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Introduction

Nuclear energy is a reliable, safe, and environmentally-friendly energy source that has had almost no new developments in the United States over the past 30 years. One possible explanation for this is that regulatory barriers for nuclear energy may make new construction prohibitively costly. Still, nuclear power accounted for 20 percent of the electricity generated in the U.S. in 2016 while producing no greenhouse gas emissions.¹

Construction of new state-of-the-art reactors in Georgia and South Carolina are ushering in a new era of nuclear energy in the U.S.² These plants are the first to be constructed in over three decades, and are expected to come online in 2019 and 2020.³ Most nuclear power plants in use today were constructed in the 1960s and ‘70s.⁴ The long lapse in new construction can be partially attributed to a strict and overly-cautious regulatory environment for the licensing and operation of nuclear power plants, as well as the lack of permanent nuclear waste disposal solutions.

The over-regulation of nuclear energy has not only led to missed opportunities with a promising energy source, but has also pushed nuclear innovation overseas. For example, the U.S. nuclear company TerraPower created a reactor design, and recently choose to partner with the China National Nuclear Corporation.⁵ James Conca, a nuclear energy expert, suggests that “the regulatory environment in America is so glacial that TerraPower and CNNC will build the first unit in China then deploy commercial versions of this new reactor to global markets within fifteen years.”⁶

This report focuses on existing nuclear reactor technologies and begins by examining the history and science behind nuclear energy, as well as its potential benefits. It then reviews government policies that affect nuclear development, construction, and waste disposal. In closing, the report examines how recent legislation impacts the growth of the nuclear industry and suggests opportunities to change the regulatory process impacting its expansion.

What is Nuclear Energy?

In the U.S., there are 61 commercially operating nuclear power plants across 30 states. These 61 plants run a total of 99 nuclear reactors, with some large plants having multiple reactors. Nuclear plants make up less than one percent of the total number of power plants in the country, but account for about 20 percent of the electricity generated.⁷ The vast majority of modern reactor designs in the U.S. are light water reactors.⁸ These reactors use water to regulate their internal temperature. This report focuses on conventional light water reactor technologies.

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Unlike wind, solar, or hydroelectric power which have specific geographic requirements, a nuclear plant can be placed near population centers. By placing nuclear power plants closer to population centers, less electricity is lost during transmission over long distances.

Despite its benefits, nuclear energy comes with a unique set of challenges, particularly when it comes to addressing radioactive waste disposal and safety concerns. Waste storage and disposal are among the largest obstacles to new power plant construction, and may have contributed to the premature closure of several plants.9

**Origins of Nuclear Energy**

Initial development of nuclear energy was driven by the creation of nuclear weapons. In 1942, scientists working on the Manhattan Project developed the first nuclear reactor and detonated the first nuclear bomb in 1945.10

Following World War II, the focus of nuclear research expanded from creating weapons to also developing nuclear power as an energy resource. The Atomic Energy Act of 1954 laid the initial groundwork for nuclear regulation in the U.S. and allowed private companies to apply for licenses to use nuclear technology.11 Three years later, the first large-scale nuclear power plant in the U.S. opened in Pennsylvania.12

During the second half of the 20th century, the U.S. experienced a nuclear energy boom. Almost all of the original 104 nuclear reactors were built before the turn of the century, many using technology from the 1970s.13 Most of the nuclear energy production in the U.S. today comes from reactors built between the late ‘60s and early ‘90s, as shown in Figure 1.14 Since 2012, five nuclear reactors have been retired, bringing the number of operational reactors to 99. Several other nuclear power plant operators have announced plans to retire reactors in the coming decade.15

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In the mid-1970s, a larger portion of the public in the United States started to view nuclear energy disfavorably. In 1979, one of the reactors at the Three Mile Island Nuclear Generating Station in Pennsylvania partially melted down. Despite being the most serious accident in U.S. nuclear history, there were no detectable health effects. Following Three Mile Island, the majority of the public opposed construction of new nuclear power plants. This was the first time a majority of Americans opposed new nuclear developments, and the change in public perception led to regulatory changes that increased costs and slowed the growth of the nuclear energy industry.

**How does Nuclear Energy Work?**

Current nuclear technologies generate electricity through nuclear fission. During fission, a neutron collides with a uranium atom, causing the unstable atom to split apart. When the atom splits apart, its neutrons collide with other atoms, beginning a self-sustaining chain reaction. In addition to releasing neutrons, nuclear fission also releases large amounts of energy as heat. In most reactors, this heat is used to boil water, creating steam that turns turbines to generate electricity.

Uranium is the primary fuel that powers most fission reactors. One kilogram of uranium can produce roughly 20,000 times more energy than a kilogram of coal. This allows nuclear energy to provide a consistent, large-scale supply of electricity with relatively small amounts of fuel. Producing fuel-grade uranium involves a long operation of mining, conversion and enrichment of heavy elements to create material that is able to sustain a chain reaction. Although

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uranium is the most commonly used fuel in most fission reactors, other countries have developed reactors which use plutonium and other heavy metals.22

Regardless of what type of fuel is used, nuclear energy is one of the most efficient energy sources. When comparing the efficiency of energy sources, a common metric used is capacity factor, the average amount of electricity a source produces divided by the maximum amount it can produce.23 The capacity factor of nuclear power is over 90 percent. Figure 2 compares the capacity factor of nuclear energy to several other common sources of electricity. As the figure illustrates, nuclear power has one of the highest capacity factors of any source of electricity generation.

Figure 2. Capacity Factor by Generating Source24

Throughout the fission process, radioactive waste accumulates and must be removed from the reactor. This waste, or spent fuel, is no longer capable of continuing the fission process but still emits radiation.25 The safe disposal of this hazardous radioactive waste is one of the main concerns of using nuclear energy.

Source: EIA

Most nuclear waste is regulated as high-level and low-level wastes. Spent fuel is categorized as high-level waste. Although spent fuel can be reprocessed, this still produces some high-level waste. Low-level nuclear wastes are materials that have become radioactive due to exposure to radioactivity. Low-level nuclear waste can range from tools to clothing used around radioactive materials. Both high and low-level nuclear waste can be stored safely so harmful radiation is contained, but finding a suitable location for long-term storage is problematic. According to a Massachusetts Institute of Technology study, waste disposal is the largest roadblock to expanding nuclear energy in the U.S.

Finding a long-term waste disposal solution is difficult politically, but not technologically. For example, the Waste Isolation Pilot Plant (WIPP) in New Mexico is the sole repository for radioactive waste from the production and research of nuclear weapons. Since its completion in 1999, approximately 91,000 cubic meters of waste have been safely stored in the facilities’ underground tunnels. The WIPP’s tunnels have been dug out of a deep salt deposit so that over time, the salt will fill in the repository.

Public Perceptions of Nuclear Energy

Despite its high efficiency in generating electricity, nuclear energy is a divisive topic among the public. Some see nuclear as a consistent, low-carbon source of energy while others believe the risk of disaster outweighs its benefits. Although risk is an industry reality, accidents are very rare. Throughout its history, there have been no deaths due to commercial nuclear power in the U.S. Nuclear power technologies incorporate effective safety mechanisms that prevent accidents from becoming catastrophic the vast majority of the time. Despite its long track record of safe operation, studies suggest that the public tends to overestimate the risks of nuclear energy when compared to industry professionals.

