SMR Site Feasibility Study for LENOWISCO

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Principal Investigators
C. Marks
J. Koza-Reinders
C. Hoying
N. Craft

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LENOWISCO Planning District Commission
372 Technology Trail Lane, Suite 101
Duffield, Virginia 24244

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DEFINITIONS

Advanced Light Water Reactor: A reactor which uses light water for moderator and coolant similar to the currently operating fleet of nuclear reactors, but also features advanced design concepts which provide significant improvements such as: inherent (passive) safety features, improved performance, load dispatching capabilities, or modular sizing to match load growth projections.

Advanced Reactor: A reactor that significantly differs from currently operating light water reactors due to utilizing different coolant or fuel. Advanced reactors may use non water coolants such as inert gas, molten salt, or liquid metal. Advanced reactors may use non zirconium clad uranium dioxide pellets for fuel such as liquid fuels dissolved in the coolant, or carbon coated uranium TRI-structural ISOtropic (TRISO) particles.

Alternative Site: Those candidate sites that are compared to the proposed site to determine if there is an obviously superior site.

Behind the Meter (BTM): An electrical generation or storage system which is on the load or customer side of a utility service meter. A BTM system delivers energy to the load without using transmission system or distribution facilities. Such a system may reduce costs associated with transmission of electricity or allow for higher certainty in future power pricing.

Candidate Areas: One or more areas within the ROI that remain after unsuitable areas (e.g., due to high population, lack of water, fault lines, distance to transmission lines) have been removed.

Candidate Sites: Those potential sites (at least four) that are within the ROI and that are considered in the comparative evaluation of sites to be among the best that can reasonably be found for the siting of a nuclear power plant.

Coolant: A substance circulated through a nuclear reactor to remove or transfer heat from the fuel to the steam cycle. The most commonly used coolant in the United States is water. Other coolants include heavy water, air, carbon dioxide, helium, liquid sodium, and a sodium-potassium alloy.

Cooling Tower Drift: Drift the term for the carryover of liquid water within the evaporated water stream of a cooling tower.

Emergency Planning Zone (EPZ): The region surrounding a reactor site where plans are in place to protect the public in the event of a radiological release. Traditional large light water reactors have a 10 mile EPZ where plans are in place to evacuate or shelter the public, as well as a 50 mile EPZ where plans are in place to avoid or reduce the consumption of potentially contaminated water or food.

Fast Neutron: A fast neutron is a neutron moving with greater kinetic energy than its surroundings. When a neutron is produced during fission it is ejected from the nucleus at high speed. The neutron is less likely to interact with a U-235 nucleus causing a subsequent fission until it is slowed down to ambient thermal speeds.

LENOWISCO Region of Interest (ROI): The LENOWISCO ROI is defined within this report as the LENOWISCO Planning District (comprised of Lee, Scott, and Wise counties and the independent City of Norton) as well as neighboring Dickenson county. This geographic region of Southwest Virginia is characterized by the availability of brownfield sites for development, minewater for cooling, rail lines for shipping, and an interest in energy generation and data center development.

Micro Grid: A micro grid is a group of generators and loads that perform as a single entity with respect to the wider electrical grid. The micro grid may receive or transmit electricity from the wider power grid during normal operations or isolate itself from the wider power grid during disturbances such as power outages. An example microgrid might contain nuclear, wind, and solar generators powering an industrial business park and data centers. A single metered substation would connect the generators and loads to the wider power grid.

Moderator: A material used in the reactor which functions to slow down high-velocity neutrons to enhance the likelihood of fission. Neutrons created in the fission process are born with high velocities which make them unlikely to result in a fission with U-235 until they are slowed down by the moderator. Reactors using ‘slow’ or ‘thermal’ neutrons to fission U-235 require a moderator such as water, heavy water, or graphite. Reactors using ‘fast’ neutrons may not require moderators in their designs.

Nuclear Regulatory Commission (NRC): The NRC is an independent agency created by Congress in 1974. This organization regulates commercial nuclear power plants and related fields. The NRC conducts licensing, inspection and enforcement of its requirements.

Potential Sites: Those sites within the candidate areas that have been identified for preliminary assessment in establishing candidate sites.

Proposed Site: The candidate site submitted to the NRC by the applicant as the proposed location for a nuclear power plant.

Region of Interest (ROI): The geographic area considered in searching for potential and candidate sites.

Small Modular Reactor (SMR): An advanced reactor design which is defined by producing 300 MWe or less from each individual reactor. Depending on the commercial developer, multiple reactors may be designed to be installed at a single site which will produce greater than 300 MWe. SMRs are envisioned to be manufactured and shipped to a site for assembly, potentially lowering costs and delays which have been associated with the construction of the current fleet of large light water reactors.

Siting Tool for Advanced Nuclear Development (STAND): The STAND tool is used to identify the feasibility of siting new advanced nuclear reactor sites. The STAND tool was developed by the National Reactor Innovation Center to incorporate data from multiple official sources in order to compare the suitability of proposed reactor sites.

Thermal Neutron: A thermal neutron is a neutron which has been slowed down to a kinetic energy equal to that of its surroundings. The slowing down process is caused by the neutron repeatedly colliding with the moderator, with each collision reducing its speed. Thermal neutrons are more likely to interact with U-235 nuclei to cause a fission reaction.

Ultimate Heat Sink (UHS): The ultimate heat sink absorbs the excess or waste heat generated by the heat source (nuclear, coal, natural gas, etc.) during the electricity conversion process. Approximately 33% of the heat generated by the heat source is converted to electricity and the other 66% is rejected to the ultimate heat sink. The UHS may be a river, lake, ocean, or air. The heat is transferred to the UHS via site specific cooling equipment such as condensers or cooling towers.

1 INTRODUCTION

Lee, Wise, and Scott counties along with the independent City of Norton are located in the Southwest corner of the Commonwealth of Virginia and comprise the LENOWISCO Planning District. The LENOWISCO Planning District is bordered by Kentucky to the Northwest and Tennessee to the South. Southwest Virginia and the LENOWISCO region are in the midst of an economic transition. Employment in coal mines throughout the region has been drastically reduced over the past several decades leading to the need for new industries and enterprises.

Convincing a stagnant industry to relocate their facilities can be a monumental undertaking. However, convincing an industry that is expanding to expand into in a new region can be as simple as providing the right conditions for growth. The LENOWISCO Planning District and neighboring Dickenson County, collectively referred to as the LENOWISCO Region of Interest[*] (ROI), are in a prime position to attract new industries with inexpensive brownfield sites, mine water for cooling, existing right of way to transmissions infrastructure, and existing rail infrastructure. Due to extensive mining operations in the area, LENOWISCO has the human expertise and the infrastructure to handle large civil construction projects. There are few environmental restrictions regarding the preservation of the existing environment because prospective SMR sites that could be located on previously mined lands offer an opportunity for a higher and better post-mine use. These factors make the LENOWISCO region stand out as a location for new nuclear in ways that are not necessarily captured by STAND and other existing siting tools. These resources could be used to grow two synergistic industries: data centers and nuclear power generation.

Data centers are facilities which house the machinery of the internet, warehouses filled with servers and computers. As consumers switch from cable to streaming, businesses switch from in person to remote work, and increasing percentages of the world is digitized, the demand for data centers will continue to grow. Data centers require large amounts of power for both server operation and cooling. Any region which can offer competitive electricity pricing will attract data centers by virtue of reducing the cost of doing business. The LENOWISCO ROI can also

[*] A "region of interest" (ROI) is the geographic area which will be investigated. This definition is used throughout the report and discussed in greater detail in Section 4.

offer geothermal cooling solutions through the innovative use of mine water, which will significantly reduce the electricity requirements of new data centers.

Small modular reactors (SMRs) are a novel type of nuclear reactor that can be used to provide carbon-free energy for industrial and residential consumers. These reactors are designed to be manufactured on short time scales and installed with minimal onsite construction to provide incremental, distributed generation capacity. In recent decades, growth in electricity demand has been offset by increased efficiency by users resulting in little to no need for additions of large generation projects. When large unmet electricity demand did exist, it was often met with new natural gas generation facilities. The Virginia Clean Economy Act (VCEA) will require 100% of Virginia's electricity to be powered by carbon-free sources by 2050. This ambitious plan will require the retirement of many fossil generation units and construction of significant new generation capacity. SMRs of all types and sizes will be necessary to provide new baseload power to replace retiring generation.

The Commonwealth of Virginia has a rich history of support for nuclear technology. Surry Nuclear Power Plant and North Anna Nuclear Generating Station are each home to two nuclear reactors which combine to provide thousands of megawatts of electricity to the civilian power grid. Meanwhile, Naval Station Norfolk provides the home port for many of the nuclear reactors which power the United States Navy. Norfolk is the home port for six aircraft carriers which were built in the shipyards of Newport News, each powered by two nuclear reactors. Norfolk is also home port for nine nuclear powered submarines. BWX Technologies, Inc. located in Lynchburg manufactures reactor cores for the U.S. Navy, has decades of industrial nuclear experience, and is developing Project Pele, a Department of Defense (DoD) sponsored microreactor. Framatome located in Lynchburg provides inspection and refurbishment of nuclear reactor components and qualification of nuclear grade parts.

