S. Women in Nuclear was formed in 1999 evolving from Women in Nuclear Global which was established in 1992 to encourage and support women in the nuclear energy industry. The mandate of U.S. WIN is to support and mentor women in nuclear and encourage the entry of women into the field as students and professionals. Both organizations share overlapping membership with ANS as well as many activities (e.g. Capitol Hill Day and K-12 outreach). Interviewees from these organizations, a national lab scientist and two utility professionals view the organizational role as complimentary to ANS and NEI. They view the organizations as a bridge for younger professionals. They identify with the need for minorities to be attracted to the industry, as does CASEnergy Coalition. “There is a need to advocate for one’s own profession”. And where there are regional and local chapters, “they can address state and local politics [that sees nuclear] only as a risk and not a benefit … state politics influence economics and local zoning”. Interviewee G comments that “advocacy is needed, since the split of the Atomic Energy Commission (AEC), we have the U.S. NRC for regulation and the U.S. Department of Energy (DOE) for research and development, who has advocacy?” (Interviewee G Transcript). This is opportunity that ANS Young Members Group, ANS Student Section Committee, WIN and NA YGN are trying to address with outreach and engagement.

This chapter examined organizations and their strategies toward securing the future of nuclear energy. They are young and established professionals speaking on behalf of nuclear –

its technical but more so its social benefits. The interviewees were illustrative as oppose to comprehensive in understanding the connections among industry sectors as well as the national, regional and local levels. Stories of actors, in addition to infrastructures, provide a deeper understanding of motives, goals and future visions. Narratives are branded and expressed in mix media environments. The messaging tends to be concise with minimal jargon, highlighting comparisons made to the international and more importantly other energy systems. The nuclear energy industry is involved in material and discursive production on several scales to propel itself ahead, providing an alternative take to what opponents have to say about nuclear energy. It is very much a project of revival and necessity to proponents and the benefits lie in energy security, environmental stewardship and increased economics. The nuclear power landscape is continually being worked upon to develop an energy identity. The pro-nuclear energy enterprise is neither neutral nor passive, there are assumptions that must be supported such as nuclear as part of the energy mix, and strategic methods to garner support for the construction and operation of nuclear power plants.

ENDNOTES

1. Defense in depth is “an approach to designing and operating nuclear facilities that prevents and mitigates accidents that release radiation or hazardous materials. The key is creating multiple independent and redundant layers of defense to compensate for potential human and mechanical failures so that no single layer, no matter how robust, is exclusively relied upon. Defense in depth includes the use of access controls, physical barriers, redundant and diverse key safety functions, and emergency response measures” (U.S. NRC, June 2016).

   Probabilistic Risk Assessment (PRA) “estimate[s] risk by computing real numbers to determine what can go wrong, how likely is it, and what are its consequences. Thus, PRA provides insights into the strengths and weaknesses of the design and operation of a nuclear power plant” (U.S. NRC, June 2016).

2. Dr. Patrick Moore’s opinion [is] “that nuclear energy is safe, clean and sustainable was f formed in the mid-1990s during the reconsideration of energy policy in light of climate change. It is obvious that nuclear energy, when replacing fossil fuel technology, reduces CO2 emissions by more than 95 percent… My primary reasons for supporting nuclear energy are that it is superior to other technologies as a long-term, cost-effective, safe and clean source of electrical power, and in the future as energy for hydrogen production, desalinization and heating for buildings and greenhouses. As the fossil fuels are diminished, which may take longer than previously thought, nuclear energy will take on a greater role in providing the basis for powering our civilization” (Forum on Energy, 2013).

   In contrast, Greenpeace maintains/states that [it] “has always fought - and will continue to fight - vigorously against nuclear power because it is an unacceptable risk to the environment and to humanity. The only solution is to halt the expansion of all nuclear power and for the shutdown of existing plants” (Greenpeace International).

3. https://youtu.be/rmSAtvyZ3VY

4. https://youtu.be/args5HvFtkM

5. Congress passed the Price-Anderson legislation in 1957 as an amendment to the Atomic Energy Act to ensure that substantial funds will be available to compensate the public in the event of a nuclear accident. Through this program, the nuclear energy industry maintains $13.6 billion in liability coverage. (NEI, 2014).

6. 4 Section 123 of the U.S. Atomic Energy Act requires the conclusion of a specific agreement for significant transfers of nuclear material, equipment, or components from the United States to another nation. Section 123 Agreements are important tools in advancing U.S. nonproliferation principles. These Agreements act in conjunction with other nonproliferation tools, particularly the Nuclear Nonproliferation Treaty, to establish the legal framework for significant nuclear cooperation with other countries. Moreover,

the Agreements allow for cooperation in other areas, such as technical exchanges, scientific research, and safeguards discussions. In order for a country to enter into such an Agreement with the United States, that country must commit itself to adhering to U.S.-mandated nuclear nonproliferation norms. (NNSA, 2014).

7. 5 Part 810-refers to the process set forth in 10 Code of Federal Regulations Part 810.Under the authority of section 57.b of the Atomic Energy Act of 1954, as amended, and in accordance with established procedures, only the Secretary of Energy may authorize, through the Part 810 process, persons to engage, directly or indirectly, in the production of special nuclear material outside the United States. This provision applies to technology transfers and technical assistance to all activities of the nuclear fuel-cycle, including non-power reactors. (Department of Commerce, 2009).

8. The D.C. Circuit Court of Appeals said … that the Nuclear Regulatory Commission must resume its long-slumbering review of the Yucca Mountain nuclear waste storage project, which the Obama administration and Senate Majority Harry Reid have labored for years to kill. “[U]nless and until Congress authoritatively says otherwise or there are no appropriated funds remaining, the Nuclear Regulatory Commission must promptly continue with the legally mandated licensing process,” Circuit Judge Brett Kavanaugh wrote for the majority in the 2-1 decision. (Dixon, 2013).

9. Bisconti Research Inc. is a key public opinion organization of NEI.

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CHAPTER FOUR – U.S. NUCLEAR ENERGY AT A CROSSROADS

4.1 – Chapter Introduction

Nuclear energy is at the nexus of scientific and political work. The industry has framed itself as a low or no carbon emitter; reliable, safe and secure baseload power; and, an advanced technology that plays a crucial role in the quality of life. It is ecologically green and should be classed with renewable technologies for current and future prosperity. This chapter will examine these claims through the interrogation of interviews with professionals from private companies (utilities and engineering firms), professional and trade organizations, academia and government agencies (that includes national labs). The nuclear power enterprise is defining and solidifying its purpose and sharing its benefit claims with various stakeholders – students, the public, media and policy makers. I will start from the interviews and link to the means of communication for the messaging. I will discuss reports and media pieces as extensions to what interviewees mentioned to confirm the argument being made in the interviews. The nuclear energy enterprise has a particular way of organizing that is claiming a necessity, an importance to the past, present and future of energy production and use.

4.2 – Why is Nuclear Energy Important?

Interviewee A worked in a multinational organization for over 25 years, working on core and fuel design, relicensing and regulation. They rose to senior management level before leaving and establishing an engineering consultancy firm. They have been active in several professional organizations and acted as one of the point persons around issues of safety analysis. In answering this question they pointed to the "unsung past that relied on 20% oil generation and 20% nuclear" (Interviewee A Transcript). The U.S. was "static in the 1980s and the political will of the executive branch in 2005 saw the need to build…it was the right thing to do". (Interviewee A Transcript). This right thing seemed solidified by the words and actions of then President Bush. He was cited as saying,

> "[c]omparing U.S. dependence on overseas oil to a 'foreign tax on the American people,' President Bush on Wednesday proposed a series of energy initiatives, including more oil refineries and nuclear plants, to combat the problem…'A secure energy future for America must include more nuclear power.'" (Berger, 2005)

In August 2005 the Energy Policy Act was signed into law. Bush reiterated the role of nuclear energy and set a needed tone for the nuclear energy industry –

> "[T]his bill will allow America to make cleaner and more productive use of our domestic energy resources, including coal, and nuclear power, and oil and natural gas. By using these reliable sources to supply more of our energy, we'll reduce our reliance on energy from foreign countries, and that will help this economy grow so people can work…Nuclear power is another of America's most important sources of electricity. Of all our nation's energy sources, only nuclear power plants can generate massive amounts of electricity without emitting an ounce of air pollution or greenhouse gases. And thanks to the advances in science and technology, nuclear plants are far safer than ever before.
>
> Yet America has not ordered a nuclear plant since the 1970s. To coordinate the ordering of new plants, the bill I sign today continues the Nuclear Power 2010

> Partnership between government and industry. It also offers a new form of federal risk insurance for the first six builders of new nuclear power plants. With the practical steps in this bill, America is moving closer to a vital national goal. We will start building nuclear power plants again by the end of this decade. (Applause)" (White House, 2016).

Nuclear power is framed as a release from dependence on other nations, economic prosperity for Americans, clearer air and reliance on national energy resources. Similar arguments were made by other interviewees, with some providing further historical context.