The accidents at Three Mile Island in 1979, Chernobyl in 1986, and Fukushima in 2011 were highly publicized, damaging the reputation of nuclear energy. Fear of nuclear radiation and potential disasters were ingrained in society through popular culture. Cultural icons such as Godzilla, the zombies from Night of the Living Dead, and the movie China Syndrome exposed Americans to an eccentric representation of what radiation exposure could do.

Despite this perception, nuclear energy has historically proven to be safer than other forms of electricity production in terms of the number of deaths per unit of energy generated, as illustrated in Figure 3. These energy related deaths are commonly caused by work related accidents or by health effects from air pollution.

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26 Ibid.
Public opinion towards nuclear energy is often strongly affected by accidents. For example, the Shoreham Nuclear Power Plant on Long Island, New York, was built but never granted an operating license due to public opposition following the Three Mile Island and Chernobyl incidents. The utility company, Long Island Lighting Company, agreed never to open the plant. The $6 billion price tag was passed on to Long Islanders via a three percent increase in their electricity rates over thirty years.

More recently, in March 2011, a magnitude nine earthquake off the coast of Japan caused a 15-meter tsunami, which damaged three reactors at the Fukushima Daiichi nuclear power plant. All three reactors were heavily damaged, resulting in a massive release of radiation and an event that the International Atomic Energy Agency considered a “major accident.” Five years after the accident there have been no reported deaths or radiation sickness.

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the nuclear disaster at Fukushima, a renewed fear of catastrophe led to the closure of 15 reactors around the globe.\textsuperscript{41} In the U.S., public opposition following the disaster may have contributed to the early closures of five reactors since 2012 with another nine planned to be closed.\textsuperscript{42}

Germany is requiring a full phase-out of their nuclear power plants in response to the Fukushima disaster. Eleven years before Fukushima, German policymakers had made a plan to phase out nuclear energy by 2022. The pace of the phase-out was slowed in 2010 in response to several reports on its impact on electricity prices. In response to Fukushima, however, the timeline of the phase-out was accelerated once again. Less than a month after the disaster, eight of Germany’s 17 nuclear power plants were closed. A 2013 study found that carbon emissions in Germany will be 23 to 77 percent higher in 2022 without nuclear energy because the country will have to use more coal and lignite to meet energy demand.\textsuperscript{43} Under this nuclear phase-out, Germany has to rapidly invest in alternative energy sources to meet EU emissions targets. Without this phase-out, Germany would have much more clean energy without requiring expensive and less-reliable energy sources.

Depending on the survey, public opinion of nuclear varies, as shown in Figure 4.\textsuperscript{44} This fluctuation in opinion is perhaps best explained by the fact that many people are uninformed about nuclear generation, and their opinions are easily swayed with contextual changes in how questions about nuclear energy are framed.\textsuperscript{45} Public opinion provides an important foundation for public policy, so educating the public about the actual risks and tradeoffs of nuclear energy could be a useful step towards reforming nuclear regulations.


Economics of Nuclear Energy

Despite the divisiveness of nuclear energy among the American public, the U.S. remains one of the leading nations in nuclear power generation. The U.S. has 99 nuclear reactors, more than any other country, with 102 gigawatts of electricity capacity. These 102 gigawatts of capacity can power about 70 million homes. But nuclear energy development in the U.S. is almost completely dormant because of high upfront costs, at least partly created by stringent regulations and licensing requirements, as well as competition from other energy sources.

Economic Obstacles to Nuclear Energy

The nuclear energy industry faces economic obstacles that have slowed the rate of its innovation and expansion. Nuclear power is one of our most promising energy sources for addressing economic and environmental concerns, but stringent regulations and poor policies have made the cost of developing new nuclear resources prohibitively expensive.

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48 One MW is capable of powering between 750 to 1,000 homes, on average (See National Hydropower Association, below). We calculated that 102 GW (102,000 MW) x 750 homes x .922 capacity factor = 70,500,000 homes.; National Hydropower Association. (2017). FAQ. Retrieved from: http://www.hydro.org/policy/faq/
Costs

In a 2008 general cost projection, the overnight cost of a new 1,100 MW nuclear power plant was estimated to be between $6 and $9 billion. Overnight costs are used in the energy industry to estimate the cost of a power plant if it were built “overnight.” As can be seen in Figure 5, the U.S. Energy Information Administration stated the overnight cost for a nuclear power plant to be $5,945/kW, higher than any other energy source. For even the smallest nuclear power plant in the U.S., that would be approximately $3.5 billion. Other factors that may be contributing to high total costs of nuclear plants are the cost and schedule overruns commonly experienced by nuclear developers.

Figure 5: Overnight costs of various energy sources. ($/kW)

The overnight cost of nuclear power plants in the U.S. has been increasing for decades. One common explanation is that new safety requirements drive up the cost of constructing new reactors. A 2016 paper in Energy Policy suggested that after Three Mile Island, “duration-related issues such as licensing, regulatory delays, or back-fit requirements are a significant contributor to the rising [overnight capital cost] trend.” Other research suggests that rising costs in the nuclear industry are largely due to regulatory flux associated with new safety requirements and uncertainty after accidents.

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51 The smallest nuclear power plant is in New York and produces 582 megawatts. (582 megawatts = 582,000 kilowatts. 582,000 kW x $5,530/kW = $3,259,990,000); Nuclear Energy Institute. (n.d.) US Nuclear Power Plants General U.S. Nuclear Info. Retrieved from: https://www.nei.org/Knowledge-Center/Nuclear-Statistics/US-Nuclear-Power-Plants


A 2012 article in the *Journal of Construction Engineering and Management* identified “regulatory ratcheting” as one of the primary causes of cost and schedule overruns.\(^5\) Regulatory ratcheting is retroactively creating regulations after a nuclear power plant has already been licensed. This requires the developer to devote time and resources to meeting the new requirements instead of moving forward with the construction. Complying with this regulatory ratcheting leads to increasing costs that exceed budgets, which are common occurrences for nuclear energy today.\(^6\)

Regulatory ratcheting may have contributed to the bankruptcy of America's largest nuclear energy company, Westinghouse Electric Company. Westinghouse's nuclear power plants in Georgia and South Carolina have experienced both cost and schedule overruns, partly as a result of new regulation. In 2009, the NRC implemented the Aircraft Impact Assessment.\(^5\) To comply with this new regulation Westinghouse had to change their reactor design several times rather than moving forward with construction, even after their original design had been approved.\(^5\) The new plants were originally slated to open in 2016 and 2017, but even their current expected completion dates of 2019 and 2020 now seem optimistic.\(^5\) Huge overruns eventually forced Westinghouse to declare bankruptcy on March 29, 2017.\(^6\) The time and resources devoted to complying with the NRC's regulatory ratcheting likely played a role in Westinghouse's bankruptcy, though it was not the sole cause.

