The Impact of Public Opinion on Nuclear Energy Projects

A Research Paper submitted to the Department of Engineering and Society

Presented to the Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements for the Degree

Bachelor of Science, School of Engineering

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Spring 2023

On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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INTRODUCTION

As the impacts of climate change are experienced around the world, there is a growing push for clean energy. When considering alternative energy sources, there are five primary options: hydroelectric, geothermal, solar, wind, and nuclear. Solar and wind power are viewed most positively by the public in a 2021 survey of 2,200 US adults across various geographies and political alignments (Jenkins, 2022). Hydroelectric and geothermal were next, with largely positive or neutral opinions. Nuclear energy was at the bottom of these technologies, having similar approval rates as coal and oil. However, to fully electrify the United States (US) on wind and solar alone would take land five times the area of South Dakota, while using nuclear would only require land half the area of New Hampshire (Yglesias, 2022). The same amount of nuclear energy can be produced from an area of land over 80 times smaller. If the US aims to reach carbon neutrality by 2035 (The White House, 2021), nuclear alternative energy sources must be considered. The advancement of nuclear energy provides both incredible opportunities and anxieties to the public.

Safety is one of the greatest concerns with nuclear reactors. Currently, the most common type of nuclear reactor is a Generation II reactor (World Nuclear, 2022), the primary sub-types of which are pressurized water reactors and boiling water reactors. These reactors use water to actively cool the fuel rods as power is generated. However, due to the high operating temperatures, the water must be pressurized so that it does not boil and continuously pumped to transfer heat. During the Fukushima boiling water reactor meltdown of 2011, environmental disasters resulted in both the grid power and the emergency generator to shut down, causing these active cooling systems to fail and the reactor to overheat (Columbia University, 2016). This caused industry-wide concerns about the safety of these plants. Newer reactors in operation are

called Generation III reactors. They are passively safe, meaning that they use spontaneous laws of nature to cool themselves both during operation and in the event of an emergency ("Use of passive safety", 2017). However, their main drawback is that their efficiency is not as high as it could be, with numbers comparable to coal generation. Future reactor designs aim to maximize both safety and profit, operating at higher temperatures to increase fuel efficiency and energy output while also using different coolants to prevent pressure buildups which caused accidents such as the explosion at Fukushima. (Touran, n.d.). However, much of the technology is not developed enough for commercial use, so there are only two in operation with others years to decades away (De Clercq, 2014). This thesis examines how public perception of nuclear energy has influenced its adoption in the US.

CASE CONTEXT: NUCLEAR ADOPTION

Nuclear reactors appear in the media most often when something goes terribly wrong. It is unlikely that someone would turn on the news and see a story about a nuclear reactor continuing to run smoothly, it simply wouldn't be news. However, the stories people do see or read about are those like Three Mile Island, Chernobyl, or Fukushima—catastrophic accidents that cause loss of life and infrastructural damage (Cho, 2021). The chronologically first of these, Three Mile Island, was the least severe, rated a Level 5 on the International Nuclear Event Scale (International Atomic Energy Agency, n.d.). During this event, large amounts of both liquid and gaseous nuclear materials were leaked into the environment. The death total is difficult to attribute due to the unknown amount or location of many of these radioactive fluids, but this accident became a key point of evidence for anti-nuclear activists in the US (Stencel, 1999). Chernobyl and Fukushima are rated as the two most severe nuclear events ever, rated as Level 7

on the International Nuclear Event Scale. These two events shook the world, each causing the loss of thousands of lives and causing widespread health and environmental damage. Each required planned and extended countermeasures such as exclusion zones and billions of dollars spent to deal with the aftermath. Because of this, public perception of nuclear energy is largely dominated by ideas of disaster and danger.