Interviewee B worked in national agencies for over 25 years as well, focusing on educational initiatives. They supported college students, reactor research and development, and nuclear engineering as well as other disciplines involved in nuclear energy study and research. They spoke to the historical context of the field and when they joined the Atomic Energy Commission in the early 1970s. They worked on the Atoms Harnessed, a curriculum development program for the secondary environment. By the mid-1990s they were heavily involved in the postsecondary level, supporting students studying this discipline while we begin to observe a decline in the number of operating reactors. "It is a matter of non-polluting versus fossil fuels, nuclear energy frees us from foreign sources, cleaner air, less expensive, source for developing nations as oppose to fossil fuels with the right controls for socioeconomic improvement" (Interviewee B Transcript). The nuclear industry is described as "helping itself after safety as a primary factor…better outages …90% capacity versus 50% in the 1980s" (Interview B Transcript).

Interviewee C spent over 20 years in the industry, 7 years on the engineering firm side and 13 years in academia. They highlighted their time at Knolls Atomic Power Laboratory as a niche of professionals that provided many opportunities. Their response to ‘why is nuclear energy important?’ couched the industry in historical accomplishments – “maintain 20% of energy generation, efficiency of [current] plants equaled 30 new plants unbuilt” (Interviewee C Transcript). Fuel reliability and the changed approach to licensing for construction and operation occurred. Instead, they point to a combined license approach. This theme continued with *Interviewee D*. They requested no recording but spoke frankly about their views on the industry. They worked 13 years in a number of roles within a multinational engineering company. They were involved in supply chain, continuous improvement and organizational development/human resources. In addition, they were on the executive of a professional organization specifically geared towards the transition of college graduates to the industry in the mid-2000s, eventually holding the presidency of this organization. A member of another more long standing professional organization, they were co-chair of a young professional congress. They described “nuclear energy as fundamental because of baseload energy, greenhouse gases, next generation [implications especially since they had a young child], investment, growing demand with stable [raw] resources…can’t do it with fossil fuel and renewables” (Interviewee D Notes). The reasons cited were multifaceted and common to many other interviewees and messaging in publications – reliability, environmental, meets demand unlike other fuel sources and for future generation. Nuclear energy is meant to embody several meanings due to its scientific, social and economic qualities. This embodiment did not waiver whether I spoke with more seasoned or new professionals.

Interviewee E was out of college 3-5 years working with a southern utility. The utility operates in a regulated environment and answers to their stakeholders and to the public through a utilities public commission. This interviewee works in core design and is a member of a career transition, from college to the workforce, professional organization. She responded to my question of nuclear energy importance by stating that “[n]uclear energy is needed for a diversified energy portfolio” (Interviewee E Transcript). Historical and contemporary accomplishments reigned true to this interviewee, activities mentioned included the global and U.S. power grid, our response to Fukushima, taking responsibility for day-to-day operation, new builds in the U.S.” (Interviewee E Transcript). It is the first interview where there was any mention of non-U.S. electric grids, Fukushima as an accomplishment and new U.S. constructions. They represent a younger female professional whose reality is more immediate and whose context tended towards nuclear energy growth. This placement of nuclear energy squarely in the future provided a place, according to Doreen Massey, in a future story-thus-far.

Interviewee F was another female employee but she worked at a northern nuclear utility and her spouse worked for a multinational nuclear energy company. She later worked at another northern non-regulated utility for over 5 years in quality assurance. She was now at a trade organization for 5 years. She recalled “at age 7 wanting to be an astronaut and later on reflected that nuclear power fuel were used in this environment … Energy awareness, nuclear energy as baseload, carbon free, safe and secure” provided her affinity to the industry (Interviewee F Transcript). Her favorite historical accomplishment happened 60 years ago, the Atoms for Peace vision. She described it “as an inspiration, using technology and world resources for innovation…nuclear energy continues with the newest technology SMR [small modular reactors], [and for] cancer research” (Interviewee E Transcript). The next historical accomplishment mentioned was Rickover…”nuclear [submarine] propulsion, [as a] model of safety, [that has led to] accountability now in nuclear energy” (Interviewee F Transcript).

Recent milestones mentioned included Calvin Cliffs, the first license extension for a power plant; it was extended for additional 20 years. It is worth mentioning that Calvin Cliffs was the backdrop for President Bush in June 2005 when he discussed new plant constructions. Addressing Maryland plant employees and the media, President Bush stated –

> "It is time for this country to start building nuclear power plants again…Nuclear power is one of America's safest sources of energy…without producing a single pound of air pollution and greenhouse gases like carbon dioxide, which many scientists tie to global warming." (msnbc.com, 2005).

Approximately $14 billion in tax incentives over 10 years was discussed in Senate and eventually signed into law, allowing for more national production of oil, natural gas, coal, nuclear and alternative energy (msnbc.com, 2005).

Interviewee G was a young nuclear engineering professional at a national lab. He was active in his regional professional organization, the American Nuclear Society (ANS), and started a nuclear engineering freshman seminar series at his alma mater. He was also involved in the new career professional organization called the North American Young Generation Nuclear (NA YGN) and a founding chair of a more established professional organizations' young members division. "It is a moral imperative" [to have nuclear energy] (Interviewee G Transcript). And this statement was substantiated by a reference to the knowledge of fission 75 years ago. The historical accomplishment of "20 years testing reactors, managing fuel resources and the rapid transition to a sustainable technology" was cited. "In the contemporary era, the commercial fleet uprates on 13 reactors, increasing [fuel] efficiency and the possibility of a 100 year reactor life/containment vessel" was cited to be the essential nature of why nuclear power exists (Interviewee G Transcript). Nuclear energy, in the minds of its architects, had been cultivated as long lasting and needed.

Interviewee H was a young nuclear engineer at a southern utility. “The splitting of the first atom and the creation of INPO [Institute of Nuclease Power Operators] after TMI [Three Mile Island accident] served as historically significant for nuclear energy”(Interviewee H Transcript). Contemporary attributes of nuclear energy lay in “new reactor design, passive safety designs and building cookie cutter parts”; it was the standardization of the construction process that made nuclear essential (Interviewee G Transcript).

Interviewees relied on safety, fuel efficiency, historical record, historic firsts and contemporary advances to make nuclear energy important in addressing present issues – dependency on non-U.S. resources, climate change, and the demand for reliable energy. Past innovations (splitting the atom, long life of fission application, the Atoms for Peace Program) and future needs (diversified energy portfolio, carbon free economy, and new modeled reactors) collide for interviewees as they make nuclear energy relevant. There have been great heights in the industry and many cite renewals of operating license and new plant constructions as key elements to the purposefulness of the U.S. nuclear power industry. One of the 21st century initial momentum has been President Bush’s support through the signing of the Energy Policy Act of 2005 for the nuclear energy enterprise. The challenges to the enterprise were seen by interviewees as real but not so insurmountable. I will now turn to these challenges and how the industry is tackling them. There is a concerted effort to address these challenges materially and discursively.

4.3 – Challenges to the Nuclear Energy Enterprise

There were themes that presented themselves among the interviewees when asked broadly about challenges to the nuclear power industry – communication issues with particular emphasis on the information available that influences public perception of the technology; technical challenges including contemporary accidents and their implications; and, who were the knowledge experts and their messaging. Another themed issue was based on the politics of and around nuclear energy. For example, politics overrode the scientific evidence on nuclear waste management. The third theme revolved around other energy technologies – low gas prices and subsidies for renewable energy courses. What follows are examples of interviewees utilizing institutional discourse on nuclear power as much as their own experiences with the technology and being in a position to explain the technology to an outsider – be they a public official or a member of the general public. They express frustration to a degree in providing scientific reasons why nuclear energy, in their expert opinion, is safe.

All but interviewee C named public perception as a challenge to the industry. Interviewee A said "[the] science of nuclear energy does not matter, [it is a] perception problem" (Interview A Transcript). Interviewee A and G spoke specifically to the fear of radiation. Interviewee A called it an "unreasonable fear" and interviewee G called for an "educational effort" and made a distinction between public information and education (Interviewee A & G Transcripts). All interviewees were members of the American Nuclear Society (ANS) and have participated or endorsed the educational outreach initiatives of the organization. Interviewees A and G also participated where needed. The need to educate about radiation and make radiation sensible has resulted in infographics, explanations and examples incorporated into learning resources and lessons during science teachers' workshops. These workshops occur in cities where the ANS holds its winter meeting and annual conference. Subsequently, there has been a development of an ANS outreach hub, the Center for Nuclear Science and Technology Information. "This Center makes the complex nuclear world easier to understand for the general public. We encourage and inspire fun nuclear education for K-12 students. Most of all, we help people learn the many benefits that nuclear science and technology brings to their lives – from their health to their safety and many conveniences in their everyday lives. Explore our site to find out what you may not know about nuclear!" (American Nuclear Society, 2016). This web presence challenges visitors to "know nuclear" (American Nuclear Society, 2016). For example, the radiation section explains ionizing and non-ionizing radiation, provides information on the three types of radiation and the ubiquitous nature of it. The benefits of radiation are also provided. A linked Discovery article by Larry O'Hanlon entitled "How Radiation Is Not Killing You" is provided along with images of the world and, as Figure 1 illustrates, radiation distribution (O'Hanlon, 2016). The article starts off –

> "This just in: According to experts, we are being irradiated by our food, water, air, the sky and even by our computers and smartphones. We are even being irradiated by certain elements stored in our own bones. Aaaagh! The enemy within! Run for your lives! But where? Where can you hide in a radiation soaked universe?
>
> Relax. It's okay. Contrary to the fuzzy notions many people have about radiation, it's actually as natural as granola and rarely harmful (and just to make it clear: I am not now and have never been on the payroll of the nuclear industry). To most people the

word “radiation” is synonymous with poisonous and deadly. Along with that are images borrowed from the pages of comic books of radiation accidents mutating humans or animals to create super powerful monsters or heroes” (O’Hanlon, 2016).