Nuclear developers need regulatory transparency and certainty. Westinghouse is just one example of a nuclear power developer that could not have planned for regulatory changes. A nuclear developer needs to know approximately how long and at what cost a new power plant can be built. When regulations change, however, the developer often cannot meet their obligations to investors. If the regulatory environment for nuclear power was more clear and certain, it might be easier and cheaper to find financing for a nuclear power plant.

The initial investment cost and regulatory hurdles of nuclear energy development can be overwhelming to developers, even though nuclear energy is cheaper over a plant’s lifetime compared to other energy sources. A common measurement of lifetime cost is the Levelized Cost of Electricity (LCOE).\(^6\) The LCOE takes into account construction, financing, and financial return over the life of the project to generate an average cost per unit of energy produced over the estimated life of the plant. Figure 6 shows the LCOE of nuclear compared to other sources of energy. As the figure shows, nuclear is more expensive per unit of energy generated than most fossil fuels, but cheaper than most clean energy sources.

Nuclear energy produces electricity at a rate of approximately $100 per megawatt-hour, although it has potential to be even cheaper with new innovations.\(^6\) Considering public interest in reducing carbon emissions, nuclear energy should be more strongly considered as a clean energy resource. If the cost of carbon was included in the price of electricity, the cost of nuclear energy would be even more competitive with other energy sources.

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61 The LCOE is the best available cost estimate and is the most commonly used to compare the costs of different energy sources, but does not account for subsidies or the regulatory environment facing different energy sources. Instead of decreasing production costs, subsidies simply transfer costs away from producers and onto taxpayers. Not only does the LCOE misrepresent the full cost of an energy source, but because subsidies vary by energy source, the levelized cost can be a misleading comparison

Further, nuclear plants produce energy more reliably than wind and solar, which can have intermittency issues related to weather patterns. Renewables also typically have seasonal fluctuations. Solar, for example, generates more electricity in the summer. Nuclear energy can be used to moderate these long-term storage and seasonality issues.\textsuperscript{63} Finally, nuclear energy has fewer limitations than hydropower because it does not require specific geographic features. All of these factors, especially when combined with an LCOE that is already relatively low, indicate that nuclear energy may be a valuable asset and a worthwhile investment.

States like Illinois and New York have expressed interest in creating out-of-market payments to nuclear energy producers to help compensate nuclear power for being a reliable energy source that can reduce emissions. These subsidies may help keep the nuclear industry afloat, but also distort regional electricity markets. Because of these distortions, the Federal Energy Regulatory Commission hosted a conference in May 2017 to discuss how regulators should organize regional electricity markets. If these out-of-market payments are enacted, they may help the nuclear industry but will likely provoke new regulations.\textsuperscript{65}

These new power market regulations could outweigh the benefits of nuclear energy subsidies, although regulators may recognize the importance of encouraging nuclear developments as a capital-intensive baseload energy source. Baseload energy sources are an important component of the electric grid as they supply enough power to consistently meet average electricity demand, and will likely become more important with increased focus on renewable energy sources.


In addition to large upfront construction costs, companies looking to build a nuclear power plant must also factor in the time for licensing and building the plant. One company building a plant in Utah is in the ninth year of a 20-year development process as of January 2017. This process includes all permitting and construction necessary before the facility becomes operational. A long and unpredictable development process discourages investors who may have to wait decades to see returns on their large investments. Fossil fuels and renewables have much shorter development timelines that represent a lower risk for investors, which may be part of the reason the U.S. nuclear industry is stagnant.

**Competition from Natural Gas**

Not only is nuclear energy one of the most efficient sources of electricity, it is also one of the cleanest. Despite these advantages, nuclear power faces price competition from other energy sources. Natural gas, the cheapest form of energy production, according to Figure 6, is the largest competitor to nuclear energy today. Electricity prices from natural gas production have a history of fluctuation, but currently sit at a 10-year low. Natural gas prices may be low, but natural gas emits high levels of methane and carbon dioxide as greenhouse gases, as well as dangerous nitrogen oxides and sulfur dioxide. Nuclear energy does not emit any of these harmful pollutants, creating a trade-off of cheaper power for more air pollution.

As policymakers try to cut greenhouse gas emissions to slow climate change, one potential strategy is to develop more nuclear energy. A 2011 NASA study found that nuclear power prevented about 64 gigatonnes of carbon dioxide from entering the atmosphere globally between 1971 and 2009. This is the equivalent of the past 35 years of carbon emissions from burning coal in the U.S. When considering total lifetime emissions, including those during construction and throughout the plant’s lifetime, nuclear power’s emissions are among the lowest of any energy source, as shown in Figure 7.

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All energy sources have a carbon footprint when including the emissions that come from constructing, maintaining, and fueling a power plant. A study by the World Nuclear Association also found that over the course of its lifetime, nuclear power emits 1.1 times more carbon than hydropower and wind, almost three times less than solar PV, and 30 times less than coal based on average emissions.72

**Regulation of Nuclear Energy**

The costs of nuclear energy are heavily influenced by additional regulations that increase the difficulty of developing new nuclear power plants. These regulations can be beneficial for protecting public health from the negative impacts of an industry. Too many regulations, however, can increase costs, reducing economic activity and innovation that could provide public benefits.73

Early regulation of nuclear energy was successful at preventing any nuclear fatalities in the U.S. while still allowing growth in the industry. But according to a Heritage Foundation report, “in the 1970s and 1980s, federal, state, and local governments nearly regulated the U.S. commercial nuclear industry out of existence.”74 As the number of regulations grew, anti-nuclear groups had more opportunities to file noncompliance suits. When more suits were

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brought against the NRC, Congress proposed new rules and regulations. These regulations were passed in an attempt to minimize the risk of a nuclear accident. Although safety regulations are important, regulators can never eliminate risk entirely without completely banning the industry. Because nuclear energy has a long and safe history in the U.S., policymakers and regulators should consider the cost of over-regulating nuclear power.

Burdensome regulations, especially for managing nuclear waste and licensing new power plants, may be reducing investment and innovation in the nuclear industry. If developers could more easily invest in nuclear energy, Americans would have more access to low-cost and clean energy.

This section will begin by examining federal requirements for the licensing and permitting of nuclear facilities. It will then discuss waste disposal and the problems associated with not having a national disposal site. Lastly, this section will look at state-level regulations and how they work in conjunction with federal regulations.

Federal Regulations

The Nuclear Regulatory Commission (NRC), an independent agency of the U.S. government existing outside of the traditional federal branches, has historically handled federal regulation of nuclear energy. Throughout the licensing process, the NRC must comply with the Atomic Energy Act, all NRC regulations, and the National Environmental Policy Act. Within the NRC, a complex network of smaller agencies and offices oversee and regulate all aspects of nuclear energy, including the mining of uranium, operating and licensing of nuclear plants, and the disposal of nuclear waste. In many cases, the regulations covering these processes are complex, time-intensive, and costly.

