Estimated Resources Necessary to Pursue an Early Site Permit for a Small Modular Nuclear Reactor Site

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Summary

This paper describes the Early Site Permit[1] (ESP) preparation, application, and review process for novel nuclear generation technologies, including Small Modular Reactors (SMRs). There is growing interest in the development of new nuclear power generation capacity as part of the clean energy transition. Much attention has been focused on technology development, but the critical first step that is often overlooked is the permitting of a site. To date, much of the activity relating to potential new nuclear generation has been concentrated at sites that have already been permitted for nuclear generation in the past, by companies that presently operate nuclear generation facilities (e.g., TVA, Southern Company, Duke). A key challenge for LG&E and KU Energy ("Companies") in considering nuclear generation as part of its future resource plans will be developing the necessary skills to navigate the Nuclear Regulatory Commission ("NRC") approval process and the identification and permitting of a site for nuclear operations.

To develop an understanding of the necessary skills, time requirements, and financial resources necessary for the Companies to realistically consider nuclear generation in the future, the Technology Research and Analysis group has interviewed staff key to nuclear generation efforts at Duke, TVA, and EPRI, as well as reviewed publicly available documents, particularly on the NRC website. This review revealed that future consideration of nuclear generation will require:

- The creation of a new five-to-ten-person team consisting of people knowledgeable and experienced in the NRC site licensing process;
- The identification of a potential site or sites that will satisfy the NRC's strict requirements related to safety and emergency response, geological stability, and numerous environmental impact tests;
- The development of local support, amongst communities and individual stakeholders, for such a project;
- Approximately five years to obtain an ESP, once the application process is initiated, with additional funds (likely over $100 million) and time (measured in years) to secure either Part 50 dual Licenses, or a Part 52 Combined License; and
- The expenditure of $50 to $100 million (we estimate $75 million in ESP-associated expenses).

If the Companies were to begin the above process in 2023, it would take approximately two years to build a team and initiate the process of site review and local outreach. If an appropriate site is identified, it will likely take an additional two years to develop the necessary ESP-specific filing documents required by the NRC. Based on the time required for the NRC to review TVA's Clinch River Site, the Companies could expect another three years before receiving ESP approval. Thus, it is likely that by 2030, the Companies would be in a position to make a decision on preferred nuclear generation technology, and the submission of related additional permitting applications (NRC Construction Permit and License to Operate, or Combined license to Operate) for a new nuclear generating unit. The timeline, at that point, will depend in part on the state of new nuclear technology development and whether other nuclear projects have received NRC construction and operating, or combined permits. Assuming the Companies are not seeking to take

[1] An Early Site Permit is approval by the NRC that nuclear generation can be built at a site but is not for the actual construction of a unit. It is a permit that the site is suitable for generic nuclear generation and is good for 20 years. Actual construction of a unit requires specific technology choice and a construction permit from the NRC that is good only for that particular technology.

significant technology risk, nuclear generation would likely be a viable technology option for the Companies by the end of the 2030s or the early 2040s.

Early Site Permitting - Timeline and Resource Commitment

This section will focus on the costs and time requirements associated with the submission and review of a Nuclear Regulatory Commission (NRC) Early Site Permit (ESP) application. All costs and time estimates detailed herein are specific to Small Modular Reactor (SMR) technology. A number of different SMR designs are currently under development, however, none are commercially available at present. As a result, a fixed estimate for ESP submission time and cost is not readily available. Instead, two timelines (one optimistic, one pessimistic) are presented to provide a high and low bound estimate for costs and time associated with submittal and review of a non-specific nuclear plant design ESP.

The optimistic timeline, illustrated in Figure 1, is based on a combination of Tennessee Valley Authority's (TVA) Clinch River Nuclear Site ESP application experience, and previous Duke Energy, non-SMR ESP applications. While the NRC is planning to streamline their permitting process in the future, this timeline is based on the current review system. Duke's estimate of $50 million is used for early site permit (ESP) application preparation[2], however this figure could reach as high as 100 million, per TVA (See Figure 2).