Although media coverage of nuclear energy is largely negative, the technology's benefits are incredibly impactful as well. Nuclear plants were utilized to generate 19 percent of the US's energy in 2021, while fossil fuels generated 61 percent, and renewables generated the final 20 percent (Energy Information Administration, 2022). As more sustainability efforts grow and are funded, the percentage of renewable energy percentage will increase. A government report projected that wind, solar, and other renewable sources will exceed one-fourth of the country's electricity generation for the first time in 2024 (Gearino, 2023) However, the amount of nuclear energy is anticipated to decrease. The US energy Information Administration projected that there will be less total nuclear electricity generation capacity in 2050 than in 2021 (Energy Information Administration, 2022). When comparing renewables to nuclear though, nuclear has a clear and impactful advantage of being reliable and distributable (Matthews, 2022). The clouds could be out, and the air could be still, but nuclear plants could continue to produce as if nothing had changed. For society to function completely off renewables, there must be an element of distributability to the grid. The ability for nuclear plants to consistently produce power means that during lower use hours, the excess energy could be stored and then drawn upon during higher use hours.

At the end of 2021, there were 93 operating commercial nuclear reactors at 55 power plants, with the average age being 40 years old (Energy Information Administration, 2022). To

put that into perspective, the average nuclear reactor was built around the time Microsoft released Word (Wright, n.d.). The Tennessee Valley Authority's Watts Bar Unit 2, which came online in 2016, was the first to do so since 1996. Another pair of reactors, which will be discussed in much greater detail further in the paper, are Units 3 and 4 at plant Vogtle in Georgia. In 2012, these two reactors became the first to receive construction approval in more than 30 years. Perhaps this is an isolated incident or perhaps it is indicative of a reintroduction of nuclear energy to the US. Unit 3 is expected to enter service in 2023, while Unit 4 is projected for early 2024 (Fitch Ratings, 2022). Once operational, these plants should provide power to Georgia for 60-80 years. This substantial amount of operational time appears to be good news for the continued production of nuclear energy.

However, more recently, nuclear plants have been shutting down due to financial factors rather than infrastructural ones. Since 2012, twelve US nuclear power reactors have been shut down (Congressional Resesarch Service, 2021). When the energy price is regulated by the state, the plants can usually generate the necessary funds to continue operation. However, when the energy price is determined by the lowest wholesale price, the nuclear reactors struggle to keep up with the low cost of fossil fuels and renewables. Since nuclear power plants are seeking to occupy the distributable niche of fossil fuels though, a nuclear plant shutting down means the energy will be offset with an increase in fossil fuel usage.

NUCLEAR ENERGY AND ADOPTION OF TECHNOLOGY

My research organized individuals with similar nuclear goals into key actor groups such as anti-nuclear activists, private companies, the government, and the broader civilian public. By

doing this, an analysis of a given case could be streamlined because an individual's actions could be categorized and indicative of the values of the group they associated with. I used such groups to examine the impact of different people's perceptions on the adoption of nuclear energy technology in the United States.

One group which deserves elaboration is the anti-nuclear activist group. Within this group, the allegiances and motivations can differ drastically, but they are all against the proliferation of this technology. Some of these individuals may come from an environmental concern standpoint, worrying about nuclear waste causing damage to the local flora and fauna. Others may come from a pro-fossil fuel standpoint, arguing that the fossil fuel industry's environmental impacts are overstated and that nuclear energy presents large and unnecessary dangers to civilians. Strangely, although these two allegiances come from drastically different sides of the environmentalist spectrum, they may band together against a given nuclear energy project. Even if a fossil fuel group does not explicitly join forces with an environmental one, their influence and disapproval of a given nuclear project may compound.

The nuclear power dynamic between civilians, the government, and private companies is a complex network of monetary and non-monetary support. Civilian influence largely comes down to political allegiances and consumer choices. If the only news an individual had heard about nuclear energy was that of a meltdown, they would obviously be against a reactor being built near their community. However, if they valued the low-carbon, comparable cost benefits more, they may be more likely to support its construction, especially if they supported the elected official proposing it. This gets more complicated as we venture into sentiments such as "Not in my backyard," or NIMBY, where an individual supports construction generally but does not want to take on any of the risks themselves. Furthermore, if a private nuclear energy project

will greatly increase their costs, consumers may be less likely to support such an endeavor. The private companies in turn would be less incentivized to invest in nuclear power without governmental support. Local civilian opposition has had a hand in bringing an end to multiple nuclear energy projects such as the US government's Yucca Mountain nuclear waste storage project (Cohen, 2022). This opposition then moves us towards our next important group: politicians. If nuclear power is disliked by the public, officials may be less likely to support it for fear of not being reelected. They may also worry that a decisive decision on a controversial topic may decrease support for their higher priority programs. However, since reactors are multi-billion dollar infrastructure projects (Department of Energy, 2021), government funding and subsidies are crucial to their increased use. Thus, the non-expert opinion of nuclear power has heavily influenced its continued development. My research examined the interplay between values and financials for the expansion of nuclear energy.

