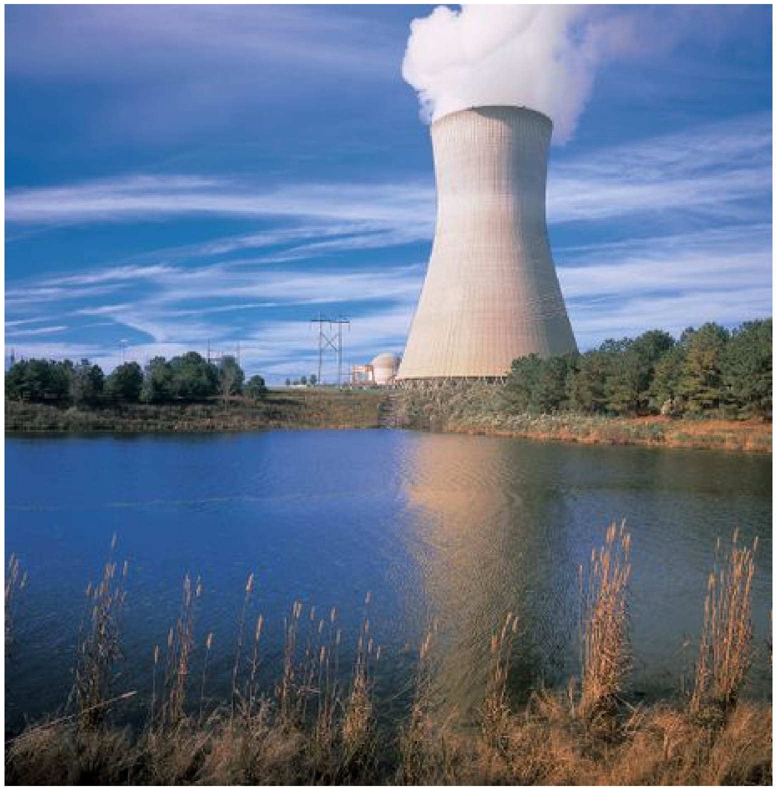

Figure 1: Duke Energy's Harris Nuclear Plant (Duke Energy, 2013)

Impacts of the Changing Regulatory Landscape on New Nuclear in the United States

by

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Executive Summary

The construction of new nuclear facilities in the United States has crawled to a halt despite an increasing emphasis on the carbon-free generation and scattered attempts to simplify regulations while addressing safety concerns. This project asks what changes in the regulatory framework led to the decline of new builds, particularly in comparison with other countries' regulations which have allowed for expanding nuclear fleets. The key questions that this research aims to address is:

1. How did nuclear power change from a regulatory and licensing perspective after the Three Mile Island accident in 1979?
2. How does that landscape compare with the current international landscape?
3. What can we infer should be reconsidered moving forwards in a new, climate-conscious landscape?

The initial hypothesis explored in this work is that an overbearing licensing process, created after Three Mile Island where safety was the dominant public policy concern, led to a changing and uncertain regulatory environment. Further, I speculated that the US domestic environment diverged from international markets because investing in large-scale, bet-the-company nuclear plants would be untenable for anything other than state-run utilities in such a regulatory environment.

This research used a mixture of methods to understand the regulatory changes that have occurred and the industry's perspective on those changes. This study consists of a qualitative examination of the historical US regulatory changes after the Three Mile Island accident, interviews with industry experts, comparisons of the domestic regulations and processes with international builds, and analysis of the environmental perspective over time.

The findings confirm that the regulatory burden is a major driver of industry divergence with international peers, though not the only significant factor. The other factors that reduced the number of new builds include lack of standardized designs, variable support from local communities, loss of experience for constructing operators, and absence of a top-down national directive. Yet, there are also key barriers to deploying nuclear power including increased involvement of outside groups, lack of expertise and supply chains, and lack of appropriately following the regulatory guidelines. As the electricity market planners look to reduce carbon emissions, nuclear energy poses a potential solution and this study outlines recommendations for the industry to use moving forward.

Acknowledgments

This research could not have been conducted without assistance from many individuals throughout the nuclear energy industry. Additionally, I want to thank my co-researcher Nathaniel Margolies who helped me on a tangential line of research as Kenan Scholars for the Energy Center and the Kenan Institute of Private Enterprise at the University of North Carolina Kenan-Flagler School of Business, without whom I could not have successfully completed this project. Finally, thank you to my advisor at the Kenan-Flagler School of Business, Professor Stephen Arbogast, who provided invaluable guidance, connection to resources, and contextualized findings in the larger energy space.

Acronyms and Abbreviations

AEC: Atomic Energy Commission

AP1000: Advanced Passive Pressurized Water Reactor

CFR: Code of Federal Regulations

COL: Combined Construction and Operating License

COLA: COL Application

DC: Design Certification

DF Design Finalization

DOE: Department of Energy

EPAct 05: Energy Policy Act of 2005

EPC: Engineering, Procurement, and Construction

EPRI: Electric Power Research Institute

ESP: Early Site Permit

LWR: Light Water Reactor

NE: Office of Nuclear Energy

NEI: Nuclear Energy Institute

NRC: Nuclear Regulatory Commission

US-APWR US Advanced Pressurized Water Reactor

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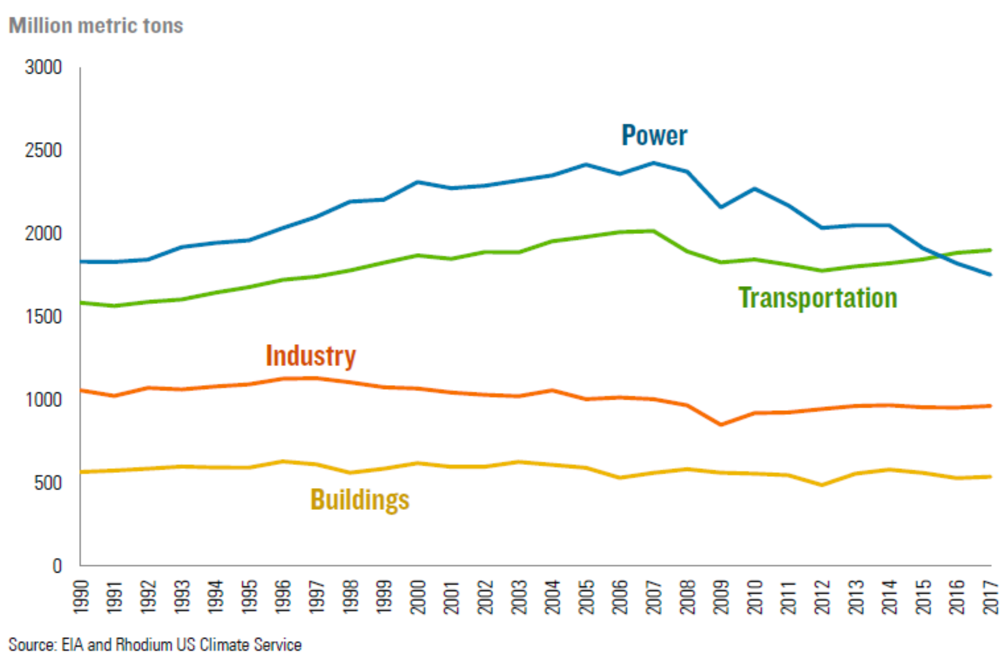
Introduction

