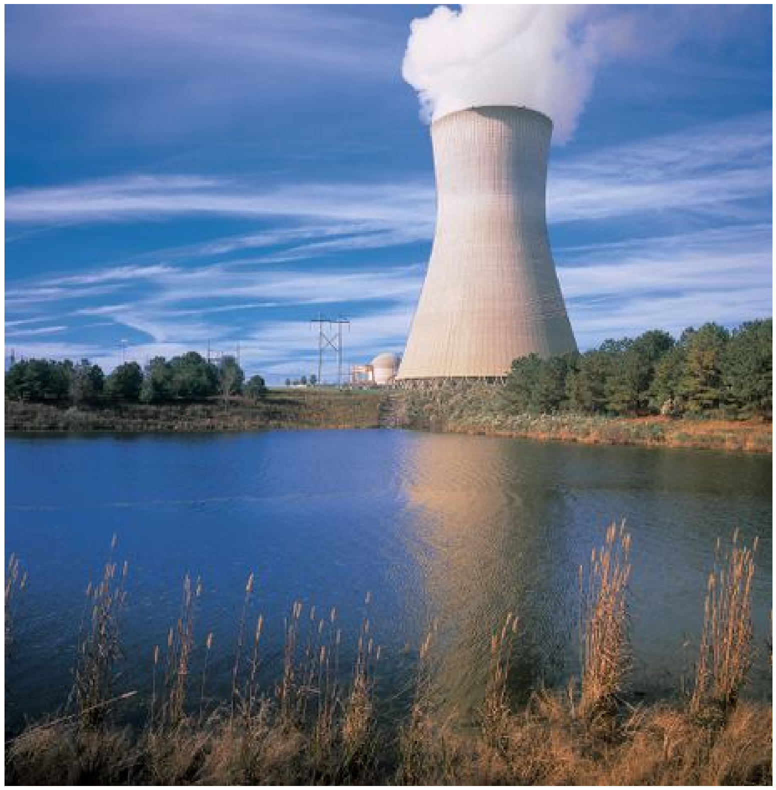

Figure 1: Duke Energy's Harris Nuclear Plant (Duke Energy, 2013)

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

by

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Executive Summary

This research investigates what changes in the domestic regulatory framework led to the decline of new utility-scale nuclear power construction, particularly in comparison with other countries' expanding nuclear fleets. Three key questions were investigated:

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?

We initially hypothesized an expanded licensing process for new construction - created after Three Mile Island (TMI) where safety was the dominant public policy concern - led to a difficult and uncertain regulatory environment. Further, we speculated the US domestic environment diverged from international peers 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 report found the original hypothesis largely validated; however, it has to be refined with several factors affecting the evolution of the US nuclear landscape versus international peers. The first concerns timing; increased regulatory burden more accurately began with the Energy Reorganization Act. Governmental focus changed from industry advancement to licensing and regulation, setting the stage for a safety-at-any-cost mantra following TMI.

This change in approach made its way into the NRC's licensing framework. Two later regulatory innovations were especially noteworthy: 1) the provision for opportunities for public hearings at multiple stages of the licensing process; and 2) an innovation of 'independent boards' to review critical licensing steps. These structural changes would facilitate opposition from groups determined to stop nuclear plant construction directly or via a 'delay until it dies' strategy.

Implementation of these post-TMI regulatory changes then coincided with increased opposition from third-party organizations and variable support from local communities. Modern attempts at streamlining the licensing burden have not addressed the issue of third-party interference. Moreover, the NRC has been reluctant to address the third-party organizations to avoid the perception of regulatory capture.

Third, the U.S. regulatory regime especially differs from international peers in one key area - the presence of a top-down national directive. The decentralized utilities operating in the U.S. have no quantitative, nationwide directives or mandates for nuclear production.

Our research draws on the examined history within the US and the experience of peer nations to suggest several changes for regulators and industry participants.

- Specific changes to licensing processes limiting obstructionist strategies by determined opponents of new builds, while protecting needed engagement from community and environmental groups raising legitimate concerns. Thus, NRC guidelines on when third-party groups can provide input must be more bright-line
- As the licensing process becomes more modular, delays or follow-up requests should only impact the relevant module of licensing. The NRC should have the authority to recognize a minor change as such, avoid repeat work, and ensure parties are only repeating licensing steps relevant to new information
- Modularity should not come at the expense of opportunities for licensing and entire facility from the outset. New information should impact only the relevant stage of licensing
- Operators should utilize more standard designs, even if those designs are slightly older. Iteration of reactor design can enter the process after establishing reliable construction processes and supply chains
- Policy should recognize that de-carbonization is cost prohibitive with current technology without the use of nuclear power, particularly with nuclear plants being retired. Production mandates – not financial incentives – are the best way to align the utilities with the regulators while promoting growth

Acknowledgments

This research could not have been conducted without assistance from individuals throughout the nuclear energy industry. We also are indebted to our advisor at the Kenan-Flagler Energy Center, 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

Data shows domestic utilities are not building new nuclear and the average age of the nuclear facilities is 37 years (Figure 3). Should this trend continue in combination with plant retirement, a current source of carbon-free baseload power will eventually be phased out. There are few proven carbon-free baseload options other than nuclear and hydropower (which has inherent limitations). The Kenan Energy Center's 2019 research project suggest that wind, solar, and storage are not yet economically viable for baseload power.