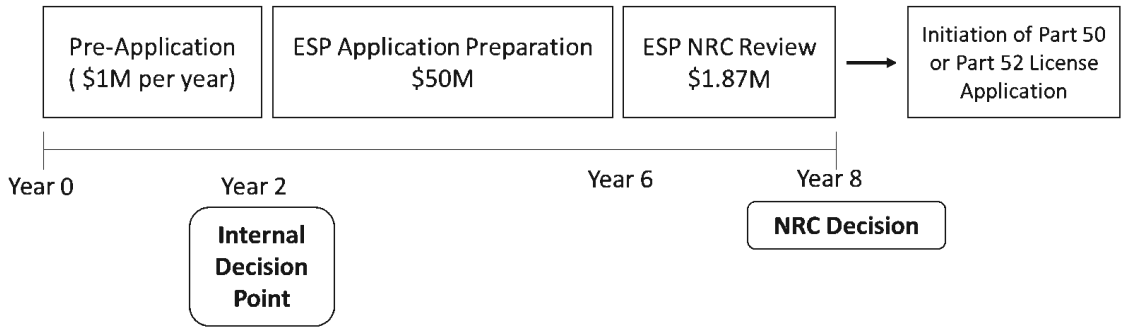

Figure 1: ESP Submission, Optimistic Timeline

The pessimistic timeline, illustrated in Figure 2, is based on a traditional nuclear reactor ESP submission and review timeline (per Dominion's experience with North Anna Unit 3). Cost estimates are based on the experience of TVA in pursuit of ESP for Clinch River.

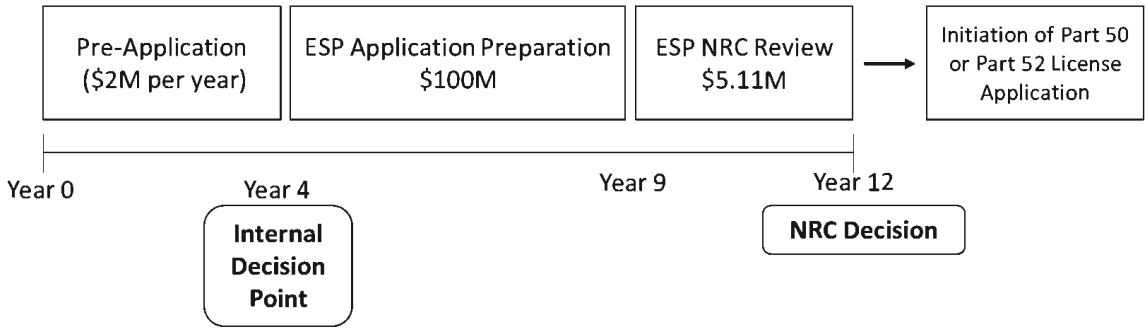

Figure 2: ESP Submission, Pessimistic Timeline

[2] Source: TVA Presentation on Clinch River Project: (https://www.ne.ncsu.edu/)

ESP and the Broader Permitting Process

The NRC was formed in 1975 following the dissolution of the Atomic Energy Commission and tasked with licensing and regulating the operation of domestic nuclear power plants. Since 1975, the NRC has issued 126 Operating Licenses, of which 103 remain active and operating. Legacy nuclear sites were permitted under the regulatory framework set forth in United States Title 10 CFR Part 50, under the auspices of the NRC. Under the Part 50 framework, nuclear sites are licensed following a two-step process, requiring that a separate Operating License and Construction License be issued.

In 1989 the NRC worked to streamline this process by establishing an alternate licensing route, governed by United States Title 10 CFR Part 52. Under the Part 52 framework, a Combined Operating license (COL) may be granted, which supplants separate Operating Licenses and Construction permits, under certain conditions. Additionally, at that time, NRC introduced the ESP as a means for an applicant to obtain approval for a reactor site and "bank" it for future use, without having an immediate understanding of installed reactor type. Before submitting a Part 52 COL application, it is recommended to obtain an ESP and Design Certification (DC). The ESP, provided for by Subpart A of 10 CFR Part 52, resolves site safety, environmental protection, and emergency preparedness issues, independent of a specific nuclear plant design. The goal of the ESP process is to permit exploration of nuclear generation, with preliminary approval, before a large commitment of capital resources is made to pursue plant design and construction specifics. Likewise, the DC assesses the reactor technology and is independent of reactor site. Should the Companies pursue nuclear permitting, the DC would be obtained from the company whose reactor technology is chosen.

Figure 3 visually outlines the role of the ESP in the Combined License application workflow.[3]

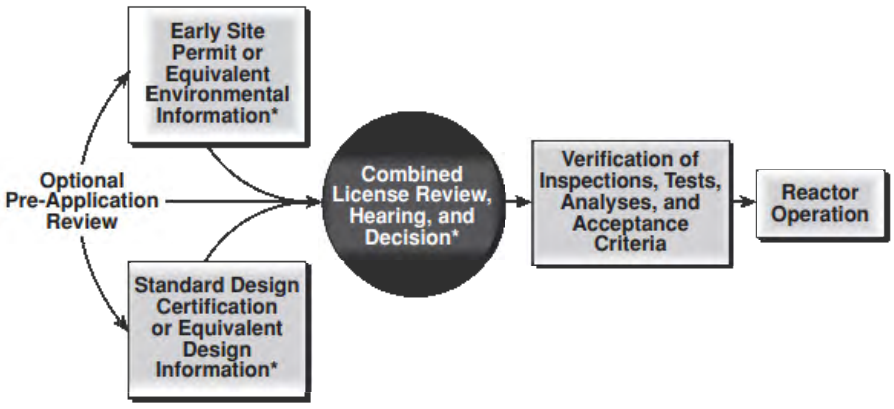

Figure 3: Relationship between Combined Licenses, Early Site Permits, and Standard Design Certifications