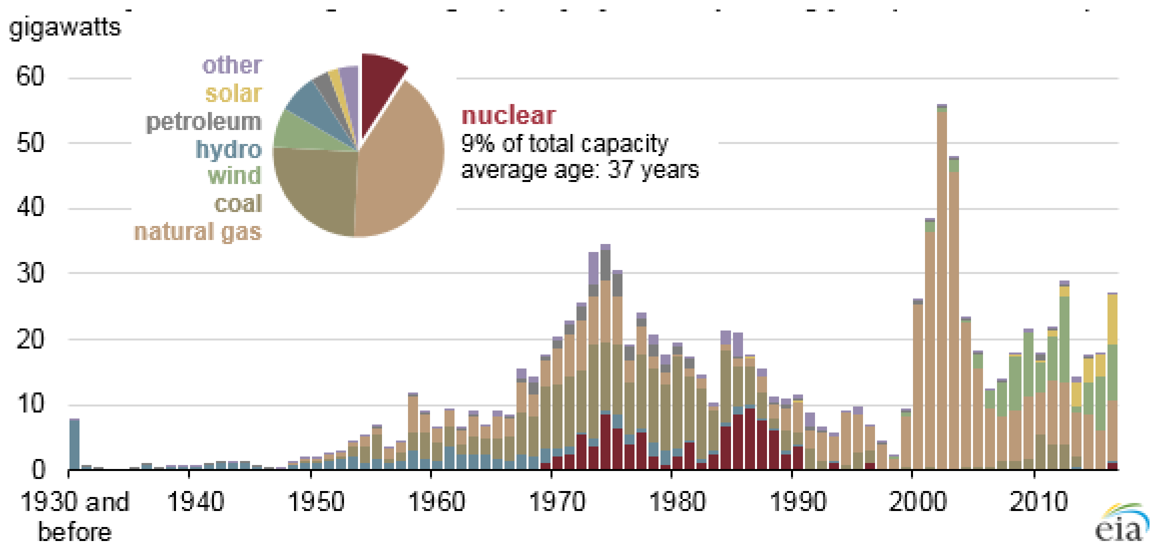
The United States energy industry is transitioning to focus ever more on the environmental impact of generation due to the threat of climate change and lower-carbon energy sources becoming cost-competitive. Many environmentalists, governments, and other organizations aim to reduce the amount of greenhouse gas emissions from the power industry. and As shown in Figure 2, carbon dioxide (CO_2) emissions from the U.S. power sector have decreased since 2007, largely due to decreased natural gas prices and an increase in renewable energy due to changing economics and regulations (Plumer, 2019). This is a move in the right direction, but the Climate Action Tracker still identifies the United States as "critically insufficient" in their commitments, which would lead to a world with a 4°C+ world (Climate Action Tracker, 2019).

Figure 2: Energy-related carbon dioxide emission quantity by sector (Rhodium Group, 2019)



This reduction in power emissions is due to a transition in energy generation used. Over the past 10 years, the renewable energy and natural gas deployment have increased, as coal new builds tapered off and there was minimal nuclear built (Figure 3). This has led to a fundamental shift in the 2019 U.S. utility-scale electricity generation mix with 38.4% produced by natural gas, 23.5% by coal, 19.7% by nuclear, and 17.5% by renewables (EIA, 2020).

Figure 3: U.S. utility-scale electric generating capacity by initial operation year (as of Dec 2016) (EIA, 2017)



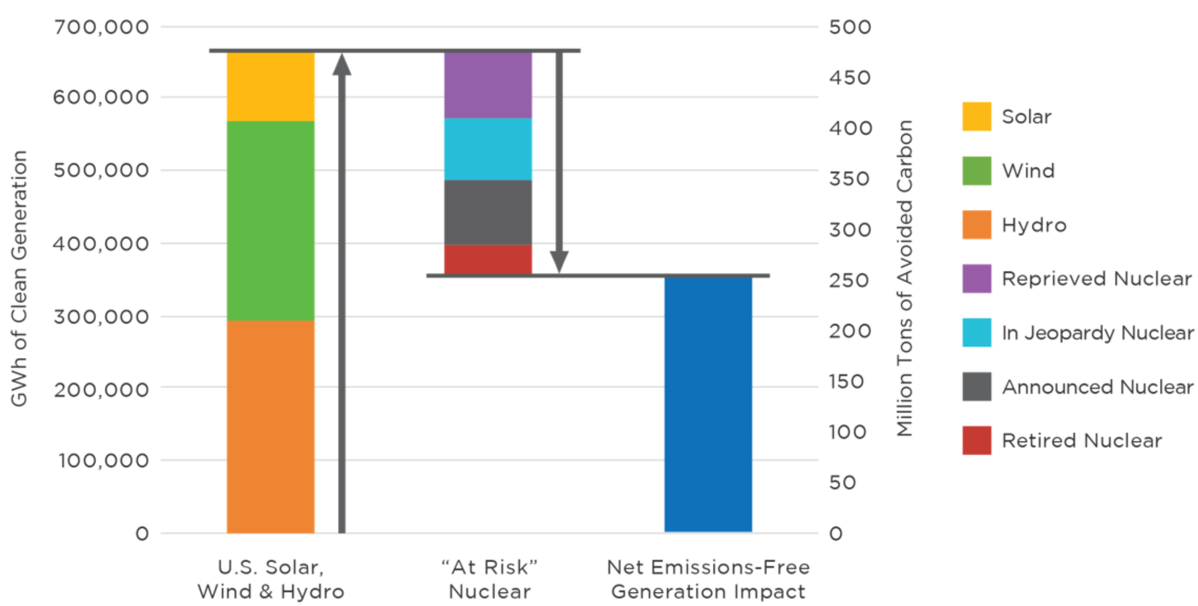
Though, nuclear generation still makes up a sizable portion of generation, that will likely change as new nuclear plant construction has dwindled in the United States. The average age of nuclear facilities is 37 years (Figure 3). The U.S. is at risk of losing this key baseload carbon-free resource. This will be a fundamental issue going forward as the nation needs a source of carbon-free baseload energy to continue meeting carbon goals and more non-dispatchable renewables come onto the grid. The electricity grid needs substantial baseload energy to maintain reliability and there are few other carbon-free baseload options other than nuclear, hydropower, and wind/solar and batteries.