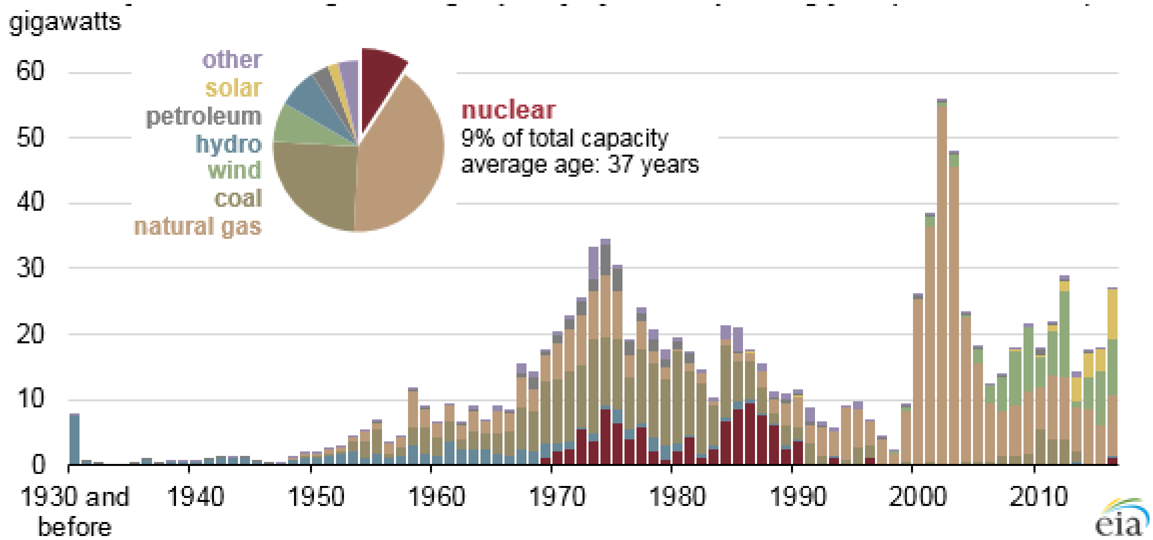


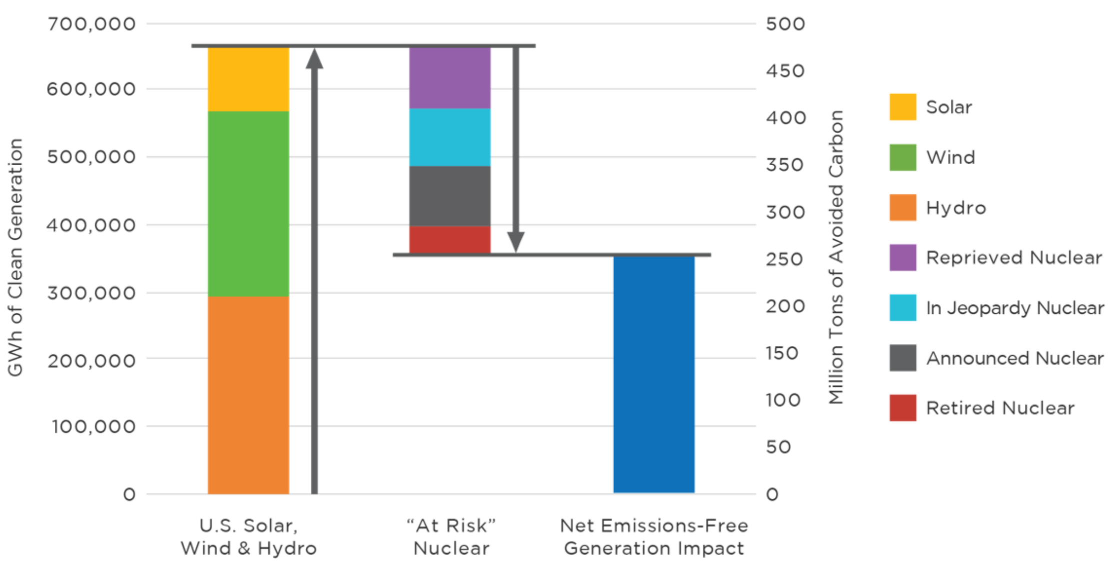
Figure 2: U.S. utility-scale electric generating capacity by initial operation year (as of Dec 2016) (EIA, 2017)

Instead, the 2019 report suggested 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 to have 100% renewables on the electricity grid, energy storage would need to be priced at $20 per kilowatt-hour in energy capacity costs, which would be 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.

However, the nuclear energy industry is facing resistance in the United States. New nuclear generation in the United States has stifled, (Figure 3) while existing nuclear generation has been taken offline (Baker, Lawrie, & Lozier). Recent cost overruns on nuclear plants have raised doubts as to 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 U.S. ScottMadden identified that the greenhouse gas emission reductions from increased renewable deployment would be significantly offset by the simultaneous reduction of the nuclear energy fleet in the United States (Figure 4). Furthermore, the study showed that “nearly 90% of the wind and solar output that has been added since 2008 would be given back (sic) to fossil sources” (Baker, Lawrie, & Lozier). With this question of carbon-free baseload generation lingering after previous Energy Center research, we set out to determine how the US arrived at the current nuclear landscape.

Figure 3: Potential Give-back of U.S. Carbon-Free Generation with Loss of “At Risk” Nuclear Generation (as of 2018) (Baker, Lawrie, & Lozier)



Methods

To determine the effects of regulatory change on the licensing and construction time length for new nuclear power plants in the United States, we first reviewed literature exploring the changes to domestic regulations for new or under-construction nuclear power plants emphasizing changes after Three Mile Island.

Second, we gathered data on the timeline of licensing and construction times over the last 50 years to determine the net impact.

In the third stage of the study, we interviewed 20 industry experts involved in the many aspects of nuclear energy within the United States. Questions were intended to identify historic – and modern - systems in nuclear regulation and the key reasons for the elongated licensing and construction timespans in the United States.

Finally, we analyzed nuclear regulations and programs around the world. Particular focus was placed on the United Arab Emirates due to their recent expansion into nuclear power and South Korea for its continued growth of both domestic generation and international engineering expertise. International practices were examined by literature review for specific countries where nuclear growth has continued. Domestic & international analyses were then compared and contrasted to identify divergent regulatory practices and their impacts.

Historical Review of Nuclear Energy in the United States

With World War II over, the US government encouraged former Manhattan Project departments to develop nuclear energy generation. The first successful attempt happened in 1951. Shortly following, the first commercial nuclear plant – in Shipping port, PA – reached full power in 1957 (U.S DOE, 2006a). At this point, private companies sprang into action and began investing in nuclear.

Pre-Three Mile Island

Even 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 in 1974 (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 the NRC historian, this change had a larger impact on the overall theme of the regime change than

TMI as it laid the framework for future changes. The regulatory mindset in the U.S. changed from 'we'll build nuclear too cheap to meter' to 'nuclear must be watched' (Wellock, 2020). It cannot be overstated that this mindset shift began *before* TMI.

Changes After Three Mile Island

The Three Mile Island event occurred when the Three Mile Island Unit 2 reactor 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 corrective actions needed to be taken and 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, TMI forced the NRC to tighten and heighten its regulatory oversight (U.S. NRC, 2018). A partial list of the modified regulations that impacted licensing and construction and their impacts are shown in Table 1.

Table 1: Examples of changes impacting nuclear power plants after Three Mile Island (nrc.gov)

CHANGE	IMPACT
NRC MANDATE	Pause on the licensing of new reactors
NUREG-0654	Increased emergency preparedness
FEMA REP[1] PROGRAM	NRC developed emergency response capabilities alongside FEMA
NUREG-0713	Greater tracking of annual total radiological exposure for plant employees
RESIDENT INSPECTOR PROGRAM	Expansion to include two on-site inspectors living near operating plant providing daily surveillance

[1] REP = Radiological Emergency Preparedness

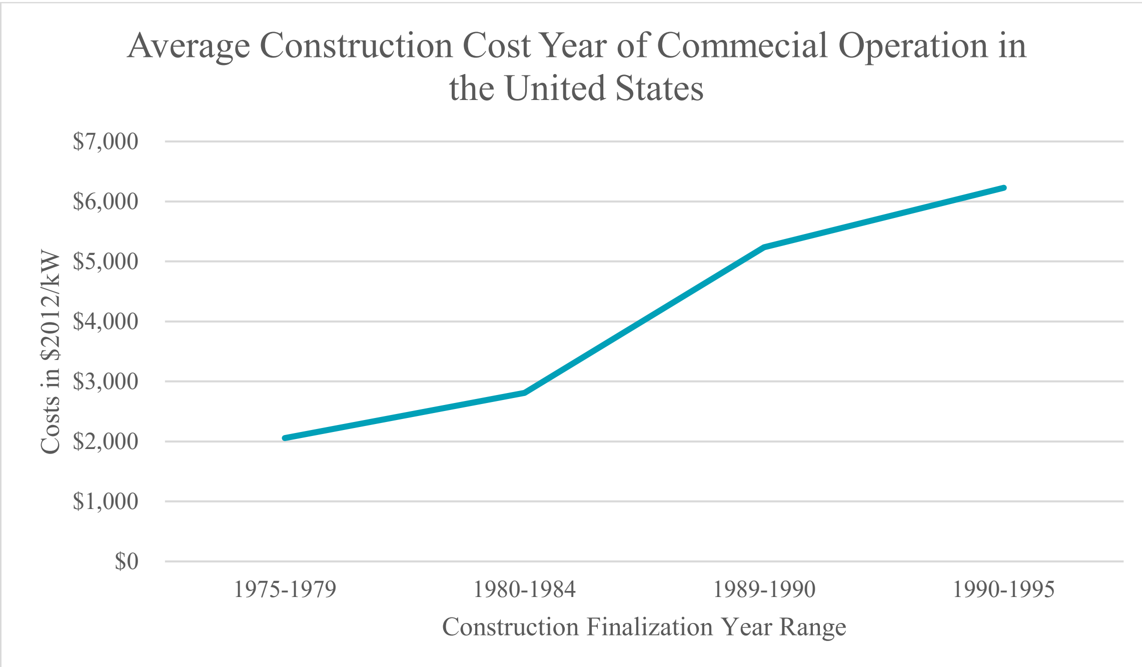
RADIATION MONITORING EQUIPMENT	Radiation protection and measurement for plant personnel and local populations.
FORMATION OF INPO	Operators organized to create an academy for operator training and sharing best practices

