WISE
Washington Internships for Students of Engineering

# Addressing How Light Water Small Modular Reactors Should be Licensed

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# Foreword

### About the Author

Philip Coyne is a student of the University of Michigan and will graduate in 2012 with a B.S. degree in Nuclear Engineering and Radiological Sciences. Philip Coyne's interest in nuclear energy started when he enrolled in an introductory class at John Hopkin's Center for Talented Youth program when he was fourteen. His interest in engineering started when he saw Star Wars: The Empire Strikes back.

### About the Washington Internships for Students in Engineering (WISE) Program

The Washington Internships for Students of Engineering (WISE) program was founded in 1980. This collaborative effort among several engineering societies has become one of the premier Washington internship programs. Its goal is to groom future leaders in the engineering profession who are aware of and can contribute to the important intersections of technology and public policy. This multi-society program is supported by the American Association of Engineering Societies. Please see http://www.wise-intern.org for more information.


### Acknowledgements

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## Executive Summary

Small Modular Reactors (SMR) are an impressive advancement in technology that can provide the world with an efficient and clean energy source. They can be built in an off-site facility and be shipped to the construction site cutting a significant amount of time during construction. They provide 300 megawatts electric or less, making them ideal for small communities and developing areas. If such an area develops beyond the energy supply of a single reactor, multiple reactors can be fitted into the power grid, providing even more power for a community.

In order for this technology to become available to the public of the United States, it must undergo a licensing process conducted by the Nuclear Regulatory Commission (NRC). The licensing process must be structured so that SMRs can be deployed in a safe and timely manner. This paper will briefly discuss the benefits of SMRs, explore the issues of Part 50 and the advantages of Part 52 of Title 10 Codes of Federal Regulation.

NRC used Part 50 during the 1970's and 1980's for licensing, however it was a system that didn't protect a utility's investment. After the Three Mile Island (TMI) accident in 1979, the interest in new orders for nuclear plants decreased sharply, and the NRC became much stricter in its regulation; the review process eventually became long and difficult to navigate. Noticing this, Congress requested that the NRC create a better process.

In 1989, Part 52 was brought into regulation and is now the preferred process of the NRC. It saves time by combining both a construction permit and operating license into a single entity, named Combined Operation License (COL). It improves on the weak points of Part 50, by incorporating a design certification process to promote standardization and moving all *mandatory* public hearings *before* the construction of the nuclear plants. It reduces the number of long and unnecessary delays; hence it helps protect a company's investment. Since Part 52 is efficient, allows for standardization, and provides options to vendors and utilities in licensing nuclear power plants, the author recommends that Part 52 be the process used to license Light Water Small Modular Reactors.

# Introduction

## *Brief Discussion of Small Modular Reactors (SMRs)*

The research and development of new nuclear technologies has driven unique innovations for today's society. One such innovation is the development of the Small Modular Reactors (SMRs). The SMR is a nuclear power plant that is smaller in size and produces fewer megawatts electric (approximately 300 MWe or less) than current large nuclear power plants in operation.[1] SMRs will require significantly less on-site preparation than their large light water reactor counterparts [1] and the smaller sizing of the units will allow the bulk of production to take place in factories, after which the modules can be shipped to the site for installation.[2] With the smaller size comes reduced costs, thus opening the nuclear market to more companies wishing to enter this growing energy field. Companies are searching on how they can become "Green" and Nuclear energy leaves a significantly smaller carbon footprint than fossil fuel plants.

The small modular Light Water Reactors (LWR) reactors may be much more practical, in some cases, than the large LWRs since small modular LWRs are designed for the production of nuclear power plants in developing areas that do not require the power output of a large reactor. Additionally, it is anticipated that more units could be added to a site if power demands increase for an area.[1]

Currently a majority of SMR designs are in the conceptual phase, but safety is a priority in all designs. SMR are designed to have passive safety features and some are designed to be built underground as well.[3][4] These small reactors may use different coolant in its design. For example: NuScale is using Light Water coolants, and Babcock & Wilcox's mPower is using Advanced Light Water coolants. Some other reactors use liquid metals, like sodium or lead bismuth, and high temperature gas coolants such as Toshiba's Super-Safe, Small, and Simple (4S), Hyperion Power Modules are liquid metal cooled reactors, and Pebble Bed Modular Reactor (PBMR) is a high temperature gas cooled reactor. The small nuclear reactors also have diverse applications, for example: LWRs are for power generation, Fast Breeder Reactors (FBR) can be used for breeding new fuel or consuming recycled nuclear waste, and High-Temperature Gas-Cooled Reactors (HTGR) can be used for heat applications.[5] Furthermore, SMR designs reduce the needs for refueling, fuel storage, and fuel handling in order to provide a long life. Some designs anticipate a variety of refueling cycles; NuScale's refueling cycle is every 24 months [19], advanced light water Babcock & Wilcox's mPower reactor is designed for refueling every 4.5 years [20]. Whereas, liquid metal cooled Toshiba's 4S reactor expects a 30 years refueling cycle [21] and Hyperion's HPM reactor design will replace reactor modules every 7 to 10 years [4]. Longer refueling cycles are significant advantages as compared to today reactors that require one to two years of refueling cycle. *This paper will be limited to LWR technology largely because the NRC licensing process is better defined for LWR technology for large reactors.*

**Table 1 Summary of the SMRs Mentioned in the Paper**

| Design | Applicant | Specifications | |
|---|---|---|---|
| NuScale | NuScale Power, Inc. | Coolant | Light Water Reactor |
| | | Power Rating | 45 MWe |
| | | Refuel Cycle | 24 months |
| mPower | Babcock &Wilcox Company | Coolant | Advanced Light Water |
| | | Power Rating | 125 MWe |
| | | Refuel Cycle | 4.5 years |
| Pebble Bed Modular Reactor | PBMR (Pty.), Ltd. | Coolant | High Temperature Helium Gas Cooled |
| | | Power Rating | 110 MWe |
| | | Refuel Cycle | Continuously |
| Super-Safe, Small, and Simple (4S) | Toshiba | Coolant | Sodium Liquid Metal |
| | | Power Rating | 50 MWe and 10 MWe |
| | | Refuel Cycle | 10 years and 30 years |
| Hyperion | Hyperion Power Generation | Coolant | PbBi Liquid Metal |
| | | Power Rating | 25 MWe |
| | | Refuel Cycle | No refuel on-site; life time: 7-10 years |

With these promises, SMR technology seems like a very attractive alternative to fossil fuel power plants and a large payoff to utility companies. However, SMR technology is merely in its design phase at this time, with many companies planning to submit their designs to the Nuclear Regulatory Commission (NRC) for review. The industry's interest in finding, developing, building, and operating advanced SMRs has placed the NRC in the challenging position, in the period of "nuclear renaissance". For the first time in thirty years there were 18 applications for combined operating licenses for 28 new large nuclear power plants[12]. In addition to this, the first SMR design certification is planned for submission in 2012.