The NRC was created by The Atomic Energy Act of 1954 which was enacted to regulate civilian and military uses of nuclear material and facilities in the U.S. The act initially established an Atomic Energy Commission as the sole regulatory agency for the development, production, and safety of both nuclear weapons and civilian use of nuclear materials. In 1974, the Energy Reorganization Act amended the Atomic Energy Act and split these responsibilities between the Department of Energy and the NRC. The Department of Energy was authorized to regulate the development and production of nuclear weapons, promote nuclear power, and oversee other energy-related work. The NRC was authorized to oversee the regulation of civilian nuclear energy.

Under the amended Atomic Energy Act, the NRC is tasked with licensing and permitting nuclear facilities. The NRC is required to establish and enforce standards as "the Commission may deem necessary or desirable in order to protect health and safety and to minimize danger to life or property." NRC regulations do increase safety, but can be an impediment to the development of nuclear power as an energy source. These regulations have made the current licensing process for new nuclear energy facilities a barrier to new nuclear developments.

Licensing Process

The process needed to obtain a license for construction and operation of a nuclear power plant is complex and involves long reviews and oversight by multiple agencies. A graphical overview of the licensing process can be seen in Figure 8. At the federal level, all regulations and licensing procedures are established by the NRC, which must conform to standards set by the International Atomic Energy Agency (IAEA) under the U.S.-IAEA Safeguards

75 Ibid.
79 Ibid.
Many NRC regulations and procedures were promulgated decades ago, and may not adequately correspond to changing trends in reactor design. Prior to 1989, nuclear power plant licensing was a two-step process requiring both a construction and a separate operating license. In 1989, the NRC introduced the Combined Operating License (COL) that combined the construction permit and operating licenses into one process. At the same time, the NRC also introduced design certifications and early site permits to encourage the development of new nuclear plants.

Early Site Permits

Early site permits reserve and approve the proposed site of a nuclear project prior to the start of construction. They last for 10-20 years and can be renewed for the same period of time. Early site permits are drafted in order to analyze the proposed reactor’s impact on the surrounding natural area by including the required environmental impact statement. Permits are also required to consider the safety of people by including emergency plans and potential impacts on the public.

Regardless of whether they apply for an early site permit, developers must provide site information and an emergency plan when they submit their COL application. Because early site permits include tests that are mandatory for the COL, these permits allow projects to get a head start on NRC requirements and potentially reduce the time needed to obtain a license.

86 Ibid.
87 Ibid.
Design Certification

The NRC is required to approve a plant’s design before an operating license can be issued. This approval is known as a design certification and is independent of site-specific details. Developers can use pre-existing designs that have already been certified by the NRC to skip the approval process.\(^9\) As of 2017, the NRC has approved six design certifications.\(^9\) Design certifications help speed up the overall licensing process, but also incentivize developers to use these pre-approved designs rather than make use of newer technology because new designs would require developers to go through a lengthy approval process. The design certification process incentivizes the use of older models that may not be as efficient or safe as newer technologies. In short, the design certification process discourages innovation.

Design certification applications are required in both the two-step and COL processes. All reactor designs must be certified by the NRC to ensure safety and avoid any negative environmental or social impacts. The NRC approved the earliest certified designs in 1997, and the most recent design certification was issued in 2014.\(^9\)

Standard design certifications are valid for 15 years, and can then be renewed. Renewals ease the regulatory process by allowing old designs to be used again while also providing an opportunity for applicants to make small updates to the design. Applications for design certification are subject to the NRC’s lengthy rulemaking process. This involves notification of all stakeholders, including the public, and a process that will address any safety issues with the proposed facility.\(^9\)

Developers may also need to revise their designs to meet the requirements of new regulations. For example, starting in 2009 all reactor designs must pass an Aircraft Impact Assessment, a regulation that requires facilities to test the impact of a large aircraft crashing into a reactor.\(^9\) This safety increase was enacted in response to the September 11, 2001 terrorist attacks, when the United States government realized the possibility of hijackers crashing an airplane into a nuclear plant.\(^9\) Even reactors that had already received a design certification had to comply with this new regulation, which required developers to spend years adjusting their already-approved designs.\(^9\)

If developers do not wish to use a design already certified by the NRC, they can submit an application for a standard design certification of another reactor design. A certified design has passed all required tests and inspections to ensure its safety and efficiency.\(^9\) In addition to the six already certified designs, nuclear power companies have submitted an additional six reactor designs for certification since 1989. Of these applications, one was suspended,

\(^8\) Ibid.;
one withdrawn, three are under review, and one is under final review. Submitting a new reactor design is possible, but it is harder than choosing a certified design that does not need to be tested.

The design certification process is time-intensive and can take up to 10 years. This lengthy timeline, in combination with a price-tag ranging from $1 to $2 billion for research, development, and design certification, often leaves nuclear developers struggling to find investors. Without investors, many developers are unable to build new facilities or technologies.

**Combined Operating License Process**

In 1989, the NRC started offering nuclear developers the Combined Operating License (COL) that combined the construction and operating licenses into one process. COLs authorize a developer to construct and operate a nuclear power plant as long as it complies with all applicable laws and regulations.

Prior to the COL, developers had to begin the two-step permitting process by applying for a construction permit. Developers could only apply for a license to operate the power plant after construction was completed. This two-step permitting process was problematic because developers would have to invest billions of dollars constructing a power plant with no guarantee they would be able to operate it and pay back their investors.

Although some opponents argue that the COL can lengthen and add unnecessary costs onto an already long approval process due to its complex nature, the license does have some inherent advantages. The COL is a marked improvement over the past licensing process, as developers can get full approval to construct and operate a nuclear facility and avoid the risk of constructing a multi-billion dollar power plant that would never generate power, such as the Shoreham Nuclear Power Plant. The Shoreham Nuclear Power Plant was built and tested at low power, but in 1989 the plant was shuttered because of concerns about emergency evacuation routes. When the power plant was closed, the utility company was left with $5.5 billion in debt for a nuclear power plant that would never generate electricity commercially.

For a COL, the NRC first reviews an applicant’s qualifications, design and site safety, and environmental impacts. The process consists of several rounds of public and agency review, as can be seen in Figure 8. Throughout the licensing process, the public has many opportunities for involvement and interaction with the developer. The developer incorporates public and agency feedback in their plans. During construction, the NRC verifies that construction meets the “Inspections, Tests, Analyses, and Acceptance Criteria.”

The NRC’s “Inspections, Tests, Analyses, and Acceptance Criteria” are derived from both the design certification and site-specific standards. These site-specific standards are included in the licensee's COL or early site permit applications. Early site permits and standardized designs were introduced in 1989, in tandem with the COL, in

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order to further streamline the process of obtaining the operating license. Complying with all of these criteria demonstrates that a plant has been constructed in accordance with all applicable regulations. Although the NRC is responsible for inspecting a nuclear facility under construction, the licensee is ultimately responsible for making sure all criteria are met through inspections, tests, and analyses.

License Renewal

Under the Atomic Energy Act, the NRC can only issue a license to operate a nuclear power plant for up to 40 years. Developers can then renew their license for an additional 20 years at the end of the initial 40-year period. Nuclear technologies can safely and reliably operate for more than 60 years, but license durations were originally limited for antitrust considerations. Because of the 40-year soft cap, however, many existing reactors were designed for a 40-year lifespan. Without this unnecessary regulation, innovative technologies could potentially generate power for much longer and at a lower lifetime cost.