Historically, the nuclear power industry has been an engine for Virginia's growth that has not moved West of Lynchburg. However, the LENOWISCO ROI is an attractive location for construction of SMRs. Brownfield sites which had previously been used for surface mining represent a significant resource for development into nuclear power sites. Low regional population density will lower the barriers to reactor siting. The mountainous region has minimal wetlands which can be disrupted by construction. Existing rail lines can be used to affordably transport construction materials to the region.

The construction of SMRs can lead to reliable and affordable electricity in the region, spurring increased interest from data center developers. Increased demand for data centers can spur additional SMR units, which are designed from the outset to support additional generation modules. Maintaining continuity of continuous construction of new reactors will lower project costs over time, resulting in lower electricity generation costs. This self-reinforcing cycle has the potential to transform the LENOWISCO ROI into a leader in carbon free generation and data center investment in Virginia.

This report describes the feasibility of siting Small Modular Reactors in the LENOWISCO ROI as a first step in the energy transformation of the region.

- Section 2 provides an Executive Summary of the report.
- Section 3 provides an overview of the different SMR technologies and their readiness for deployment.
- Section 4 provides a description of the requirements to site a nuclear power plant and assesses the viability of various sites in the LENOWISCO ROI.
- Section 5 provides an overview of the various government incentives which are available for SMR construction.
- Section 6 provides a review of the various industrial uses of nuclear power.
- Section 7 provides an overview of the requirements for the sale of electricity on the PJM market.
- Section 8 provides an overview of the economic effects of nuclear power plant construction and operation within the region.

2 EXECUTIVE SUMMARY

The LENOWISCO Planning District and neighboring Dickenson County, collectively referred to as the LENOWISCO ROI, has several unique features that make it an ideal site for one or more small modular reactors (SMRs) or advanced reactors (ARs). Among them are ample brownfield sites, low regional population density, significant land with low environmental regulatory burden, nearby transmission lines, existing rail lines, and specifically, its supply of mine water which is geothermally cooled to 51°F. These features also make the area an excellent location for an industrial partner such as a data center.

More broadly, Virginia as a whole provides fertile ground for new nuclear projects. Dominion Energy has operated the two units at North Anna Nuclear Generating Station and the two units at Surry Nuclear Power Plant for fifty years. The state is also home to several universities with elite engineering programs and is home to many consulting firms and manufacturing facilities with decades of experiencing supporting the nuclear power industry. The utilities that service the state of Virginia and LENOWISCO are enthusiastic for future nuclear projects. When contacted regarding this project, the utilities expressed support for the development of nuclear projects in LENOWISCO ROI.

This study was completed to determine the feasibility of constructing multiple SMRs in the LENOWISCO ROI. This study has several key elements which are discussed in the following subsections.

2.1 Potential Nuclear Technologies Considered

Section 3 of this report reviews the nuclear technologies available and being actively researched, as well as the potential nuclear technologies considered for LENOWISCO ROI. The basics of each design are explained for background because each, if brought to market, could be successful in LENOWISCO.

As it relates to this study, the most important difference among the discussed designs is the power output. The chosen design should provide an amount of electricity that matches what is demanded by co-located and nearby customers. In general, larger reactors will output the most power, but also take up more land and resources for operation. Many of the designs discussed in this report are considered small modular reactors (SMRs). These plant designs are intended to scale in size according to the needs of the region and the available space. Several SMR developers are nearing demonstration stages of testing, and most are aiming to be commercially available during the late 2020s. The designs highlighted in this report as potentially good fits for LENOWISCO and commercially available within this decade are the following.

- GE-Hitachi BWRX-300 a BWR with 1-2 300 MWe modules.
- TerraPower Natrium a 345 MWe SFR.
- NuScale VOYGR 6 a PWR with up to 12 60 MWe modules.
- X-energy XE-100 a HTGR with 4 80 MWe modules.
- BWXT Project Pele a HTGR that produces 1-5 MWe.
- Ultrasafe Micro-Modular Reactor a HTGR with 2 5 MWe modules.
- Westinghouse eVinci a SFR that produces 5 MWe.

2.2 Potential Site Evaluations

In Section 4 of this report a review of the regulations involved with nuclear reactor siting was performed. A community outreach survey was also conducted, with all respondents in agreement that nuclear energy should be considered for electrical generation.

Eight locations in the LENOWISCO ROI were reviewed for their suitability with respect to siting a proposed SMR or microreactor. The review was conducted using the Siting Tool for Advanced Nuclear Development (STAND) which aggregates data from multiple governmental sources and ranks the proposed sites with respect to socioeconomic, proximity, and safety suitability. Five comparison sites outside of LENOWISCO that are being considered for future nuclear projects were also included. The STAND tool indicates that each of the LENOWISCO sites compare favorably to the comparison sites (i.e., the LENOWISCO sites are as good or better than the sites selected for future SMR projects).

Further, the STAND tool likely underestimates the value of the LENOWISCO sites, especially accounting for the co-location of data centers or other industry. This is because the STAND evaluation does not account for potential future load growth or the retirement of existing generation assets. It also does not account for numerous inexpensive brownfield sites, an abundance of water resources (including Lake Keokee, the Clinch River and its tributaries, and millions of gallons of mine water for cooling), existing right of way to transmissions infrastructure, and existing rail infrastructure.

The LENOWISCO ROI also has the human expertise and the infrastructure to handle large civil construction projects.

Additionally, LENOWISCO benefits from the presence of the Energy DELTA (Discovery, Education, Learning & Technology Accelerator) Lab an energy testbed located in Southwest Virginia focused on leveraging previously-mined land as a proving ground for the commercialization and deployment of innovative energy technologies. It is a signficant differentiator for the LENOWISCO ROI because it has the potential to support any necessary research and development required to site SMRs in the region. It also serves as a facilitator for the numerous partnerships that will be needed in order to ensure the project's success. These factors make the LENOWISCO region stand out as a location for new nuclear in ways that are not necessarily captured by STAND and other existing siting tools.

The favorability of multiple sites in the region is in and of itself a potential asset. The siting of multiple reactors in the region has the potential to result in a regional industry and local skilled workforce which will benefit all sites.

2.3 Governmental Incentives for Nuclear

A variety of governmental incentives exist that could be applied to nuclear projects in the LENOWISCO ROI. The largest source of federal funding comes from the Inflation Reduction Act which could potentially provide millions or billions of dollars to nuclear developments in LENOWISCO. The other incentives could each provide several million dollars.

The Inflation Reduction Act provides the Production Tax Credit (PTC) and Investment Tax Credit (ITC), one of which may be selected for a new SMR project within the LENOWISCO ROI. LENOWISCO is well positioned to access these funds, as one of the two 10% boosters applies for siting in energy communities (for which LENOWISCO certainly qualifies). Along with the other 10% booster that can be captured if enough of the components of the project are manufactured domestically, LENOWISCO can take full advantage of the funds available. With the boosters, the PTC provides an inflation adjusted $30/MWh in tax credits for every MWh of power produced and the IRA provides 50% of the capital cost for a plant through tax credits. This makes LENOWISCO a competitive region for SMR vendors looking to fully capture the benefit of this legislation. Further, the IRA also provides $40 billion in loan guarantees.

LENOWISCO is also well qualified to access funds from the Infrastructure Investment and Jobs Act (IIJA), which provides funding for clean energy projects on current and former mine land. This makes LENOWISCO more desirable for SMR vendors. However, this funding is set to expire in 2026.

Some of the sites have features that qualify as abandoned mine land and therefore management of these features could be completed with funding (likely a few million dollars) from the Abandoned Mine Land Economic Revitalization Program (AMLER).

2.4 Use of Nuclear Power for Dedicated New Facilities

Virginia is the world leader in data center construction. While the majority of this growth has been in Northern Virginia, some of this growth has also taken place in the LENOWISCO ROI. One of the motivations for this project was to evaluate the potential synergy between nuclear power and new facilities (such as data centers).

Nuclear is well suited for customers with a need for affordable and reliable power (such as a data centers) because most nuclear power plants are designed to operate at full power at all times, aside from planned refueling periods when power plants are offline (generally a few weeks every 18-24 months). This is why nuclear power has a greater than 90% capacity factor, meaning that in a given year the power plant provides on average 90% of its rated capacity (generally 100% except for refueling periods). This is significantly higher than other carbon free energy sources such as solar and wind with capacity factors around 25% and 36%, respectively.

The co-location of a nuclear facility and a designated customer provides benefits to both the power plant and the customer. The customer receives a guaranteed wholesale power rate absent costs for transmission and line losses. In return, the power plant can receive a guaranteed power price consistently higher than fluctuating market values. The primary drawback to such an arrangement is the commercial vulnerability one entity would face if the other entity stopped supplying or consuming power.