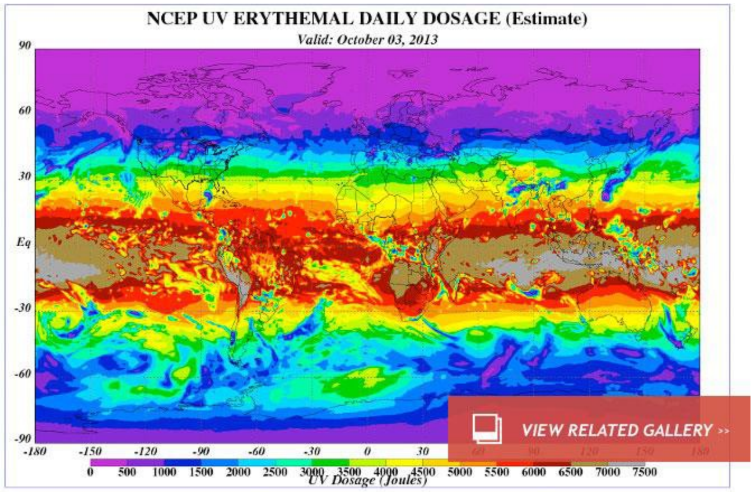

Figure 32: How Radiation Isn't Killing You

The educational branch of the professional organization links to third party experts to demonstrate that radiation is omnipresent and non-harmful – “as natural as granola” (O’Hanlon, 2016). A more nuisance examination is featured in the infographic and in subsequent subpage comments such as **“**Too much radiation, like too much of anything, is harmful” is explained and “Did You Know” boxes provide real life examples (American Nuclear Society, 2016).

“**DID YOU KNOW?**

- Most people who died at Hiroshima did not die from the radiation; most died from the blast of the bomb and subsequent fires.
- Studies have shown that cellular cultures (protozoa) could not grow normally when they were deprived of background radiation (Luckey TD.)
- Between 1978 and 1987, 108,000 nuclear submarine workers were compared

to 700,000 other shipyard workers. There were 24% fewer cancers among those exposed to low-doses of radiation.

- The Colorado Plateau, with higher background radiation levels, has 15% fewer cancers than the national average” (American Nuclear Society, 2016).

Examples normalize the interaction of workers, populations, cellular cultures and nature with radiation. It is explained as a necessity for normal growth of protozoa and when there is exposure the incidences of damage or death are low. This website also speaks to precautions that should be taken or are taken. For example, ALARA, as low as reasonable achievable, is explained graphically and in text as shown in Figure 2. Radiation detection techniques and devices are explained.

Figure 33: ALARA. as low as reasonably achievable

Under Applications there is a publication entitled “A Day in the Life of an Atom”[1]. This pamphlet walks readers through a typical day and their interaction with radioactive items. For example, we wake at 6 am and turn on the electricity. It is explained that in the U.S. 20% of our electricity comes from nuclear power. At 6:10 am we are reminded that if we put contact lenses into saline solution overnight, that said solution was irradiated to avoid microbes’ growth. Twenty minutes later we are dressing and the cotton fabric used for our clothing benefitted from radioactive tracking processes in its production. We are only 30 minutes into our day and radiation has positively impacted our lives. By the time we are on our way to work or school, we should be thankful for the vulcanized vehicle tires (rubber made hard by radiation). Fast forward and by the end of our day whether we are making evening dinner [or having takeout], spices in the U.S. are irradiated unless otherwise stated. By the time the reader is getting ready for bed, radioisotopes in the smoke detector are geared to keep them safe while we sleep. The atom is in service to us, in a beneficial manner, throughout the day. Most interviewees state that this type of messaging is not being heard and understood. It is this absence of voice that finds a space for various initiatives, reproduces nuclear energy as a misunderstood servant to humankind.

Educational resources are also available through Nuclear Connect online where educational standards are explicitly mapped for teachers. For example, the irradiated bean seeds exercise tries to address the "fear of radiation causes some people to believe that food that is irradiated becomes radioactive. The irradiated bean seeds in this experiment have been exposed to various levels of gamma radiation, but are not radioactive and are completely safe to handle" (American Nuclear Society, 2016). The lesson goes onto explain that,

> "You cannot tell how much radiation the seeds were given by looking at them. These seeds were harvested and irradiated after the plants were mature. However, you will be able to observe differences in the plants growing from these seeds" (American Nuclear Society, 2016).

Again, the advantageousness of radioactivity is presented. The 'In the Classroom' section provides resources on various industries and the benefits of radiation/radioisotopes. For example, the publication "Harvest to Home" explains the benefits of radiation to a population's food supply as a circle of life – from controlling pests to enhancing livestock productivity and health to maximizing crops and food safety[2]. Interviewees and their associated organizations have identified a need and are providing resources to assist educators, students and the public in diminishing the fear of radiation. This education is also being done with policy makers through the ANS Nuclear Fundamentals Technology Program started in 2012, Figure 3.

It is taken to lessen/dispel expressed dangers from the minds of policy makers. In doing so, the hope is that the business of writing nuclear-related policy is more informed.

Figure 34: The ANS Nuclear Fundamentals Technology Program for Capitol Hill Staffers

Interviewee B spoke about non-technical issues being a concern. For example, the "psychological images of the China Syndrome or that any accident will be catastrophic" (Interviewee Transcript B). Incidents cited included "radiation contamination, plant explosion, TMI [Three Mile Island] and textbooks' negative portrayal...It is a love-hate relationship" (Interviewee Transcript B). Interviewee F posed the question "how safe is safe". To these questions, organizations such as Argonne National Lab, the U.S. Nuclear Regulatory Commission and the Nuclear Energy Institute (NEI) produced material that include fact sheets, news briefs, a You Tube Channel and increasing information on social media. All aspects of the industry have responded in a similar vein. Case in point, "NEI provides accurate and timely information on the nuclear industry to members, policymakers, the news media and the public" (NEI, 2016). Argonne National Laboratory (as other labs including Idaho National

Laboratory and Oak Ridge National Laboratory), the U.S. Department of Energy, Office of Nuclear Energy and the U.S. Nuclear Regulatory Commission have similar presence through reports, FAQs (frequently asked questions) and multimedia presence to answer such questions as ‘how safe is safe’ and, provide technical documents. In the Nuclear Engineering section for Argonne National Laboratory (ANL), as through other publications and websites about nuclear energy, spotlights technical reports and experts attempt to explain the significance of past accidents and what must be done through video shorts. This approach was echoed by interviewees from various divisions with the nuclear enterprise. The World Nuclear Association’s “Fukushima and Chernobyl: Myth versus Reality” 13-minute video, added as an ANL online, provides examples of the rationale requested to contextualize Chernobyl and Fukushima nuclear accidents (World Nuclear Association, 2016). Public health impacts are discussed by scientific experts such as Dr. Gerry Thomas, director of the Chernobyl Tissue Bank at the Imperial College in London. She is positioned as a world authority on molecular pathology before she explains her anti-nuclear transformation and subsequently explains why particular nuclear accidents must be put in perspective. Dr. Thomas’ view on nuclear technology is mentioned in the piece, “I was anti- nuclear” then her work caused personal reassessment (World Nuclear Association, 2016). Dr. Thomas contextualizes the science, she states that “the only observable public health impact to radiation after Chernobyl has been the more than 6000 thyroid cancers of which only 15 have proved fatal…Fewer than 50 have died of the emergency workers…fraction of victims, which significant represents the 100s of 1000s if not millions of victims predicted after the accident” (World Nuclear Association, 2016). She goes onto explain “the whole body doses to 6 million residents is about 9 milliSiverts…80% of lifetime dose delivered by 2005…about what we will get from a CT scan…Do we sit there and panic about a CT scan? No, we don't and we need to keep that in mind" (World Nuclear Association, 2016). Everyday radiation levels are also explained in this video, fact sheets and by other experts. Dr. Thomas states "[w]e expose ourselves to radiation voluntarily. We can't avoid it. We live in a radioactive world" (World Nuclear Association, 2016). The viewer is left to make the connection that although nuclear accidents are worrisome; one of the major accidents has contained human impact. Counter narratives and debates continue and speak to related long term health effects. We thus see a battle for the minds of the public in this exchange; an exchange that relies on no direct correlation. For instance, Holt speaks to studies done by Wertelecki of the University of Southern Alabama and the World Health Organization (WHO). In many respects there is no definitive conclusion. "Wertelecki's study concentrated on the Rivne province of Ukraine, about 200 km from the Chernobyl plant. Its northern half, Polissia, was classified as being 'significantly affected' by the disaster and the ground, as well as food, in the area still contains low doses of radioactive cesium 137" (Holt, 2010). The study showed that "22 of 10 000 babies were born with a neural tube defect compared with the European average of nine per 10 000 babies" (Holt, 2010). The issue that Holt and others have raised is a lack of evidence of a direct link. Alcoholism and poor diet may also be a variable (Holt, 2010). The WHO report reviewed scientific studies completed and reported 20 years on the level of radiation exposure received by various populations in the area. In Table 1, liquidators were responders (e.g. firefighters, reactor operators, recovery workers). The Table figures, through its comparison with natural and medical procedures, suggests a particular reading of the accident – disastrous and comparable to life saving medical measures, close to natural background numbers for a significant portion of the population.