The renewal process, similar to the licensing process, requires extensive environmental and safety reviews. These reviews can be redundant because the NRC already conducts about a thousand regular inspections of nuclear facilities a year to ensure safety. To be approved for a license renewal, the applicant must analyze the aging facility and complete a generic environmental impact statement. The NRC highly encourages public involvement throughout this renewal process, which can inadvertently add additional time and uncertainty costs for the developer.

Power Uprates

Since the 1970s, nuclear utilities have added upgrades or made changes to existing nuclear facilities to increase the maximum amount of power they generate. Increasing generation through these alterations is known as a power uprate. The NRC regulates the amount of electricity a nuclear facility can generate because too much electricity can create substantial physical demands on parts of a power plant, which can be a safety concern.

When a nuclear operator wants to generate more electricity through a power uprate, they must submit an official request to the NRC. As part of the request, the nuclear operator must analyze the physical effects of higher electricity production. The NRC reviews these analyses before a power uprate is approved. In some cases, higher electricity production requires major and costly modifications to ensure safety.


115 Ibid.
Waste Disposal

A 2003 report by the Massachusetts Institute of Technology found that one of the largest obstacles to the expansion of the nuclear industry in the U.S. is the lack of a comprehensive plan for disposing and storing nuclear waste. Over the last 40 years, nearly 80,000 metric tons of high-level nuclear waste has been stored on-site at nuclear power plants without a long-term strategy. As more waste is being produced by reactors around the nation, storage at these on-site storage facilities is pushing the already over-limit sites beyond capacity. Waste disposal has been an ongoing political battle for decades with no clear end in sight.

The Nuclear Waste Policy Act of 1982 regulates nuclear waste disposal in the U.S. The act assigns the Department of Energy the responsibility to oversee the siting, construction, and operation of a deep-geologic repository for long-term storage of nuclear waste. The Environmental Protection Agency (EPA) was tasked with ensuring that waste does not affect public safety and health, and the NRC was given responsibility for regulating and licensing the repository itself. Nuclear facility operators need to dispose of spent nuclear fuel, but no long-term facility has ever been opened for commercial use. The NRC must approve any potential long-term repository once all EPA standards are met. Because nuclear waste storage is such a contentious political issue, however, states often get involved in regulating and selecting waste disposal sites.

The Nuclear Waste Fund and Yucca Mountain

Under the Nuclear Waste Policy Act, the Department of Energy was required to select sites and develop long-term storage facilities for high-level nuclear waste. The Nuclear Waste Policy Act also established the Nuclear Waste Fund, which has collected over $20 billion from ratepayers and another $20 billion in interest between 1983 and 2015 to fund the construction of these waste disposal repositories. To this day, there is still no national nuclear waste disposal repository in operation, although the Department of Energy was legally required to have a national repository built by 1998.

About $11 billion of the approximately $40 billion collected to construct a repository has been put towards Yucca Mountain, the designated national waste repository. When the repository was not completed by 1998, many utilities began suing the Department of Energy, and at the end of fiscal year 2015 the Department reported spending about $5.3 billion in settling these claims. The Department of Energy suggests that the total liability will reach $27 billion, although this assumes that they can begin accepting waste in 2021. Recent proposals by President Donald Trump have revived interest in the reinstatement of Yucca Mountain as the proprietary nuclear waste storage facility for the nation, but it is still unknown whether the Department of Energy can meet their obligations.

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122 Ibid.
The Department of Energy selected nine potential locations for a waste repository in 1983. Three years later, President Reagan approved three potential sites, but it was not until 1987 that Congress amended the Nuclear Waste Policy Act to state that Yucca Mountain in Nevada was the only viable site to be considered. In 2002, President George W. Bush approved the Yucca Mountain plan, despite ongoing lawsuits against the waste repository. Nevada Governor Kenny Guinn attempted to veto the site, but Congress overrode the objection and designated Yucca Mountain the official repository for the nation's nuclear waste.

The Department of Energy began working towards licensing the repository, but in 2008 the EPA raised the standards for compliance for safely protecting people from radiation from 10,000 years to one million years. In March of 2009, Secretary of Energy Steven Chu announced that the Department of Energy would terminate the Yucca Mountain repository program, citing a lack of knowledge and challenging the nuclear energy industry to seek better interim and long-term storage solutions. After decades of work and billions of dollars, Yucca Mountain was stopped before it could ever be used to store nuclear waste.

The Department of Energy made an official decision to stop work on Yucca Mountain in 2009, and filed a motion to withdraw the site's license application with the NRC the next year. The NRC tried to fight back by denying the motion, claiming that the decision would violate the Nuclear Waste Policy Act. The situation became even more complicated when Congress cut federal funding for the site in 2010. Congress has not appropriated any additional funding since 2010, effectively killing the Yucca Mountain waste repository.

In 2010, Obama established the Blue Ribbon Commission on America's Nuclear Future to review policies for nuclear waste disposal. In 2012 the Commission released a report that suggested solutions to help the nuclear industry's waste disposal issues. The Commission emphasized the importance of these policy reforms by arguing that “this nation's failure to come to grips with the nuclear waste issue has already proved damaging and costly and it will be more damaging and more costly the longer it continues.”

Despite the project being effectively shut down, in 2013 the U.S. Court of Appeals for the District of Columbia Circuit ordered the NRC to continue to license Yucca Mountain. The NRC still has funding, but Yucca Mountain itself does not. In January of 2015, the NRC found that the Department of Energy's license application for the repository met all standards and regulatory requirements. The NRC is still required to resolve challenges from the public and interested parties although Yucca Mountain has no funding. The NRC will continue to spend more time and money to resolve public opposition to Yucca Mountain, despite the fact that the project will likely not move forward.

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forward.\textsuperscript{131} According to the Government Accountability Office, Yucca Mountain was terminated because of “social and political opposition to interim storage and permanent disposal sites, not technical issues.”\textsuperscript{132}

To this day, almost 80,000 metric tons of nuclear waste are being stored on-site at nuclear facilities throughout the U.S. There are no long-term options for storing this waste, and the amount of waste continues to grow by about 2,200 metric tons each year. The Government Accountability Office suggests that these on-site storage facilities are already nearing full capacity.\textsuperscript{133}

Although several miles of tunnels have been prepared to store nuclear waste under Yucca Mountain, they will likely sit empty unless recent political decisions can be reversed.\textsuperscript{134} Before taking office, President Trump announced plans to reopen discussions of Yucca Mountain.\textsuperscript{135} By March of 2017, President Trump had proposed $120 million in funding to revive the facility.\textsuperscript{136} If Congress approves the funding to make Yucca Mountain a permanent repository for nuclear waste, the nuclear energy industry may finally have a long-term waste disposal solution.