2.5 Use of Nuclear Power for Sale to the Grid

This section reviews the potential for sale of electricity to the bulk power grid from a nuclear plant sited in the LENOWISCO ROI. The general structure of the power market and the role of generating assets within that structure was summarized. In order to connect to the PJM grid, the proposed new generation asset must fund a three-step study phase through the PJM to determine what infrastructure may be required to ensure grid stability. This study would be performed by the utility proposing the new generation project, perhaps in conjunction with LENOWISCO. The LENOWISCO Planning District features three different utility service areas including both regulated and deregulated utilities, only one of which (Appalachian Power Co.) is a member of the PJM. This represents a potential hurdle as well as an opportunity. In areas of interest external to the LENOWISCO ROI, utilities such as Utah Association of Municipal Power Systems (UAMPS) have shown interest in partnering together for initial SMR development and deployment as a means of spreading potential risks. LENOWISCO is uniquely suited for a deal between multiple utilities, and a single disinterested utility will not prevent siting a reactor elsewhere in the region. Interviews were conducted with both Appalachian Power Co. and Dominion Energy, and both utilities indicated interest in the construction of large SMRs in the 100's of MWe output to replace the output of retiring fossil units. The potential for coal-to-nuclear power plant transitions was also described. No such coal plants are located directly in the LENOWISCO Planning District. However, in nearby Carbo, a retired coal plant (AEP's Clinch River Unit 3) may provide an opportunity for such a transition.

2.6 Economic Effects of Nuclear Infrastructure

New SMRs are expected to cost hundreds of millions or billions of dollars to construct (total capital investment cost). This cost is expected to be heavily subsidized by various federal funding programs (discussed in Section 5). The initial construction period will result in a large amount of temporary employment and spending in the community prior to plant operation. During operation the plant will directly employ 10-300 people, depending upon the selected design, which will result in up to 1200 total jobs added to the community. The directly created power plant jobs will require various levels of education, but it is expected that approximately half of the jobs will not require a college degree. Even plant designs that are small and autonomous will provide benefits to the community in the form of tax revenues for the host county or locality.

3 POTENTIAL NUCLEAR TECHNOLOGIES CONSIDERED

The following sections provide a brief description of the nuclear technologies expected to be available. Some designs have inherent strengths that make them better suited for particular applications than others.

3.1 Types of Reactors

The current generation of reactors (sometimes referred to as Generation III) mainly use water as the primary coolant. Coolant is defined as the fluid that is circulated through the reactor to remove or transfer heat. Generation III reactors can be broadly grouped as pressurized water reactors (PWRs, examples include Surry and North Anna in the state of VA), boiling water reactors (BWRs, examples include Brunswick in NC and Limerick in PA), and pressurized heavy water reactors (PHWRs, examples include CANDU reactors in Canada).

Advancements in reactor technology have enabled reactors to operate at much higher temperatures which improves thermal efficiency. Some of these designs utilize coolants other than water to facilitate these higher temperatures. Therefore, the next generation of reactors (Generation IV) are differentiated by the types of coolant they use. These reactors are molten salt reactors (MSR), sodium cooled fast reactors (SFR), lead cooled fast reactors (LFR), high temperature or very high temperature reactors (HTGR or VHTR), and gas cooled fast reactors (GFR).

Molten salt reactors are defined by their use of molten salt as their coolant. These reactors can use various salt chemistries, and some incorporate dissolved fuels into the molten salt. Dissolved fuels enable the operators to make changes to fuel chemistry and concentration without shutting down to refuel. MSRs can operate at temperatures between 500°C and 750°C. Current research for MSRs is focused on characterizing and mitigating the corrosion of the molten salts on the structural materials of the reactors.

Sodium cooled fast reactors and lead cooled fast reactors are very similar designs. Both use molten metal to cool the reactor and utilize a fast neutron spectrum. SFRs employ sodium as their coolant, which is nonreactive with respect to the structural materials. Sodium is reactive to air and water and requires securely designed coolant systems in order to avoid ingress of air and water. LFRs use lead to cool the reactor. Among the advantages of lead is its ability to absorb large quantities of heat. Current research is focused on high performance materials for extended reactor operating periods. Both of these reactors operate between 300°C and 500°C, however, lead has a much higher boiling point compared to sodium and could reach higher temperatures to improve efficiency.

Very high temperature reactors and gas cooled fast reactors are also very similar in their designs. Both of these reactors employ helium as their coolant and reach the highest temperatures of the designs being developed (up to 1000°C during operation). Similar to the SFR and LFR, the GFR utilizes fast neutrons. VHTRs use thermal neutrons and need to be moderated by graphite. There is experience in the United Kingdom (UK) with graphite moderated reactors. Current research is focused on the development of materials capable of withstanding the high temperatures.

3.2 Reactor Sizes

Nuclear reactors can be described by their electrical power output in addition to their nuclear technology. Reactors generate heat in order to produce electricity, but not all of the heat is converted to electricity, much of it is discharged to the environment. This is true for both nuclear reactors and fossil plants. The heat which is generated is referred to in terms of Megawatts Thermal (MWth) while the electrical output is referred to in terms of Megawatts Electrical (MWe). Throughout this report reactors are always referred to by their electrical output, MWe. Many use cases for advanced nuclear reactors involve the use of heat as well as electricity (e.g., some methods of hydrogen generation).

Many reactors include multiple units at the same site (e.g., Surry has two units). Some reactors are designed for specific efficiencies from operating multiple units at the same site. Others are designed to be completely independent and derive synergies from co-location only due to use of common infrastructure beyond the plant boundary (e.g., common right of ways to connect to the electric grid). In the context of SMRs, multiple units at the same site are sometimes referred to as modules.

3.2.1 Large Reactors (600-1500 MWe)

Currently, most reactors in operation are large reactors. These reactors produce 600-1500 MWe and are predominantly traditional light water reactors and heavy water reactors[*]. These reactors require large areas of land and (usually) large bodies of water for cooling and are therefore

* There are several gas cooled plants that utilize superheated CO2 as a coolant in the UK.

normally located along coastlines, lake fronts, or rivers. For scale, Surry Units 1 and 2 produce roughly 840 MWe and North Anna Unit 1 and 2 provide roughly 950 MWe.

3.2.2 Medium Sized Reactors (300-600 MWe)

Medium sized reactors are defined by an output between 300-600 MWe. Due to the economies of scale when the current fleet of nuclear reactors were built, it was more economical to build large facilities that produce as much power as possible. The design of medium sized reactors were a development step in the design of large reactors.

3.2.3 Small Modular Reactors (<300 MWe)

Small Modular Reactors (SMRs) generally have outputs of less than 300 MWe. The term "modular" comes from the design goal of being able to add more reactors to a site to increase the scale of the electricity output to match the expected demand. SMRs are designed to have their largest components small enough to be able to be built in a factory and transported to the build site for assembly. This significantly decreases construction time, the overall project cost, and the risk of cost overruns.

The physical size of these reactors is generally small, while plant size is more variable. Some plant designs, such as the Natrium developed by TerraPower and GE-Hitachi, take upwards of 65,000 m^2 (15 acres) with the goal of multiple reactors being used together to output large amounts of electricity. Other reactors are designed to be small and power remote locations. These plants are the size of a truck or a house. A common design goal of SMRs is to provide variability in output to ensure that the reactor is used efficiently and effectively without taking up more space than necessary.

Other SMR designs are being created to cover lower electricity generation ranges (between 50 MWe and 80 MWe) and take up less space. These plants are designed to increase the number of reactors with minimal increase to plant size in order to create a multi-unit site with increased power output. This allows the plant to scale to the demand of the region.

3.2.4 Microreactors (1-10 MWe)

Multiple designers are creating microreactors, which generate 1-10 MWe. These reactors are designed to take up as little space as possible and can provide power for remote locations. These designs require little to no maintenance and are designed to be completely or mostly autonomous.

3.2.5 Cooling Water Requirements

When generating electricity, cooling is needed to condense the steam which is exhausted from the turbine generator. The steam exhausted from the turbine generator is at low pressures and no longer has enough energy to be useful for electricity generation. However, the steam still contains thermal energy (heat) which must be removed in order to be condensed into liquid water. It is necessary to return the steam to liquid water in order to pump it back to the steam generator and repeat the process.

This cooling requirement exists for all steam-cycle electrical generators (nuclear, natural gas, or coal powered). The cooling is provided by the environment, typically in the form of a local water source or ambient air which is known as the ultimate heat sink. Water cooling is typically 5-7% more efficient than air, when it is available [1]. However, care must be taken to ensure that the planned water usage will not affect the local environment as described in Sections 4.2.4.1.2 and 4.2.4.2.1.

Power plants can employ different kinds of cooling technologies, including dry cooling, cooling towers, and reservoirs, to mitigate the amount of water required by the plant. Dry cooling utilizes ambient air to cool the condenser and requires a large cooling surface area, increasing initial construction expenses. Large reservoirs (lakes, oceans, mine water, etc.) are suitable for once through cooling, where water is pumped into the power plant for cooling raising the water's temperature by 10-20°F, and then discharged. The warmer water is returned to the reservoir where it cools from contact with the earth and air. This requires high water flow rates but does not consume the water from the reservoir. Cooling towers remove heat by evaporating cooling water into the atmosphere, they require less water from the source stream or river to operate. Cooling towers do not return much of the withdrawn water from the source, they instead discharge it to the atmosphere as vapor. Cooling towers are expensive to construct and operate but are a good option for cooling reactors sited in areas without natural reservoirs or high flow rate water sources.