Population (years exposed)	Number	Average total in 20 years (mSv)[1]
Liquidators (1986–1987) (high exposed)	240 000	>100
Evacuees (1986)	116 000	>33
Residents SCZs (>555 kBq/m2)(1986–2005)	270 000	>50
Residents low contam. (37 kBq/m2) (1986–2005)	5 000 000	10–20
Natural background	2.4 mSv/year (typical range 1–10, max >20)	48
Approximate typical doses from medical x-ray exposures per procedure:		
Whole body CT scan	12 mSv	
Mammogram	0.13 mSv	
Chest x-ray	0.08 mSv	
[1] These doses are additional to those from natural background radiation.		

Table 4: Doses received from the Chernobyl accident

The work of science versus media accounts is to this day contested. The WHO report goes onto speak to the tragedy of Chernobyl through the reporting of cancers several years out. For example,

> A large increase in the incidence of thyroid cancer has occurred among people who were young children and adolescents at the time of the accident and lived in the most contaminated areas of Belarus, the Russian Federation and Ukraine. This was due to the high levels of radioactive iodine released from the Chernobyl reactor in the early days after the accident. Radioactive iodine was deposited in pastures eaten by cows who then concentrated it in their milk which was subsequently drunk by children. This was further exacerbated by a general iodine deficiency in the local diet causing more of the radioactive iodine to be accumulated in the thyroid. Since radioactive iodine is short lived, if people had stopped giving locally supplied contaminated milk to children for a few months following the accident, it is likely that most of the increase in radiation- induced thyroid cancer would not have resulted (WHO, April 2006).

One implication is that the consumption of contaminated milk and deficient diet is as much to blame as the high risk technology accident. But if not for the accident we would not be seeing nearly 5000 thyroid cancer cases in children (WHO, 2006).

Dr. Thomas also discusses the Fukushima-Diachii accident “in real terms I doubt there will be any radiological consequences to the whole population at all” (World Nuclear Association, 2016). Another expert Professor Abel Gonzalez, of the International Committee on Radiological Protection, makes the link between two of the nuclear industry’s accidents to place risk in a particular perspective. He states, “The second big impact of Chernobyl was thyroid cancer in children…because children [were] drinking contaminated milk. Well this is not the case in Fukushima” (World Nuclear Association, 2016). Dr. Gonzalez also spoke to the emergency workers procedures at both accidents, stating that at Fukushima it was “a magnitude less than Chernobyl firefighters and helicopter operators…so I think it is unlikely they are to suffer long term consequences going forward. No public health impact due to radiation is expected” (World Nuclear Association, 2016). In closing the video poses the question “What has been their impact?” To which the response from Dr. Malcolm Crick, Principal Officer for the UN Scientific Committee Atomic Radiation, is “trauma, stress and anxiety. Countermeasures that have disrupted our lives, changed politics of the nation, social infrastructure, the economy” (World Nuclear Association, 2016). As interviewee H from one of the U.S. utility commented “we can’t explain what we do” so too does Dr. Crick explains,”[t]he scientific community has to do a better job at communicating to the public” (Interviewee H Transcript). Dr. Crick goes onto to add that “[w]e have to have it in our programs of work for the future…to the public and policymakers” (World Nuclear Association, 2016). The role of the expert is essential, a comment that is reinforced in my interviews.

Interviewees A and C view the role of the nuclear energy professional as advocate. Interviewee B commented that there was an "advocacy need at high levels…to develop best nuclear plant and technology for the U.S. and to share with other nations" (Interviewee Transcript B). Interviewee D asks that "we advocate outside job in a non-nerd way" (Interviewee Transcript D). And interviewee E wants us to use our technical expertise in sharing information with the public and cited the Capitol Hill Day as an example. In May, nuclear experts volunteer to visit the Capitol, meeting with Congressional staffers. Expert knowledge is provided to make understandable and by extension favorable a technology.

Interviewees D and G spoke to the technical role professionals play advancing technologies around reactor design and non-power facility design (Interviewee D & G Transcripts). For example, Dr. Leslie Dewan, co-founder and chief executive officer of TransAtomic was named a TIME Magazine "30 People Under 30 Changing the World", an MIT Technology Review "Innovator Under 35," and a Forbes "30 Under 30" in Energy (TransAtomic, 2016). TransAtomic wants to develop a molten salt reactor where fuel is optimized up to 96% versus in the current light water reactors where optimization is only 3-5% (TransAtomic, 2016). Images are used to communicate its safety and efficiency and it is reinforced by an available technical report. Molten salt reactors are graphically compared to light water reactors and conversational text explains why it is safe, reliable, low costs and good for society –

> "The liquid fuel is also much more resistant to structural damage from radiation than solid materials – simply, liquids have very little structure to be damaged. With proper filtration, liquid fuel can remain in a molten salt reactor for decades,

> allowing us to extract much more of its energy" (TransAtomic, 2016).

Everyday science is under modification for the future. For example, 1960s research work and a current technical paper are contextualized for present work. Expert knowledge is provided through the technical report to substantiate the company, its work and an industry.

> "The 1960s Oak Ridge Molten Salt reactor was proven to be extremely safe, but it was expensive, required highly enriched fuel, and had a low power density. We've modified this design to make it more compact, more affordable, and more power-dense than the original, while retaining its tremendous safety benefits. Furthermore, our modifications allow our design to tap into the immense amounts of energy left behind in spent nuclear fuel, and use this waste as a fuel source" (TransAtomic, 2016).

The current work of the company allows for four solutions that have plagued the nuclear industry to be solved – ecological stewardship, public safety, nonproliferation and cost-efficiency (TransAtomic, March 2016). The tagline of the report states "[o]nly an advanced reactor that meets all four goals at once can truly change the game and allow for broad adoption of nuclear power" (TransAtomic, March 2016). The report tells a technical story, it uses visuals to compare current operating and under construction reactors to this future design. In Figure 4, comparisons are drawn to show the molten salts' technical advantages.

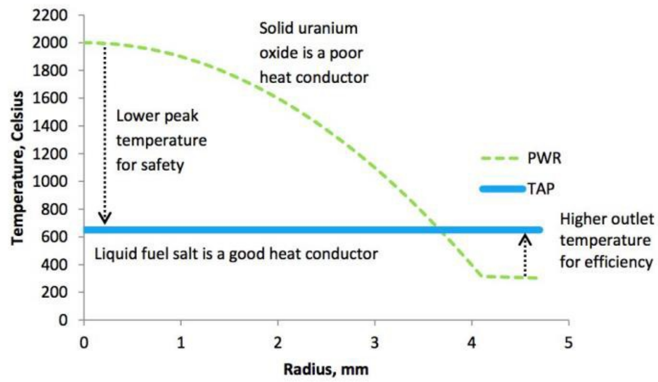

Table 5: Temperature profile of a light water reactor's solid fuel pin, from center to edge, compared to temperature profile for a TAP reactor fuel-salt

In the "What's Next" section of TransAtomic's website, graphics are once again used to indicate completion of testing and provide a status report. For example, 18% of the validation and refinement is complete. It is represented in text but more powerfully in a dynamic scale format. The level of knowledge of the reader is taken into account as well – they start with graphics and common language and progress to technical speech. The reader is carried from "[r]un lab-scale experiments and refine the design for the demonstration facility" to "[r]unning laboratory-scale tests of key components and materials for our reactor…[c]orrosion, radiation, and high- temperature materials tests are being conducted" (TransAtomic, 2016). It is an uncomplicated narrative of the science of nuclear energy and its advancement.