In response to regulatory changes, the industry responded to ensure compliance and improve organization. In 1979, industry participants created the Institute of Nuclear Power Operations (INPO) 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 main rational for this was that the industry as whole was judged by the worst player. By keeping everyone accountable and given the best practices, industry hoped to eliminate 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 retrofit costs - suggesting the nuclear industry spent approximately $5 billion on retrofit-related costs (GAO, 1982). These changes also resulted in continued construction cost increases, shown in Figure 5 as the average construction cost per kilowatt of all U.S. nuclear plants. These costs were largely unexpected or added on later, making utilities wary about the true cost of new nuclear builds. Additionally, increased financing costs due to extended construction periods resulted in longer timelines before recouping costs.

Figure 4: Average Construction Cost Year of Commercial Operations in 2012 adjusted $/Kw (Navigant Consulting, Inc., 2013)



Every industry participant we spoke to was clear in their approval of most post-TMI regulatory changes. There appeared to be consensus that the industry was lacking sufficient oversight beforehand, and the changes were a net positive for the industry. However, the incident also catalyzed the mindset shift that was already underway at the NRC. The transition from 'build generation too cheap to meter' to 'nuclear must be watched' accelerated significantly. Additionally, the NRC continued to add more and more new requirements over the years, which our interviewees stated led to overly restrictive and protective regulations.

The TMI aftermath also led to an increase in opposition to nuclear from the general public. This opposition was not only the 'not in my backyard' variety (or NIMBY), but broader (Rosa & Dunlap, 1994). Public support for nuclear power dropped by nearly a third – 69% to 46% – and resistance to nuclear power took on a new life (Ramana, 2011).

Environmental and community organizations demanded and achieved opportunities for public hearings at multiple stages of the licensing process. Moreover, the NRC, in an effort to avoid accusations of being captured by the industry, incorporated an innovation of 'independent boards' to review critical licensing steps. Collectively, these regulatory add-ons have allowed determined opponents of nuclear plants to pursue a 'death by delay' strategy, wherein the licensing process is so prolonged and uncertain that large cost overruns frequently render new plants uneconomic. This structural 'multiple bites at the apple' for project opponents is largely absent in foreign locations. As will be discussed later, the foreign avenue for formal opposition is wrapped into a political process and mostly ends when leaders (elected or otherwise) finalize energy plans.

New Licensing Procedures Post-TMI

The Energy Policy Act of 1992 (H.R. 776), aimed at improving energy efficiency (102nd Congress, 1992), created an all-in-one licensing process under 10 CFR Part 52 for new nuclear reactors. Part 52 enabled utilities to apply for both a construction and operating permit at one time to prevent nuclear plants from receiving their construction permit without ever receiving the operation permit. Several had previously suffered that fate (Squassoni, 2009).

Key Changes in the 2000s

President George W. Bush supported a nuclear power renaissance during 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). His administration's 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)/Final Design Approval (FDA) for advanced reactor designs, and Combined Construction and Operating License (COL) (Johnson, 2002). Under NP 2010, the DOE would pay up to half the industry's costs of seeking regulatory approval for new reactor sites, applying for licenses, and preparing detailed plant designs (Squassoni, 2009). As of today, there have been two groups assisted in preparing the combined Construction and Operating Licenses (COLs): Dominion Resources for the GE Economic Simplified Boiling Water reactor (ESBWr) and NuStart.

The main regulatory component of the administration's effort was the Energy Policy Act of 2005. Among its provisions spanning the energy industry, the act extended the Price-Anderson Nuclear Industries Indemnity Act through 2025. Legislature authorized cost-overrun forgiveness of up to $2 billion total for up to six new nuclear power plants. The act also authorized: a production tax credit of up to $125 million total a year, estimated at 1.8 US¢/kWh during the first eight years of operation for the first 6.000 MW of capacity; loan guarantees of up to 80% of a project's cost to be repaid within 30 years or 90% of the project's life; $2.95 billion for R&D and building of an advanced hydrogen cogeneration reactor at Idaho National Laboratory; and standby support for new reactor delays for the first six reactors (Energy Policy Act 2005) (Squassoni, 2009). New nuclear in the United States had fallen by the wayside and these subsidies were crucial aspects of the plan to entice utilities to invest in new nuclear.

During this time, the NRC created Early Site Permits (ESP), which allow reviews of site safety, environmental, and emergency planning considerations before utilities submit site-specific reactor design reviews. ESPs have 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).

In hindsight, the actions of the 2000s created a better financial landscape for new nuclear yet did little to address the overall timeline. Whether concrete steps to shorten the construction timeline would have acted as a more effective subsidy is an area for further research, but the level of financial subsidy necessary for a 10+ year investment needed to be higher than what was offered.

Current Regulations

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

Figure 6 shows an ideal timeline for how the Two-Step Licensing Process. The process first required applicants to receive the construction license (CL), then after construction would receive the operating license (OL). Figure 7 similarly shows an ideal timeline for the new permitting process where the construction and operating license (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, both processes should also take around 10 years to have the plants operational. Recent plants have opted to submit their permitting applications under 10 CFR Part 52, but no rules prohibit applicants from applying under 10 CFR Part 50.

Figure 5: 1970- Today Licensing Structure: 10 CFR Part 50 (World Nuclear Association, 2015)

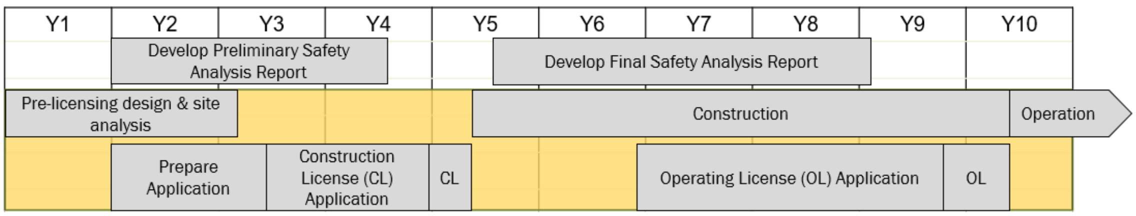
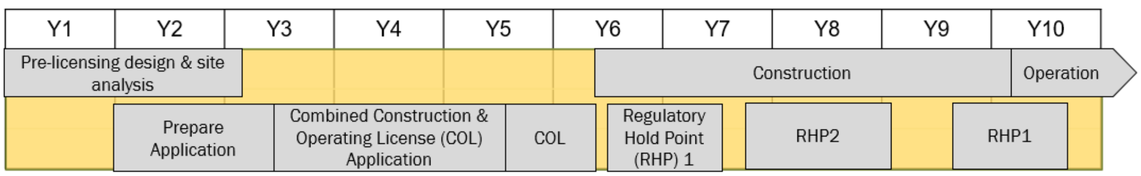


Figure 6: Additional post-2005 Structure: 10 CFR Part 52 (World Nuclear Association, 2015)



What might be a minor change for both the operator and the NRC can open the window for a new round of public opposition to delay or stop construction.