### *Introduction of 10 CFR Part 50 and Part 52 Licensing Process*

The NRC was created in 1975 as the result of the Energy Reorganization Act of 1974. Its mission is to regulate the nation's civilian use of nuclear materials, to provide reasonable assurance of adequate protection of public's health, safety, security, and the protection of the environment.[6] The NRC regulates nuclear material by developing regulations and policies for nuclear related materials, licensing and certifying applicants, overseeing licensee operations and facilities, and conducting reviews and research of facilities and their operators.[7]

The agency previously used Part 50 of Title 10, Code of Federal Regulations as their licensing process for civilian nuclear reactors. From 1970 to the mid-1970's, there was an increased interest in nuclear power plant construction; and that resulted in a long waiting time for licensing review at the NRC. After the 1979 Three Mile Island (TMI) Accident, the NRC became stricter in its regulation, changing licensing requirements for reactors causing *even longer* delays during the reviewing process for some utilities. After the TMI accident, people's fear of nuclear accidents reached a climax; protestors caused serious delays during the review process, and in many cases, stalled the development, construction, and operation of nuclear reactor plants. The delays in almost all steps of the licensing process created major financial loss for the utility companies, and as the result, customers incurred increased electricity rates. Congress took note of these problems and prompted the NRC to provide a solution, leading to the birth of 10 CFR Part 52, in 1989.

While Part 52 is 20 years old, this process has not been used for any plants in the current nuclear reactor fleet. Since SMR technology is so new, there is a concern how any designs or construction projects will be governed by Part 52. The NRC has certified four large reactor designs under Part 52. These designs are GE Nuclear Energy Advanced Boiling Water Reactor, and three designs from Westinghouse System 80+, AP 600, and AP 1000. However the Design Certification process has not been tested for small reactors, let alone for a *modular* reactor design. This concern is augmented when there has not been any construction or operating licenses since 1976, especially since the Combined Operation License (COL) process of Part 52 has not been tested at all. Knowing this, the issue of using an untested process to certify and license new technology is a serious topic that must be explored. This paper will review the previous and current licensing process, namely 10 CFR Part 50 and Part 52, of the NRC and determine the best possible solution for the deployment of SMRs in a safe and timely manner.

The next few sections will give the background information on the 10 CFR Part 50 and Part 52 licensing processes, analysis of the applicability of Part 52 to SMR development, and my recommendations for improvements to ensure that SMRs are deployed in a safe and timely manner.

## Background on Reactor Regulations

In this section both Title 10, Code of Federal Regulations, Part 50 (10 CFR Part 50) and 10 CFR Part 52 are briefly described.

### *10 CFR Part 50*

Part 50's licensing process was the only process used for the nuclear reactors ordered prior to the publishing of Part 52. Part 50 is can still be used for the operation of a nuclear power plant today.

In the licensing process that is governed by 10 CFR Part 50, the applicant must first obtain a construction permit to start the construction of a facility as specified by 10 CFR 50.10. In order to obtain this construction permit, the applicant must submit a Preliminary Safety Analysis Report (PSAR) 50.34 (a). Additionally, an Environmental Report is required 10 CFR 50.30(f). The objective of the PSAR is for utilities to have a preliminary plan for their facility before any construction begins. The objective of the Environmental Report is to have an analysis on how the nuclear power plant facility would affect the site environmentally. When the NRC approves the construction permit, construction of the facilities may begin. During the construction process, the NRC will perform many inspections that may result in alterations of the design. An operating license may eventually be issued once all hearing issues have been resolved and the NRC approves of the final design. After obtaining an operating license, operation can begin once the plant has been constructed.

During the construction of the site, a Final Safety Analysis Report (FSAR), which is based on the PSAR, is created. An applicant must submit an application for an Operating License, in which includes the FSAR, before obtaining the operating license and loading of fuel into the reactor vessel cannot occur until an operating license is obtained. Section 50.34 (b) details the technical information for a FSAR. Both the PSAR and FSAR contain basic descriptions of the site, commitment of the licensee in the areas of administration, construction, operation, radiation protection, emergency planning, and physical security. The PSAR is the basis for FSAR; it remains substantially unchanged after the construction permit issuance. Hence all changes as required by the NRC inspection reviews or occurred during the construction of the site must be incorporated, by the applicant, into the FSAR. The NRC must approve of all details of the FSAR before the operating license is issued. One should keep in mind that the operating license review occurred in parallel with the construction of the facility.

Also, as described in 50.34, additional documents are needed before the license is finally issued, such as a Physical Security Plan, Safeguards Contingency Plan, and a Protection Against Unauthorized Disclosure. These additional documents contain analyses that were required after the Three Mile Island accident, to show that the design of the plant has taken into account the “lesson learned” from it.

In accordance with 50.58 (b)[9], before the construction permit and before the operating license issuances, public hearings are held and public comments collected. During these hearings the public may bring up issues concerning the facilities, such as quality assurance, site related concerns, thermal discharge to bodies of water, environmental issues, etc. NRC reviews the comments and may request the applicant to make appropriate changes based upon them.

10 CFR Part 50 offers advantages in allowing the applicant to start construction based on a preliminary design, and the operating license review is carried out during the construction of the plant. With the flexibility the design might not have to be as completed as it should be and it allows the NRC to inspect the construction, ensure changes to the design and construction are followed, and the NRC stays transparent to the public with public hearings and comments.

There are weak points in 10 CFR Part 50. It brings a concern known as "Design as you build". The issuance of a construction permit based on the PSAR was a weak point because the PSAR is a preliminary analysis, it did not contain a more complete analysis and design for the plant. Constructing a nuclear plant based on preliminary analysis would result in many cycles of changes, inspections, reviews, and incorporations of changes and updates into FSAR, which cause delays and cost overruns. Some analyst viewed that the applicants took a calculated risk in building a nuclear plant based on a preliminary design, and hoped that the plant would have been acceptable to the NRC. It proved that such risks cost the utilities capital and licensing delays.

During the time period when Part 50 was used, there was a lack of standardization of the facilities and the reactor design. Each reactor would have something that made it unique from the others, making the process of review for each reactor at the NRC a time consuming process. The NRC would not have any precedent to base their review process off of because it could have been a new design or had different site features that the NRC were not used to dealing with.