Communication remains key for several interviewees. They spoke to the need to engage with many stakeholders – the public, students, policy makers and other scientists. Interviewee H stated, "As an engineer/industry we can't explain what we do" (Interviewee H Transcript). Interviewee G cited communication as a key challenge. There is a "need for more advocacy…[w]hen the Atomic Energy Commission (AEC) split into the U.S. Nuclear

Regulatory Commission (NRC) and the U.S. Department of Energy (DOE), no one inherited the advocacy piece" (Interviewee Transcript G). What was covered included regulation, research and development respectively. To adequately promote what the nuclear enterprise had to offer was marginalized. Since the 2000s, efforts have been made by a number of organizations to effectively communicate the technology, its applications and benefits. The ANS, NEI, DOE, NRC, Duke Energy and various colleges have developed outreach programs. For example, an interviewee was involved in the U.S. Department of Energy's Harnessed Atom Program, "a new middle school science, technology, engineering, and math (STEM) curriculum extension that focuses on nuclear science and energy. It offers teachers accurate, unbiased, and up-to-date information on the roles that energy and nuclear science play in our lives. The curriculum includes essential principles and fundamental concepts of energy science" (U.S. Department of Energy, 2016). For general public and policy makers, the work of such organizations as Nuclear Matters serves as an example. "Nuclear Matters works closely with partner organizations that recognize the value of America's nuclear energy plants. This growing roster of allies is integral to our efforts to educate the public on the clear benefits of nuclear energy and to explore possible policy solutions to preserve this essential energy resource" (Nuclear Matters, 2016). These partners include ANS, NA YGN, Carolinas' Nuclear Cluster and U.S. Women in Nuclear (WIN); interviewees are members of these organizations and spoke of the need. The mission of Nuclear Matters is "to inform the public about the clear benefits that nuclear energy provides to our nation, raise awareness of the economic challenges to nuclear energy that threaten those benefits, and to work with stakeholders to explore possible policy solutions that properly value nuclear energy as a reliable, affordable and carbon-free electricity resource that is essential to America's energy future” (Nuclear Matters, 2016). Interviewee D and G reiterate the need to “advocate outside the job in a non-nerd way” and “to advocate for own profession” (Interviewee D & G Transcripts). It is about the present actions for the future of the technology. This future will not just happen, the interviewees suggest a need to advocate for the technology to frame the conversation and have impact.

Interviewee B framed the place of nuclear in relation to fossil and renewables, “we need them all” (Interview Transcript B). While other interviewees, A and G, place the future of nuclear in several political spaces. Interviewee A placed the future of nuclear energy in state and local politics, “they see only risk not benefit” then she goes on to state that “politics and industry [are off cycle]…long cycle, 10 years to design reactor but early research and development, [is] on annual funding basis” (Interviewee Transcript A). Interviewee G reminded us that state politics influence economics and local zoning (Interviewee Transcript G). Interviewee F states that we have “politicized technology, there is political manipulation” (Interviewee Transcript F).

The same holds true when the discussion turns to nuclear waste management. Interviewee A reminds us that “waste is a political and technical problem” but we are “wast[ing] good fuel” (Interviewee Transcript A). Light water reactor fuel has energy within that will need to be reprocessed if further energy can be extracted. Yucca Mountain was researched and named the national waste repository and has not come into existence. The future of the Yucca repository is characterized by interviewee B as “a political football” (Interviewee Transcript B). Interviewee C states that the “benefit [to citing Yucca is that] we can control it, know where it is” (Interview Transcript C). Interviewee E suggests that “Yucca has political hurdles" (Interviewee Transcript E). When asked to elaborate, it is the nexus where "politics meets technology" (Interviewee transcript E). The President's Blue Ribbon Commission on America's Nuclear Future (BRC) is deemed by interviewee A as "a political game to end run Yucca" (Interviewee Transcript A). The BRC, as explained in chapter 2, was tasked with reviewing the backend of the nuclear fuel cycle and asked to make suggestions. Among the recommendations was a national repository. The position statement of the ANS also supports the interviewees' position, "As part of the Mountain project to proceed to submit a license application to become the nation's proposed geological repository—subject to demonstration that the site is suitable and safe" (American Nuclear Society, 2016). These expert statements rely on scientific information and the stature of the professional organization to give legitimacy to statements. The Public Policy Committee of the ANS, reviews topics that may need a statement. Position statement #80 on Yucca Mountain provides such expert knowledge. They rely on The U.S. Nuclear Regulatory Commission (NRC) and its "legislatively well-defined regulatory process to evaluate the safety of the proposed Yucca Mountain Site to meet both the scientific requirements and the institutional requirements" (American Nuclear Society, 2016). The science behind the repository is substantiated by "the U.S. National Academy of Sciences and the equivalent scientific advisory panels in every major country support geological disposal of such wastes as the preferred safe method for their ultimate disposal (American Nuclear Society, 2016). Reliance is placed on scientific bodies nationally and internationally. Lastly, there is reliance on an existing repository for long lived transuranic waste from nuclear weapons, the Waste Isolation Pilot Plant. It is with these expert connections that interviewees make statements and work with such organizations as ANS and NEI have produce, what the Nuclear Energy Institute (NEI), backgrounders. These backgrounders are a collage of reliable data – fact sheets, policy briefs, white papers and reports & studies, figure 35.

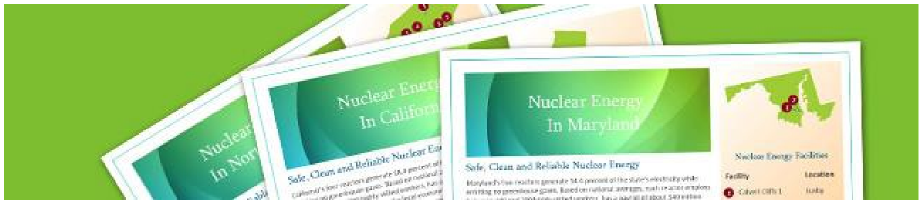

Figure 35: Nuclear Energy Backgrounders

Interviewees expressed a guarded optimism when they discussed the future of nuclear as a renaissance in the making. Interviewees A thought that it was an overstatement since it was dependent on the economy and affected by the cost of natural gas (Interviewee A Transcript).

Interviewee B also agreed that it was dependent on the economy, suggesting "it was a revival but still not holding own" (Interview B Transcript). Others were unsure, interviewee D, or gave a yes/no response, interviewees E and H. Interviewee H thought "many factors come into play…moving forward with design of new reactors, putting the COLs [construction operating licenses] for NRC reviews" (Interview H Transcript). Fukushima was a pause for interviewees E and H. It was dependent on how the Fukushima-Diachii accident was handled. Then there were interviewees C, F and G who agreed there was a nuclear renaissance occurring. Interviewee C, E, F and H saw it occurring internationally and cited construction in China. International construction is cited as where growth of the industry will occur and interviewee F suggested that "the U.S. influences the world" (Interview F Transcript). Interviewee G took a slightly different perspective to the renaissance query, he said "yes, 75 years of this field, no darkness, nuclear medicine, industrial radioisotopes" all play a role in the usefulness of the technology to society (Interview G Transcript). These coincide with the messages of several of the professional organizations and their campaigns. For example, Nuclear for Climate (N4C) calls itself a “a grassroots initiative, which brings together scientists and professionals of the global nuclear community [members of the French Nuclear Energy Society (SFEN), the American Nuclear Society (ANS) and the European Nuclear Society (ENS)], and also citizens who believe that in order to fight climate change we have to act now. They believe that nuclear is part of the solution” (Nuclear for Climate, 2015). They concur with the Working of the Intergovernmental Panel on Climate Change (IPCC) that “80 percent of global electricity will need to be produced with low-carbon technology (compared with 30 percent today) in order to contain climate change. During the same period, global demand for electricity should double to meet the basic needs of humanity in terms of population growth and development goals” (Nuclear for Climate 2015). In Figure 6, the savings of carbon emissions throughout respective life cycles (construction, operation, decommissioning) are illustrated.

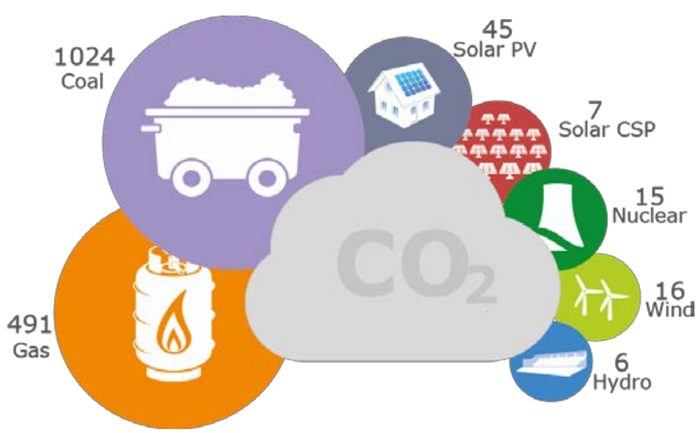

Figure 36: CO2 emissions produced by 1kWh

Campaigns are aimed at international, high profile events such as the COP 21 to influence perception and policy. Nuclear energy is made visible, as part of the environmental solution, as well as made visible for public acceptance, Figure 36.