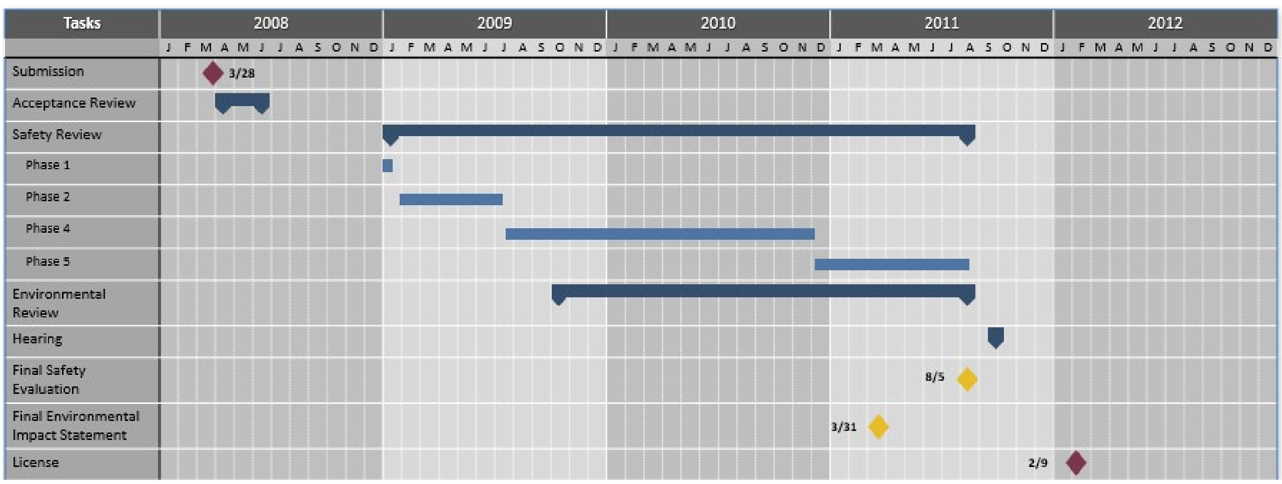
New Nuclear Construction Time in the United States

The sample size of domestic new nuclear is small. Drawing significant statistical conclusions is difficult and rough observations are the best option. We thus draw on the two most recent examples of domestic construction as representative of the modern experience.

Before Vogtle, the newest rectors to enter the domestic fleet were Tennessee Valley Authority's Watts Bar Unit 2 (June 2016) and Watts Bar Unit 1 (May 1996) (EIA, 2019). TVA suspended construction of Unit 2 in 1985 – nearly 80% complete with the project – due to lower expected power demand (U.S. NRC, 2016). During the time of increased interest in nuclear energy in 2007, TVA informed NRC of its plan to resume construction of Watts Bar Unit 2 (U.S. NRC, 2016). The TVA Watts Bar Unit 2 operating permit was issued on October 22, 2015, with commercial operation the following year. Therefore, re-initiation of construction to commercial operation took approximately 9 years, and that for a unit which was once close to completion.

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

Figure 7: Timeline of Vogtle 3 & 4 Application Review (U.S. NRC, 2017)



The project completed all first quarter 2019 milestones, including setting the Unit 4 pressurizer and the Unit 3 containment vessel top head (Georgia Power, 2019). Based upon the company's current analysis, the Vogtle project remains on track for completion within the Georgia PSC-approved schedule of November 2021 (Unit 3) and November 2022 (Unit 4). So far, their project planning process has lasted over 10 years (Georgia Power, 2019).

Review of International Nuclear Regulatory Systems

To better understand the domestic impact of regulation, we examined nuclear power regimes in other countries. In particular, we investigated the regulatory and political impact on the industry.

Nuclear energy 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).

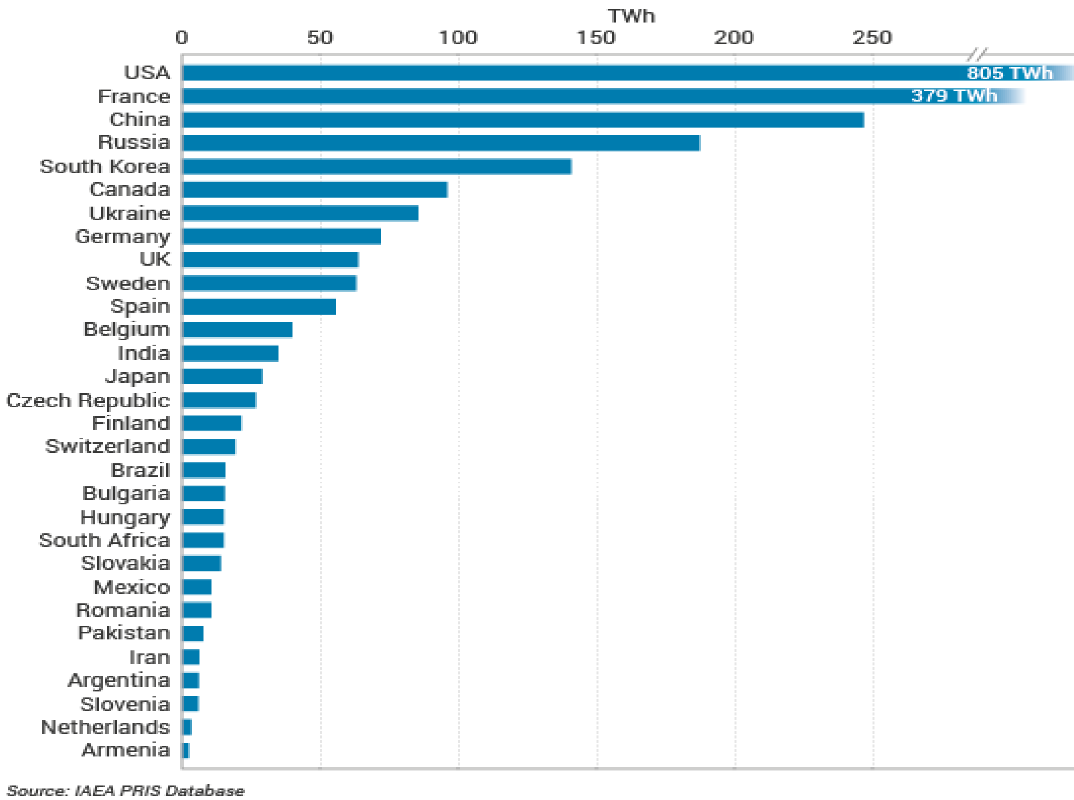
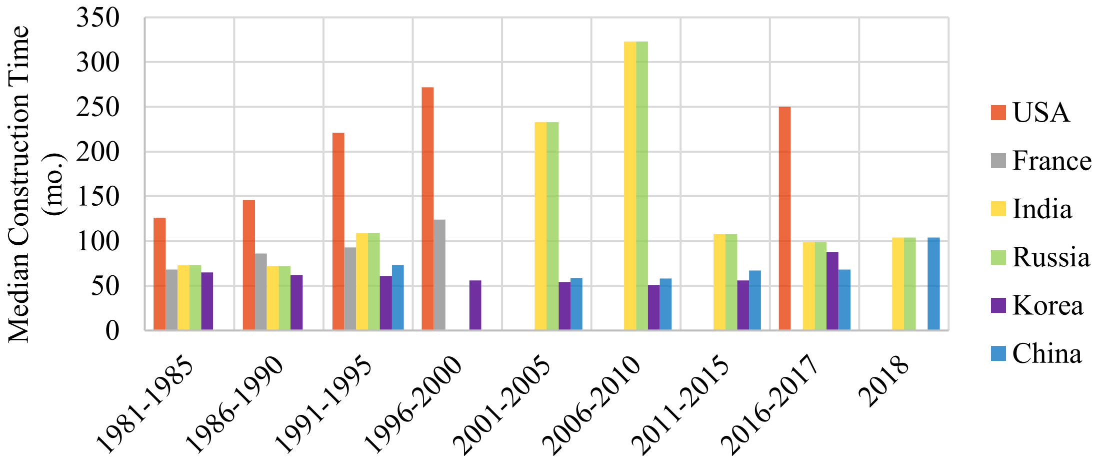