Additionally, the public can enter comments and put in challenges during the hearings for the construction permit and operating license. Though the NRC allows for transparency to the public, many groups could manipulate this licensing process to delay the operation of nuclear facilities for extended periods of time. The result of these long delays for operation of a facility for which construction had been completed would cost utility companies a considerable amount of capital causing the utility company to transfer the over-run cost to the consumers, creating a higher rate that customers must pay, when the plant went into operation.

The delay would result in a company losing its budget for the project and being forced to either shut down the project, or require further investment. This type of situation has happened before where companies did shut down their reactor projects. In a rare situation, the community refused to participate in Emergency Planning for the Shoreham plant on Long Island after the construction was completed. The plant was sold for a single dollar and was shut down permanently. Transparency is good; however to allow the public to cause such havoc after such commitment posed great financial risk to utility companies.

10 CFR Part 50 process allows utilities to start the construction earlier and the NRC to conduct the Operating License review while the plant is constructed. Although the applicant can start the construction early under Part 50, the operating license may not be issued, and it was not issued any faster. The process took about 10 to 14 years from the time the construction permit is issued to the time the plant may operate. Noting this, Congress requested that the NRC recommend a solution.

### *10 CFR Part 52*

In 1989 the NRC published 10 CFR Part 52 in response to Congress' request; today it is the *preferred* process for licensing a nuclear power plant. It was designed to have a single hearing prior to issuing a Combined Operation License (COL). Furthermore, Design Certification (DC) and Early Site Permits (ESP) were introduced. The overall 10 CFR Part 52 process is depicted in the below figure. Vendors may apply for a DC or Design Approval (DA) while utilities apply for an ESP. The NRC staff reviews applications and may issue an ESP or a DC (or DA). The utilities apply for a COL, referencing either an ESP, or a DC, or both, or none. Utilities may start construction upon the issuance of a COL from the NRC. During the construction, the applicant is responsible for conducting Inspection, Tests, Analysis and Acceptance Criteria (ITAAC); the NRC verifies regulation with ITAAC. The NRC reviews all aspects of the plants and decides upon an Operating Decision.

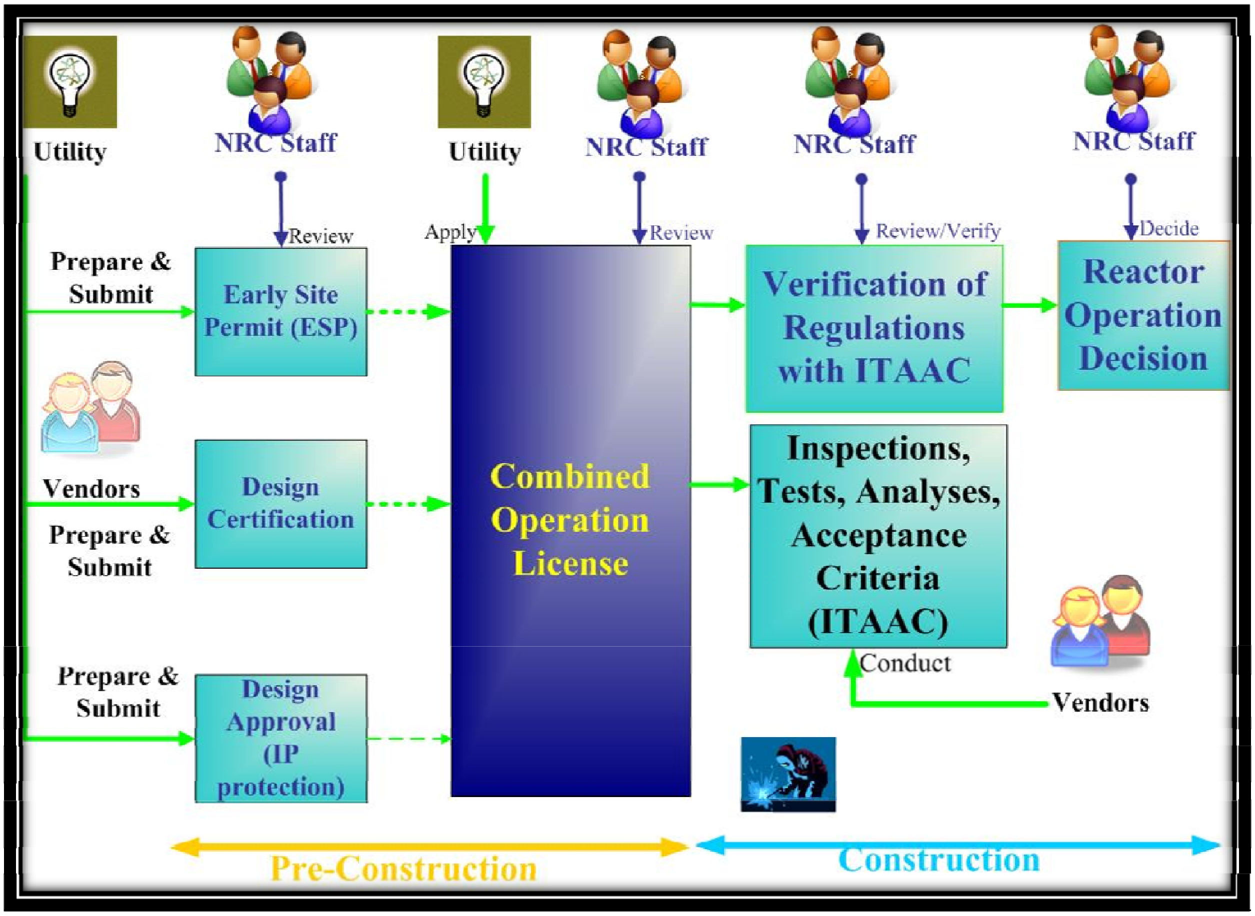


**Figure 1 Overall Steps of 10 CFR Part52 Licensing Process**

**Early Site Permit (ESP) -** The overall objective of the ESP is to determine if a specific location could support the construction of a nuclear power plant facility. Utilities that are intending to obtain a COL should apply for an ESP. An ESP allows the utility to "bank" the site, for future use (within 10-20 years). The ESP process enables completion of the site evaluation component of the nuclear plant before a utility makes a decision to build a plant. Ideally, this would be a good incentive for a utility to apply for an ESP *before* applying for a COL. *An ESP can be referenced in an application for a COL, allowing the NRC confirmation that the site is qualified for a nuclear power facility, shortening the review process* as compared to a COL application without a reference to an ESP. *Moreover, utilities may transfer or sell their ESP to other companies, if they desire.* The time for the review process for an ESP could take 2-3 years. The technical information is outlined in 10 CFR 52.17. This includes an overview of the facility, site safety feature requirements, and emergency situations planning. An additional Environmental Report is also required from the applicant for the ESP.