In general, steam cycle power plants are only 30%-50% efficient at converting thermal energy into electricity. This means that at least half of the thermal energy produced by the power plant will be rejected to the local environment through the condenser. The cooling requirements are directly related to the size of the reactor, and how efficiently the plant converts thermal energy into electricity. Due to the differences in scale between current Generation III reactors, SMRs and microreactors, the water requirements for these generation facilities can vary by orders of magnitude. Due to their reduced size, SMRs and microreactors have significantly lower requirements for access to cooling water, which makes them suitable for a variety of siting locations which were unsuitable for larger Generation III reactors. Additionally, methods such as dry cooling, employed by NuScale for their SMR design, can save up to 90% water when compared to traditional cooling mechanisms [2].

In order to estimate cooling water usage in a once through or reservoir environment Equation [1] can be used.

$$\dot{Q}\ (MJ/s) = \frac{\dot{m}\ \left(\frac{kg}{s}\right) * c_p \left(\frac{kJ}{°\mathrm{C}\ kg}\right) * \Delta T\ (°\mathrm{C})}{1{,}000\ (\frac{kJ}{MJ})} \qquad [1]$$

Where:

- $\dot{Q}$ is the rejected energy of the power plant, equal to thermal megawatts produced minus electrical megawatts produced (MJ/s or MW)
- $\dot{m}$ is the mass flow rate of cooling water required (kg/s)
- c_p is the specific heat of water, a constant equal to 4.18 (the amount of energy required to heat a kg of water by 1 degree Celsius) (kJ/°C-kg)
- ΔT is the temperature rise of the water used (°C)

If a cooling tower is used, Equation [1] is modified to Equation [2] which accounts for the energy required to vaporize water into steam.

$$\dot{Q}\ (MJ/s) = \frac{\dot{m}\ \left(\frac{kg}{s}\right) * [(c_p \left(\frac{kJ}{°\mathrm{C}\ kg}\right) * \Delta T\ (°\mathrm{C})) + \Delta H_{vap} \left(\frac{kJ}{kg}\right)]}{1{,}000\ (\frac{kJ}{MJ})} \qquad [2]$$

Where:

- ΔH_{vap} is the heat of vaporization of water, a constant equal to 2,260 (the amount or energy required to turn one kilogram of liquid water into vapor) (kJ/kg)

These equations were used to generate the estimated cooling water requirements for some reactor designs as shown in Table 3-1.

3.3 Commercial Vendors

Demonstration projects are currently in development for multiple reactor sizes. These demonstration projects will provide a proof of concept that the reactors function as designed and will resolve licensing process questions with the NRC. There are many reactors currently in pre-application processes with the NRC and are in the process of working with different organizations to develop demonstration projects. These different designs are discussed in Table 3-1.

Table 3-1 Summary of Commercial Vendors

Vendor	Reactor Type	Power Output (MWe)	Staff	Plant Footprint [1]	Site Footprint [1]	Once Through Cooling Water Requirements [2] Million gpd (Million gpd/MWe)	Evaporative Cooling Water Requirements [2] Million gpd (Million gpd/MWe)
GE-Hitachi BWRX-300	BWR	300	75	8,400 m^2 (2 acres)	26,300 m^2 (6.5 acres)	570 (2.0)	5.0 (0.018)
TerraPower Natrium [3]	SFR	345	250	65,000 m^2 (16 acres)	180,000 m^2 (44 acres)	620 [3] (1.8)	5.5 (0.016)
NuScale VOYGR 12	PWR	720 (12 60 MWe modules)	270	4,877 m^2 (1.2 acres)	140,000 m^2 (35 acres)	1,600 (2.3)	14 (0.020)
X-energy XE-100	HTGR	320 (4 80 MWe modules)	3	12,700 m^2 (3 acres)	130,000 m^2 (32 acres)	464 (1.4)	4.1 (0.013)
BWXT Project Pele	HTGR	1-5	2	15 m^2 (0.004 acres)	<2,000 m^2 (< 0.5 acres)	None, air cooled	

Table 3-1 Summary of Commercial Vendors

Vendor	Reactor Type	Power Output (MWe)	Staff	Plant Footprint [1]	Site Footprint [1]	Once Through Cooling Water Requirements [2] Million gpd (Million gpd/MWe)	Evaporative Cooling Water Requirements [2] Million gpd (Million gpd/MWe)
Ultrasafe Micro-Modular Reactor [4]	HTGR	10 (2 5 MWe modules)	0 [4]	12,500 m^2 (3 acres)	< 20,000 m^2 (< 5 acres)	None, air cooled	
Westinghouse eVinci [5]	SFR	5	2	15 m^2 (0.004 acres)	<2,000 m^2 (< 0.5 acres)	Assumed to be air cooled	

[1]Unless otherwise noted, the areas for plant and site footprints are found on the ARIS IAEA database [6].

[2] Per the methodology described in Section 3.2.5. A 10°F temperature rise was assumed for the once through cooling water calculation. A 51°F water supply was assumed for the evaporative cooling water calculation. The water requirements are shown for each reactor type accounting for the number of modules the vendors plan to deploy per site. The water requirements for each design are also shown normalized to MWe in order to illustrate that these reactors all have similar cooling requirements for each MWe generated.

[3]A design MWth rating for the Natrium reactor could not be identified. The reactor was assumed to be 35% efficient (986 MWth).

[4] In the U.S., the minimum number of personnel is governed by NRC regulations. Minimum on-site personnel requirements specific to microreactors have not been determined.

3.3.1 Large SMR Scale

The GE-Hitachi BWRX-300 is an SMR design that is closer to NRC acceptance than others. The BWRX-300 is a boiling water reactor designed to produce 300 MWe per reactor (or per unit or module). This design uses a plant footprint of 8,400 m^2 (2 acres) with 75 staff required during operation after construction. Currently the BWRX-300 is planned for demonstration construction at the TVA Clinch River Nuclear Site in Oak Ridge, Tennessee with construction of the demonstration reactor planned to be completed between 2027 and 2028. As the licensing application process continues, and construction of the TVA nuclear site continues, the BWRX-300 will become a more viable option for different locations around the country interested in SMR technology. The BWRX-300 requires typical grid connections and has the option for once-through cooling (i.e., the temperature rise associated with final cooling water is low enough that a small stream can be used instead of a large thermal reservoir like a lake), allowing for more options for locations than a traditional power plant which requires large volumes of cooling water [6,7].

The TerraPower Natrium is an advanced reactor that is closer to being licensed than most. The Natrium is a 345 MWe sodium-cooled fast reactor, with a plant size of 65,000 m^2 (16 acres) employing 250 staff after construction. Note that the Natrium reactor is not a modular reactor, and the stated plant size is believed to be necessary for each unit. The Natrium has a demonstration project underway in Kemmerer, Wyoming, on the site of the soon to be retired Naughton Coal Plant. After this demonstration, TerraPower plans to have the first commercial Natrium reactor running by 2028. Currently the reactor is in the pre-application process with the NRC and is an Advanced Reactor Demonstration Program (ARDP) award recipient. The estimated cost for each reactor aims to be under 2 billion dollars [8,9,10].

3.3.2 Medium SMR Scale

The NuScale SMR design for their VOYGR plant is the first SMR design to be approved by the NRC for use in the US and is an ARDP winner. The NuScale SMR is designed to produce 60 MWe using a smaller, scalable version of the PWR technologies. The VOYGR plant design currently calls for up to 12 modules, to produce a total of 720 MWe when the whole plant is constructed. This plant is planned to take up 4,877 m^2 (1.2 acres) and employs 270 staff after construction. The NuScale VOYGR SMR plant is to be built at Idaho National Labs and plant operations are planned to begin in 2030. NuScale is also working to identify sites in Wisconsin and Missouri [11,12].

The X-energy XE-100 is a pebble-bed, high-temperature gas reactor producing 80 MWe. This design utilizes four reactors per plant, producing 320 MWe total. The XE-100 plant is designed to take up 12700 m^2 (3 acres) and employ up to 10 staff after construction. X-energy is also a recipient of the ARDP award from the NRC and is using this award to deliver their 4-module plant design to Energy Northwest's Columbia Nuclear Plant in Washington state by 2027. Currently the XE-100 is in the pre-application process with the NRC [13,14,15].

Other mid-sized SMRs like Holtech's SMR-160 and Kairos Power's Fluoride Salt-Cooled High-Temperature Reactor are under development.

3.3.3 Micro SMR Scale

The BWXT Project Pele microreactor is a high-temperature gas-cooled reactor that is designed to produce 1-5 MWe. This reactor is designed to be transportable and simple to set up in order to provide power to remote locations. This reactor will be built by BWXT under a contract awarded by the US Department of Defense Strategic Capabilities Office. The microreactor is planned to be delivered to a demonstration site at the Idaho National Laboratory by 2024. The Project Pele microreactor system is designed to be transported in a 20-foot-long shipping container, which holds the complete plant. This reactor is designed to require two staff during operation. BWXT's Project Pele microreactor will be the first advanced microreactor built in the US and, while it is currently a DoD funded, non-commercial project, it may be available to consumers in a similar timeline to other advanced SMRs [16,17].