[3] https://www.nrc.gov/docs/ML0421/ML042120007.pdf

Preparing for Early Site Permit Application

The ESP application must address the safety and environmental characteristics of the site and evaluate potential obstacles to developing an acceptable emergency plan. It also offers certified plant designs, which can be used as pre-approved designs to shorten the approval process. In preparing an application for an ESP, applicants must conduct extensive site characterization studies and analyses to document the site's suitability for a standardized nuclear plant design. These studies involve data collection and analysis in a number of technical disciplines; input from each of these disciplines is required to complete the Site Safety Analysis Report (SSAR) and the Environmental Report (ER) portions of the ESP application.[4] The information needed for an ESP application is shown in Figure 4.

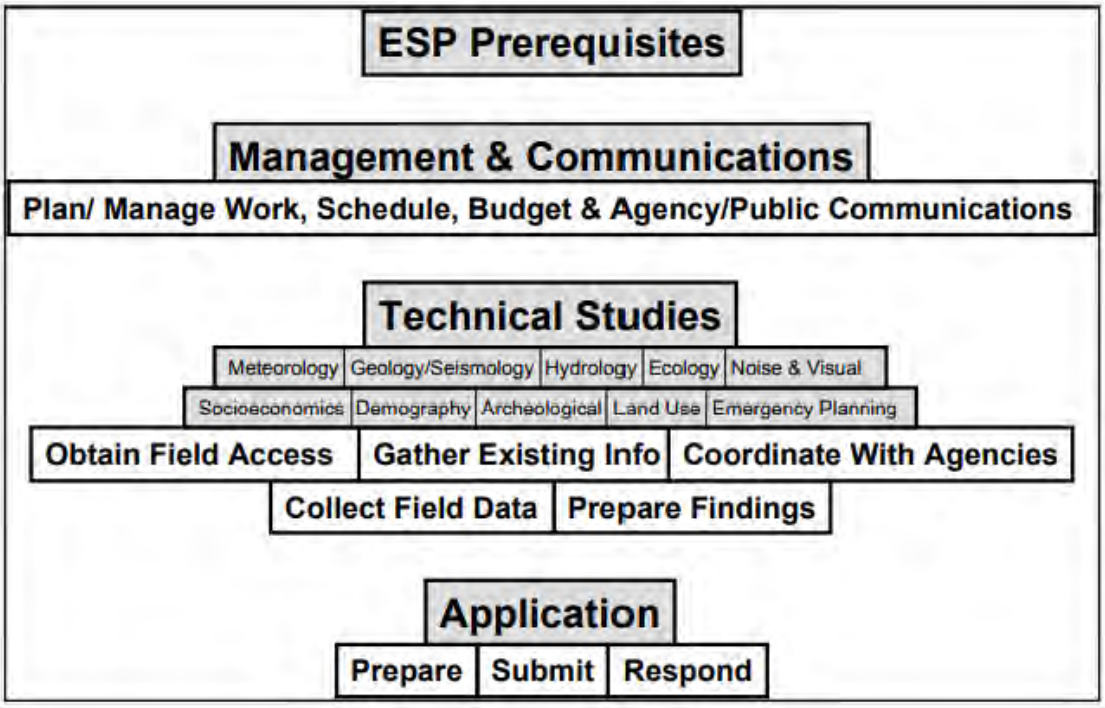

Figure 4: ESP Preparation and Application Topics

An ESP can also allow for a limited work authorization to perform non-safety site preparation activities before a combined license is issued. After the NRC staff and the Advisory Committee on Reactor Safeguards (ACRS) complete their safety reviews, the NRC issues a *Federal Register* notice for a mandatory public hearing. The ESP is initially valid for 10-20 years and can be renewed for additional 10–20 year time periods[5]. According to the EPRI Early Site Permit Model Program Plan, preparing the ESP should take approximately three years. If planning to build a reactor at an existing generation location, then the process could be shortened by up to 12 months. Applicants should initiate discussions with NRC as early as possible in the ESP planning process to determine how data from operational, environmental, and radiological monitoring programs from existing plants can be used in the ESP application.