The framework I relied upon for my research was Everett M. Rogers's Attributes of Innovations and their Rate of Adoption (1983). This framework analyzes how an individual or group's perception of a technology changes the speed with which they accept and use it. It breaks an individual or group's perception down into five categories—relative advantage, compatibility, complexity, trialability, and observability—and uses those categories to explain a technology's rate of adoption. In addition to the perception, four slightly more tangible variables were determined to influence adoption rate: type of innovation decision, communication channels, nature of the social system, and extent of change agent's promotion efforts. Although these four other variables may overlap with each other—such as promotion efforts changing communication channels—they provide helpful structure to examine more concrete variables. These categories and external factors influence each other, changing the amount satisfaction

required for one if another changes. For example, farmers in Sweden adopted more complex farming technologies if the information communication was interpersonal (Petrini, 1968). If they simply saw mass media ads for the technology, they were significantly less likely to adopt it.

This framework aids my investigation on the adoption of nuclear energy incredibly well. It allowed me to analyze key groups of individuals such as the US government, private energy companies, or communities near a proposed reactor and use their perceptions to explain the outcome of a given event. It also allowed me to organize data I found into the different categories. Information such as a fossil fuel advocate's opinions on a project give insight into that group's perceived relative advantage. More concrete data such as local approval ratings for nuclear or energy bill increases due to nuclear projects was used to learn about the nature of the social system. Data such as activist activities or articles could also be indicative of the nature of the local social system. It was difficult to find evidence for every category of every group of every case, but this framework facilitated my analysis of a given nuclear project's outcome. Analyzing the data was also an interesting challenge because all the facts could be the same—such as nuclear energy being zero emissions versus coal's heavy emissions—but the perceived environmental advantage is completely different between different groups. I used all the data I could find to determine which groups and perception categories had the greatest influence on nuclear energy projects in the US.

RESEARCH QUESTION AND METHODS

The research question I asked was: How have social perceptions of nuclear energy influenced its adoption in the US? The transition away from fossil fuels is not a purely technical

one, requiring strong governmental and civilian support to occur in addition to technological advancements. Therefore, I explained and contextualized what is holding nuclear energy back from widespread use.

To investigate this research question, I used a series of case studies of proposed nuclear infrastructure. The goal was to compare instances where the nuclear project was successful against instances where it was shut down and to explain why some succeeded and others failed. Data such as government funding, private funding, public outreach, and geographical history with nuclear power was collected for each case. The three cases analyzed were the operational Plant Vogtle in Georgia, the failed Virgil Summer nuclear expansion project in South Carolina, and the early shut down of Indian Point Energy Center. These three cases were chosen because they give a variety of outcomes while minimizing the number of independent variables outside the scope of this paper such as type nuclear project (storage vs power generation) and country. The Georgia and South Carolina cases had incredibly similar setups while having completely different outcomes, and the Indian Point case was slightly less recent, allowing for an examination of an outcome further down the line.

For each case, I identified the key groups involved and use Everett M. Rogers's Attributes of Innovations and their Rate of Adoption (1983) to analyze why a given group was or was not keen on adopting nuclear technology. I also examined the amount of power each group had on the final decision. If a given group was incredibly for or against the project but has very little power, their opinions were less influential for the outcome of a case. Each case was organized into a timeline, categorizing activities, responses, and secondary responses from each group of interest to provide the most appropriate analysis of action and outcome. Due to the

tightly coupled nature of the Georgia and South Carolina projects, the timeline of events will be discussed jointly, and the timeline for Indian Point will be detailed separately.