In 2019, the Kenan-Flagler Energy Center identified that current battery and renewable energy generation technologies would fail to provide a carbon-free electricity grid at a reasonable cost. Instead, the grid needs a hybrid approach, with a "broad mix of electricity generation, including roles for renewables, natural gas, storage, and nuclear energy" (UNC Kenan-Flagler Energy Center, 2019). Similarly, a recent study found that energy storage needs to be at least $20 per kilowatt-hour in energy capacity costs to have 100% renewables on the electricity grid (Ziegler, et al., 2019). That energy storage cost requires approximately a 90% drop from current prices (Ziegler, et al., 2019). This indicates that at the current costs of electricity, nuclear energy is a crucial part of a carbon-free energy mix.

The nuclear energy industry is facing resistance in the United States. Over the past 30 years, new nuclear generation in the United States has stifled (Figure 3) while existing nuclear generation is being taken offline (Baker, Lawrie, & Lozier). Recent cost overruns on nuclear plants have raised doubts about whether traditional new nuclear is feasible. Meanwhile, existing nuclear capacity is declining due to age, unprofitability of plants, and forms of price competition that do not value either their zero-carbon nature or their ability to operate at high capacity levels for long durations (Haratyk, 2017).

There are large environmental implications of the early retirement of nuclear in the United States. ScottMadden identified that the greenhouse gas emission reductions from increased renewable deployment could be offset by the simultaneous reduction of the nuclear energy fleet in the United States (Figure 4). Furthermore, the study showed that if fossil fuel sources replace at-risk nuclear plants that are closing or are likely to close, "nearly 90% of the wind and solar output that has been added since 2008" would be replaced (Baker, Lawrie, & Lozier). This indicates that nuclear generation is a key resource to continue to lower greenhouse gas emissions.

Figure 4: Potential reduction in clean generation increases from the loss of "at-risk" nuclear generation (as of 2018) (Baker, Lawrie, & Lozier)



Major barriers to building out new, advanced nuclear facilities include the costs, uncertainty of licensing and construction timelines, and the recent issues faced by the Summer and Vogtle nuclear new builds. These issues together have stopped the regulated utilities from pursuing new nuclear builds in the United States as they complete their Integrated Resource Plans. This research focuses specifically on identifying the reason for regulatory uncertainty and changes to the regulations that leads to the elongation of licensing and construction timelines. I focused this research on the regulated utility markets as they currently have the most favorable market environment to build new nuclear power plants.

My initial hypothesis to explain the reduction in new nuclear power plant builds is that the current United States nuclear licensing process was created during a period where safety was the dominant public policy concern and when alternative forms of power generation, such as coal-fired plants, were not seen as posing a public welfare concern. The U.S. domestic environment diverged from international markets because investing in large-scale, bet-the-company nuclear plants would be untenable for anything other than state-run utilities in such a regulatory environment. The research poses a question to whether this perspective and the regulatory barriers it spawned, needs to be revised in the wake of climate emerging as an important global health and welfare issue.

Methods

To determine the effects of regulatory change on the licensing and construction time length for new nuclear power plants in the United States, this study followed four steps. First, I conducted a qualitative review of the changes to domestic regulations for new or under-construction nuclear power plants, with an emphasis on changes after Three Mile Island. This stage consisted of a literature review and exploring the regulatory impact on new plant construction. Secondly, there I collected data on the timeline of licensing and construction times over the last 50 years to determine the net impact.

In the next stage of the study, my colleague, Nathaniel Margolies, and I interviewed 15 industry experts involved in the many aspects of United States nuclear energy. The full question list is in Appendix A: Interview Questions. These questions were intended to identify historic cause and effects in nuclear regulation and the key reasons for the elongated licensing and construction timespans in the United States.

There was a review of nuclear regulations and programs around the world. International practices were examined by literature review for specific countries where nuclear growth has continued. Domestic & international analyses were then compared to identify divergent regulatory practices and their impacts.

Finally, the study qualitatively assessed the changing perception of top environmental organizations from the 1970s to 2020. The analysis was conducted by reviewing public statements by the organizations and a qualitative review of studies on changing environmental perceptions of nuclear energy.

Historical Review of Nuclear Energy in the United States

The United States nuclear regulatory regime has greatly changed since its inception. The early atomic research in the United States was done in World War II under the code name Manhattan Project to create weapons for war (U.S DOE, 2006a). Once the war was over, the United States government encouraged the same departments to develop nuclear energy for electricity generation, which they successfully did in December 1951 (U.S DOE, 2006a). The first commercial nuclear plant, in Shippingport, PA, reached full power in 1957, which spurred private companies to invest in the industry (U.S DOE, 2006a).

Pre-Three Mile Island: A Regulatory Mindset Shift

Before TMI, there was a fundamental change in the way that the United States regulated nuclear energy with the replacement of the Atomic Energy Commission (AEC) with the Energy Research and Development Administration and the Nuclear Regulatory Commission (NRC) by President Ford (NRC, 2019). The shift away from AEC was part of a larger change from a licensing agency to a regulatory body monitoring ongoing operations (Wellock, 2020). Per an NRC historian, this change had a larger impact on the purpose and goals of the regime than TMI as it laid the framework for future changes and focus areas. The regulatory mindset in the U.S.

changed from ‘we’ll build nuclear too cheap to meter’ to ‘nuclear must be watched’ (Wellock, 2020).

Changes After Three Mile Island

The Three Mile Island event was when the Three Mile Island Unit 2 reactor unfortunately partially melted down on March 28, 1979 (U.S. NRC, 2018). This resulted in a small radioactive release that ended up having “no detectable health effects on plant workers or the public” (U.S. NRC, 2018). Though this incident did not harm anyone, it drastically changed the public’s perception of the industry and how the regulators dealt with owners and operators to ensure the plants operate safely.

Due to the largescale public impact of the event, the NRC determined that it needed widescale corrective actions. After analyzing the impacts, the NRC identified that the key changes were “emergency response planning, reactor operator training, human factors engineering, radiation protection, and many other areas of nuclear power plant operations” (U.S. NRC, 2018). Additionally, it forced the NRC to increase regulatory oversight in a multifaceted way to address public concerns (U.S. NRC, 2018). A full list of the modified regulations that impacted licensing and construction and their impacts are shown in Table 1.