The Ultrasafe Micro-Modular Reactor is a high-temperature gas-cooled reactor designed to produce 5 MWe. This design calls for two reactors per plant, intending to produce 10 MWe with a plant size of 12,500 m^2 (3 acres). This reactor is being licensed in both Canada and the US. The University of Illinois at Urbana-Champaign (UIUC) is planning to engage in pre-application activities with the NRC to build a test version of the Ultrasafe MMR on their campus. The reactor is planned to be operational in Canada in 2026 and the reactor at UIUC is planned to operational in the following year. This reactor plant is designed to be easily scalable to meet demand as needed. If more than the initial two reactors are needed, the site is designed to house more reactors easily and efficiently [18,19,20].

The Westinghouse eVinci microreactor is a sodium-cooled fast reactor designed to produce 5 MWe. Initial design work for this reactor was initially conducted under Project Pele, but it was not selected by the Department of Defense for further advancement. The eVinci microreactor is currently in the pre-application phase of NRC licensing but is planning to have a demonstration unit ready for construction and testing by 2025. Westinghouse has been working with Pennsylvania State University to explore siting a test reactor on their campus. Similar to BWXT's Project Pele reactor, the eVinci reactor is designed to be transported in a shipping container to remote sites. This allows for electricity generation wherever it is needed with minimal set up time [21,22,23,24,25].

Other microreactors are in development, such as the X-energy XE-mobile, Radiant, and the Toshiba Energy Solution's MoveluX. However, these reactors are still in development.

3.4 Implications of Nuclear Technology Options for LENOWISCO

In general, it is assumed that the specific type of reactor installed is not important to this feasibility study. Each of the designs discussed in this report are much smaller than those currently operating in the domestic commercial fleet (such as Virginia's Surry and North Anna which generate 840 MWe per unit and 950 MWe per unit, respectively). The newer designs considered for LENOWISCO are designed to be smaller and more economical to build. Multiple modules can be co-located to scale with the power output that is needed. A driver behind this economic construction is the idea that the largest components in each design can still be manufactured in a factory and transported to the build site. This significantly decreases construction time, the overall project cost, and the risk of cost overruns. Many designs also rely on air cooling and do not eject large quantities of heat to a nearby body of water or river, minimizing the impact they will have on the surrounding area. Further, each of the designs are much smaller than the large LWRs that came before them. It is reasonable to plan for these designs to be co-located with the customers that will use their power.

The primary differentiating factor between the designs is the power output. The chosen design should supply the same amount of electricity that that is demanded by co-located and nearby customers. Sites that require 300 MWe or more should consider a large SMR such as the GE-Hitachi BWRX-300 (a BWR with 1-2 300 MWe modules) or the TerraPower Natrium (a 345 MWe SFR). A site that needs 60-300 MWe should consider multiple modules of a medium sized SMR such as the NuScale VOYGR (a PWR with up to 12 60 MWe modules) or the X-energy XE-100 (a HTGR with 4 80 MWe modules). A site that needs <50 MWe should consider one or more micro reactors such as the BWXT Project Pele (a HTGR that produces 1-5 MWe), the Ultrasafe Micro-Modular Reactor (a HTGR with 2 5 MWe modules), or the Westinghouse eVinci (a SFR that produces 5 MWe).

4 POTENTIAL SITE EVALUATIONS

The selection of a site for a nuclear power plant is a multi-step process which is performed following the guidance in NUREG-1555 (US NRC, 2007e) and Regulatory Guide 4.2 (US NRC, 2018) [26,27]. The first step of this process is identifying a "region of interest" (ROI) which is the geographic area which will be investigated. The LENOWISCO Planning District and neighboring Dickenson County geographic footprint is the region of interest for this project.

This ROI has numerous benefits that make it ideal for SMR development. These include numerous inexpensive brownfield sites, an abundance of water resources (including Lake Keokee, the Clinch River and its tributaries, and millions of gallons of mine water for cooling), existing right of way to transmissions infrastructure, and existing rail infrastructure. Further, LENOWISCO has the human expertise and the infrastructure to handle large civil construction projects. There are few environmental restrictions regarding the preservation of the existing environment because prospective SMR sites that could be located on previously mined lands offer an opportunity for a higher and better post-mine use.

From the ROI, a number of candidate areas are identified for further analysis. Candidate areas are large tracts of land which could provide multiple locations for a nuclear site. The candidate areas are identified by applying exclusionary and avoidance factors to the ROI (e.g., avoiding areas with no cooling water availability, avoiding national parks, or avoiding areas with high population density). Potential sites were identified within LENOWISCO for further analysis. The potential sites were selected with sufficient diversity in order to demonstrate that the major trade-offs between siting locations have been assessed. As the project moves forward, the identified candidate sites could be clarified and narrowed for further screening (e.g., water supply, transportation access, transmission line access, ecological effects). In further screening, preferred sites may become clearer. Subsequent examinations and analyses would then be performed for a specific site by either economic developers and/or a utility. Moreover, this initial evaluation illustrates that each site reviewed within this Feasibility Study meets the preliminary threshold of siting an SMR.

Within the LENOWISCO ROI, some example sites were chosen to demonstrate the range of sites that could be available. The STAND tool was used to evaluate the suitability of these areas and some comparison sites for nuclear development. The comparison sites, include conventional nuclear power plants, potential SMR sites outside of LENOWISCO, and current coal and natural gas power plants. The STAND tool was used to assess the suitability of the sites for a baseline case where all of the attributes relevance is set to medium, a microreactor, and a 300 MWe SMR.

The remainder of this section is structured as follows.

- Section 4.1 identifies examples of potential sites from the LENOWISCO ROI.
- Section 4.2 provides the regulatory considerations that apply to siting nuclear power plants.
- Section 4.3 discusses the inputs gathered from community stakeholders.
- Section 4.4 discusses the factors which affect siting that are included in the STAND analysis.
- Section 4.5 discusses the use of the STAND tool and the results of the STAND analysis.
- Section 4.6 provides an overview of why the LENOWISCO Planning District ROI is particularly well suited for the siting of new nuclear power plants.

4.1 Example Potential Sites

A number of sites have been identified as being attractive options for nuclear reactor siting. These sites are described in Section 4.1.1, and were evaluated with the STAND tool as described in Section 4.5. In addition to the sites identified in the LENOWISCO ROI, four sites outside of the region were chosen for STAND evaluation to provide a comparison. The four comparison sites are described in Section 4.1.2.

4.1.1 Potential LENOWISCO Sites

The following sections provide descriptions of each example site.

4.1.1.1 Limestone

The Limestone site is located at the coordinates 36.7315, -82.7653. The approximate location is shown in Figure 4-1 and Figure 4-2. The Limestone site consists of roughly 4 acres of currently available land in Scott County (as shown in Figure 4-3) making it potentially large enough for multiple 300 MWe units. It is also adjacent to a Kentucky Utility transformer and an AEP substation. The site is a former quarry with caves and rock features at a constant 55°F and mine water at a constant 51°F. It is also located near a residential area which must be considered during siting. Tempur-Pedic, a mattress manufacturer, has a manufacturing facility near the site. They and the residential community could serve as existing potential customers. This site has access to rail lines for transportation. The Limestone site does not have any mines intersecting it.