Figure 8: Nuclear Generation by Country 2018 (World Nuclear Association, 2020)

The United States average construction time has slowed over the past thirty years (Figure 10) (World Nuclear Association, 2020). Korea has consistently built facilities and is a leader in advanced technologies (World Nuclear Association, 2020). More recently, China ramped up nuclear programs with an increased focus on large-scale, carbon-free energy. France and Sweden had rapid expansion of nuclear power in the late years of the 20th century, though recent political resistance in both countries has resulted in few new builds and some early decommissioning. The differences in approach and outcome are driven by policy structure and standardization.

Figure 9: International Nation Construction Period Length (International Atomic Energy Agency (IAEA), 2019)



United Arab Emirates (UAE)

The newest country to build nuclear electricity generation is the United Arab Emirates (UAE), which finished loading fuel into the Unit 1 of the Barakah Nuclear Energy Plant on March 3, 2020 (Otaiba, 2020). Part of an overall endeavor to build 4 units, Barakah was spurred by a 2006 report by the states in the Gulf Cooperation Council analyzing the future of energy in the countries and planning to peacefully use nuclear energy (World Nuclear Association, 2020). The region experienced a 668.75% increase in electricity demand from 1990 to 2017, partially due in part to the increase in the use of desalinization for potable water (IEA, n.d.).

After the 2006 report was published, the UAE worked with its allies to ensure the international community supported the building of a nuclear plant. In 2009, the nation founded a 'Supreme Council of Energy', an independent legal entity that oversees all of the UAE's energy needs (World Nuclear Association, 2020). The UAE also established a Nuclear Energy Program Implementation Organization, which in turn set up the Emirates Nuclear Energy Corporation (ENEC) as an Abu Dhabi public entity (World Nuclear Association, 2020). To fund the nuclear energy project, ENEC created " joint-venture arrangements to foreign investors for the construction and operation of future nuclear power plants" (World Nuclear Association, 2020). This regulatory and company funding structure allowed the first project, Barakah Nuclear Energy Plant, to kick-off with a goal of building a four-unit plant.

Critically, ENEC knew there was not enough experience in the UAE to staff the Barakah project and requested proposals from international organizations. In 2009, ENEC chose the bid from the KEPCO-led consortium for four AP1000 units (World Nuclear Association, 2020).

> "The value of the contract for the construction, commissioning, and fuel loads for four units was about $20.4 billion, with a high percentage of the contract being offered under a fixed-price arrangement. The consortium also expects to earn another $20 billion by jointly operating the reactors for 60 years. In March 2010 KEPCO awarded a $5.59 billion construction contract to Hyundai and Samsung for the first plants." (World Nuclear Association, 2020).

With a deal in place, construction broke ground with a targeted first unit online by 2017 (World Nuclear Association, 2020). However, a one-year delayed followed by a failed comprehensive readiness review in 2018 lead to the start-up date being pushed back 1.5 years. The plant has successfully fueled the first unit in 2020 and expects the construction of the other units to now process on time.

The fast deployment of the UAE's first nuclear power plant was enabled by the leadership of a unilateral government, experience and support from outside organizations, and lack of public dissent. The nuclear project was developed by a public company, allowing it to go through many regulatory barriers more quickly than places like the United States. Parallel construction of components also enabled construction efficiency (World Nuclear Association, 2020). Korean expertise played a critical role in the initial planning and construction, but also in handing off knowledge to the local workforce. And while 'lack of public dissent' is an oversimplification of the political regime, the end result is few opportunities for third-party groups to insert themselves into the process or delay the timeline.

South Korea

The organization of Korean nuclear agencies is modeled on the American system, though the resulting industry is quite different. The post WWII Atomic Energy Department (AED) bore great similarity to the American Atomic Energy Commission. Yet, already, the AED had one critical difference – the Director of the AED reported directly to the Korean president. Later changes will expand on this theme of nuclear power being tied to the overall political landscape for energy in the country from the top down.

Initial work done by the AED shared the same public/private partnership model as the American counterpart. There was a heavy focus on research with the ultimate aim of energy independence. The move towards regulation from advancement began only slightly earlier, with the creation of the Office of Atomic Energy in 1967 and the first round of regulations for nuclear power established in 1969.