Table 1: Key New or Modified Requirements that Impacted Nuclear Power Plants after Three Mile Island (NRC, 2019) (Navigant Consulting, Inc., 2013)

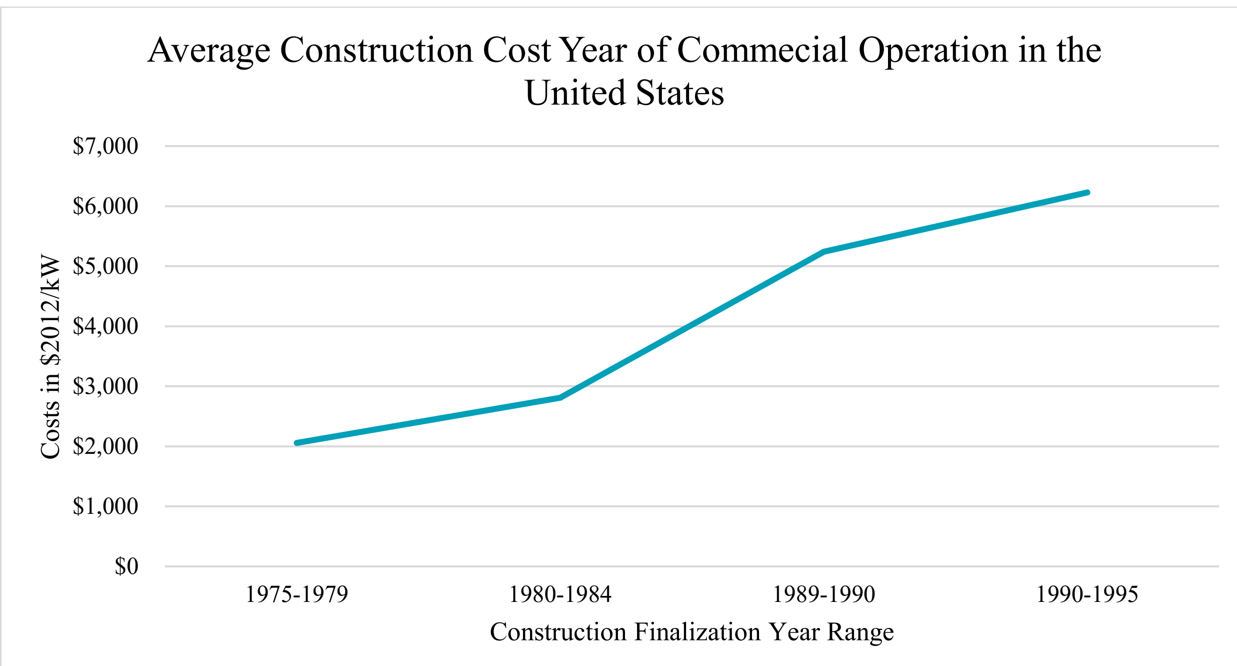
IMPACT	NEW REQUIREMENTS
Sudden Change to Projects	• Pause on licensing of new reactors • 3 independent studies initiated to determine needed changes
NRC Organization Changes	• Restructured leadership, increasing control of Chairman • Reorganization of major divisions
More Stringent Engineering Requirements	• NRC developed emergency response capabilities
Additional Operating Requirements	• Fire protection, piping, and feedwater systems • Containment building isolation • Plants ability to shut down automatically • Reliability of components
More Stringent Engineering Requirements	• New operator training requirements • Radiation protection for plant personnel and local populations
Increased Monitoring	• Collection of plant performance data by the NRC • Certain data was made publicly available
External Community Involvement	• More public meetings involving plant decisions • More public review periods for new plants

In response to regulatory changes, the industry made structural changes to ensure compliance and improve organization. In 1979, the Institute of Nuclear Power Operations (INPO) was created to allow the utilities and other companies in the nuclear energy space to coordinate and "promote the highest levels of safety and reliability" (Institute of Nuclear Power Operations (INPO), n.d.). Additionally, the interviewees described that there was an increased incentive to share data, best practices, and lessons learned with utilities and other industry players in industry groups. The industry holds the sentiment that it is judged by the worst player. By keeping everyone accountable and given the best practices, there was a hope that there would no longer be bad actors.

Impact of Post-TMI Changes

In 1982, the General Accounting Office (GAO) estimated that the TMI accident and the associated changes caused $14 million per reactor in backfit and retrofit costs, which means the nuclear industry spent approximately $5 billion on retrofit-related costs (GAO, 1982). These changes also resulted in a continued increase in construction costs, which is shown in Figure 5 as the average overnight construction cost per kilowatt of construction of all U.S. nuclear plants. These costs were largely unexpected or added on later, which made utilities wary about the true cost of new nuclear builds as the government could change laws in the middle of the licensing and construction process. These costs additionally do not include the increased financing costs as the construction period extended and they were unable to begin operating to recoup costs.

Figure 5: Average Construction Cost Year of Commercial Operations in 2012 adjusted $/Kw (Navigant Consulting, Inc., 2013)



New Licensing Procedures Post-TMI

The Energy Policy Act of 1992 (H.R. 776) aimed at providing improved energy efficiency (102nd Congress, 1992). It created an all-in-one licensing process under 10 CFR Part 52 for new nuclear reactors so that utilities could get their construction and operating permit all at one time.

This change intended to prevent nuclear plants from receiving their construction permit, but never being able to get the operation permit, which occurred several times (Squassoni, 2009).

Key Changes in the 2000s

President George W. Bush supported a nuclear power renaissance in the United States in the early 2000s claiming in a May 24, 2006 speech, "for the sake of economic security and national security, the United States of America must aggressively move forward with the construction of nuclear power plants" (Hoagl, 2006). This support for nuclear was founded in a desire to be less reliant on foreign fuel sources when natural gas prices were high.

The Nuclear Power 2010 (NP 2010) program was launched in February 2002 and aimed to get new nuclear plants ordered by 2005 and operational by 2010 (Johnson, 2002). The plan included a Phased Action Plan that would allow DOE to “support key R&D and assist industry to demonstrate unproven NRC processes,” including the Early Site Permit (ESP) Application, Design Certification (DC) for advanced reactor designs, and Combined Construction and Operating License (COL) (Johnson, 2002). Under NP 2010, the DOE would “pay up to half of the industry’s costs of seeking regulatory approval for new reactor sites, applying for licenses, and preparing detailed plant designs” (Squassoni, 2009). The cost is approximately $550 million to implement the plan (Squassoni, 2009).