[4] EPRI Early Site Permit Model Program Plan, EPRI Project Manager, E. Rodwell
[5] Source: NRC Early Site Permit Applications (https://www.nrc.gov/)

Per the NRC, an application for an ESP must contain the following information:

- The boundaries of the site, including a discussion of the exclusion area for which the applicant has the authority to remove or exclude persons or property
- Characteristics of the site, including seismic, meteorologic, hydrologic, and geologic data
- The location and description of any nearby industrial, military, or transportation facilities and routes
- The existing and projected future population of the area surrounding the site, including a discussion of the expected low-population zone around the site and the locations of the nearest population centers
- An evaluation of alternative sites to determine whether there is any obviously superior alternative to the proposed site
- The proposed general location of each plant on the site
- The number, type, and power level of the plants, or a range of possible plants planned for the site
- The maximum radiological and thermal effluents expected
- The type of cooling system expected to be used
- Radiological dose consequences of hypothetical accidents
- Plans for coping with emergencies

An overview timeline for preparing an ESP application is shown in Figure 5.

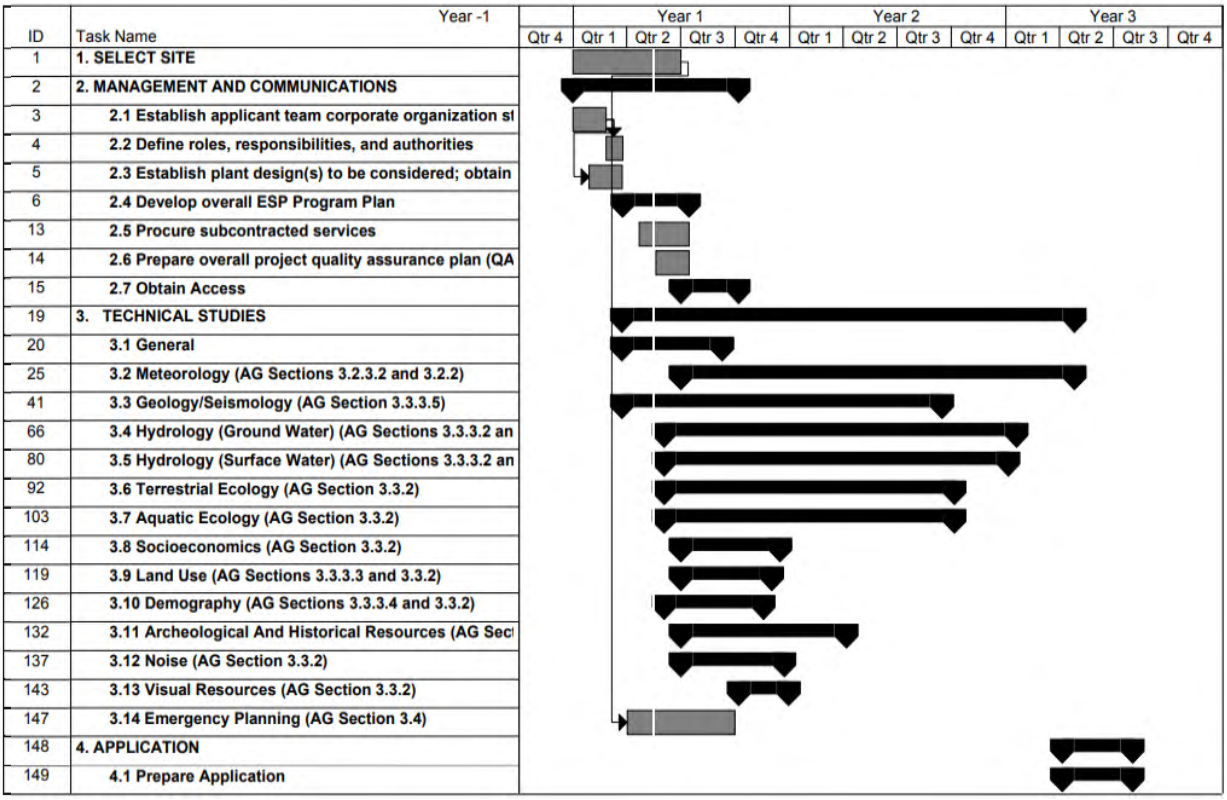

Figure 5: ESP Preparation Gantt Chart

Preparation of an ESP application will typically start with organizational, planning, subcontracting, and public/institutional policy development, followed closely by the legal, public relations, and agency interface actions necessary to complete preparation for the technical studies.

Pursuing Part 50 – Separate Construction and Operating Licenses

The licensing route defined in 10 CFR Part 50 describes a process whereby an applicant files for a construction permit and an operating licensing using a two-step process. Under this process, an applicant first applies for a construction permit. Upon approval of this permit, and as construction nears completion and design information becomes final, the applicant files for an operating license. The NRC last issued a Construction Permit under the Part 50 regulatory regime in the 1970's (more recent applications and approvals have been for Part 52 COL permits).