RESULTS

Social perceptions have largely slowed the adoption of nuclear energy in the US, causing the cancellation or decommissioning of many viable reactors. These perceptions were found to be primarily influenced by money, although safety concerns were also found to be a key factor. Action manifested in forms such as protests, calls for investigation, lawsuits, and political action. The three cases analyzed show that the low trialability of nuclear energy coupled with its enormous buy-in cost make constructing new reactors an extremely tall task.

In 2007, the South Carolina General Assembly passed the Base Load Review Act, which allowed SC utility companies to charge their customers ahead of time for plant construction projects (Holland, 2018). One year later, South Carolina Electric & Gas (SCE&G) and Santee Cooper announced plans for a $9.8B nuclear expansion project at Virgil C. Summer plant (Gillman, 2019). A similar project with a $14B cost estimation was approved for construction at plant Vogtle in Georgia in 2012, managed by Southern Nuclear and Georgia Power (WRDW, 2023). Both multi-billion dollar projects contracted with Westinghouse Electric Company as the lead contractor and selected the AP1000, a newer and reportedly safer reactor, as their chosen model (Pulmer, 2017). However, due to the novelty of the reactor, many design features and safety changes were made, causing delays and driving the price of each project up drastically. In response to the increased financial need, SCE&G used the Base Load Review Act to allow them to increase the monthly rates of their South Carlina customers from an average monthly utility

bill of $107 in 2009 to $148 in 2016 (Scoppe, 2018). This drastic increase put significant financial pressure on the civilian public and decreased support for the project. Then, in 2017, Westinghouse filed for bankruptcy but reached agreements with both projects which would allegedly allow them to continue if funding persisted. However, for South Carlina, the cost had become too high, and in that same year SCE&G and Santee Cooper announce the termination of the projects (Scoppe, 2018). Customers of SCE&G continued to be charged increased rates for some time after the cancellation was announced, but that topic is slightly outside the scope of the paper. On the other hand, Georgia decided to continue work on the project, allowing Southern Company to step in with Bechtel and take over the project. The plant Vogtle reactors were successfully constructed by the end of 2022, costing over double the projected price ($14B to $30B) and increasing Georgia Power customer rates only after the project was well underway (Kyler, 2022). Thus, the Georgia project succeeded in building new nuclear reactors while the South Carolina project failed.

The third case of interest was the Indian Point Energy Center, a power plant which was operational for 60 years but was shut down prematurely. During its operation, Indian point operated 25 miles away from New York City and supplied about 25% of the city's power (Mcgeehan, 2021). The two operational reactors were nearing a twenty-year extension on their Nuclear Regulatory Commission (NRC) licenses, but safety concerns arose due to the plant's proximity to New York City especially after the Fukushima meltdown of 2011. Many environmental groups such as Riverkeeper advocated for and hailed the shutdown as a success, claiming that renewable energy would replace the energy lost from the plant's closure and that this closure protected the Hudson River (Riverkeeper, n.d.). However, the renewables claim turned out to be incorrect, as three natural gas-fired power plants have been introduced between

2018 and 2021 to offset the energy Indian Point had been providing (Energy Information Administration. 2021). New York Governor Andrew Cuomo was a particular advocate for the closure of the plant, ostensibly for safety reasons. He opened investigations with multiple state departments and was a strong voice against the plant's continued operation. However, Environmental Progress also found that two of Cuomo's top former aides worked with a major Cuomo campaign contributor, the natural gas company Competitive Power Ventures (CPV), to close Indian Point (2017). CPV then went on to open one of the three gas plants introduced to offset the nuclear plant's closure. Another factor contributing to the closure of Indian Point was sustained low wholesale energy prices, which reduced projected annual revenue of the nuclear plant by $160 million (Nappi & Kakridas, 2017). Thus, in 2021, the fully functional plant permanently ceased operations and natural gas took its place.