The main regulatory component of this effort was the Energy Policy Act of 2005, which addressed the energy industry at large. There were many financial incentives in this act for new builds to be first movers and to minimize risk. A key action was the extension of the Price-Anderson Nuclear Industries Indemnity Act to 2025, which authorized cost-overrun forgiveness up to $2 billion total for a maximum of six new nuclear power plants (Center for Nuclear Science and Technology Information, 2005). The Act also authorized a production tax credit of estimated at 1.8 US¢/kWh for up to $125 million total a year, for the first eight years of operation of the first 6.000 MW of capacity (NEI, 2020). The Act authorized loan guarantees of up to 80% of a project’s cost to be repaid within 30 years or 90% of the project's life (U.S. Department of Energy, 2010). It authorized spending $2.95 billion on research and development along with building an advanced hydrogen cogeneration reactor (World Nuclear Association, 2020). And finally, it authorized standby support for new reactor delays for the first six reactors (Energy Policy Act 2005).

The Energy Policy Act of 2005 created significant subsidies for the nuclear industry, specifically for the first new nuclear reactors, including “production tax credits, energy facility loan guarantees, cost-sharing, limited liability, and delay insurance” (Squassoni, 2009). These subsidies were crucial aspects of the plan to entice utilities to invest in new nuclear since it had been such a long time for new nuclear in the United States.

During this time, the NRC created Early Site Permits (ESP), which creates an option process to review site “safety, environmental, and emergency planning considerations” before utilities submit site-specific reactor design reviews (Squassoni, 2009). This permitting mechanism has largely not been used, with utilities directly submitting COLs, but there have been three ESPs for Clinton, Grand Gulf, and North Anna project sites (Squassoni, 2009).

Current Regulations

In the United States, there are two main routes for obtaining the necessary licenses to build a new nuclear power plant: Two-Step Licensing Process and Combined License. The Two-Step Licensing Process was first established in 1989, but there was a large effort in the early 2000s to ensure a smoother licensing process. The newer, simplified option for licensing a new nuclear energy plant is codified under 10 C.F.R. Part 52 of NRC’s regulations.

Figure 6 shows an ideal timeline for how the Two-Step Licensing Process first required applicants to receive the Construction License (CL), and then after construction would receive the Operating License (OL). Figure 7 similarly shows an ideal timeline for the new permitting process where the COL is received at the beginning of the project and the NRC certifies that the construction was built to the correct standards at the very end. Both processes include a pre-licensing process, which in the United States could consist of a design certification or early site permit. In the best-case scenario, they should also take around 10 years to have the plants operational, but this has not shown to be true with recent builds in the United States.

Figure 6: 1970- Today Licensing Structure: 10 CFR Part 50 (World Nuclear Association, 2015)

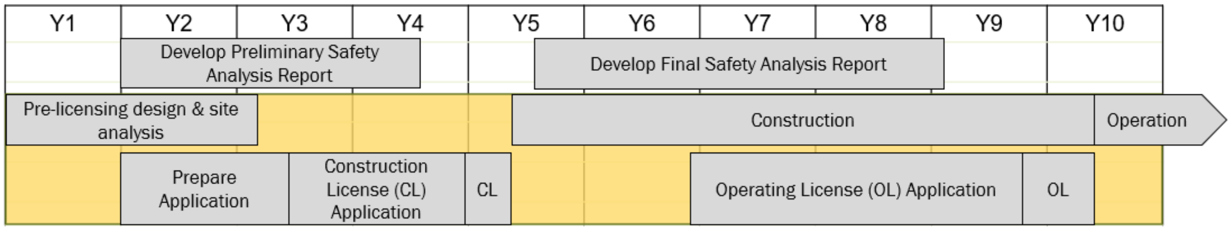
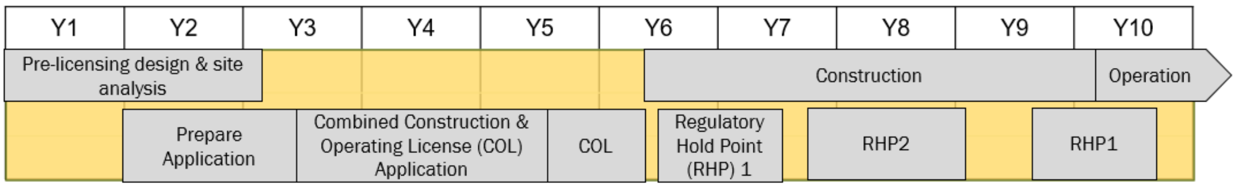


Figure 7: Additional post-2005 Structure: 10 CFR Part 52 (World Nuclear Association, 2015)



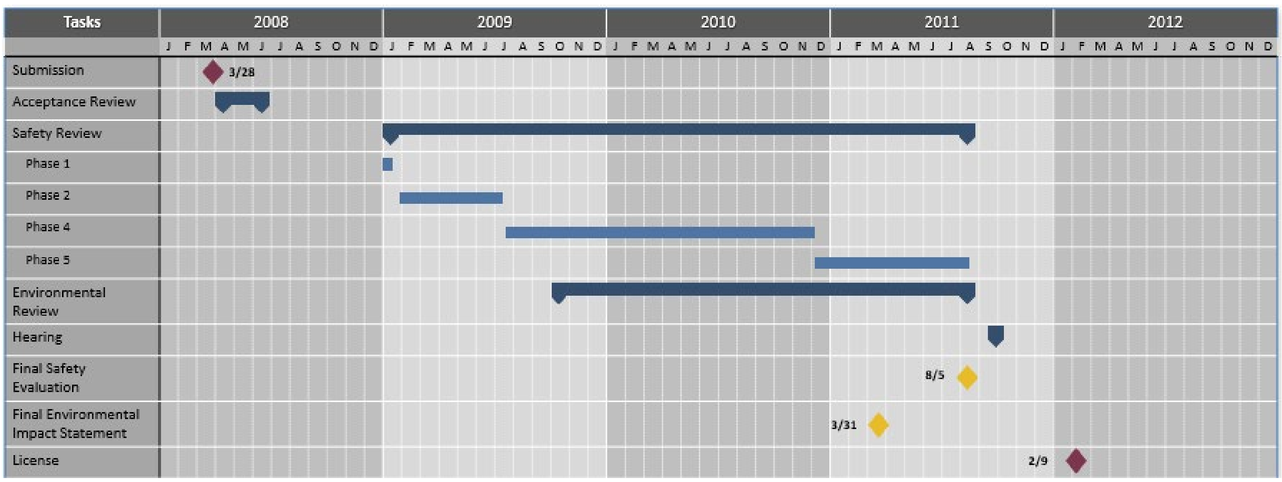
The recent plants have opted to submit their permitting applications under 10 CFR Part 52, but there is nothing prohibiting applicants from applying under 10 CFR Part 50. During the interviews, we heard that the COL, in theory, should have made the licensing, construction, and approval for operation easier, but it tends to lock applicants into a single plan. Should anything change during construction, it is very difficult to get approval from the NRC to adapt to that change. This makes the utility increase the amount of time that they are waiting for change approvals or comments from the public.