The Part 50 application route does not require an ESP first be secured before additional permitting steps be completed (Part 50 licenses are, in effect, stand-alone permits).

The process flow for Construction Permit application review is detailed in Figure 6, as per the NRC Nuclear Power Plant Licensing Process document[6]

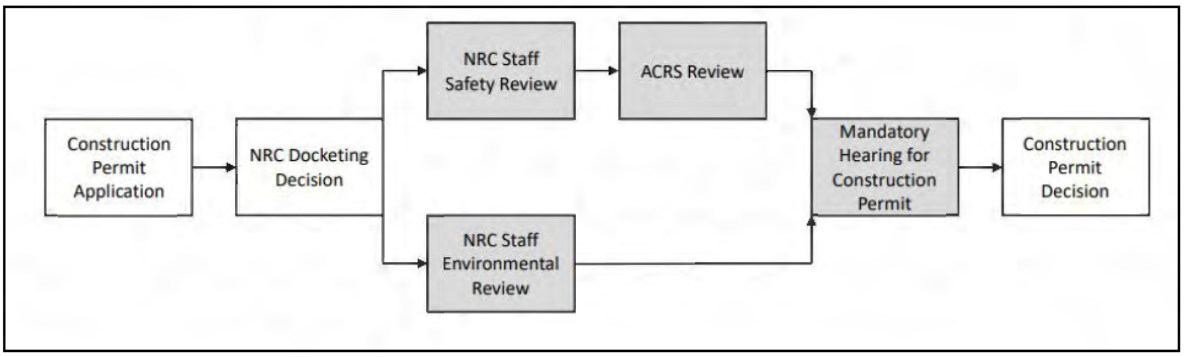

Figure 6: Part 50 Construction Permit Application Process

Further, the Part 50 Operating License review process is outlined in Figure 7. The Operating License application process may not be initiated until construction is nearing completion.

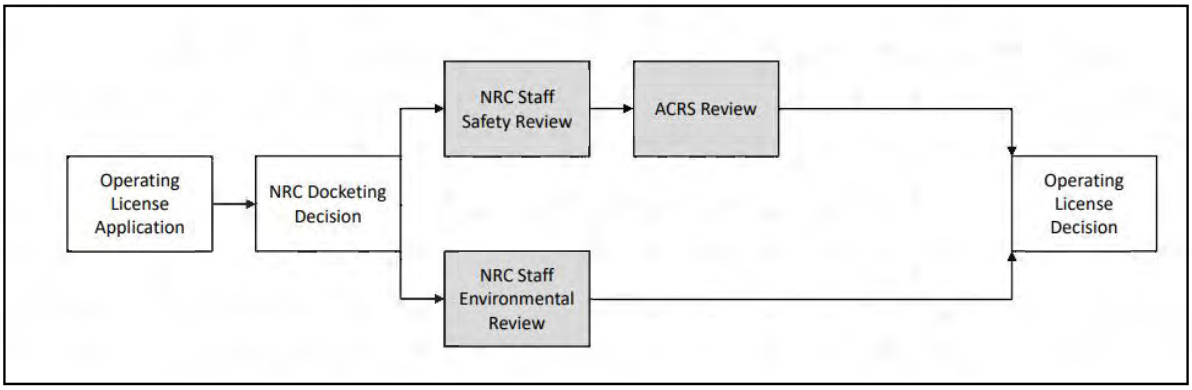

Figure 7: Part 50 Operating License Application Process

[6] https://www.nrc.gov/docs/ML0421/ML042120007.pdf

The information collected during the Part 50 application process is divided into three major categories: general, safety, and environmental. A primary benefit of the Part 50 application is that construction may begin early in the licensing process and that design changes are permitted during construction. An inherent drawback in this flexibility is that the issuance of an Operating License may be delayed as the result of design modification or evolution during the construction process. [7] Additionally, the time commitment required to successfully secure both Part 50 licenses may be greater than that of the Part 52 COL process.

Pursuing Part 52 - Combined Operating License

Following Approval of the ESP:

The licensing process defined in 10 CFR Part 52 (the COL process) is the second alternative for the final permitting step, and is a less intensive option than the Part 50 operating license application. A COL allows applicants to reference previous findings of DC or ESP proceedings for much of the information in a COL application. Additional activities to develop information specifically for the COL will also be necessary. To prepare for the COL application, companies need control and use of a site with an approved ESP and a nuclear power plant design with an approved DC that fits in the ESP site parameters. The information needed for the COL application is restricted to site, design, and operational issues not addressed in the ESP.

COL applications are reviewed by NRC, ACRS, and Atomic Safety and Licensing Board (ASLB). The process after submitting the COL is shown in 8. After COL approval comes NRC verification that the plant was constructed correctly before operation.