Examining the first two cases in tandem is incredibly helpful because it gives insight into how heavily money influences public opinion. In both cases, actors involved include politicians, state energy organizations, contractors, and the civilian public (SC or GA respectively). Each group has their own perceived attributes of innovation. Roger breaks this set of variables down into five categories: relative advantage, compatibility, complexity, trialability, and observability. In 2008, 606 randomly selected South Carolinians were surveyed about their opinions on nuclear energy and the decision-makers involved in public hearing processes. They ranked safety and climate change as top priorities, indicated that they mostly trusted the officials, and 67.9% said they were somewhat or strongly in favor of expanding nuclear energy in South Carolina (Besley & University of South Carolina, 2013). However, of particular interest is that 60.3% of responders believed the cost of nuclear energy would be less than or equal to other available sources. These responses are very helpful for determining the perceived relative advantage of

nuclear for civilians and politicians. Their strong support of a nuclear project (and thus an initial willingness to adopt in 2008) comes from their belief that it is good for the environment and cheaper. Though a similar survey could not be found for Georgians, a similar perception is presumed due to the state's history with nuclear power and the hundreds of jobs created by the project. The other perceived attributes of innovation for civilians and politicians are rather straightforward. The compatibility is high, as proven by both state's histories with nuclear energy. The complexity was high due to the novelty of the reactor designs, and the trialability was incredibly low—one could not simply try a limited version of a nuclear reactor, billions of dollars were needed to begin operation. Many of these values and perceptions can be said to be similar for the state energy organizations, though their perception of relative cost advantage was different. In the South Carolina case, SCE&G were unworried about the cost—the Base Load Review Act simply allowed them to charge it to the customers ahead of time—so the relative advantage for them to build a reactor was very high. In Georgia, no such act existed, but the other perceived attributes made a strong enough case to continue while temporarily keeping electrical rates the same for their customers.

However, why did one project succeed and one fail? It is my assertion that charging their customers ahead of time was a key factor in dictating where one project succeeded and the other failed. South Carolina energy customer rates had increased by 40% well before Westinghouse filed for bankruptcy in 2017 and reevaluation was necessary. Thus, when reevaluation was necessary, customers were already frustrated, as their perceived relative advantage of decreased cost was shown to be completely incorrect for this project. Thus, their opinion on appropriate rate of adoption for nuclear energy decreased drastically, causing the project's termination. On the other hand, the Georgia project organizers waited to increase customer pay rates until after

the project was reconfirmed. In an Energy News Network article, writer David Kyler asserts that "burying the cost overruns in customer billing also protects the commissioners from overdue accountability for their decision to continue the project in 2017, when there was prime opportunity to terminate it" (2022). Kyler also states that in 2019, 2.7 million Georgia residential customers began paying $278 more per year. However, the reapproval was already complete, meaning the civilian public's anger and decreased relative advantage fell on deaf ears and the project continued. This rather sneaky decision to continue by the elected officials at the Georgia Public Service Commission (SPC) allowed Georgia Power to protect its profits, protecting investors and pushing the cost onto customers instead. Thus, it can be inferred that the Georgia SPC and Georgia Power perceived a huge relative advantage for themselves and their positions of power allowed them to spur the project on and increase its rate of adoption. Despite the carbon emission advantages, if the public's personal costs increase, the chance of a nuclear project succeeding decreases.

Examining the closure of Indian Point shows similar instances of financial priorities clashing with moral ones, but also gives more insight into how power dynamics influencing rate of adoption. After the Fukushima meltdown, the US urged Americans withing 50 miles of Japanese nuclear plant to evacuate (Maese & Vastag, 2011). Given that Indian Point was 25 miles from New York City, this evacuation radius was bound to spark some worry. The key groups involved were similar but more specifically identifiable than those of the first two cases. Civilian action took shape in organizations such as the Sierra Club and Riverkeeper, groups which advocated for the permanent closure of the plant. To use Roger's framework, such groups perceived the technology as being incompatible with existing values and needs of potential adopters. Although these environmental groups valued low carbon emissions, the incompatibility