New Nuclear Construction Time

Before the latest round of controversial nuclear builds in the 2000s, the newest rectors to enter into services were Tennessee's Watts Bar Unit 2 (June 2016) and Watts Bar Unit 1 (May 1996) (EIA, 2019). During the construction of Units 1 and 2 in 1985, TVA suspended construction of Watts Bar Unit 2 (U.S. NRC, 2016). Then during the time of increased interest in nuclear energy as previously discussed, TVA informed the NRC in 2007 of its plan to restart the construction of Watts Bar Unit 2 (U.S. NRC, 2016). The Tennessee Watts Bar Unit 2 operating permit was issued on October 22, 2015. Therefore, from re-initiation of construction to the issue of the operating permit took approximately 10 years.

Vogtle is currently the only project that is still under construction in the U.S. Unit 3 and 4 had the COL permit issued on February 10, 2012 and have yet to be approved for operations. Work began in 2009 to prepare the site, and after receiving their COL they began construction in 2013 (Staff reports, The Atlanta Journal-Constitution, 2017). The construction was supposed to be completed by 2016 for ($14 B) for Unit 3 and 2017 for Unit 4, but they are still under construction (EIA, 2019).

Figure 8: Timeline of Vogtle 3 & 4 Application Review (U.S. NRC, 2017)



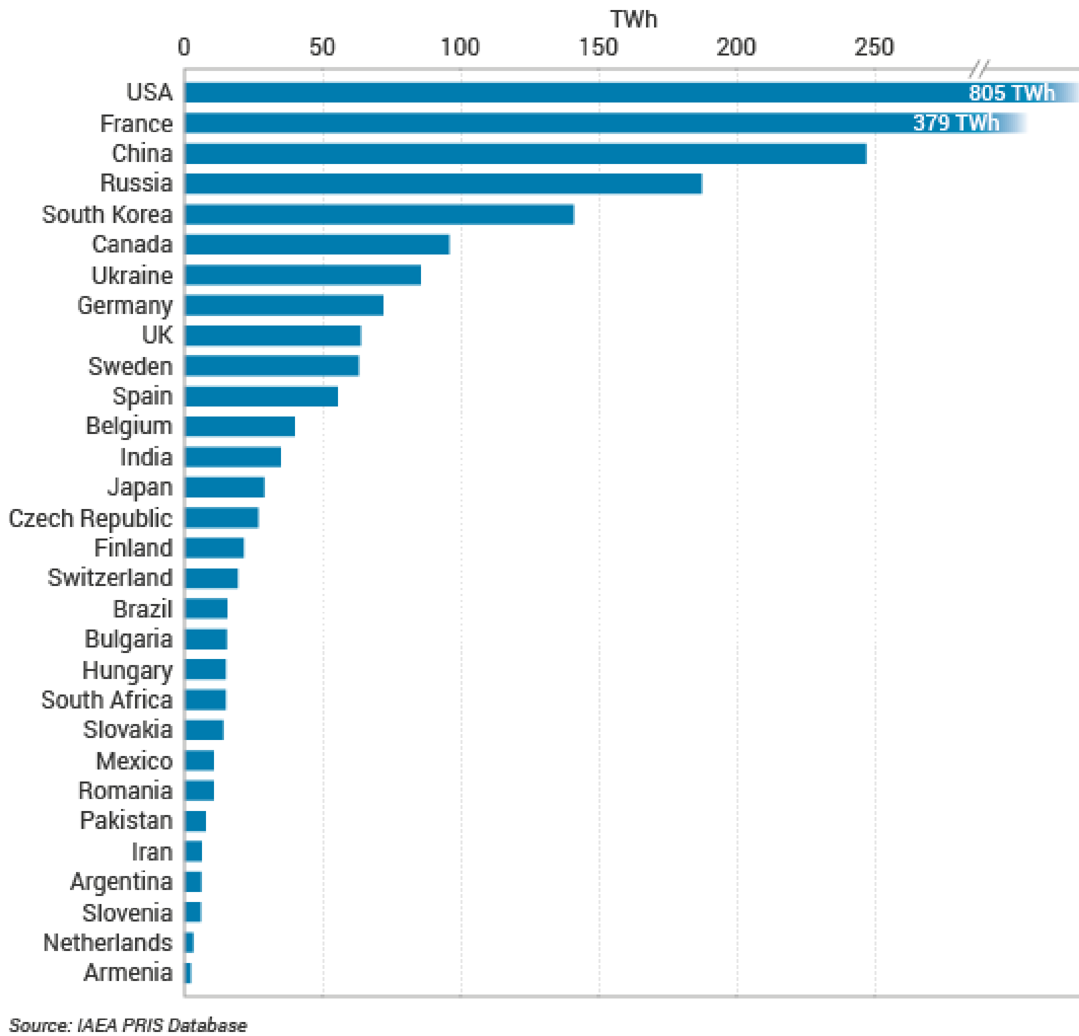
In a recent update from Georgia Power, the project successfully completed all milestones in the first three months of 2019 (Georgia Power, 2019). This indicates an improvement in project management as they have previously missed key construction milestones. Based on the company's current analysis, the Vogtle project is now on track for the updated project deadline approved by the Georgia Public Service Commission (PSC). The new goal dates are November 2021 for Unit 3 and November 2022 for Unit 4 (Georgia Power, 2019). So far, their project planning and construction process has lasted over 10 years.

Review of International Nuclear Regulatory Systems

To understand how the United States has created an ecosystem where nuclear energy is not favored is being closed early, and is not being built, it is important to look at the trends of new nuclear in other countries and infer who has been successful at continuing to deploy nuclear power plants. Though nuclear energy is not favored worldwide, it provides approximately 10%