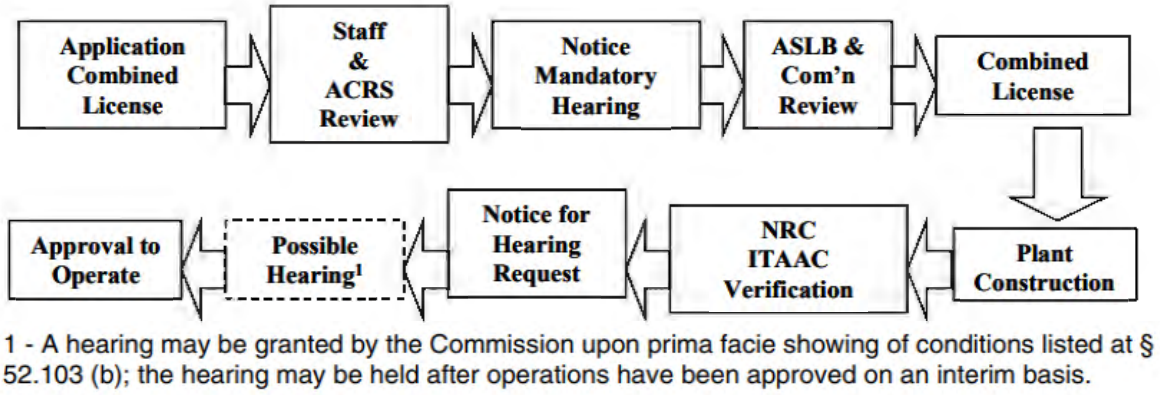

Figure 8: Process for Approval After COL Submission

According to the EPRI Combined Operating License Model Program Plan, the COL application process takes over three years. The COL specifies information necessary to ensure that the facility has been constructed and will be operated in agreement with the license and applicable regulations. Based on The COL issued to Southern Nuclear Operating Company for Vogtle, the NRC COL application review takes around four

[7] https://gain.inl.gov/SiteAssets/GAIN_WebinarSeries/2021.03.31_RegulatorySeries-3/Presentations/01-Burdick_OverallProjectRisk_31Mar2021.pdf

years[8]. After issuing a COL, the NRC authorizes operation of the facility after verifying that the required inspections, tests, and analyses required were completed and deemed satisfactory.

Benefits of the Part 52 process include a greater degree of finality in the licensing process and significant recent experience across the US nuclear industry in the COL application procedure. The primary drawbacks of the Part 52 process include a lack of operational units permitted under the COL regime (Southern Company's Vogtle units 3 & 4 are nearing completion following Part 52 licensing), changes to design conducted during construction require licensing review, and all regulatory review must be completed prior to commencement of construction.

Early Site Permit Costs

Expenditures related to ESP application fall into three broad categories – scoping costs, application preparation costs and review costs. Scoping costs can be as little as several hundred thousand dollars, or as high as several million. These scoping costs are highly variable and depend upon several factors, including the experience of the scoping team, experience of the interested company, and whether the proposed site is greenfield, brownfield or legacy nuclear.

The primary ESP costs comprise funding needed to formally prepare the permit application. Based on discussions with experienced utilities, the lowest total ESP application cost was indicated at $50 million, based on the experience of Duke (Duke has extensive internal experience in nuclear site permitting). TVA indicated that they expended $200 million in funding for ESP preparation (costs associated with gathering the necessary site data and compiling/submission) for the Clinch River site. TVA plans to allocate an additional $200 million to prepare a plant design, COL application, and project plan[9]. Dominion spent $600 million in pursuit of both licenses.

Building a Nuclear Team

For a major nuclear project, a team will need to be assembled to manage permitting application submission. To head the team, an expert with experience managing reactor projects would need be hired. The expert would then need to hire a team of 5-10 people for the project. Five nuclear engineers would be a part of LKE or PPL, and the other 5 could be contracted subject matter experts for relevant topics in nuclear site evaluation (relating to the two primary concerns of the ESP – environmental and health/safety risk), including hydrologists, seismologists, qualified industrial hygienists, etc. The total cost of the company team's salaries would likely range from $1-$1.5 million annually.

Agency Interactions

Throughout the permitting process, applicants are required to engage with, respond to, and otherwise generally interact with a large number of federal agencies and offices. Each individual agency and office has unique jurisdiction and responsibilities. These range from document certification, technical consultation, technical review, health and safety review, environmental review, to enforcement. Should the Companies wish to pursue consideration of ESP preparation and application, it would be prudent to

[8] Source: NRC Vogtle COL Application (https://www.nrc.gov/)
[9] Source: *POWER* Magazine (https://www.powermag.com/)

have a robust understanding of what agencies, offices, and partners will require engagement, and at what stage of application preparation.