Section 52.21 requires that a hearing and administrative review be conducted before issuing the ESP. The NRC submits a copy of the early site permit application to the Advisory Committee on Reactor Safety (ACRS). During this hearing, the presiding officer does not allow contentions concerning benefits of construction or operating, or allow analysis of alternative sources of energy if the issues are not addressed in the application. In a public hearing, together with the NRC staff, the ACRS reviews the Safety Evaluation Report (SER) and the Environmental Impact Statement (EIS) for each ESP application. If the applicant satisfies all the criteria required by the NRC, and if NRC determines the site is suitable for possible construction and operation of a nuclear plant, then an ESP will be issued, allowing limited work authorization (LWA) if the applicant has requested it.

**Design Certification** is the process where a vendor may submit a design for a facility for approval to the NRC. This process should take approximately 4-5 years. During this process, a vendor is required to submit an FSAR. The objective of this FSAR is to have a thorough analysis of the facility and its capabilities. Requirements for the technical information to be included in a DC application can be found in 10 CFR 52.47. Like ESPs, Design Certifications can be referenced in COL applications (though a DC is not necessary to apply for a COL). The idea behind Design Certification is to get designs approved for future projects or in one word: *standardization*.

**Combined Operation License (COL) –** The Combined Operation License is the central theme of 10 CFR Part 52. The process encourages for standardization of nuclear plants by referencing a DC in the COL application, resolves safety and environmental issues *before* authorizing construction by reference an ESP, and provides meaningful public participation. A COL authorizes construction, with specific conditions, and operation of a nuclear power plant, at a specific site. Upon the issuance of a combined license, the utility may start the full construction of a facility, in addition to permitting the operation of the facility once it has been complete, after the NRC verifies the ITAAC.

The application process for a COL is similar to that of an operating license. There will be a public hearing before the COL is issued. A COL application may reference a DC, an ESP, both DC and ESP, or neither a DC or an ESP. Although all choices are allowed to the utilities when applying for a COL, *it is recommended from the NRC that the COL application should include both the ESP and DC*. The reason is that the COL process is intended to review how the certified design works at a particular site, with specific terrain, water access and other factors [14]. Hypothetically, if a utility decides to reference an ESP or a DC in a COL application, then it helps the NRC to review the application faster. This is due to the fact that the NRC would have already approved of the ESP or the DC. Furthermore, when issues have been resolved during the ESP and DC reviews, the NRC will not allow for these issues to be raised again during the COL review.

The NRC has intended for the 10 CFR Part 52 licensing process to address the weak points of 10 CFR Part 50; it brings the following advantages as the result:

- Standardize the design of reactor plant by the Design Certification process.
- Identify and resolve issues early in the decision making process in both DC and ESP reviews, whether the issues are design, environmental, or site-related safety.

- The NRC stays transparent to the public and achieving public acceptance. At the same time, the NRC encourages meaning public participation by not allowing previously resolved issues to be brought up again in later processes, causing endless delays.
- Give assurance to the utilities that their investments are protected. COL process issues the operating license before the plant is constructed gives the utilities incentives for their investment and assurance that the plant will be in operation after a complete construction and thoroughly reviewed and inspected by the NRC.

# Analysis

## *Early Site Development (ESP) and Design Certification (DC) for SMR LWR*

Commissioner Svinicki reported at the Capitol Hill Symposium VIII on June 8th, 2010, that the NRC has received 18 COL applications and 13 have been docketed and are in active review.[10] However, none of these applications are for SMR LWRs. The next section will give an analysis of the feasibility of using 10 CFR Part 52 for SMR LWRs.

### Early Site Permits (ESP)

Commissioner Klein strongly encouraged that applicants reference both an ESP and DC in their COL applications [11] . Some sites that have used 10 CFR Part 52 to obtain an ESP are Vogtle, Dominion, and Grand Gulf showing that the ESP process has been tested as a separate step that is not in the context of the combined operation application. Therefore it is not known how the COL review will treat the situation in which the issues have been resolved in the ESP review and are again brought up.

### Design Certification (DC) for SMRs

There are no certified designs for SMR LWRs. Looking at the NRC's website, it is evident that the industry is working hard in designing the next generation of advanced reactors with many technological innovations, but none have actually made an application for design certification. The current fleet of the nuclear power plants is made up of light water reactors, therefore, it is natural that the first Small Modular Reactors should use the LWR technology, since it would likely be easier for the NRC to adapt the current regulations for large LWR plants to LWR SMRs. The NRC still has to consider issues related to the "modular" nature of SMRs and its size. The question arises: should Part 52 be used for the licensing of SMR LWRs? If 10 CFR Part 52 is used, then (i) how will the Design Certification for the new technology be laid out and (ii) would the 10 CFR Part 52 timeline be reasonable so that the utility companies would not be penalized for delays. To use an unproven licensing process (DC portion of 10 CFR Part52) for an untested technology

(SMR) would be a major risk; one risk involves the safe and timely deployment of a SMR power plant.

There are no certified designs for SMR technology at this time. We should be reminded that one of the objectives when Part 52 is standardization. The standardization is a great approach in general; it is especially applicable to *modular* reactors. The idea is analogous to pooling resources. A vendor submits a DC and gets the approval for the design. When it is approved, it is available to applicants who want to build the facility, use the same technology and design. As more vendors submit designs, and as more designs become approved, the pool gets bigger with more choices and the process becomes easier to navigate, reducing time in building new plants at new locations, and giving assurance that the technology is safe.

Two approaches that can be taken to prove that the design is sound:

1. **Undergo pre-licensing testing to prove that your plant works, under 10 CFR Part 50.**

This is the approach that GE is using for their first kind Power Reactor Innovative Small Module (PRISM) [14]. The rationale behind the approach is that GE can push the innovative technology into construction faster, with the intention that the plant will go into operation quicker. During the process of obtaining the Operating License, the utility may apply for Design Certification of its PRISM.

2. **Build a prototype reactor to obtain the Design Certification (DC)**

In order to certify a design that would work beyond the design on paper, it would be prudent, at the very least, to build a prototype. For many innovative designs that are not LWR, it is important that a prototype is constructed and tested. On July 27, 2010, the Babcock and Wilcox (B&W) company announced that it will build a prototype of the mPower at its Center for Advanced Engineering and Research (CAER) in Bedford, Virginia [24]. The prototype is using electric, not nuclear materials, as the source of energy; the prototype will be used to "collect data to verify the reactor design and safety performance", as announced by B&W. Similar efforts of building a prototype can be done to verify that the design would work in a larger scale than the paper design.