Figure 37: COP 21 Nuclear Energy Attendees (Nuclear For Climate, 2016)

The media outlet is also important. Professional organizations are using social media more often. For example, Nuclear for Climate launched a Facebook prior to COP 21 and this is linked to tag #NuclearforClimate.

Interviewees expressed the importance of the nuclear energy, challenges, their role as advocates and what the future holds for nuclear power production. In all, nuclear really does matter, today and into the future, there are obstacles to full buy-in but the technology has contributed in the past and will continue into the future. The optimism that took nuclear energy into the 21st century is not as bright 10-15 years in but nuclear professionals have come to realize their role to promote the necessity of nuclear to the public, policy makers and media. Interviewees spoke to various initiatives to enhance the visibility of nuclear energy.

4.4 – Chapter Conclusion

One of the overall aims of the nuclear energy enterprise is to make visible the good of the technology – how it impacts our lives and put into a particular context the high risk consequences of such a needed technology for standard of living, innovation, global leadership and the environment. Interviewees relied on safety, fuel efficiency, historical record, historic firsts and contemporary advances to make nuclear energy important in addressing present issues – dependency on non-U.S. resources, climate change, and the demand for reliable energy. Past innovations (splitting the atom, long life of fission application, the Atoms for Peace Program) and future needs (diversified energy portfolio, carbon free economy, and new modeled reactors) collide for interviewees as they make nuclear energy relevant. The moral imperative based on historical context and its architects are reinforced.

The storytelling of the materials produced by technical and trade organizations and used by their expert volunteers convey simple, safe and reliable. The object of all interaction is one of relatability; whether they are speaking to the general public, politicians, educators, school children or media representatives. There is work done by nuclear technology through the science and its experts. Claims are made real through promotional materials; claims of a reduced reliance on foreign fuel sources and that nuclear energy play a role as an environmental solution to climate change. Challenges of the nuclear power industry are presented as solvable; it's a matter of communication. Perceptions and comfort are needed and reinforced through the use of data. This data must be translated from a scientific speech to more commonly accessible pieces – infographics, lesson plans, teacher hands-on workshops, educational website (Center for Nuclear Science & Technology Information) – so that nuclear can be known. Fact sheets, news briefs, You Tube channels, curriculum and social media are also used for the purpose of making nuclear more understandable and less fearful. The professional as advocate can then use these tools in the conveyance of nuclear energy and its place moving into the future. Images and comparisons to what is naturally occurring, such as background radiation, is used to communicate safety. The nuclear energy industry has political work to do and as this chapter demonstrates it is as much the medium as the messenger's use of the various medium that is deployed.

ENDNOTES

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2. http://nuclearconnect.org/in-the-classroom/for-teachers/from-harvest-to-home

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CHAPTER FIVE: THE GEOGRAPHY OF THE U.S. NUCLEAR INDUSTRY

5.1 – Overview

As we enter the 21st century, the status of the U.S. nuclear energy industry is in flux, dependent on actions by industry, government, circumstance (e.g. accident, climate) and public opinion. Its renewal coincides with several initiatives taken by government and capitalized in particular ways by energy organizations be they utilities, engineering firms, professional societies, educational institutions, national laboratories, trade organizations and/or research and regulatory governmental branches (e.g. the U.S. Nuclear Regulatory Commission, U.S. Department of Energy). Nuclear fission has unleased upon society benefits and cautionary tales that are currently being privately and publicly debated. The broader energy landscape is also in flux, whether we discuss the concepts of clean coal, renewable energy systems, fossil fuel utilization or climate change, resource extraction and utilization, electrification, energy poverty, byproducts, risk, accidents, to name a few themes in contemporary energy geography. “Energy is far and away the most significant international resource system and political economic nexus, weighing in as the defining concern of a majority of the largest companies, parastatal firms and national enterprises” (Zimmerer, 2011, 705).

Understanding the practice of nuclear science provides insight into its physical and social construction; it provides us with a geography of a high-risk technology. I examined the production sites of nuclear science – the manufacture of physical materials (e.g. nuclear fuel fabrication, power plants and electricity) as well as the imagined ones (e.g. nuclear energy as a necessity where it becomes part of energy independence, national security and environmental stewardship). Moreover, in these real and imagined sites there are cultural meanings that influence and are influenced. What does a future economic-environmental model look like for the nuclear energy sector? My research will add to an understanding of the nuclear fuel cycle in the U.S. industry; adding to recent geographical work by Eyles and Fried (2012) on rhetoric and reality of the nuclear energy sector in Ontario Canada; by Garcier (2009) on the nuclear renaissance and uranium fuel cycle supply; by Proops (2001) on the politics and language of nuclear; by Jasanoff and Kim (2009) on sociotechnical imaginaries of nuclear power in the U.S. and S. Korea; and, by Hecht (2006) on the shifting nature of the geography of nuclearity where claims of nuclear nationalism, global nuclear order and environmental stewardship are examined. I assessed some of the variables and intersections involved in the U.S. nuclear energy industry's story-thus-far, its claim for nuclear energy necessity. The industry has positioned itself as an essential contributor to the reduction of carbon emissions, reliable energy production and national security. A nuclear identity that allows the U.S. to remain relevant as a leading technological innovator continues to be forged through various communication devices – industry reports, policy statements, conventional and new social media, to name a few. Through an examination of these discursive media, pro-industry interviews and anti-nuclear reports, a fluidity of the U.S. nuclear energy industry is shown. This fluctuation makes its continued study important for the field of energy geography. The interplay among other energy sources (fossil fuels and renewables), climate arguments (carbon emissions and global warming), national and international economy health, and industry variables (capital costs, high-risk technology, nuclear byproducts, and construction times) affect its relevance as well. The U.S. nuclear energy industry's breadth thus warrants continued research.

5.2 – Methods & Questions

To assist with the overall research project and more specifically with an understanding of the industry's culture and before my interviews, I employed a participation observation research approach. "Only by participating with others can [researchers] better understand lived, sensed, experienced and emotional worlds" (Crang and Cook, 2007). It "uniquely involves studying both what people say they do and why, and what they are seen to do and say to others" (Cloke et al, 2004, 169). It allowed me to build trust, begin to learn the technical language of nuclear science and technology and provide an environment where hopefully canned responses were minimized. My association with the U.S. nuclear industry spans 15 years, working in a university nuclear engineering department and participating in their professional organizations. My closeness to the subject matter and the individuals providing insight were of concern. However, my positionality also assisted with follow-up questions wherever elaboration was needed. My "[e]thnographic findings [were] not therefore 'realities extracted from the field' but [were] 'intersubjective truths' negotiated out of the warmth and friction of an unfolding, iterative process" (Parr, 2001). I, as in the words of Steve Herber, "move[d] from outsider to [partial] insider as [I] comprehend[ed] the world from the insider's point of view" (Herbert, 2000, 556). I was also concerned with the selection of materials that would shine a mostly positive light on the industry. There was a loss of detachment that I felt at times with this approach, so to reduce this likelihood I conducted a discursive review of industry reports as well as an analysis of legislative and anti-nuclear movement reports. The analysis of responses to counter arguments by pro-nuclear actors and their material was my attempt to incorporate resistance perspectives to the technology and serve as one form of counter balance in my research.

Overall my methods (including interviews and discourse analysis) allowed me to describe and interpret actions (textual and orally) of interviewees, industry sectors, and multimedia materials (reports, legislation, presidential directives, multimedia materials [e.g. You Tube channels, documentaries] on the health of the U.S. nuclear industry. How was it reproducing itself? What challenges were tackled? What were some of the strategies and justifications behind their actions? How were discourses negotiated? The ultimate goal was to answer the question on whether the industry is in resurgence, holding its own or in a decline from their perspective and reading of the larger society to which the industry belongs. Interviews allowed me to ask industry professionals their perspective. Discourse analysis (Faircloth, 2006; Phillips, 2002) assisted me in examining the geographical imaginaries of nuclear energy. What was the landscape reproduced? How were key messages constructed and disseminated?

My governing thesis questions included –

1. What is the geography of the contemporary U.S. nuclear energy industry? How is industry's knowledge claims constructed and defended? Chapter 2

2. What work does the industry do in the world, and how is this work reflected in current geographies of nuclear energy, real and imagined? Chapter 3

3. How is the industry (re)producing space for its future significance? Has it been successful? Why or why not? Is the nuclear renaissance of the U.S. nuclear energy industry alive? Is the industry expanding, surviving and/or on the way out? Chapter 4 and 5

5.3 – Nuclear Energy Industry – Its Current and Future Geography

In Chapter 2, I provided a contemporary status of the industry. The U.S. is among the top 5 nuclear generating nations in the world, producing 798.6 billion kWh of power. Other nations include France (418 billion kWh), Russia (169.1 kWh), South Korea (149.2 kWh) and China (123.8 kWh) (NEI, April 2015). Within the U.S., compared to other energy sources, nuclear power contributes 19.9% of the overall national electricity compared to fossil fuels (67%), hydropower (6%), and renewables (7%) (EIA, March 2015). And there is new reactor construction abroad and at home – "approximately 70 nuclear power reactors are under construction, equivalent to 20% of existing capacity, while over 160 are firmly planned, equivalent to half of present capacity" (WNA, February 2015). This status is not without critique over high construction costs and delays (between $6 and $9 billion for each 1,000 MW plant), safety and security concerns. Accidents at Three Mile Island (1979), Chernobyl (1986) and Fukushima Diiachi (2011) have reinforced skepticism of this technology. Yet the industry has and continues to reframe itself through an active material and discursive process. It positions itself as a safe technology that contributes greatly to the national need for energy and international stature.