came from the perceived danger to their own health. To them, the danger of meltdown in such close proximity to a populated city center far outweighed the positives associated with net-zero emission energy. Safety concerns along with pollution worries caused this group to be incredibly against the adoption of this technology so close to NYC. On the political side, Andrew Cuomo is the primary figure of interest. Based on the multitude of safety investigations he opened, Cuomo saw the plant as a danger and was seeking reasons to shut it down. Another attribute which Roger cites as having large impacts on an innovation's rate of adoption is incentives. In this case though, the incentives were against the continued adoption of nuclear energy. Perhaps Cuomo was incentivized by the prospect of gaining green votes, but this is largely speculative. Cuomo's primary incentives were financial, as he had received donations of upwards $200,000 dollars from CPV and other energy companies during his campaigning in 2009 (Environmental Progress, 2017). Then, as wholesale energy prices continued to decrease Indian Point's profitability, the plant's perceived relative advantage decreased significantly for Cuomo. Thus, when CPV was seeking a new power purchase agreement, Cuomo was more than happy to shut down Indian Point. CPV leveraged their incentive-based power to slow the adoption of nuclear energy and open a niche for the continued use of natural gas power plants.

DISCUSSION

For some of these cases, there are inherent limitations associated with them. For instance, Plant Vogtle in Georgia has only recently begun operation. It is entirely possible that a similar sequence of events will happen there as happened to Indian Point—safety and profitability concerns mount enough to shut down a fully operational plant. The scene is already set with discourse over increased energy rates for Georgians. Roger's framework's perceived relative

advantage of nuclear energy being cost-comparable to other sources is challenged when organizations fail to stay under budget and put the financial burden on consumers. Furthermore, consumers are less willing to "try" nuclear energy due to the low trialability from the immense initial cost. Thus, the desire to continue to adopt this technology falls significantly in these instances. However, at the time of this paper, the reactors are functional and operational, finally generating power after a long, and costly road. One last limitation of this work is that these three cases may not be perfectly representative of the adoption of nuclear energy across the US, but I believe they give helpful points for analysis.

In the future, I will use the knowledge gained from this research to advocate for nuclear energy projects in more precise ways. This action could come in the form of having conversations with people about the truly enormous dangers of climate change. Perhaps if that is understood more then people would be more willing to pay a little more for cleaner energy. However, efforts would also be directed towards keeping companies and politicians accountable and preventing any consumer exploitation such as egregious energy bill price increases. These efforts could take the form of joining nuclear energy advocacy groups and aiding them in contacting representatives involved in nuclear project renewal or oversight process. Hopefully then, acts such as the Base Load Review Act would not be passed, preventing instances such as South Carolinians being charged ahead of time for a project which was never completed. This research has shown me the interplay between people, money, and technology.

Within my engineering practice, this research will be a key reminder that organization is of paramount importance for project completion. If Westinghouse had been more organized and prepared, perhaps they would not have needed to file for bankruptcy, and perhaps the South Carolina plant would be operational. Such disorganization doubled the cost of one project and

killed another—I do not want this to happen to me on future projects! I will remember these instances and use resources such as budgeting sheets to aim well under budget. That way, if things do cost more than expected, projects hopefully still will finish around the expected cost. This research will also spur me on in my goal of fighting climate change. It was incredibly disheartening to research so in depth about failed net-zero generation efforts, but it has only increased my desire to help.

CONCLUSION

In short, money talks. The first two cases showed how much increased costs can decrease public opinion of a given project, while the third showed how incentives can push funds away from nuclear energy. In future studies, I would recommend expanding the number of cases to give more insight to the research question. Examining more cases with different types of outcomes would allow for different angles of analysis. Perhaps a reactor which was proposed but never approved would give some insight into why different projects made it further into the development process. Future studies should investigate if public opinion was a factor in such early-death cases. Discovering substantial evidence for these cases would be inherently difficult due to the short-lived nature of the ideas, but with enough searching a case could likely be found. The only cases examined in this paper made it billions of dollars into their lifespans. Investigating cases which did not make it as far would provide new evidence for different conclusions. However, from these three cases, the takeaway is that convincing to sacrifice personal welfare for the greater good is incredibly difficult. It is both the government's and our own responsibility to hold each other accountable both financially and environmentally. If we as civilians keep ourselves informed and get involved in political discussions on climate change, it

will display support for low emission energy. Hopefully then, the US will continue to push for a cleaner, more sustainable future.

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