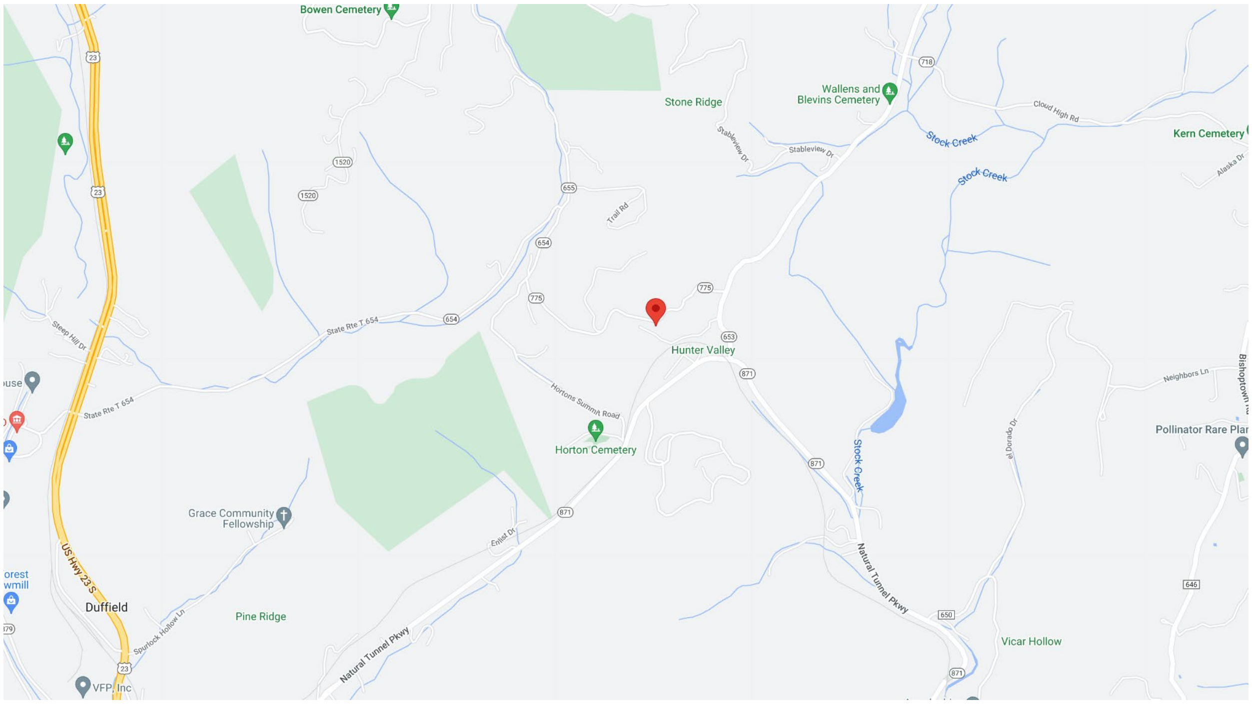

Figure 4-1 Limestone Google Maps Pin

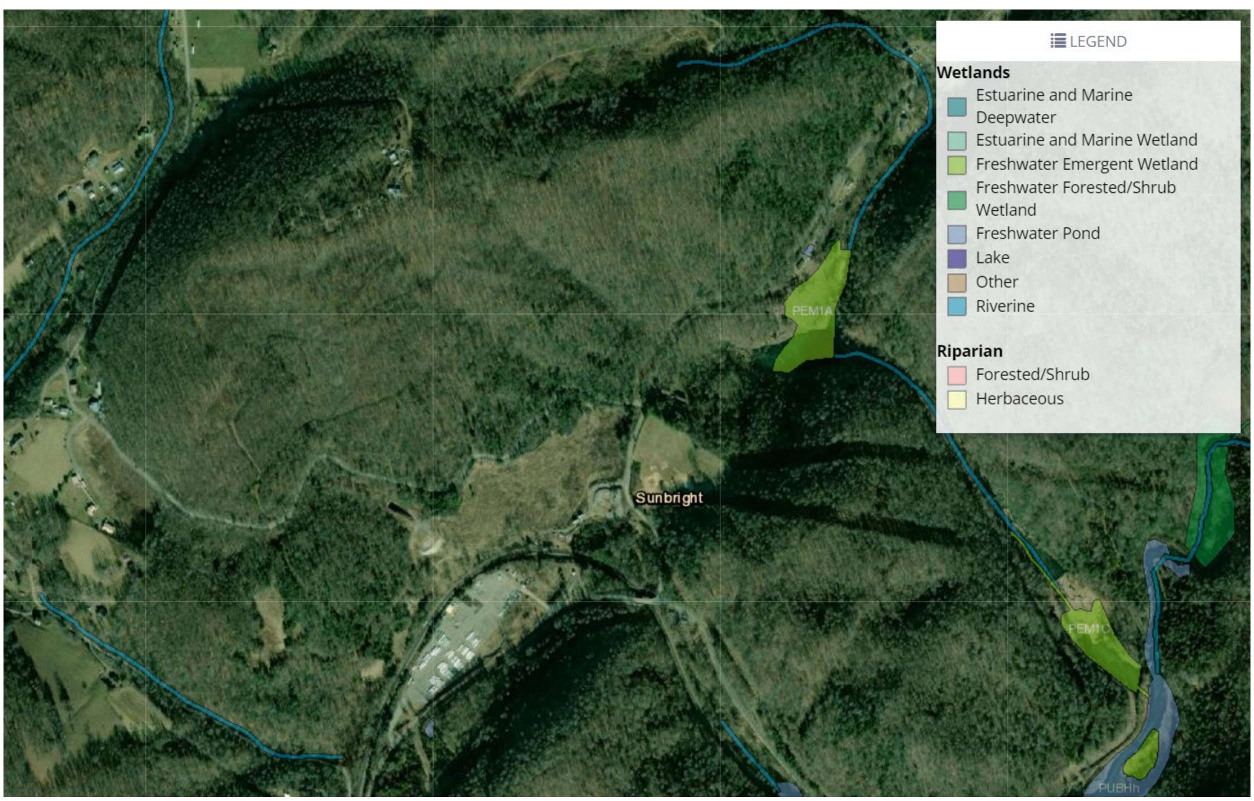

Figure 4-2 Limestone Wetlands Map

Figure 4-3 Limestone Site Expected Acreage

4.1.1.2 Lee County

The Lee County Site is located at coordinates 36.8680, -82.8554. The approximate location is shown in Figure 4-4 and Figure 4-5. It is across Route 606 from the Bullit Site (discussed in Section 4.1.1.3). Surface Mine Reclamation on these specific 10 acres are nearing completion (as shown in Figure 4-6). This site is potentially large enough for multiple 300 MWe units. This site has access to rail lines for transportation and is less than a mile from Lake Keokee. This site has an AML feature (see Section 5.3) that has $500,000 in AMLER grant funding comitted. There are underground mine seams below the site (Dorchester, Imboden, and Wilson Mines) with mine water available for SMRs and potentially for use such as cooling for data centers. At present, backfill material is on-site that could possibly be utilized to shape a SMR pad. The site is located near a KU sub-station.