3. **<u>Cost-share Program from DOE</u>**

Similar to the cost-share program for Early Site Permit [23] , the DOE continues the cost-share program for Design Certification. With the support of the DOE, [18] the program will select two SMR LWRs designs from the industry, work with the industry in preparing and submitting the DC applications, and report the lesson learned from the process. It is recommended that the program continue to support designs other than LWRs.

## *Timeline for SMRs Under 10 CFR Part 52*

The central theme of 10 CFR Part 52 is the COL. The NRC intends for the COL to require applicants to provide the details of the designs, avoiding the "design as you build" practice, thus increasing the success of the design. The COL process invites public comments, informs and engages the public early in the process for meaningful participation, avoiding the superfluous delays. Last, the COL encourages standardization of nuclear plant designs.

The NRC is responsible to ensure the safety of the public and environment when nuclear materials are involved, yet the process should be more efficient and should shorten the time from start to finish, protecting the industry in their investment. The question of Part 52 being able to ensure SMR LWR development and deployment in a safe and timely manner must be considered. In this section, several different options that an applicant may use, and the total estimate time is calculated; this provides a measurement metric to answer the question.

- Early Site Permit (ESP) and Design Certification (DC) applications are submitted for NRC Review in sequential steps, Figure 2, page 16
- ESP and DC applications are submitted in parallel steps, Figure 3, page 25

- ESP, DC, and COL applications are submitted for review in parallel steps, Figure 4, page 26.

It is expected that the earliest DC submissions will be made in 2012. An ESP review is estimated to take about 33 months [12] (or 2-3 years at the maximum time); a design certification review is expected to take 36-60 months [12] (or 3-5 years). It is projected that the COL review will take about 42 months (or 4 years at its maximum). [12] Part 52 is structured so that all hearings will be held before the COL is issued, and therefore no delays in licensing will occur. This will allow a construction period of 60-72 months (or 5-6 years) for both construction and the Inspection, Tests, Analysis, and Acceptance Criteria (ITAAC). [14] Data given for ESP, DC, and COL are estimated; construction data is based on historical data that was used to build large reactor plants.

For the first build, in the worst case, when the ESP and DC applications are submitted in sequential steps, it could take about 14-17 years to build a nuclear power plant that is ready for operation. If an applicant follows Part 50, they may get the plant built and ready for operation in 8-9 years; hence there is no time saved using Part 52.

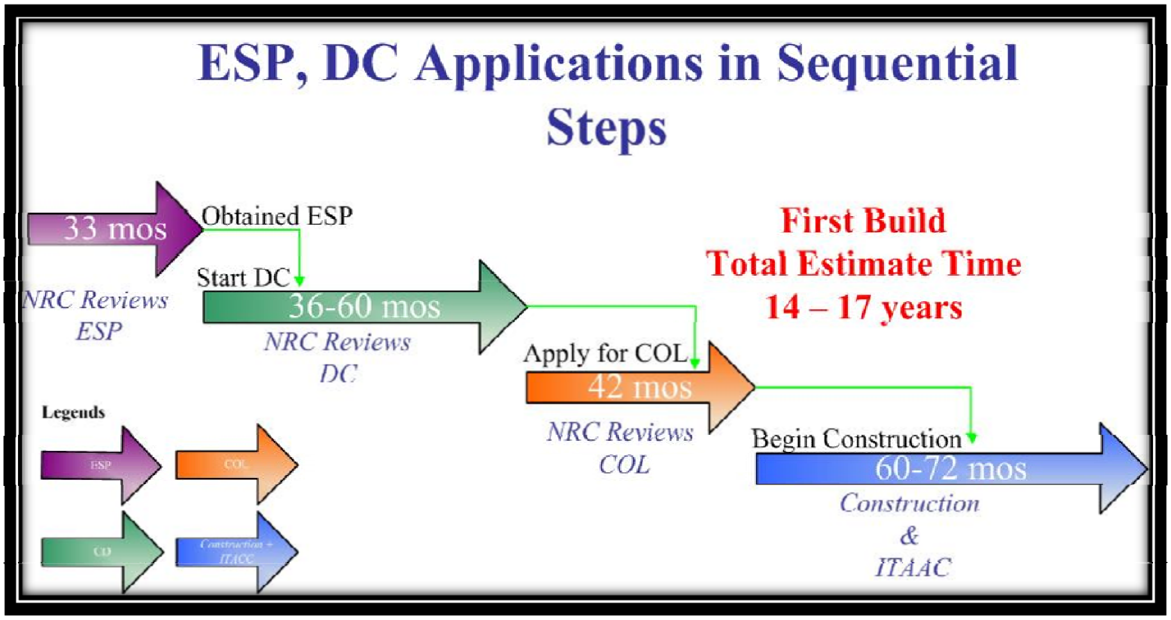


**Figure 2  14-17 Years is the Estimate Time when ESP and DC Applications are in Sequential Steps**

**Table 2 Option 1 ESP and DC Applications Submitted in Sequential Steps.**

*Estimate time for a nuclear power plant to be built and ready for operation, under 10 CFR Part 52*

| | ESP[12] | DC[12] | COL[12] | Construction and ITAAC [14] | Estimate Total Time |
|---|---|---|---|---|---|
| First Build | 33 months | 36-60+ months | 42 months | 60-72 months | 14-17 years |
| Subsequent Build | 33 months | Not needed | 30 months [14] | 48 months | 9 years |

Another option is the ESP and DC applications are in parallel, followed by a COL application. The total estimate time (for this option) from start to finish is approximately 11-14 years, which is still longer time than if the applicant uses 10 CFR Part 50 for licensing.