Although the security and viability of Yucca Mountain has been contended historically, the Waste Isolation Pilot Plant (WIPP) in New Mexico demonstrates how deep geologic repositories can be an effective method of waste storage. The site currently serves as a repository for radioactive waste from the production and research of nuclear weapons. The WIPP stores waste in an underground storage facility located 2,150 feet below the surface.\textsuperscript{137} Since its completion in 1999, approximately 91,000 cubic meters of waste have been stored in the facilities’ underground tunnels. The WIPP’s tunnels have been dug out of a deep salt deposit so that over time, the salt will fill in the repository.\textsuperscript{138}

Since its opening, WIPP has operated flawlessly until February of 2014, when an improperly filled storage drum exploded and leaked. Thankfully, the facility’s safety measures performed as designed and the leak was quickly contained, creating no significant harm to human health or the environment.\textsuperscript{139} Although there was no risk of human or environmental harm, the overly cautious attitude towards the incident drove cleanup costs above $500 million and took three years to complete. Fortunately, the WIPP itself is still 10 years ahead of schedule and billions of dollars under budget thanks to the design and location of the facility.\textsuperscript{140}

**Alternative Waste Disposal Methods**

Besides geologic repositories, other methods of nuclear waste disposal have been explored historically, though never seriously considered. Many of these alternative methods have been considered unusable due to international laws and regulations. Some of these methods, however, may be potential solutions to the problem of waste disposal and storage.


\textsuperscript{132} Ibid.


\textsuperscript{140} Ibid.
From the 1940s up until 1970, the U.S. used ocean disposal to dispose of radioactive waste from nuclear weapons and energy production. During this period, an estimated 89,000 barrels of radioactive waste were dumped into both the Pacific and Atlantic Oceans.\textsuperscript{141} International regulations such as \textit{The London Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter}, \textit{Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal}, and \textit{MARPOL} 73/78 placed a global ban on the marine disposal of radioactive waste as early as the 1970s.\textsuperscript{142}

Recently, the Department of Energy has been investigating Sub-Seabed Disposal as a method of waste disposal. This method differs from Ocean Disposal by requiring that wastes be buried in the sediment of the ocean floor to prevent any radioactivity from entering the water.\textsuperscript{143} Although only briefly mentioned by a few officials in the U.S., the process has been more strongly considered by the United Kingdom and Sweden, though it has yet to be implemented largely due to international maritime laws.\textsuperscript{144}

\begin{itemize}
\item \textsuperscript{141} U.S. Environmental Protection Agency. (n.d.). \textit{Learn About Ocean Dumping}. Retrieved from: https://www.epa.gov/ocean-dumping/learn-about-ocean-dumping
\end{itemize}
Depending on the specific needs of a nuclear power plant, a developer can choose or combine any of the three decommissioning processes.

- **DECON**: The DECON process consists of immediately dismantling a reactor and removing radioactive contaminants until the NRC deems the facility safe.

- **SAFSTOR**: The SAFSTOR process, or “deferred dismantling,” accounts for the majority of decommissioning strategies. SAFSTOR involves maintaining and monitoring a closed nuclear power plant to allow the radioactivity to decay to a point where the plant can be safely dismantled and decontaminated.

- **ENTOMB**: The ENTOMB process is the most intensive decommissioning option and has never been used on an NRC-licensed facility. ENTOMB requires the developer to permanently encase the site with concrete or a similar material to prevent radioactive contaminants from escaping. The facility must be maintained and monitored until the radioactivity decays to a safe enough level for the NRC to terminate the license.

Another, more recently proposed technique is direct injection waste disposal. Direct injection, otherwise known as deep borehole storage, involves the drilling of deep boreholes into bedrock, at depths of approximately 3,000 to 5,000 meters below the surface. Waste is stored in special containers and deposited into the lower portions of the hole, which is backfilled, sealing the waste deep below the surface. In 2014, the U.S. Department of Energy published a report that strongly advocated the use of deep borehole storage instead of a single, large repository. The Department of Energy concluded “Preliminary evaluations of deep borehole disposal indicate a high potential for robust isolation of the waste, and the concept could offer a pathway for earlier disposal of some wastes than might be possible in a mined repository.” The public would likely be concerned with the environmental repercussions of this method, which could make direct injection unfeasible in the U.S.

### Decommissioning Nuclear Facilities

Radioactive waste is generated from both the operation and decommissioning of a nuclear facility. When a nuclear power plant’s license is about to expire, the developer must begin decommissioning the facility. Decommissioning requires the plant operator to safely remove the high and low-level wastes produced in a nuclear power plant.

The decommissioning process for a nuclear power plant is fairly straightforward. The NRC regulates the decommissioning of nuclear facilities, which requires safely removing a facility from service as well as reducing the level of residual radioactivity.

There are three different licensing strategies for decommissioning a nuclear reactor: DECON, SAFSTOR, and ENTOMB. After a facility is closed, the operator must fully decommission a nuclear power plant within 60 years.

The decision to use a specific decommissioning strategy, or the combination of multiple strategies, may be based on the availability of waste disposal sites and the decay rate of the waste on site. Nuclear power plant licensees are required to provide the NRC with early notification of planned decommissioning, and all information must be made available to both the public and the NRC. Before a plant can begin operation, the owner or operator is required to ensure funding will be available for decommissioning. This funding is usually a trust-fund or a guarantee from the parent company. The decommissioning fund generally ranges from $300 to $400 million.

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149 Ibid. Pg. V.


151 DECON, SAFSTOR, and ENTOMB are not acronyms, but rather the formal names for different decommissioning processes.


154 Ibid.

155 Ibid.
Without an established and viable long-term waste disposal policy, decommissioning a nuclear reactor can be unpredictable and expensive. During the 1990s, several nuclear power plants were decommissioned amidst the political battles over Yucca Mountain. The NRC allowed some nuclear licensees to sell part of their land while requiring them to keep a small area licensed to store spent fuel. These independent spent fuel storage installations are still subject to the scrutiny of NRC licensing and regulation, and the owners are responsible for the security, maintenance, insurance, and funding for eventual decommissioning. This may be a reasonable way to regulate the disposal of waste, but not when developers are expecting the government to provide a waste disposal site as outlined in the Nuclear Waste Policy Act. If the government is not going to build a national waste repository, developers need to have their own solution for waste disposal.

Many developers built nuclear power plants and paid millions of dollars to the Nuclear Waste Fund for a government-operated waste disposal site. In total, billions of dollars from the fund went toward the construction of Yucca Mountain, which was supposed to be the national nuclear waste storage facility. Without Yucca Mountain, some developers are now being held liable for managing this waste under an NRC license. Nuclear developers could not anticipate this increased cost and extended management timeline, which shows just how unpredictable operating a nuclear power plant can be under the current regulatory environment. The current uncertainty in waste regulation is a major deterrent to future investments in nuclear energy.

Other Federal Regulations

Many of the regulations enacted for nuclear power were created specifically to protect public health and safety from nuclear energy’s potential impacts. There are other federal regulations, however, that were created as blanket regulations that apply to multiple forms of energy rather than targeting nuclear power specifically. When nuclear-specific regulations are combined with other pertinent regulations, developers have to navigate a complex regulatory environment that can discourage them from actually building new power plants.