The revival of the industry took off under President George W. Bush's administration – a promise to build upon nuclear power's 20% share of electricity production. In May 2001, Vice President Dick Cheney introduced the National Energy Policy Report that spearheaded key legislation, the 2005 Energy Policy Act, and industry action. It asked the Nuclear Regulatory Commission (NRC) to evaluate and expedite licensing of advanced reactor technologies; review and relicense operating plants; ask the Department of Energy and the Environmental Protection Agency to access nuclear energy's contribution to clear air; to employ best science towards a nuclear waste repository; and, to support the Price-Andersen Act as an insurance policy, to name a few components in support of the technology (NEPD Group, 2001, 5-17). The stage was set to expand nuclear power production through improved efficiency, new construction and research & development programs. For example, the Nuclear Power 2010 Program called for one or more nuclear power plants to be ordered by 2005 and plants started by 2010 (Johnson, 2002). Its contribution to energy reliability, environmental stewardship and national innovation would therefore be reinforced. Dr. Ernest Moniz, future U.S. Secretary of Energy, stated –

> "As greenhouse gases accumulate in the atmosphere, finding ways to generate power cleanly, affordably, and reliably is becoming an even more pressing imperative. Nuclear power is not a silver bullet, but it is a partial solution that has proved workable on a large scale" (Moniz, 2011).

Yucca Mountain National Repository figures predominantly in the contemporary geography of nuclear energy. It moved from an external labscape through a discursive reconfiguration to an essential location for long-term nuclear waste management. Spent fuel is a valuable commodity with reserved energy that, in the future, may be extracted for further energy. The counterargument made by MacFarlane (2003) and Kuletz (1998) were geological and legal rights respectively. MacFarlane, for example, pointed to the seepage of an identifiable isotope, chlorine-36, into the groundwater from the Pacific tests as a possibility at the Yucca site (MacFarlane, 2003). The Western Shoshone peoples' claim to the land was minimized using the Bureau of Land Management right to speak on behalf of the indigenous peoples and strip ownership (Kuletz, 1998, 148). Challenged science and contested land ownership are juxtaposed with the essential nature of nuclear energy – its energy value, its economic contribution (for example, General Electric-Hitachi's relocation incentives), and its environmental contribution.

The commitment to nuclear power production as part of the energy mix continued under President Barack H. Obama's "All of the Above" Energy Policy even though there were continued questions around nuclear viability in light of technological risk, capital costs, material byproducts and energy resource competition.

> "We can't have an energy strategy for the last century that traps us in the past. We need an energy strategy for the future – an all-of-the-above strategy for the 21st century that develops every source of American-made energy." (Obama, 2012)

Hearing the renewed call, the nuclear industry increased its science activism and engaged in more public and administrative outreach. This engagement has as its goal to impact the future of nuclear.

In Chapter 3, entitled "The Future of Nuclear", I examined the mechanisms and messaging put forth by proponents. How is the U.S. nuclear energy industry framing its future? Who are involved and what impacts do their policies and reports, mix media campaigns, and advocate work contribute to the staying power, resurgence or demise of nuclear energy? Where does this framing lead us? In the early 2000s, the American Nuclear

Society's Nuclear News started a Renaissance Watch section. It provided an update on the industry's advancement based on politics, technology, economics and environmental impact. Commissioned reports, for example, the 2003 and 2007 MIT Studies on the Nuclear Fuel Cycle, the 2005 Advanced Fuel Cycle Initiative (AFCI), the 2006 Global Nuclear Energy Partnership (GNEP) and the 2007 Energy Independence and Security Act, all spoke to various aspects of nuclear energy growth. Respectively, the MIT Studies spoke to nuclear waste management and the development of advanced recycling technology; the AFCI spoke to safe, secure, economic and sustainable expansion of the technology; and, the Energy Independence and Security Act spoke to greater energy independence and security. However in the face of the 2011 Fukushima-Diiachi nuclear accident, the industry focused on enhanced reactor safety of under construction models and a procedural review of the current fleet. The review of nuclear safety protocols especially for beyond-design events as the 2011 accident demonstrated saw the inclusion of defense in depth (redundancy) and probabilistic risk assessment to prepare for the unforeseen (U.S. NRC, 2011).

By 2012 future designs were also part of the framing of nuclear and I examine the introduction of small modular reactors, fuel conversion from nuclear warheads to fuel for both the U.S. and Russia (The Megatons to Megawatts Program), and bilateral nuclear cooperation agreements with emerging nuclear nations (for example, the United Arab Emirates) as continued forward momentum for the industry. There were/are setbacks; other nuclear states are making agreements with emerging states, such as the India-Russia deal for not less than 12 nuclear reactors in the next two decades (Modi, 2015).

The work of nuclear organizations and pro-nuclear professionals were also examined. Such organizations as CASEnergy, the American Nuclear Society, and Georgia Power and

Light use infographics, public outreach websites, and ‘what’s the benefit’ videos to relay their message of safe, reliable, and employment generating. Images that include nature and a diverse set of individuals enjoying the benefits of nuclear energy are relayed. For example, in the ANS “Top Ten Myths of Nuclear Energy”, the image of the power plant serves as a backdrop to everyday activities in Figure 1 – a walking couple, fields of crop and a mailbox – they represent the normalization of the technology, the everyday-ness of nuclear production.

Figure 35: Nuclear Connect, Know Nuclear,
http://www.nuclearconnect.org/know- nuclear/talking-nuclear/top-10-myths-about-nuclear-energy

Much is conveyed in the imagery as in the text of infographics. The social benefits narrative focusses on the ubiquitous of the technology in our advanced/advancing economies. It is a needed technology for us to enjoy our lifestyle. And the construction of the next generation of reactors, for example the AP1000, will be done more safely for further enjoyment. Westinghouse speaks to the passive safety design that requires no off site intervention for 72 hours after an accident. This statement is in relation to the Fukushima-Diiachi accident where active intervention was needed, but delayed, to cool the melting reactor core.

ANS policy statements also frame the nuclear energy debate. These statements reinforce the supporting science of the technology. For example, the International Cooperation for Expansion of Nuclear Energy (ANS-79-2006) hopes to influence policy makers, legislators, media and the public with its stance on nuclear expansion. With the force of nuclear experts behind it, the policy statement states,

> "[t]he American Nuclear Society supports expanded use of economical nuclear energy to meet growing electricity demand in the world and endorses programs to expand the peaceful use of nuclear energy while minimizing the risks of proliferation…[n]uclear energy is safe, environmentally friendly, reliable, and affordable. As economies around the world continue to grow, the need for abundant, near-carbon-free, reliable, and low- cost energy resources will grow as well. The United States should work with partnering nations to develop proliferation-resistant recycling technologies to produce more energy, reduce waste, and minimize proliferation concerns" (ANS, Position Statement 79-2006, http://www.ans.org/pi/ps/).

The benefits of the technology will be achieved as the U.S. technology is deployed and collaborating with the U.S. on research can reduce risk. ANS Washington DC representative, Craig Piercy, then uses these statements as he petitions for industry support. Such organizations as Nuclear Energy Institute, using Bisconti Research data, engage in branding campaigns to highlight the advantages of nuclear energy. And young professionals, North American Young Generation Nuclear and Women in Nuclear, speak as community members who work and live nuclear benefits. They participate in Capitol Hill Days and in pre-college student and educator outreach.

In Chapter 4 I hear from nuclear energy experts, in their own words, why nuclear energy is important, challenges the industry must address and the role of professionals. Interviews occurred with several experts from various aspects of the industry – national laboratories, utilities, engineering firms, regulatory agency, universities and professional organizations. “Why is a nuclear energy important?” solicited responses around the need for baseload power, clear air, independence from foreign sources, following the mandate of Atoms for Peace for safe, peaceful use of the technology, large energy capacity, part of the energy mix, and job creation. Nuclear energy was associated with being a necessary technology for the environment, national security and energy diversification. Challenges focused on public perception of the technology especially around issues of radiation, accidents and proliferation. Nuclear waste was viewed as both political and technical issues. The proposed Yucca Mountain National Repository was seen as political and public hurdles. The role of the nuclear engineering professional was as an advocate and they had to address public perception. Moreover, to the question of whether we were witnessing a nuclear renaissance the response eared on the affirmative however cautiously. The Fukushima-Diiachi accident was seen as a pause to steady growth. In addition, other dampening variables included the cost of natural gas and plant economics.