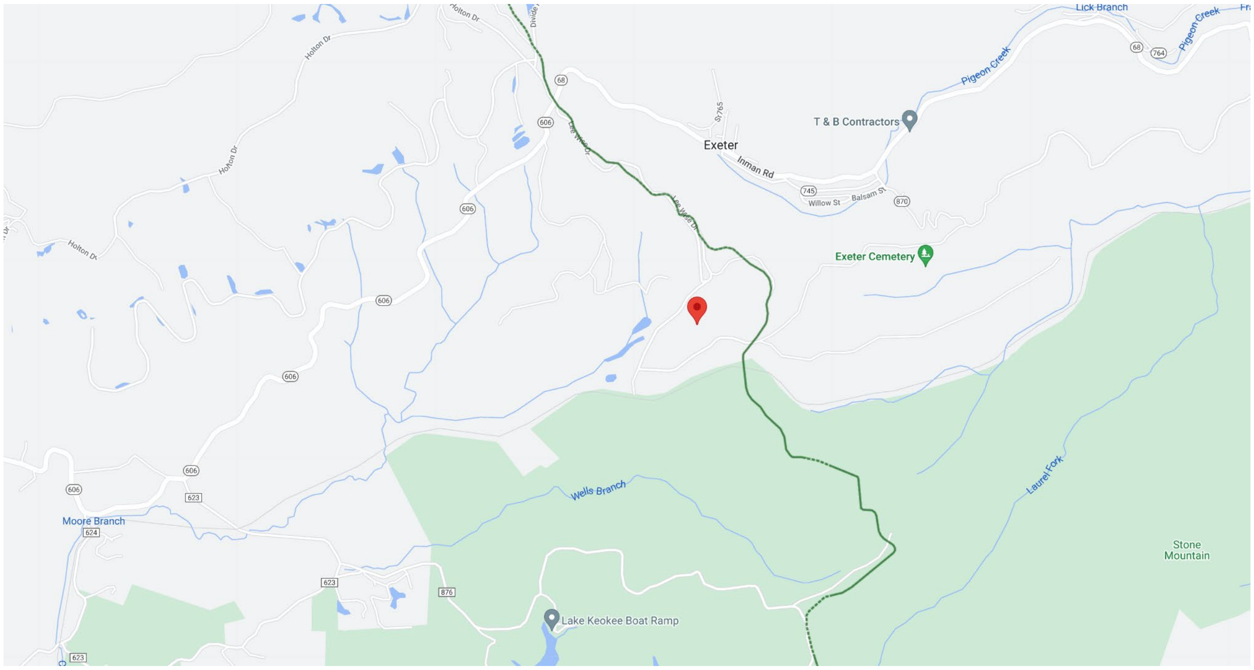

Figure 4-4 Lee County Google Maps Pin

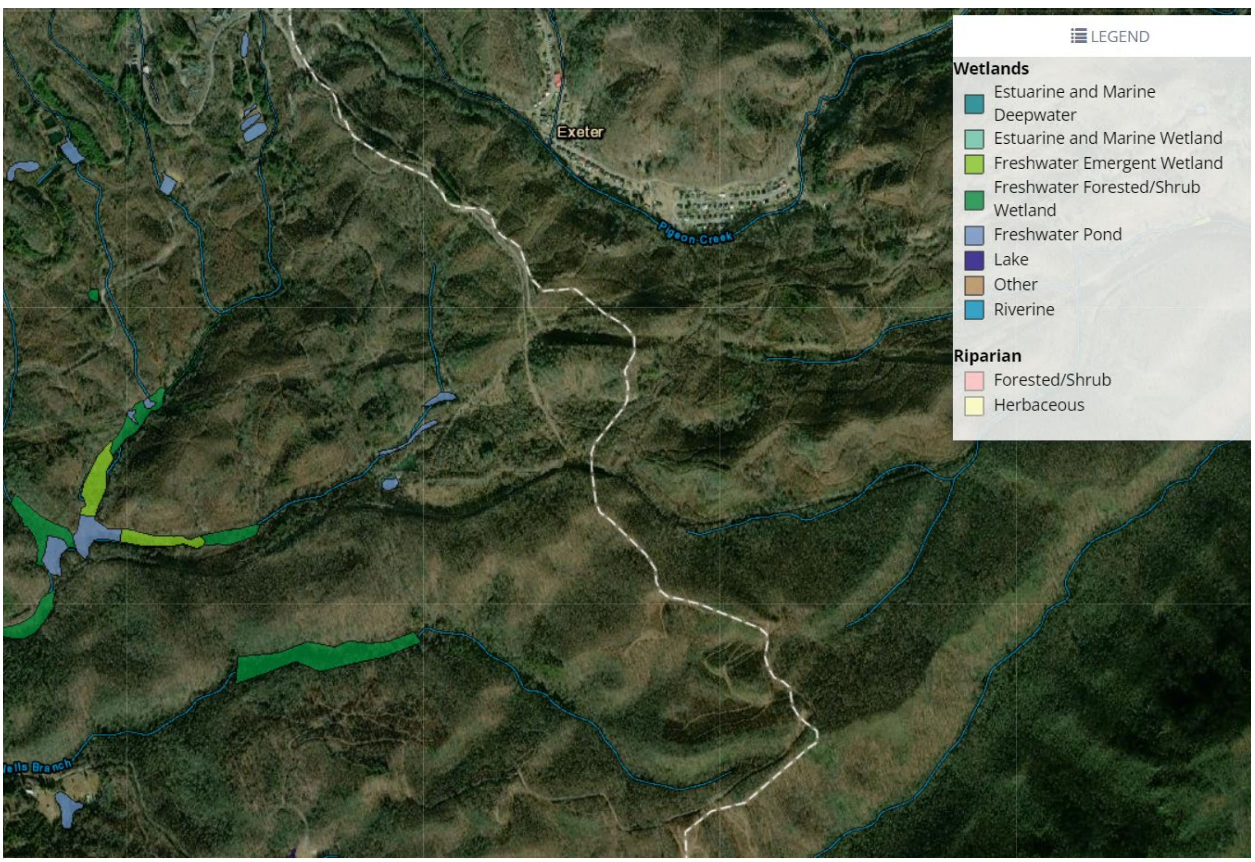

Figure 4-5 Lee County Wetlands Map

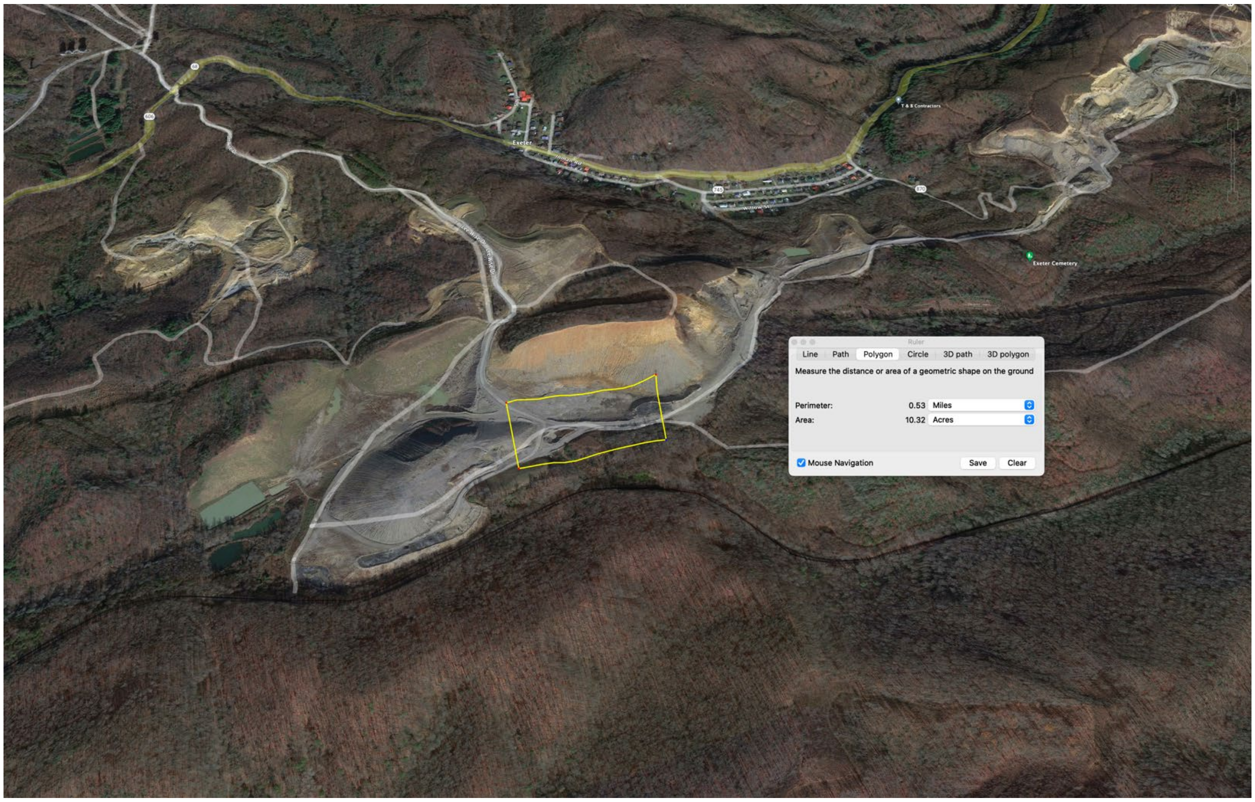

Figure 4-6 Lee County Site Expected Acreage

4.1.1.3 Bullit

The Bullit site is located in Wise County at coordinates 36.8867, -82.8581 and is very close to the the Lee County border. It is across Route 606 from the Lee County Site (discussed in Section 4.1.1.2). The Bullit site's approximate location is shown in Figure 4-7 and Figure 4-8. This is the largest potential SMR chosen as an example site with over 4,000 acres available to be built on. One example within this Bullit tract is a 76 acre portion of currently available land in Wise County (shown in Figure 4-9). This parcel is large enough for multiple 300 MWe units. There are three underground mined seams below the Bullit site with substantial amounts of mine water available for SMRs and for other uses such as cooling for data centers.