One of the most far-reaching regulations that has a significant impact on nuclear development is the National Environmental Protection Act (NEPA). NEPA requires federal agencies to evaluate the environmental impacts of a proposed action. Under NEPA, the NRC must consider the environmental effects of a proposed nuclear facility.

To comply with NEPA, the NRC must draft an environmental impact statement. The environmental impact statement requires the NRC to analyze the impacts of a new nuclear facility on air and water quality, wildlife, vegetation, natural resources, and property of cultural significance. Environmental impact statements have required increasingly more time and money to prepare, creating additional uncertainty in the regulatory process. Between 2003 and 2012, the DOE estimates the median cost for an environmental impact statement to be $1.4 million. The average length of an environmental impact statement in 2012 was 4.6 years.

Nuclear power plants require large amounts of water, especially for cooling systems. Constructing a new plant requires the developer to consider the effects of this water use on local ecosystems. Under the Clean Water Act, the water used to cool nuclear power plants is regulated as a pollutant when discharged. To remove the water used to cool a power plant, a developer needs a National Pollutant Discharge Elimination System permit. As a condition for these permits, the developer must conform to national technology-based standards established by the EPA. These

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156 Ibid.
standards require the use of the best technology available to minimize the environmental impacts of dumping warm water into local water sources.161

The Department of Transportation is in charge of regulating the labeling, packaging, and transportation of nuclear waste.162 Waste storage and transportation containers, however, must meet NRC requirements.163

Fuel for nuclear power plants is regulated by the Department of Energy. The agency oversees the enrichment process, assesses the domestic trade of the DOE’s inventory of uranium, and reports on the uranium purchase agreement program with Russia.164

One last regulation that has a large impact on nuclear development in the U.S. is the “foreign owned, controlled, or dominated” provision of the Atomic Energy Act. This provision prohibits foreign ownership or control of U.S. reactors. This reduces the number of qualified potential plant owners and operators. The vague wording of the provision has also sparked debates on the how much partial ownership of a nuclear power plant a foreign company can have.165

**State-level Regulation**

In addition to various federal regulations, individual states can impose further requirements on nuclear power plants. Some states encourage nuclear development while others have placed restrictions on new construction. Several states have placed restrictions on nuclear development to address the lack of proper waste disposal facilities.166

**Agreement States**

Certain states have opted into an agreement with the NRC giving them the authority to license and regulate nuclear materials within their state. These states are known as agreement states. Under this agreement, states are given the ability to regulate their nuclear source materials, byproducts, and certain special nuclear materials so long as they comply with the NRC’s federal-level requirements. By regulating their own nuclear industries, even subject to NRC standards, states can create more efficient processes that save developers time and money. Currently, 37 states have entered into these agreements, which can be seen in Figure 9.167


State participation in Agreement State programs.\textsuperscript{168}

Source: Nuclear Regulatory Commission

One of these agreement states, Illinois, operates 11 reactors, more than any other state in the nation. Illinois also has the highest nuclear generation capacity of any state.\textsuperscript{169} The agreement state program may contribute to the success of the nuclear power industry in Illinois. Most states that use nuclear power are agreement states, but not all. Michigan, for example, has several nuclear power plants but is not an agreement state.\textsuperscript{170}

State-level Regulation of New Facilities

Some states have opted to restrict or ban the construction of new nuclear power plants altogether. In total, 14 states have restrictions on the construction of new nuclear power plants: California, Connecticut, Hawaii, Illinois, Maine, Massachusetts, Minnesota, Montana, New Jersey, New York, Oregon, Rhode Island, Vermont and West Virginia. These restrictions vary, as Minnesota has a complete ban on constructing new nuclear power facilities, whereas New York bans the construction of nuclear power plants in some parts of the state.\textsuperscript{171}

Other states have passed legislation that aims to find solutions for the disposal of nuclear waste. For example, Oregon legislation states that before the construction of a new nuclear power plant can begin, "the Energy Facility Siting Council must find that an adequate repository for the disposal of the high-level radioactive waste" is


available.\textsuperscript{172} Many other states, including California, Connecticut, Illinois, Maine, and West Virginia have similar legislation.\textsuperscript{173}

Many states also require legislative and voter approval of new construction. Voter approval of all proposed new power plants is required in the states of Maine, Massachusetts, Montana, and Oregon.\textsuperscript{174} For example, Montana Code specifically states “that substantial public concern exists” and the public has “the exclusive right to determine whether major nuclear facilities are built and operated in the state.”\textsuperscript{175} If other sources, such as hydropower, wind, or fossil fuels required voter approval for new construction, the construction of new plants would be a lengthy, time-consuming process with increased costs.

In some cases, approval by the state legislature is required for the construction of a new nuclear power plant to begin. The Hawaii State Constitution for example, states “No nuclear fission power plant shall be constructed or radioactive material disposed of in the State without the prior approval by a two-thirds vote in each house of the legislature.”\textsuperscript{176} In addition to Hawaii, Illinois, Massachusetts, Rhode Island, and Vermont also require legislative action for the approval of new nuclear construction.\textsuperscript{177} Requiring legislative approval of new nuclear construction makes new developments more costly and increases the development timeline. Because there have been almost no new developments in the past several decades, however, it is difficult to accurately measure how prohibitive these policies are. Illinois, for example, generates more nuclear electricity than any other state, despite requiring legislative approval. All of Illinois’ reactors were already in operation or finishing construction by the time legislative approval was required in 1987.\textsuperscript{178} The legislative approval requirement may be discouraging investments in nuclear in Illinois.

Recent and Proposed Policy Changes

Policymakers have recognized the need to address obstacles to using nuclear energy in the U.S. One of the largest obstacles is the lack of a long-term storage site for nuclear waste. Despite a history of opposition to the Yucca Mountain Project, President Trump is proposing more funding to restart the waste disposal site, which could help expand the nuclear industry.\textsuperscript{179}

The recent Energy Policy Act of 2005 and the Combined Operating License may have helped the regulatory environment for nuclear energy, and several bills proposed in Congress could help further. Even with these changes,

\begin{itemize}
  \item[174] Ibid.
\end{itemize}
however, there is still room to improve the regulatory environment for nuclear energy. An improved regulatory environment, in combination with new innovations, may decrease the cost and time necessary for constructing a nuclear power plant.

**Recent Legislation**

The most recent act pertinent to nuclear electricity generation is the Energy Policy Act of 2005. The act provides subsidies for future nuclear projects through production tax credits and loans.

In order to mitigate the enormous construction costs of building a nuclear reactor, the Energy Policy Act establishes a loan guarantee program for new nuclear power projects through the Department of Energy. These loans can cover up to 80 percent of the total project cost. Loan guarantees are strong financial incentives that make the government liable if the developer defaults. Further, these guarantees allow developers to finance their debt at reduced interest rates, which creates another financial incentive for nuclear energy producers.