Numerous offices exist under the purview of the NRC. However, only a specific subset of these are relevant to the interests of utility-based nuclear power generation, and help facilitate aspects of the application review process. These offices, and their individual roles are:

- **Advisory Committee on Reactor Safeguards (ACRS):**

  Reviews and advises the Commission with regard to the licensing and operation of production and utilization facilities and related safety issues, the adequacy of proposed reactor safety standards, technical and policy issues related to the licensing of evolutionary and passive plant designs, and other matters referred to it by the Commission.

- **Atomic Safety and Licensing Board Panel (ASLBP):**

  Conducts hearings for the Commission and performs such other regulatory functions as the Commission authorizes.

- **Office of Nuclear Material Safety and Safeguards (NMSS):**

  Responsible for the licensing and regulation of facilities and materials associated with the processing, transport, and handling of nuclear materials, including uranium recovery activities and the fuel used in commercial nuclear reactors.

- **Office of Nuclear Reactor Regulation (NRR):**

  Conducts a broad range of regulatory activities in support of the Commission's safety and security strategic goals. These activities encompass licensing, oversight, siting, rulemaking, and incident response for operating commercial nuclear power reactors, new commercial nuclear power reactors, advanced reactor technologies, and non-power production and utilization facilities.

- **Office of Nuclear Regulatory Research (RES):**

  Recommends regulatory actions to resolve ongoing and potential safety issues for nuclear power plants and other facilities regulated by the NRC, including those issues designated as generic issues (GIs).

- **Office of Enforcement (OE):**

  Oversees, manages, and directs the development and implementation of policies and programs for enforcement of NRC requirements.

- **Office of Investigations (OI):**

  Develops policy, procedures, and quality control standards for investigations of licensees, applicants, their contractors or vendors, including the investigations of all allegations of wrongdoing by other than NRC employees and contractors. Keeps Commission principals currently informed of matters under investigation as they affect public health and safety matters.

- **Regional Offices (Regions R-I, R-II, R-III, R-IV):**

Executes established NRC policies and assigned programs relating to inspection, licensing, incident response, governmental liaison, resource management, and human resources.

Kentucky is in Region II. Region II offices are located in Chattanooga Tennessee and Atlanta Georgia.

Pursuing a Partner

An alternative to developing a nuclear team from scratch would be to partner with an experienced nuclear operator. This would bring instant expertise and experience to the process and would likely be viewed favorably by the NRC. This would also allow for sharing of financial risk as the process proceeds over many years. Both Duke and TVA mentioned partnering as a potential to manage risk and enhance credibility with the NRC. A challenge for the Companies in finding such a partner is agreeing on the potential geographic location of a project given that the Companies are not in an RTO.

In April of this year, it was announced that TVA has partnered with Ontario Power Generation (OPG) on efforts relating to SMR technology development for application at both the TVA Clinch River Site and the OPG Darlington Nuclear Facility. This partnership has seen no transfer of monetary funds. Instead, the focus is on supporting the commercialization of certain GE-Hitachi SMR technology, through the sharing and cross-collaboration of resources. Both TVA and OPG possess extensive organizational understanding and personnel experience in conventional nuclear generation technology. The two organizations have both publicly acknowledged a current lack of expertise specific to SMR technology, but hope that collaborative efforts in this area will help develop this expertise over the coming years. If this approach is successful, and TVA is able to bring SMR technology online at its Clinch River Site, the TVA team will be the only utility in the US with expertise in the areas of SMR permitting, construction and operation.

TVA Clinch River Permit Process and Technology Choice

As a part of TVA's New Nuclear Program, the company is investigating advanced nuclear reactor technologies for potential deployment. TVA's Clinch River currently has the only approved ESP for an SMR design in the country. The Clinch River nuclear ESP application was over 8,000 pages long and took 43 months for approval, following submission.[10] [11]. According to the NRC, it took approximately 46,000 hours to review the application[12]. The permit was for two or more small modular nuclear reactor modules producing a maximum combined 800 MWe. TVA used the Plant Parameter Envelope approach in its application for its analysis of the site, as the ESP approves the location but is independent of reactor design. Although a reactor design is not specified, TVA has identified bounding parameters for a nuclear plant, which the NRC will use to evaluate the suitability of the site for the building and operation of a new nuclear plant.