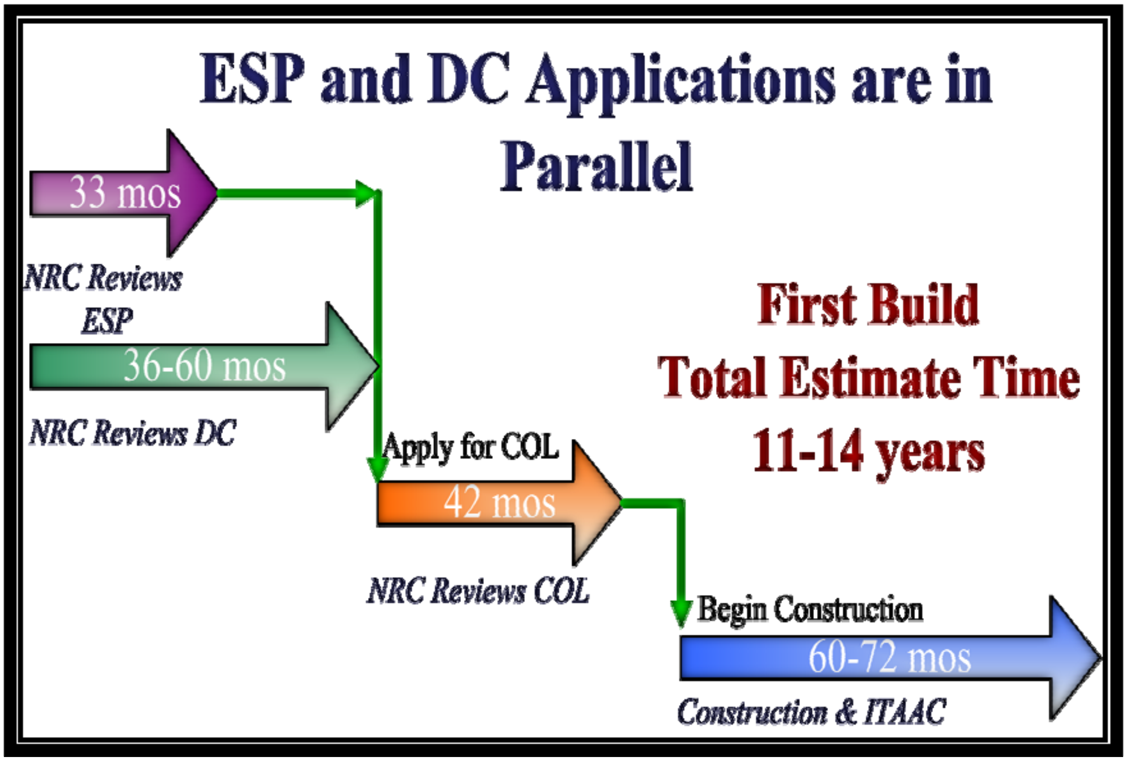


**Figure 3 11-14 Years is the Estimate Time when ESP and DC Applications are in Parallel Steps**

**Table 3 Option 2 ESP and DC Applications Submitted in Parallel Steps.**

*Estimate time for a nuclear power plant to be built and ready for operation, under 10 CFR Part 52. Since ESP and DC applications are submitted at the same time for review, DC time for review is the determining factor in the total time.*

| | ESP[12] | DC[12] | COL[12] | Construction and ITAAC [14] | Estimate Total Time |
|---|---|---|---|---|---|
| First Build | 33 months | **36-60+ months** | 42 months | 60-72 months | 11-14 years |
| Subsequent Build | 33 months | Not needed | 30 months [14] | 48 months | 9 years |

There is yet another strategy that AREVA suggested when it introduced its Evolutionary Power Reactor (EPR) design to the US market [25]. Immediately after the submission of a DC, AREVA applied for the COL, as shown in below illustration. In this approach, AREVA showed that it is feasible that the utility may apply for the COL soon after the DC application was filled by a Vendor, and making reference to the DC.  With this option, the nuclear power plant will be ready for operation in 10-11 years, for the first build.

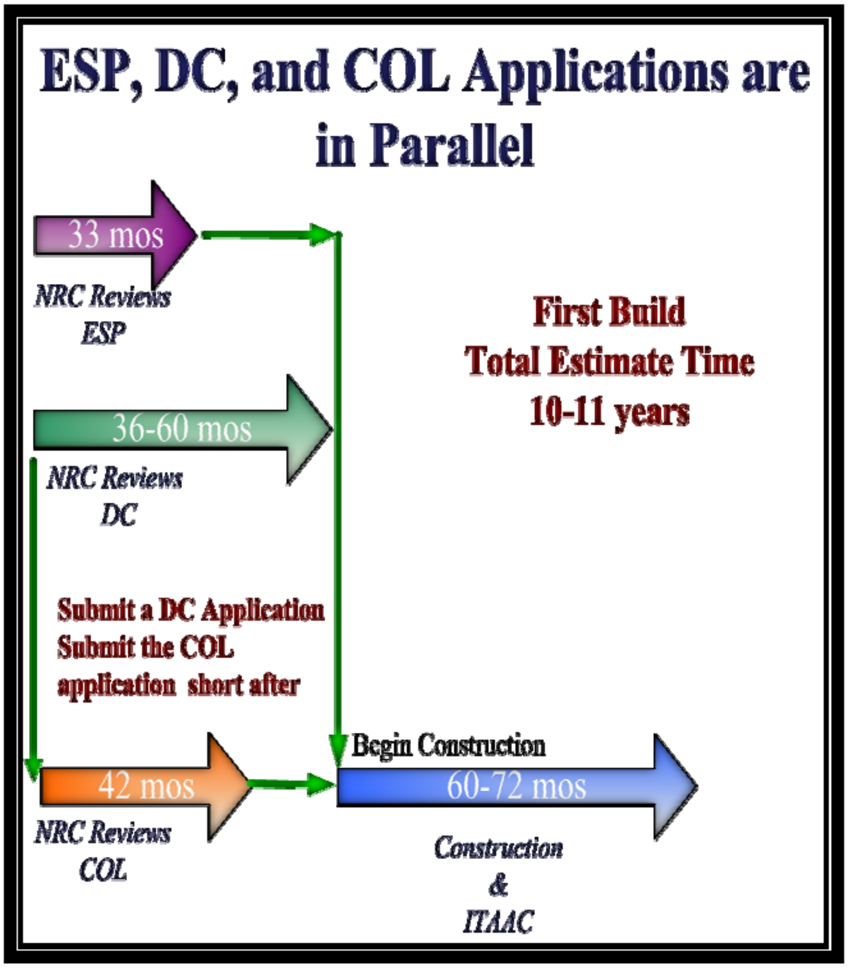


**Figure 4  10-11 Years is  the Estimate Time when  ESP, DC, and COL Applications are in Parallel**

**Table 4 Option 3 ESP, CD, and COL Applications Submitted in Parallel Steps.**

*Estimate time for a nuclear power plant to be built and ready for operation, under 10 CFR Part 52.  Since ESP, DC, and COL  applications are submitted at the same time for review, DC time for review is the determining factor in the total time.*

| | ESP[12] | DC[12] | COL[12] | Construction and ITAAC [14] | Estimate Total Time |
|---|---|---|---|---|---|
| First Build | 33 months | **36-60+ months** | 42 months | 60-72 months | 10-11 years |
| Subsequent Build | 33 months | Not needed | 30 months [14] | 48 months | 9 years |

After the first group of reactors is licensed, then only an ESP and COL application will be required, assuming that a DC is referenced in the COL. In this case, the COL is estimated to take about 30 months (or 2.5 years). In this case, the ESP and COL can be conducted sequentially. This will result in the plant being operational in 9 years total. From all options, it is shown that 10 CFR Part 52 licensing process begins to show its advantages in the subsequent builds of a certified design—the procedure is simpler when a utility would only need to prove that its site is suitable, via the ESP process, and that the design standardization may help in shorten the licensing process.