There is work done by nuclear technology through science, legislation, discourse and its experts. Claims are also made real through promotional materials; claims of a reduced reliance on foreign fuel sources and that nuclear energy play a role as an environmental solution to climate change. Challenges of the nuclear power industry are presented as solvable; it’s a matter of communication. The industry has and needs to increase its science activism and engage in more public and administrative advocacy. It continues to stress its relevance even with mixed reviews.

Through material and discursive analyses along with interviews, my judgement is that the status of the U.S. nuclear industry lies between endurance and cautious expansion. Nuclear energy has remained a 20% contributor to baseload energy in the U.S. despite nuclear power plant decommissioning and former nuclear powers such as Germany divesting of their nuclear power plants, as well as continuing public concerns around radioactivity, waste and accidents. As an active counter to the forward yet slowed momentum of the industry are calls from nuclear opponents. Watchdog organizations have continued sounding the alarm for better oversight and the phasing out of the technology, they include actions by NC WARN, Sierra Club and Union for the Concerned Scientists, to name a few. Although counter groups were not a primary focus, I engaged with some of their arguments through the lens of how they were answered by proponents of nuclear science and engineering.

Nuclear energy is a high-risk technology requiring continual material and discursive action to create, preserve and expand its relevancy. The industry is engaged in its story thus far – it is one of nuclear necessity at present and into the future. Legislation, industrial reports, science and professionals as well as administrative and public outreach play important roles in making the case for nuclear energy. Industry actors are increasingly engaged with stakeholders around key issues of safety, security and stewardship. The positioning of the U.S. nuclear industry has centered on baseload power production (energy security), carbon emission reductions (environmental stewardship) as well as economic growth & innovation (national security). Where is science practiced? It is practiced in the technology and the rhetorical language. The industry is increasing involved in both arenas for its revival to occur. Is the industry exiting? No … Is it enduring? Yes … Is it expanding? Perhaps… the actions it takes today towards public opinion, collaboration with other energy sources and its own innovation will dictate the strength of the road forward. Non-supporters and watchdog groups have assisted the industry in moving forward forcing reviews, material change and public accountability. The nuclear energy renaissance is much slower than predicted but it has not stopped the U.S. industry at home or abroad.

It is an industry to be continually examined – new construction in current nuclear nations; emerging nuclear nations; advanced plant designs (e.g. small modular reactors, very high temperature reactors); decommissioning in the U.S. and abroad; continuing concerns about accidents; scientific innovations; a nexus between nuclear technology and climate change or other established or emerging energy systems; nuclear nonproliferation; and, nuclear waste management to name a few topic areas. The U.S. nuclear energy industry is merely in a slower revival period than earlier forecasted. In addition, with the election of President Trump in 2016, the direction of the U.S. nuclear industry is up for consideration. Early predictions by the Nuclear Energy Institute suggest, “Trump’s energy plan proposes to remove ‘bureaucratic blocks’ to innovation and energy exploration. He says he will ensure that government does not favor one energy generator over another and will allow the energy marketplace to determine the best mix of domestic energy sources” (NEI, Oct. 19, 2016). What an America First Energy Plan will look like and its impact on nuclear energy is currently uncertain and adds another level of research to energy geography.

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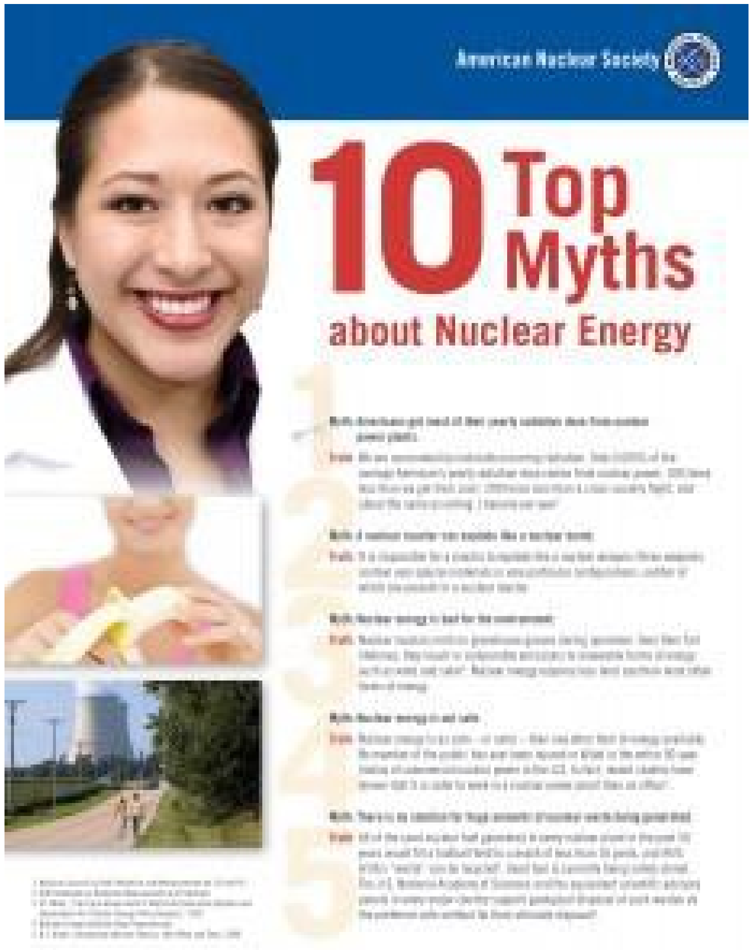
APPENDIX 1 – ANS TOP TEN MYTHS

(http://www.nuclearconnect.org/know-nuclear/talking- nuclear/top-10-myths-about-nuclear-energy)



1: Americans get most of their yearly radiation dose from nuclear power plants.

Truth: We are surrounded by naturally occurring radiation. Only 0.005% of the average American's yearly radiation dose comes from nuclear power; 100 times less than we get from coal [1], 200 times less than a cross-country flight, and about the same as eating 1 banana per year
[2].

2: A nuclear reactor can explode like a nuclear bomb.

Truth: It is impossible for a reactor to explode like a nuclear weapon; these weapons contain very special materials in very particular configurations, neither of which are present in a nuclear reactor.

#3: Nuclear energy is bad for the environment.

Truth: Nuclear reactors emit no greenhouse gasses during operation. Over their full lifetimes, they result in comparable emissions to renewable forms of energy such as wind and solar

[3]. Nuclear energy requires less land use than most other forms of energy.

4: Nuclear energy is not safe.

Truth: Nuclear energy is as safe or safer than any other form of energy available. No member of the public has ever been injured or killed in the entire 50-year history of commercial nuclear power in the U.S. In fact, recent studies have shown that it is safer to work in a nuclear power plant than an office [4].

5: There is no solution for huge amounts of nuclear waste being generated.

Truth: All of the used nuclear fuel generated in every nuclear plant in the past 50 years would fill a football field to a depth of less than 10 yards, and 96 % of this “waste” can be recycled [5]. Used fuel is currently being safely stored. The U.S. National Academy of Sciences and the equivalent scientific advisory panels in every major country support geological disposal of such wastes as the preferred safe method for their ultimate disposal[6].

6: Most Americans don’t support nuclear power.

Truth: In a survey conducted in September 2013, it was found that 82% of Americans feel nuclear energy will play an important role in meeting the country’s future electricity needs, and half believe this importance will increase with time. In addition, 84% of respondents favor renewing operating licenses for nuclear power plants that continue to meet federal safety standards. Also, 77% believe that nuclear power plants operating in the United States are safe and secure, a four percentage point increase from last February[7].

7: An American “Chernobyl” would kill thousands of people.

Truth: A Chernobyl-type accident could not have happened outside of the Soviet Union because this type of reactor was never built or operated here. The known fatalities during the Chernobyl accident were mostly emergency first responders [8]. Of the people known to have received a high radiation dose, the increase in cancer incidence is too small to measure due to other causes of cancer such as air pollution and tobacco use.

8: Nuclear waste cannot be safely transported.

Truth: Used fuel is being safely shipped by truck, rail, and cargo ship today. To date, thousands of shipments have been transported with no leaks or cracks of the specially-designed casks [9].

9: Used nuclear fuel is deadly for 10,000 years.

Truth: Used nuclear fuel can be recycled to make new fuel and byproducts [10]. Most of the waste from this process will require a storage time of less than 300 years. Finally, less than 1% is radioactive for 10,000 years. This portion is not much more radioactive than some things found in nature, and can be easily shielded to protect humans and wildlife.

10: Nuclear energy can't reduce our dependence on foreign oil.

Truth: Nuclear-generated electricity powers electric trains and subway cars as well as autos today. It has also been used in propelling ships for more than 50 years. That use can be increased since it has been restricted by unofficial policy to military vessels and ice breakers. In the near-term, nuclear power can provide electricity for expanded mass-transit and plug-in hybrid cars. Small modular reactors can provide power to islands like Hawaii, Puerto Rico, Nantucket and Guam that currently run their electrical grids on imported oil. In the longer-term, nuclear power can directly reduce our dependence on foreign oil by producing hydrogen for use in fuel cells and synthetic liquid fuels.

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