[10] Source: TVA Presentation on Clinch River Project: (https://www.ne.ncsu.edu/)
[11] Source: NRC Clinch River Nuclear Site (https://www.nrc.gov/)

[12] Source: Chattanooga Times Free Press (https://www.timesfreepress.com/)

Prior to initiating the ESP permit application process, TVA formally engaged the NRC on several occasions, starting in 2010, with the intent of notifying the NRC and the public of their interest in exploring possible licensing and construction of SMR modules at the Clinch River Site. An initial letter, detailing TVA's key assumptions for the possible licensing and construction of SMR modules, was furnished to the NRC in November of 2010. In a letter dated Dec. 1, 2010, the NRC provided response to this initial notification and scheduled a public hearing. In this hearing, TVA outlined their plans for proposed SMR modules at the Clinch River Site and outlined a number of assumptions surrounding the 10 CFR Part 50 licensing process and proposed future interactions with the NRC to discuss regulatory framework structure.

In January of 2012, following a final Regulatory Framework Workshop between TVA and the NRC, TVA officially exited the pre-application fact-finding phase of their New Nuclear Program, and initiated the formal ESP application preparation process. The process, as has been detailed above, compiled data from numerous technical studies over the following four years. During this time, TVA maintained regular communication with the NRC for the purpose of clarification and guidance. Along with utilizing in-house competent persons to oversee this process, TVA heavily relied on outside experts to guide this process.

In May of 2016, TVA tendered its Clinch River ESP application to the NRC. The general review process was initiated by the NRC two weeks later and followed the following schedule:

- Safety Review Initiated – August 2017
- Safety Review Completed, Safety Evaluation Report Issued – June 2019
- Environmental Review Initiated – April 2017
- Environmental Review Completed, Environment Impact Report Issued – April 2019
- Mandatory Public Hearing – August 2019

On Dec. 19, 2019, the NRC issued ESP-006 to TVA, for the Clinch River Nuclear Site in Oak Ridge, TN. With this issuance, completion of the Clinch River ESP preparation, submittal and review process was achieved nine years following TVA's initial fact-finding efforts, and at a total cost of approximately $200 million.

The Clinch River ESP application process included the following documents, which may be referenced at the NRC public-facing website[13]:

- Application Information
- Review Schedule
- Applicant Documents
- NRC Documents
- Request for Additional Information – Response Documents
- Advanced Safety Evaluation Report
- Final Safety Evaluation Report for ESP
- Scoping Summary Report
- Final Environmental Impact Statement
- Granted ESP

[13] https://www.nrc.gov/reactors/new-reactors/smr/clinch-river.html

In 2022, TVA is focusing on the COL permit. TVA is allocating $200 million to deliver a plant design, Part 52 operating license, and project plan to the NRC over the next one to two years[14] [15]. TVA has announced that its preferred SMR technology is the General Electric-Hitachi BWRX-300. Pending approvals, TVA anticipates a first GEH BRWX-300 unit could be operational at the Clinch River Site as early as 2032.

The GEH BWRX-300 design is currently under pre-application review by the NRC. The NRC notes the following – "The staff of the U.S. Nuclear Regulatory Commission (NRC) is currently engaged in pre-application activities for the GEH BWRX-300 small modular reactor (SMR), including the review of numerous licensing topical reports (LTRs) describing the design approaches and methodologies for the BWRX-300 SMR in advance of a 10 CFR Part 52 COL application. The BWRX-300 is a ~300 MWe water-cooled, natural circulation SMR with passive safety systems. As the tenth evolution of the Boiling Water Reactor (BWR), the BWRX-300 represents the simplest, yet most innovative BWR design since GE began developing nuclear reactors in 1955. The design of the BWRX-300 is based on the U.S. NRC-licensed, 1,520 MWe Economic Simplified BWR and is designed to provide clean, flexible baseload electricity generation."[16]

The NRC expects that the formal application review process for the GEH BWRX-300 could begin as soon as 2023, however this timeline wholly relies on the preparedness of GE-Hitachi. Assuming this review process can begin and commence with minimal interference or interruption, it is reasonable to assume that the GEH BWRX-300 could receive approval by the latter half of the decade.

Conclusion

The transition to lower CO_2-emitting generation has stimulated interest in nuclear generating technology. The Companies have no experience in nuclear generation and conversations with experienced nuclear operators such as Duke and TVA as well as a review of publicly available information, particularly from the NRC, indicate that significant resources of knowledge, experience, time, and money would be required to make nuclear generation a viable technology option in the future. This review also identified that even if the Companies commit to beginning the nuclear journey in the near future, it would likely not be in a position until the end of this decade to have the option to proceed with an actual project (assuming the streamlined Part 52 timeline, a Part 50 timeline could be even longer). Thus, from a future resource planning perspective, nuclear generation is unlikely to be a viable replacement for the Companies' retiring coal fleet until the end of the 2030s at the earliest with the 2040s being more plausible at this time.

[14] Source: GE Nuclear Energy (https://www.ge.com/)
[15] Source: S&P Global (https://www.spglobal.com/)
[16] https://www.nrc.gov/reactors/new-reactors/smr/bwrx-300.html