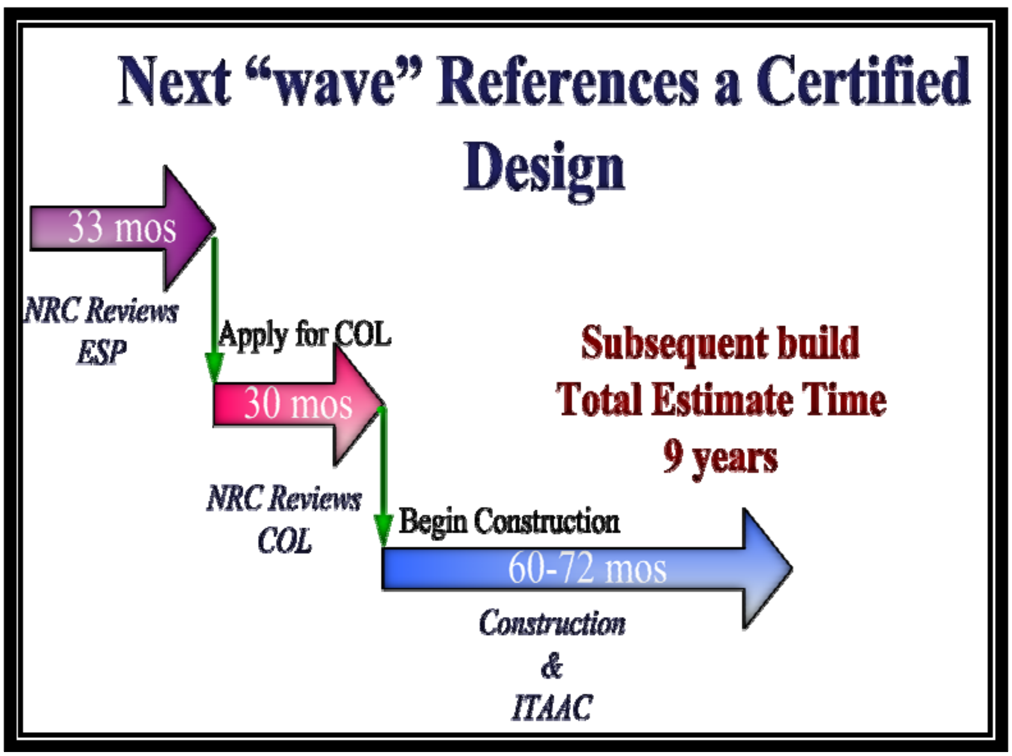


**Figure 5 – 9 years is the Estimate Time for Subsequent Build of a Certified Design**

Safety issues are brought up with 10 CFR Part 52 where the operating license is issued prior to the plant being built. The NRC proposed the Inspection, Tests, Analysis, and Acceptance Criteria (ITAAC) to ensure the safety to public and environment when the plant is in operation. It is the responsibility of the licensee to make sure their facility is safe for the public and environment. The ITAAC process occurs shortly after the construction of the plant begins in order to ensure that all aspects adhere to the referenced design. Afterwards, the NRC will conduct its own inspection of the facility. This inspection is more of a sample inspection rather than a complete investigation of the facility.

10 CFR Part 52 provides a number of options for the applicants to choose from in order to apply for the COL. The applicant could benefit from a shorter time frame in having their plant in operation if they choose an appropriate option. The standard design of a nuclear plant is especially attractive in the shortened time frame for subsequent builds, which is highly probable for Small Modular Reactors. With the ITAAC process, the safety in operations for the plant is shifted to the licensee, with overseeing power of the NRC. The public should be safer with three different parties reviewing a single facility: the vendor ensuring their design is safe, the utility inspecting the constructed facility, and the NRC supervising during the entire process.

### *Quality of Applications and NRC Review Process*

During the analysis, it became apparent that the time delays in the review process and constructing of the nuclear power plants could be attributed to the “Quality of Applications” and “Quality of NRC Review Process”. From the first glance the factors do not seem to relate to policy and SMRs. However, with more understanding of the cause, this is an issue of the Licensing Process. Furthermore, this issue may become worse with 10 CFR Part 52.

On July 24, 2008 at the Global Nuclear Renaissance Summit, Commissioner Klein said, "Yet, I have also said many times that our ability to review applications quickly depends directly on the quality and completeness of those applications." He added "In addition, the design certification applications and some COL applications received to date initially lacked information that the staff needs to complete its review."[11] This statement suggested that some applications were not only incomplete, but lacked the quality needed for quick review by the NRC.

However on June 8, 2010, Commissioner Svinicki said "…the NRC has put in place the right structure and given that structure adequate resources to handle new reactor-related work…" and "On the human capital and workforce front, half of the agency's staff has now been at the NRC for six years of less."[10] This statement suggests that the NRC structure was not adequate and that the NRC lacked the resources and the quality of resources, which in turn contributed to the long review process. On the other hand there is debate among the industry of the vagueness of the application requirements versus the quality or completeness of the response. With these statements in consideration, this section will look into this matter.

Section 52.47 states: "The application must contain a **level of design information** sufficient to enable the Commission to judge the applicant's proposed means of assuring that construction conforms to the design and to reach a final conclusion on all safety questions associated with the design before the certification is granted."[16] It is quite troublesome that the required technical content of the application is merely described as "level of design information"; the lacking of specification is left to the interpretation of the readers. Each reader, applicants and reviewers, might and will interpret the 'level of design information' differently; hence leading to the applications being labeled as an "incomplete submittal".

On April 6, 2010, the NRC held a briefing on New Reactor Issues – Design Certification [16]; at the briefing, a collection of vendors (Westinghouse, Toshiba, GE-Hitachi, and AREVA) gathered and gave feedback of the design certification process. A majority of comments praised the NRC for its communication with the industry with Hitachi expressing that Part 52 and the Design Certification Review, and ESP process is working well. Most participants gave the NRC good comments on the mechanism and frequency of the communication, communication occurs at all levels, and schedules are taken seriously, etc. However, all companies seemed to convey the same problem: guidance from the NRC, "Level of design detail", "Process for handling evolving regulatory requirements and guidance must be clear", "acknowledgement of acceptability" [17] . Looking through this list, one can extrapolate that the NRC doesn't give clear specificity of what it is expected. When there are regulatory changes, there is no guidance on how to handle them. Whether the source of changes is the evolving regulatory changes or change requests from the applicants or the timing of the changes, changes are disruptive. In short, it is not a quality issue with the applications, but rather the applications do not provide the "level of details" that the reviewer requires. And the NRC contributes to the issue because it is not clear in specifying the "level of details", and requirements are changed from reviewer to reviewer.