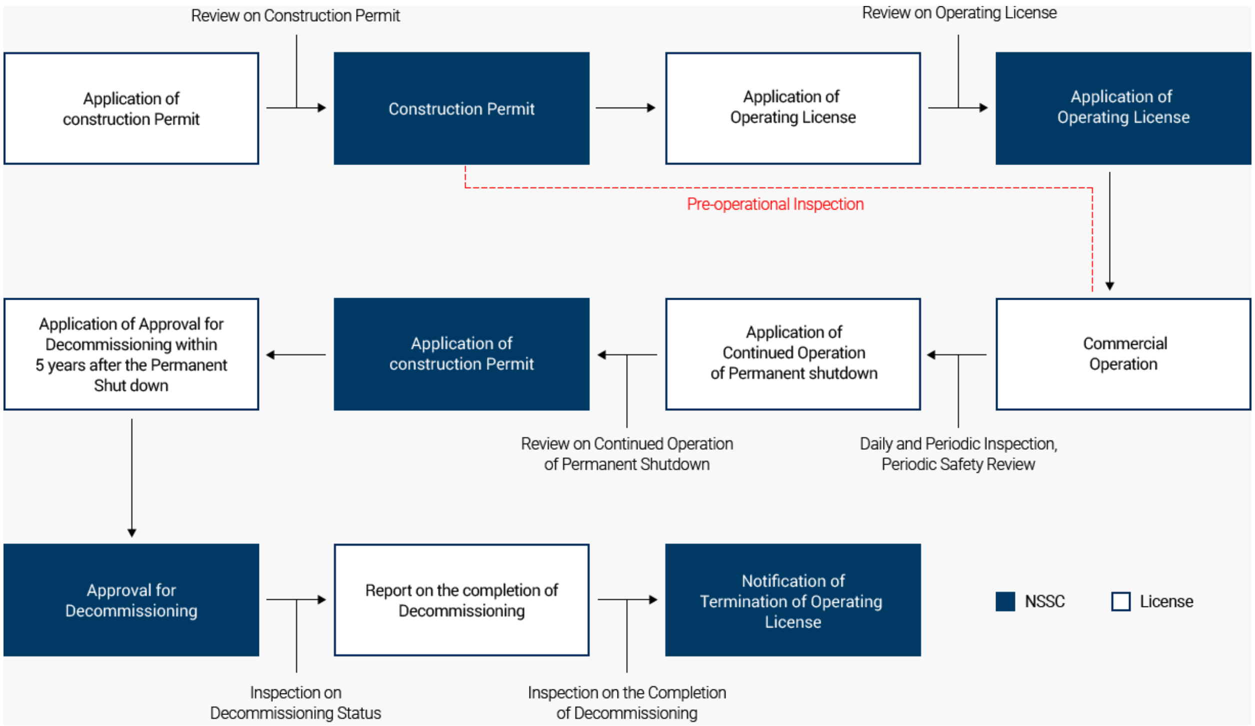
These first regulations, however, were written with the first nuclear plant, Kori 1, in mind. The *First Long Term Plan for Electricity Supply*, written in 1967, specified the intention for this first plant. The construction of the plant was thus tied to the overall political energy policy in the country. Regulation would continue to develop with later plans for energy (newer versions referred to as the *Basic Energy Plan*). These energy plans dictate the energy needs of the country and how the country's state-owned utilities will meet those needs. Nuclear has maintained a place in those plans through the current day.

It is impossible to overstate the significance of this change in approach as it relates to regulatory burden. The current regulatory body in Korea – the Nuclear Safety and Security Commission – uses nearly identical targets for safety as the American NRC. However, the NSSC is part of the political apparatus working towards the Basic Energy Plan. Stonewalling progress on a nuclear plant in Korea is not something the NSSC can walk away from the same way the NRC can walk away from a project in the United States. The same government asking the owner/operator to run the plant is asking the contractor to build the plant and asking the NSSC to keep the plant safe. The end goal of all organizations involved are the same – get nuclear plants running safely using best available information.

As a result, the Korean timeline for construction has tended to be markedly faster than the American timeline despite a nearly identical process. Instead of a private utility doing a feasibility study and presenting the case to local regulators, the national government handles the energy needs and feasibility studies centrally. Korea Hydro and Nuclear Power (KHNP) is the sole operator for nuclear in the country and files for the necessary permits. Permitting is analogous to the Part 50 domestic regime of first filing for a construction permit and following up with an operating permit.

There are a number of other permits for KHNP to file, again modeled on American equivalents (ie: Environmental Impact Assessment, Electrical Utilities Construction Plan from the Ministry of Trade Industry, and Energy). Based on available data, the target timeline for new builds to complete all of these steps two years. The NSSC specifies a goal of 15 months for previously licensed designs and 24 months for new designs (NSSC, 2020).

Figure 10: Korean Licensing Process



Even with delays, a new build in South Korea at this stage is already likely two or three years ahead of an American counterpart. The most recent two projects in Korea took five years for construction (Shin Kori 5 & 6) and eight years (Shin Kori 7).

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

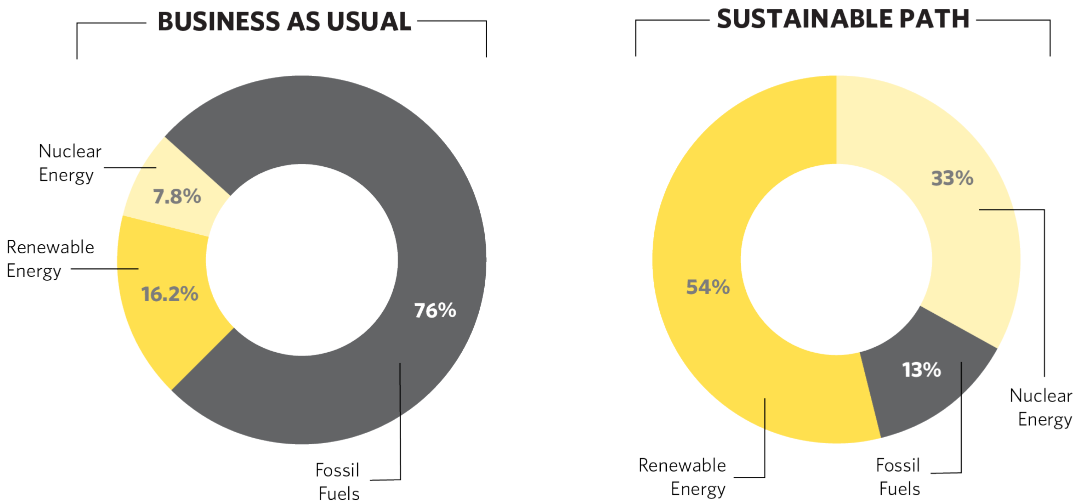
Non-Profit	Post-Three Mile Island (1980-1985)	Current (2021)
Environmental Defense Fund	Anti-nuclear energy	Supports maintaining nuclear that will be replaced by fossil fuel generation
Sierra Club Foundation	Anti-nuclear energy	Anti-nuclear energy
Greenpeace Fund	Anti-nuclear energy	Anti-nuclear energy
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. 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 12).

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



While not explicitly representing any environmental group, the Democratic Party primaries in advance of the 2020 elections expressed a range in views. The Democrats have pitched themselves as the environmentally focused party, with each of the leading candidates expressing a different view on nuclear power. Senator Bernie Sanders was vocally anti-nuclear on concerns about waste storage while Senator Elizabeth Warren expressed no view (Daily, Nuclear Power, 2020). On the other end of the spectrum, Mayor Pete Buttigieg and President Joe Biden each expressed outright support for nuclear power, with President Biden focused more on next generation nuclear technologies. This lack of shared opinion expresses the broad divide for nuclear support among environmentally focused individuals.

Conclusion

Timelines for new nuclear builds have continued to extend with new regulations and industry changes well after the events of TMI. Yet, due to the complexity of the social, environmental, political, and economic forces pushing on the industry, no one change elongated the licensing and construction timeline alone. The other non-regulatory themes identified in this study are:

- **Mid-project changes in requirements**: Before Three Mile Island, immediately afterwards, and to this day, expectations for constructing or operating a nuclear plant in the U.S. have evolved faster than utilities can keep up. International disasters only serve to catalyze these changes, particularly after Chernobyl, 9/11, and Fukushima. Utilities are forced to change or abandon their already set plans and incur additional costs.

- **Increased public participation**: After the Three Mile Island accident, safety at the expense of all else dominates the conversation around nuclear power. Advocacy groups elongate the permitting and review process through public comment periods and public meetings. When the COL was created with Part 52, regulators made a mild attempt at limiting the level of advocacy group involvement. Yet, utilities and the NRC are hesitant to push back and make decisions due to fear of regulatory capture and public perception.