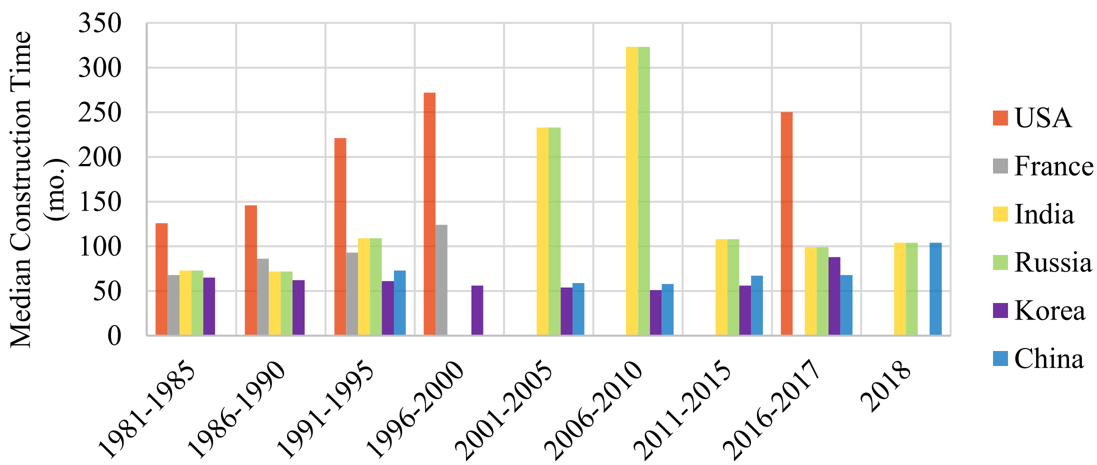
of the world's electricity from only 440 power reactors (World Nuclear Association, 2020). Most nuclear electricity generation is in very few countries, with the United States having the largest generation of 805 TWh (Figure 9).

Figure 9: Nuclear Generation by Country 2018 (World Nuclear Association, 2020)



As shown in Figure 10, the United States and Sweden similarly ramped up their nuclear fleet in the 70s and 80s, slowing in the last 30 years due to safety concerns (World Nuclear Association, 2020). France has consistently built facilities and is a leader in advanced technologies (World Nuclear Association, 2020). China and Korea have recently ramped up nuclear programs, due to a need for a lot of carbon-free energy (Zhou, 2020) (Kim, Shin, & Chung, 2011). Interviewees also noted that the top-down policies in China and UAE have helped to drive nuclear development as barriers are removed. Additionally, interviewees stated that the standardization in nuclear design is key to the fast development in Korea and China.

Figure 10: International Nation Construction Period Length (International Atomic Energy Agency (IAEA), 2019)



Environmental Community Perception

Due to the environmental community's complex historical and current perspectives on nuclear energy, it is worth considering if they will help turn the perspectives on nuclear energy. There has been a recent turn in the support for nuclear energy in the United States. As Stewart Brand, the founder of the Whole Earth Catalog, aptly stated: "it's not that something new and important and good had happened with nuclear, it's that something new and important and bad has happened with climate change" (New York Times News Service, 2005). This shift by some acknowledges that if we need to quickly reduce the emissions from the United States' energy mix, nuclear energy should be at least part of the conversation.

Though there are changing sentiments in some aspects of the environmental community, not all are changing their anti-nuclear leanings. Sierra Club and Greenpeace still are strongly anti-nuclear (Table 2). Sierra Club strongly believes that nuclear disasters make nuclear energy too dangerous, stating "although nuclear plants have been in operation for less than 60 years, we now have seen three serious disasters" (Sierra Club, n.d.). Similarly, Greenpeace is concerned that "nuclear power is dirty, dangerous and expensive" (Greenpeace, n.d.).

Table 2: Environmental non-profit's stance on nuclear energy over time

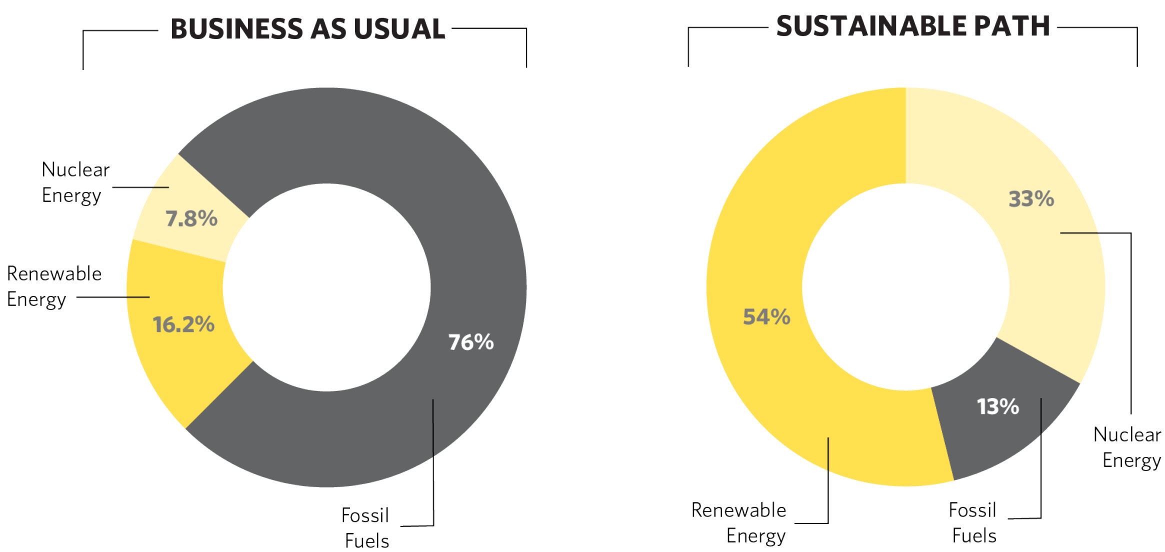
Non-Profit	Post-Three Mile Island (1980-1985)	Current (2020)
Environmental Defense Fund	Anti-nuclear energy	Supports maintaining nuclear that otherwise would be replaced by fossil fuel generation
Sierra Club Foundation	Anti-nuclear energy	Anti-nuclear energy
Greenpeace Fund	Anti-nuclear energy	Anti-nuclear energy
The Nature Conservancy	No formal comment on nuclear energy	Supports increasing share of energy from nuclear (The Nature Conservancy, 2018)
Union of Concerned Scientists	Anti-nuclear energy	Supports increasing share of energy from nuclear

However, there any are many environmental organizations that no longer outright deny that nuclear energy can be a part of a good energy mix. The Environmental Defense Fund (EDF) has a nuanced viewpoint on nuclear energy, generally supporting policies that keep nuclear in service that would otherwise be replaced by fossil fuels. EDF supported ZEC in Illinois when the policies "designed and implemented right, they can yield significant long-term environmental benefits" (Finnigan, 2017). However, in 2018, EDF supported shutting down a California nuclear plant because in that situation "continuing to operate an aging and increasingly unnecessary source of baseload power – or power that cannot ramp up and down quickly – doesn't make sense" (Koehler, 2018).