The Energy Policy Act also provides Production Tax Credits of 1.8 cents per kilowatt-hour (kWh) to encourage the development of new reactors. This incentive, however, only applies for the first 6,000 MW and eight years of operation. Projects must also be operational before 2021 to receive the tax credits. The Vogtle 3 and 4 reactors in Georgia, and the Summer 2 and 3 reactors in South Carolina are the only projects likely to be completed by this date. The Production Tax Credit factored into the decision to take on both projects and is a large incentive for companies to develop projects that can be operational by 2021. The Production Tax Credit is a strong incentive, but may not be strong enough to encourage many new developments considering all the costs and uncertainty surrounding new plant construction in the U.S.

**Licensing Changes**

In addition to subsidies, a recent change to the licensing process for nuclear power plants may encourage more development. The NRC began revising the original two-step licensing process in 1989, and in 2007 developers were allowed to start using the new Combined Operating License (COL) process. The COL gives a nuclear developer more certainty that a power plant will generate electricity, which makes it an improvement over the two-step process.

The combined licensing process does have its drawbacks, however, as it makes it harder to modify construction plans as needed. With the original two-step process, a developer could freely adjust their design during construction, but under the combined license, they must go through an amendment process to make any changes to the original plan. This amendment process is costly and time-intensive. The NRC charges $265 an hour to review these amendments, which can add up when a developer needs to make several changes. In 2013 alone, the Vogtle reactors in Georgia needed more than a half dozen license amendments.
The Nuclear Energy Institute claims it takes nine total years for any developer to build a new nuclear facility, five of which are dedicated to drafting an application and waiting for NRC approval.\(^\text{188}\) The NRC estimates it takes about 30 months to review a license application using a certified design, and four to five years for uncertified designs.\(^\text{189}\) These estimates are optimistic compared to the realities of developing new nuclear power, as shown by the time it took the six units with Combined Operating Licenses to obtain licenses.

The first three projects to apply for combined licenses received them within four to seven years. Vogtle Units 3 and 4 filed for a license using a certified design in 2008 and received one in 2012.\(^\text{190}\) Operators at the Summer plant also applied for a license using a certified design in 2008 and were approved in 2012.\(^\text{191}\) Fermi Unit 3 submitted their license application for a then-uncertified design in 2008 and received a license in 2015.\(^\text{192}\)

The most recently licensed units, however, took much longer than the Nuclear Energy Institute’s claim of a five-year licensing process. License applications for two reactors at the South Texas Project were submitted in 2007 and did not complete the licensing process until 2016, nine years later.\(^\text{193}\) Levy Nuclear Plant Units 1 and 2 also received their license in 2016, but began the licensing process in 2008.\(^\text{194}\) These timelines are much longer than the total estimated time needed, and do not include the time required to draft an application. Part of the reason the licensing process for these projects was so long may have been because developers needed to amend their applications to comply with the NRC’s new Aircraft Impact Assessment rule.\(^\text{195}\)

Out of the six projects that hold combined licenses, none are currently operational.\(^\text{196}\) The Vogtle reactors will be the first U.S. nuclear power plants to be built in the past 30 years when construction is finished in 2020.\(^\text{197}\)

These six licensed projects show the COL process takes much longer to complete than estimates suggest, even if it is shorter than the original process, which sometimes took as many as 12 years.\(^\text{198}\) These long and unpredictable regulatory timelines delay project construction, which could be problematic for developers who are trying to finish in time to qualify for production tax credits from the Energy Policy Act. The combined license is more streamlined than the dual licensing process, but not as effective in practice as it may seem on paper.


Proposed Legislation

Most nuclear bills in Congress address military concerns or nuclear research. The Interim Consolidated Storage Act of 2017, however, would amend the Nuclear Waste Policy Act of 1982 and regulate the disposal of high-level waste.\(^{199}\)

If passed, the Storage Act would authorize the Secretary of Energy to make contracts for storing high-level waste with a licensed interim consolidated storage facility.\(^{200}\) This means that the Department of Energy would be able to contract temporary waste holding facilities and move nuclear waste off site starting five years from the act’s passage.\(^{201}\)

The Storage Act was introduced in January of 2017 and referred to committee.\(^{202}\) If passed, this bill could potentially be a short-term solution to the nuclear waste storage problem until more permanent facilities can be built.

Another recently proposed reform is the Nuclear Energy Innovation and Modernization Act, which was proposed by a bipartisan group of eight senators in March 2017. The purpose of the bill is to encourage innovation and advancement of nuclear energy in the United States by streamlining the reactor licensing process and allowing advanced reactors to be licensed. Additionally, the bill is intended to create more transparency and accountability for the NRC’s budget as well as the uranium regulatory process.\(^{203}\)

Our Policy Suggestions

Two of the largest regulatory hurdles the nuclear industry faces are the design certification process and nuclear waste disposal. Reforming these areas could encourage the development of new, advanced nuclear technologies as well as expansion of the overall nuclear energy industry within the United States. Policymakers should encourage the growth of the nuclear energy sector if the United States is to continue to strive for clean and reliable electricity. Some suggested policy changes that could help increase investments in nuclear energy include:

- **Improve the design certification process to reduce the time and cost needed to obtain certification.**
  
  To encourage more investments in nuclear energy, the NRC should simplify or eliminate unnecessary tests within the design certification process while maintaining basic safety standards for new plants.

- **Develop an effective long-term waste disposal solution to reduce developer uncertainty.**
  
  Without a viable waste disposal option, nuclear developers have to store their own waste on-site. This adds uncertainty and a large financial burden. There are a number of potential solutions the NRC could pursue, including building a permanent waste storage facility, allowing permanent on-site waste disposal, or using innovative new waste disposal methods.

- **Alleviate public fears and concerns surrounding nuclear power by educating the public about the realities of nuclear power.**
  
  Many nuclear regulations were created in response to unfounded public fears of nuclear power. If nuclear energy companies or government agencies better educated the public about the prospects of nuclear power, they could decrease opposition and help remove unnecessary regulations.

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● **Shorten the duration of the licensing process to reduce costs.**
   Reducing the time it takes to obtain a license would provide nuclear developers with greater certainty and would reduce regulatory compliance costs.

● **Ease the Combined Operating License amendment process.**
   Nuclear developers currently face a difficult amendment process to make necessary changes. If the NRC eases the amendment process, nuclear developers can make necessary design changes more easily. An overly burdensome amendment process discourages innovation, safety, and the economic viability of nuclear power.

**Conclusion**

Nuclear power has lots of potential to increase the amount of electricity generated in the U.S. without added greenhouse gas emissions. Nuclear is an inexpensive, reliable, and safe energy source that can be widely developed throughout the country.

Nuclear power does face a number of problems, however, many of which are regulatory. Public fears about the safety of nuclear drive regulators to create new rules that often discourage investments in nuclear energy in favor of energy sources with an easier regulatory environment. Some of the biggest barriers to constructing new nuclear power plants are the licensing and design certification processes, as well as the lack of a viable nuclear waste disposal solution. As regulatory barriers to nuclear accumulate, the U.S. loses out on an important clean energy source.

If Americans want to transition to a clean energy economy, policymakers need to consider the importance of proven energy sources like nuclear. But as long as the public fears nuclear, regulators will continue to look for ways to promote safety without considering the unintended consequences of an overly burdensome regulatory environment.