It is predicted that the lack of specific requirements will become more difficult for applicants to navigate under Part 52. To quote the Branch Chief of Advanced Reactors at the NRC, William Reckley, "…this question about 'level of detail' in an application is a long-standing one and has been made somewhat more complicated under the Part 52 licensing processes."[14] Under 10 CFR Part 50, the operating license is issued based on a FSAR, with a completed plant, completed pre-service testing, inspection; whereas under 10 CFR Part 52, the operating license is issued based on design information, provided by the plant designer, or vendor. Since it is an operating license, the NRC reviewer will want to know the level of details of the plant construction that the applicant does not know, as the information is not available until the plant is under construction, which might be years away.

As stated above, it is recognized that there is the “level of details” that is required from the applicants, but the “level of details” is not well formulated by the NRC. The problem may persist (and potentially worsen) under the 10 CFR Part 52 licensing process; it certainly would cause delays in the process. It seems that NRC has taken steps to trying to rectify this long standing problem. Lacking experience and insights into the cause of the problem, the author does not wish to form an opinion or any recommendation.

# Conclusion and Recommendations

Small Modular Reactors show a great promise for the world's clean energy source. They are designed to be fit into a working grid and can power a small community and can be added as needed for a larger population. They can be built in off-site facilities and shipped to the construction site. They are the future of nuclear energy.

The two licensing processes that are provided are both viable options for delivering SMRs to the public. 10 CFR Part 50 is a tested process and it has proven itself as a long process and it does not take into account that as more plants are ordered and constructed, the design can be standardized. 10 CFR Part 52 is an alternative process. It works towards standardizing the reactors through the design certification (DC) process.

After analyzing Part 50, Part 52, and considering how new SMR technology is, *it is recommended that Part 52 be used for the upcoming wave of applications for SMR technology,* for the following reasons.

- **Time from start to ready for operation:** It is shown that there is no time advantage of using Part 52 over Part 50 for the *first time* a design is ordered. However for subsequent builds, the time it takes to build a nuclear plant under Part 52 begins to show advantage. For the modular nature of the SMRs, it is expected as more plants are built under Part 52, the *average* building time of a nuclear plant will be shorter.
- **Standardization:** The design certification process will begin to facilitate the standardization of the nuclear reactor plant. With design certification, Part 52 is more flexible than Part 50 because it allows utilities to choose a certified design.

- **Safety:** Part 52 will ensure these reactors will be developed and deployed in a safe manner through how the licensing process is structured. Many issues related to safety, whether it is an environmental impact, site-related safety, or conceptual design safety, are examined, resolved, and decided early in the process. The safety issues are continued through the construction and operations through vigilant inspections and reviews.
- **Public acceptance:** Through this investigation it is noted that the NRC is truly a transparent agency to the public. The NRC makes all non-sensitive information available to the public and encourages public participation by informing it about meetings and hearings to attend. The openness in the flow of information is highly appreciated and should be continued with the NRC. Under Part 52, the safety issues are addressed early in the process, with public hearings and meaningful participation, as the result, Part 52 process gains public acceptance, or at least achieving public and community non-rejection of the use of nuclear power plants.

At the same time some relevant issues were found during the analysis. These issues are as follows:

- The Combined Operation License (COL) of 10 CFR Part 52 and the construction process under the COL are untested.
- Does Part 52 allow for the safe and timely deployment of SMRs?
- How the quality of applications and the NRC review process can be improved?

From the analysis a few options have been provided. There are at least three plausible options for the proper testing and assurance of design certification. The first option is to conduct pre-licensing testing for each component of a design to give sufficient data and assurance that the design is certifiable. A second option would be to use the DOE's cost-share program to help in the research, design, and development of a prototype design to assure that the technology is proven for the submission of a design certification. A third option would be to use Part 50 to construct the first reactor plant and then use the data from the fully constructed facility to submit a design certification application.

The planned cost-share program encourages collaboration between DOE with the Industry, in starting the momentum to exercise the new 10 CFR Part 52. There should be a greater effort between the three entities to increase information exchange in order to create clearer channels of communication, guidance, and progress with the exploration of innovative technologies. In addition, one of the goals of the DOE cost-share program is to support the industry and resolve the application completeness for specificity in the level of details. Since the cost-share program for ESP was successful, the cost-share program for DC is highly applauded and supported; it should start immediately.

It was analyzed in the previous section that the maximum amount of time for the first wave of SMRs, from start to finish, could be as long as approximately 14-17 years; while the minimum amount of time is estimated to be about 10-11 years. For the subsequent power plants with a certified design, the time is 9 years. It is hoped that the NRC process is more efficient in the future so that the time will be shorter than 9 years as more plants are constructed. As mentioned, many safety issues are examined and resolved, with reviews and public hearings, early in the process, and the safety in construction, emergency planning, and operations are vigilantly monitored and inspected by the NRC. Thus, safety will be in the hands of the licensee, the NRC, and the vendor. Last, but not least, Part 52 should continue to be transparent to the public; it invites public and community acceptance, without it, nuclear technology would not be advanced.

Part 52 will certainly deliver SMRs in a safe and timely fashion for subsequent reactors, and should therefore be used.

It is noted that there are communication issues concerning applications between the NRC and applicants. Many of the communication issues resulted directly from the new process of Part 52. The communication issues may result in the delay of the review process, and perhaps frictions among parties. The communication issues may arise for many different reasons, ranging from lack of level of detail in the requirements, to guidance on how deal with changes (whether it is regulatory changes, or change requested from the vendors or applicants). However, this topic is beyond the scope of this paper and the author does not have enough analysis to make any solid recommendations.

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# Abbreviations

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| 10 CFR Part 50 | Title 10, Code of Federal Regulations, Part 50 |
| 10 CFR Part 52 | Title 10, Code of Federal Regulations, Part 52 |
| ACRS | Advisory Committee Reactor Safeguard |
| CFR | Code of Federal Regulations |
| COL | Combined Construction and Operation License |
| EPR | European Pressurize Reactor |
| FSAR | Final Safety Analysis Report |
| ITAAC | Inspections, Tests, Analysis, and Acceptance Criteria |
| LWR | Light Water Reactor |
| PSAR | Preliminary Safety Analysis Report |
| RAI | Request for Additional Information |
| SER | Safety Evaluation Report |
| SMR | Small Modular Reactor |
| SSAR | Site Safety Analysis Report |