Similarly, the Union of Concerned Scientists is primarily interested in keeping current plants open and ensuring that their policies to ensure safe plant operations. In 2018 they conducted a study and determined that "nearly 35 percent of the country's nuclear power plants, representing 22 percent of US nuclear capacity, are at risk of early closure or slated to retire. To help avoid the worst consequences of climate change—and avoid costly overreliance on natural gas—we need carbon-reduction policies that better reflect the value of low-carbon electricity" (Clemmer, Richardson, Sattler, & Lochbaum, 2018). The Union of Concerned Scientists also couched their support for public funding in the need for accompanied "consumer protection, safety requirements, and investments in renewables and energy efficiency" (Clemmer, Richardson, Sattler, & Lochbaum, 2018).

Of the environmental non-profits researched, The Nature Conservancy is the most supportive of new nuclear generation worldwide. Though in the past they have not commented openly about nuclear energy, they recently included nuclear as part of their Sustainable Path for the future. The Nature Conservancy believes that to meet worldwide energy demands and address climate change, 33% of electricity should come from nuclear energy (Figure 11).

Figure 11: The Nature Conservancy's changing energy portfolio analysis (The Nature Conservancy, 2018)



There are critics of this change in support. Researchers have found that the public's growing acceptance with nuclear power is consistent with the notion of a "forgetting period," when there is an intense period of concern right after an environmental incident and then over time the incident becomes more palatable in memory (Culley & Angelique, 2010).

Analysis

As outlined, the timeframe for licensing and the associated costs of new nuclear power plants in the U.S. have increased since Three Mile Island (TMI) accident in 1979. Directly after TMI, there was an increase in the licensing, construction, and certification timeline due to the new regulations to address safety concerns and appropriately minimize risk. However, over the years the continual new addition of regulations has created burdens on new constructions such that new builds are too risky. Due to the complexity of the social, environmental, political, and economic forces pushing on the industry, no one regulation or aspect elongated the licensing and construction timeline. Though the main driver of the regulation risk is that the NRC maintains the capability of changing regulations and requirements during the licensing and construction period. For example, after Fukushima, a utility with a COL for a nuclear plant had to reassess its flood plan studies, which causes a multi-year long delay. Utilities fear that if they start building a new power plant, they could likely face cost overruns and delays should a safety incident occur at any other nuclear power plant.

Another main driver of the longer new build timeline is the change of regulations to include more 3rd party reviews and public participation. After the Three Mile Island accident, there has been an overarching concern for nuclear safety. The permitting and review process is longer because different advocacy groups can participate in the permitting and review process through public comment periods and public meetings. With the creation of the COL, the NRC tried to limit the amount of advocacy group involvement. But utilities and the NRC are hesitant to push back and make decisions based on how the actions are perceived by the population. Environmental non-profits historically used these reviews to slow down or stop new nuclear project development. As these non-profits begin to support nuclear, the risk of delays to extended review periods will be minimized.

However, this study shows that the safety-driven increase in new requirements for new nuclear plants is not the only barrier for new builds. The industry has faced a lack of expertise in planning and construction since there have been very few newly constructed nuclear power plants in the last 30 years. This lack of human capital is pervasive across the supply chain and it spans the know-how for the planning process, all the way to not having knowledgeable suppliers of concrete.

Additionally, there were issues in the most recent new builds because they did not follow the new regulation procedure correctly: Per our interviews, Part 52 intended to have the procedure to first approve the technology of the leading nuclear power plant and then, allow all other plants to use the same approval for the following nuclear plant applications. In the 2000s, utilities were encouraged to apply for permits due to the economic incentives and other energy factors. Hence, they did not wait for the first plant to be fully approved. This meant that the permits were amended each time the initial permit application was amended, creating much additional work and delays.

Though these are not the only barriers to new nuclear power plant builds in the United States, these four reasons in addition to safety requirements are the main drivers increased construction time and cost overruns. These factors span each part of the new construction process, indicating that utilities that are looking to build new nuclear have additional risks at each step. The diversity of the factors at play also indicates that any corrective actions to make new nuclear more feasible will also need to be diverse and will take concentrated efforts of the electricity industry, regulators, environmentalists, and the population.

Recommendations and Conclusion

Based on the interviews conducted, there is limited utility interest in moving on building new nuclear in the United States. The factors identified increased new build construction risk, which the industry observed at Summer and Vogtle. These risks add to the high upfront and operating costs of the plants, which make them uneconomic in certain markets. The industry is in a wait-and-see mode for whether necessary changes occur to that address the identified factors and larger economic issues. Industry experts state that a new consideration would require increased natural gas prices, carbon pricing, and a simplification of the regulatory system. At this time, it is unlikely for these changes to occur. Instead, there is an increasing interest in small module nuclear plants as a solution to build carbon-free generation and minimize safety and financial scale risks.

Though large-scale new nuclear builds are paused the energy industry can take a few steps to make nuclear more favorable in an environment that is more climate conscious. First, industry groups should ensure that newly gained industry knowledge is not lost. They should also work with the NRC and other relevant agencies to appropriately simplify regulations and incorporate technology. The industry can partner with supportive environmental groups to change policies and shift public opinion. Lastly, they can support small module nuclear research and development. Together, these steps will help to reduce barriers and adapt to the changing energy industry conditions.

Due to the identified barriers, without major changes, new nuclear plants builds are unlikely in the United States. Regulations have created increased regulatory uncertainty over the years, which has increased the average length of the new nuclear timeline. This research found that in addition to the regulatory barriers, the industry is now inexperienced at building these large, bet-the-company projects, and does not have the adequate supply chain and adequate craftsmen available, which adds to the new project risk profiles. Based on this analysis of the state of the industry and current regulations, it is unlikely for there to be new nuclear built in the United States without changes to the economic landscape and regulations.

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Appendix

Appendix A: Interview Questions

Standard Questions for Nuclear Energy Research Conversations

1. If you were involved with the industry before Three Mile Island:
    a. Can you describe the process of building a new plant at the time?
    b. What were the dominant concerns?
    c. Motivations?
    d. What were the basic economic drivers? (Fuel cost? Retail power pricing? Construction cost?)
2. If you were involved with the industry during Three Mile Island:
    a. What were the key points of conversation surrounding the incident?
    b. What were your immediate business strategy concerns?
    c. What happened to in-progress builds?
3. In the era since Three Mile Island, what has been the most influential or important regulatory change?
    a. What is your opinion of that change?
4. What is your opinion of nuclear energy from an environmental point of view?
    a. What features of nuclear generation do you view as environmentally positive? Negative?
    b. How do you view the waste fuel disposal issue?
    c. What are your environmental and safety concerns from normal operations and end of life planning?
5. What are the major barriers to new nuclear generation today?
    a. Regulatory?
    b. Technological?
    c. Environmental?
    d. Financial?
6. What changes to the nuclear generation space would you encourage?
    a. How should advocacy for that change look?
7. If you are familiar with international nuclear energy projects, what international examples of nuclear generation stand out as noteworthy or potential learning opportunities?