- **Lack of expertise**: Since the United States has not constructed many nuclear power plants in the last 30 years, there is a lack of technical experience. This lack of human capital is pervasive across the supply chain and it includes having the know-how for the planning process, all the way to not having knowledgeable suppliers of concrete.

- **Operators failing to use regulatory procedure properly**: Part 52 was intended to create a procedure for approving the technology of a leading nuclear power plant and allowing follow-on plants to use the same approval for their applications. Economic incentives in the 2000s accelerated operators' plans, and they did not wait for the first plant to be fully approved. Permits had to be amended each time the initial application was amended, creating additional work and delays.

Recommendations

The domestic roadblocks outlined in this analysis have led to an industry now too inexperienced to build large, bet-the-company nuclear projects. Side effects of these roadblocks – including an atrophied supply chain and dearth of skilled labor – serve as knock-on effects exacerbating the core issues.

Given the likely necessity of nuclear power to play a role in the immediate future of decarbonization, we outline five ideas for change. These changes impact regulators, industry players, and third-party groups as all three would need to change for the domestic landscape to once again be favorable to new nuclear construction.

1. Change the licensing process to limit obstructionist activity

The current landscape for building nuclear for operators versus stopping new builds for obstructionists is highly asymmetric in favor of obstructionists. These opponents need only delay the new build indefinitely to make the cash flow timing of the new build unattractive, and each step of the licensing process today is filled with opportunities for delay. Third-party groups can thus guarantee victory; no domestic operator has deep enough pockets to let a bet-the-company nuclear project drag ad infinitum.

At the same time, we recognize the role independent, third-party groups serve in providing input beyond the regulator/operator dynamic.

We suggest changing the licensing process such that third-party input strictly be timed with NRC feedback during the licensing process – and otherwise put on hold until the next major NRC review. This change would allow an operator to address all feedback, make changes, and move forward with certainty.

2. Do not require complete resubmission for small changes during the licensing process

Back and forth between a regulator and operator is healthy but requiring operators to repeat unchanged work is not. When the NRC requires changes to a plan, document, or proposal, there needs to be a method by which regulators can recognize a change as small or compartmentalized. Follow-up can address the specific change, leaving the other parts of the licensing process unaffected. Avoiding repeat work and the associated delay allows operators a far greater chance of keeping projects on schedule and thus makes them more attractive.

3. Continue to modularize licensing processes but support the full project

Part 52 was an important step in creating project certainty beyond Part 50 licensing. Yet it created a new problem in the form of ‘everything-up-front’ requirements. Each amendment requires significant resubmissions and creates a fresh source of delay. The burden of so much up-front work made operators as wary of Part 52 as of Part 50, though for different reasons.

We suggest a different approach to making the licensing process modular. The combined construction & operating license idea from Part 52 should stay, but the initial lift should be made smaller while the hold points expand in role. Specifically, a process by which an operator has full project confidence – and the initial lift is manageable – while a regulator has regular checkpoints during which they can stop parts of construction if issues are found.

4. Consistently use standard designs across operators

Taking advantage of existing, standard designs is an important step for operators to restart the domestic industry for new builds. A single, widely used design can simplify regulatory burden, reestablish supply chains, and begin the recreation of engineering expertise.

5. Enact nuclear power mandates, recognizing and valuing the carbon-free nature of nuclear

Nuclear has been left behind the other carbon-free generation options in terms of incentives, subsidies, or tax-treatment on a large scale. Unlike solar and wind, direct consumer adoption is also not a feasible way to drive cost curves down. Incentives will be necessary.

The goal must also be solution oriented for all parties, inspired by the South Korean model for new builds. Specifically, South Korea sets up the need for new builds within energy plans, and operators and regulators both see a target to work towards.

In a decentralized operator economy, like the U.S., mandates solve this problem. Operators and regulators are both incented to meet the goal, cost curves are driven down as all parties gain experience, and the burden of dealing with third-party input rests in political hands (which tend to be better equipped for the task).

Operators can help push policy change forwards by aggressively pursuing re-engagement from environmental activist groups. These groups have remained quiet on nuclear in this time of increasing solar and wind adoption. Popularity with activists has made policy favoring renewables much easier to palate, and a similar public opinion shift recognizing the carbon-free nature of nuclear technology can be a powerful engine of policy change.

Works Cited

102nd Congress. (1992, October 24). *H.R.776 - Energy Policy Act of 1992.* Retrieved from Congress.gov: https://www.congress.gov/bill/102nd-congress/house-bill/776/text/enr

Baker, E., Lawrie, S., & Lozier, B. (n.d.). *Spinning Our Wheels: How Nuclear Plant Closures Threaten to Offset Gains from Renewables.* Retrieved January 11, 2020, from ScottMadden Management Consultants: https://www.scottmadden.com/insight/spinning-our-wheels/

Clemmer, S., Richardson, J., Sattler, S., & Lochbaum, D. (2018). *The Nuclear Power Dilemma.* Union of Concerned Scientists. Retrieved from https://www.ucsusa.org/resources/nuclear-power-dilemma#ucs-report-downloads

Climate Action Tracker. (2019, Dec 2). *The United States*. Retrieved from Climate Action Tracker: https://climateactiontracker.org/countries/usa/

Culley, M. R., & Angelique, H. (2010, March 16). Nuclear Power: Renaissance or Relapse? Global Climate Change and Long-Term Three Mile Island Activists' Narratives. *Am J Community Psychol, 45*, 231–246.

Daily, M. (2020). *Nuclear Power*. Retrieved from https://www.politico.com/2020-election/candidates-views-on-the-issues/energy-environment/nuclear-power/

Daily, M. (2020). *Nuclear Power*. Retrieved from https://www.politico.com/2020-election/candidates-views-on-the-issues/energy-environment/nuclear-power/

Duke Energy. (2013, June 12). *Common Myths About Nuclear Energy*. Retrieved from Duke Energy: Nuclear Information Center: https://nuclear.duke-energy.com/2013/06/12/common-myths-about-nuclear-energy

EIA. (2017, April 27). Retrieved from Most U.S. nuclear power plants were built between 1970 and 1990: https://www.eia.gov/todayinenergy/detail.php?id=30972

EIA. (2019, December 26). *How old are U.S. nuclear power plants, and when was the newest one built?* Retrieved from https://www.eia.gov/tools/faqs/faq.php?id=228&t=21

EIA. (2020, Feb 27). Retrieved March 5, 2020, from What is U.S. electricity generation by energy source?: https://www.eia.gov/tools/faqs/faq.php?id=427

Finnigan, J. (2017, April 17). *Why We Still Need America's Nuclear Power Plants — At Least for Now*. Retrieved March 16, 2020, from Environmental Defense Fund: http://blogs.edf.org/energyexchange/2017/04/17/why-we-still-need-americas-nuclear-power-plants-at-least-for-now/

GAO. (1982). *GAO/RCED-M-27 NRC Backfitting.*

Georgia Power. (2019, October). Retrieved from Vogtle 3 & 4: https://www.georgiapower.com/content/dam/georgia-power/pdfs/company-pdfs/Vogtle%20Update%20October%202019.pdf

Greenpeace. (n.d.). *Nuclear Energy*. Retrieved March 27, 2020, from Greenpeace: https://www.greenpeace.org/usa/global-warming/issues/nuclear/

Haratyk, G. (2017, November). Early nuclear retirements in deregulated U.S. markets: Causes, implications and policy options. *Energy Policy, 110*, Pages 150-166.

Hoagl, J. (2006, July 16). Bush's Nuclear Energy. *The Washington Post*. Retrieved February 1, 2020, from https://www.washingtonpost.com/archive/opinions/2006/07/16/bushs-nuclear-energy/c74b3b21-827c-4258-a96a-6a65fa8840db/

IEA. (n.d.). Retrieved March 2, 2020, from United Arab Emirates: https://www.iea.org/countries/united-arab-emirates

Institute of Nuclear Power Operations (INPO). (n.d.). *About Us*. Retrieved March 10, 2020, from http://www.inpo.info/AboutUs.htm

International Atomic Energy Agency (IAEA). (2019). *Nuclear Power Reactors in the World.* Vienna, Austria.

Johnson, S. (2002, April 15). Nuclear Power 2010 Program Overview. *Presentation to the Nuclear Energy Research Advisory Committee*. Retrieved from https://www.energy.gov/sites/prod/files/Presentation%20-%202010%20Program%20Overview%20-%20Presentation%20to%20the%20NEAC.pdf

Koehler, L. (2018, January 23). *California says goodbye to its last nuclear power plant. What will replace it?* Retrieved March 16 2020, from Environmental Defense Fun: http://blogs.edf.org/energyexchange/2018/01/23/california-says-goodbye-to-its-last-nuclear-power-plant-what-will-replace-it/

Navigant Consulting, Inc. (2013). *Assessment of the Nuclear Power Industry - Final Report For EISPC and NARUC.*

New York Times News Service. (2005, May 16). Nuclear power finding favor in unusual place. *The Baltimore Sun*. Retrieved from https://www.baltimoresun.com/news/bs-xpm-2005-05-16-0505160119-story.html

NRC, U. (2019, Jan 28). *History*. Retrieved Jan 25, 2020, from https://www.nrc.gov/about-nrc/history.html

Otaiba, Y. A. (2020, March 4). A Successful Mideast Nuclear Deal. *Wall Street Journal*. Retrieved March 8, 2020, from https://www.wsj.com/articles/a-successful-mideast-nuclear-deal-11583367406

Plumer, B. (2019, Dec. 3). Carbon Dioxide Emissions Hit a Record in 2019, Even as Coal Fades. *The New York Times*. Retrieved Jan 11, 2020, from https://www.nytimes.com/2019/12/03/climate/carbon-dioxide-emissions.html

Rhodium Group. (2019, January 8). *Preliminary US Emissions Estimates for 2018*. Retrieved March 10, 2020, from https://rhg.com/research/preliminary-us-emissions-estimates-for-2018/

Sierra Club. (n.d.). *Nuclear Free Future*. Retrieved March 16, 2020, from https://www.sierraclub.org/nuclear-free

Squassoni, S. (2009). *The US Nuclear Industry: Current Status and Prospects under the Obama Administration.* Ontario: The Centre for International Governance Innovation.

Staff reports, The Atlanta Journal-Constitution. (2017, December 20). Timeline: Plant Vogtle through the years. *The Atlanta Journal-Constitution*. Retrieved from https://www.ajc.com/news/local-govt--politics/plant-vogtle-timeline/wfQKABLCNutdld3RQPNwaL/

The Nature Conservancy. (2018, October 15). *The Science of Sustainability*. Retrieved from The Nature Conservancy: https://www.nature.org/en-us/what-we-do/our-insights/perspectives/the-science-of-sustainability/

U.S DOE. (2006a). *The History of Nuclear Energy (DOE/NE-0088).* Washington DC: Office of Nuclear Energy,Science and Technology. Retrieved March 15, 2020, from https://www.energy.gov/sites/prod/files/The%20History%20of%20Nuclear%20Energy_0.pdf

U.S. NRC. (2016, May 5). *Watts Bar Unit 2 Reactivation*. Retrieved from https://www.nrc.gov/info-finder/reactors/wb/watts-bar.html

U.S. NRC. (2017, September 25). Retrieved from Issued Combined Licenses and Limited Work Authorizations for Vogtle, Units 3 and 4: https://www.nrc.gov/reactors/new-reactors/col/vogtle.html#review

U.S. NRC. (2018, June 21). *Backgrounder on the Three Mile Island Accident*. Retrieved from U.S. NRC: https://www.nrc.gov/reading-rm/doc-collections/fact-sheets/3mile-isle.html

UNC Kenan-Flagler Energy Center. (2019). *Meeting the Renewables Intermittency Challenge.* UNC Kenan-Flagler Energy Center.

Wellock, T. (2020, Jan 28). Nuclear History Conversation. (S. Vondracek, & N. Margolies, Interviewers)

Weyler, R. (2011, July 7). *Nuclear Delusions*. Retrieved March 20, 2020, from https://www.greenpeace.org/usa/nuclear-delusions/

World Nuclear Association. (2015). *Licensing and Project Development of New Nuclear Plants.* Licensing & Permiting Task Force.

World Nuclear Association. (2020, Feb). *Nuclear Power in France*. Retrieved March 15, 2020, from https://www.world-nuclear.org/information-library/country-profiles/countries-a-f/france.aspx

World Nuclear Association. (2020, March). *Nuclear Power in Sweden*. Retrieved March 15, 2020, from https://www.world-nuclear.org/information-library/country-profiles/countries-o-s/sweden.aspx

World Nuclear Association. (2020, March). *Nuclear Power in the United Arab Emirates*. Retrieved from https://www.world-nuclear.org/information-library/country-profiles/countries-t-z/united-arab-emirates.aspx

World Nuclear Association. (2020, Feb). *Nuclear Power in the World Today*. Retrieved March 13, 2020, from https://www.world-nuclear.org/information-library/current-and-future-generation/nuclear-power-in-the-world-today.aspx

Ziegler, M. S., Mueller, J. M., Pereira, G. D., Song, J., Ferrara, M., Chiang, Y.-M., & Trancik, J. E. (2019, Nov 2). Storage Requirements and Costs of Shaping Renewable Energy Toward Grid Decarbonization. *Joule, 3*(11), Pages 2867-2869.

Appendix

Appendix A: List of Individuals Interviewed

Adam Reichenbach, Duke Energy

Austin Young, Nuclear Regulatory Commission

Bob Bement, Arizona Public Service

Chris Fallon, Duke Energy

Chris Vlahoplus, ScottMadden

Christopher Fallon, Duke Energy

Dale Klein, Former Nuclear Regulatory Commissioner

Eric Williams, Nuclear Energy Institute (NEI)

Glen Allen Snider, Duke Energy

Jackie Coombs, Utah Associated Municipal Power Systems (UAMPS)

Kate Nolan, Duke Energy

LaVar Webb, Utah Associated Municipal Power Systems (UAMPS)

Marcus R. Nichol, Nuclear Energy Institute (NEI)

Matthew Kalemba, Duke Energy

Mike Squires, Utah Associated Municipal Power Systems (UAMPS)

Robert McMurry, Duke Energy

Ron Degregorio, RDK Group

Tom Wellock, Nuclear Regulatory Commission Historian

Tracey LeRoy, Duke Energy