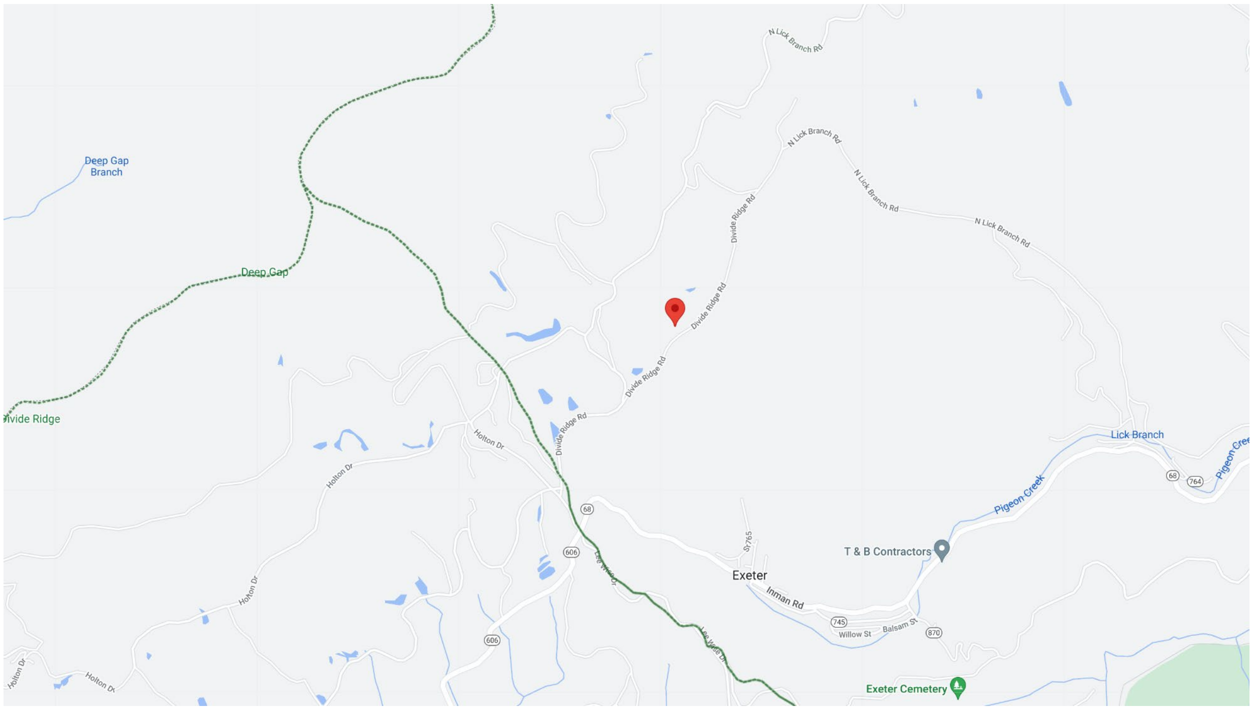

Figure 4-7 Bullit Google Maps Pin

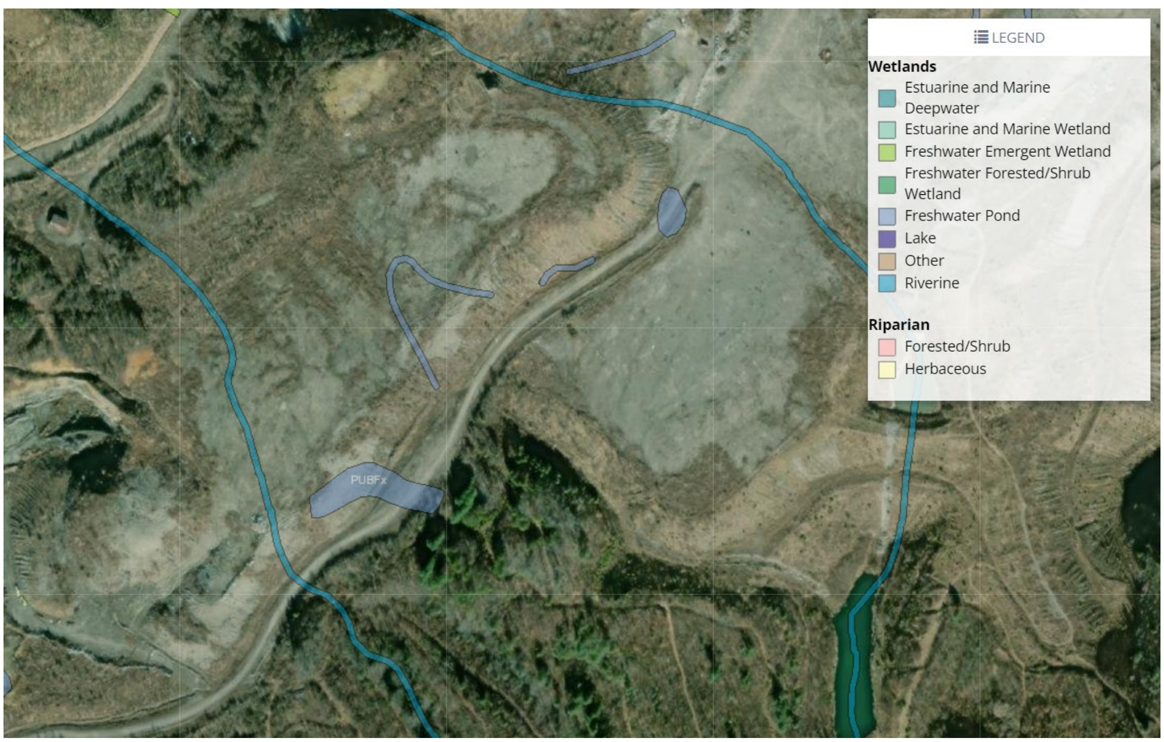

Figure 4-8 Bullit Wetlands Map

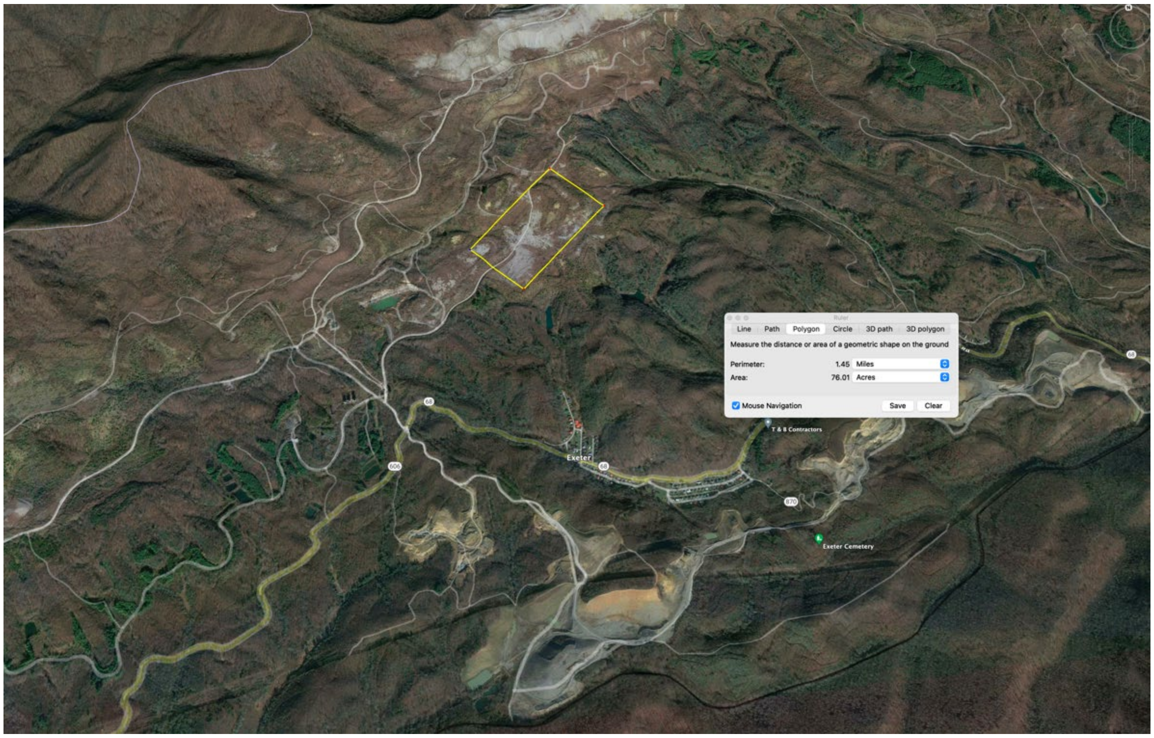

Figure 4-9 Bullit Expected Site Acreage

4.1.1.4 Red Onion

The Red Onion site is located at coordinates 37.1221, -82.5381. The approximate location is shown in Figure 4-11 and Figure 4-12. It is near the intersection of Wise and Dickenson counties. The Red Onion site consists of 25 acres of currently available land in Dickenson County (as shown in Figure 4-12) making it potentially large enough for multiple 300 MWe units. No coal has been mined at this site in over 30 years. This site is located near Red Onion prison (built in the late 1990s) which must be considered when evaluating evacuation zones. The Red Onion site intersects with the Clintwood, Imboden, Imboden Marker, Lower Banner, and Norton Mines.

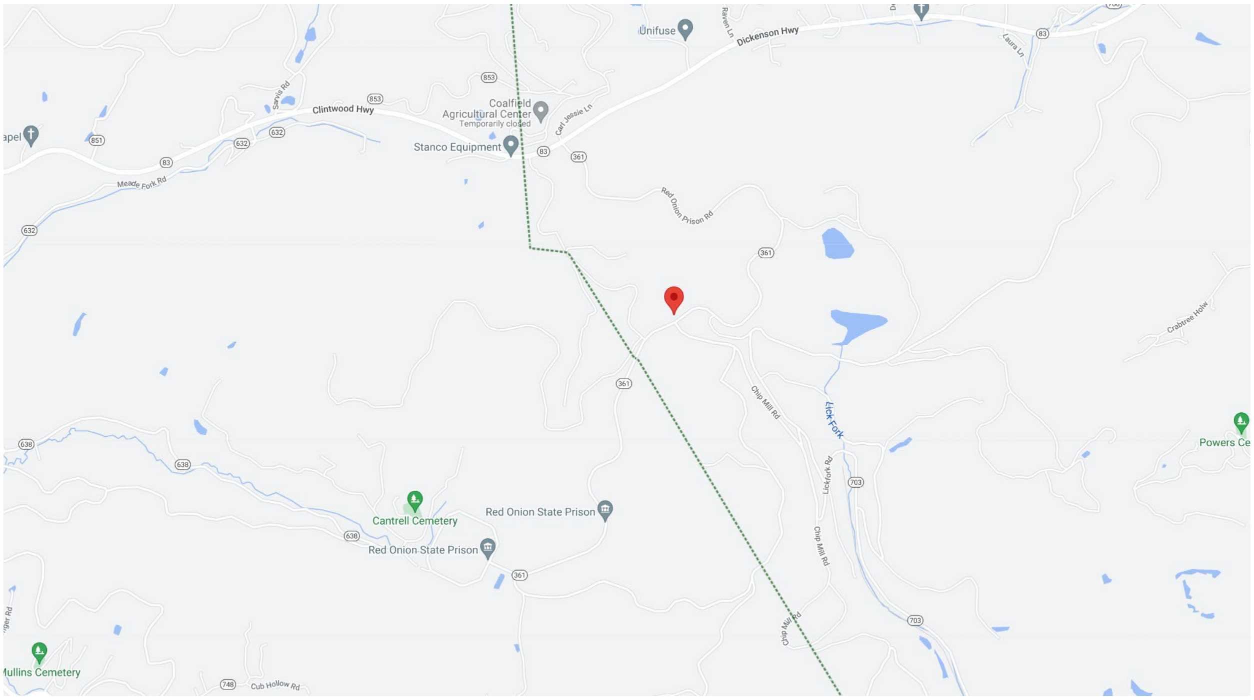

Figure 4-10 Red Onion Google Maps Pin

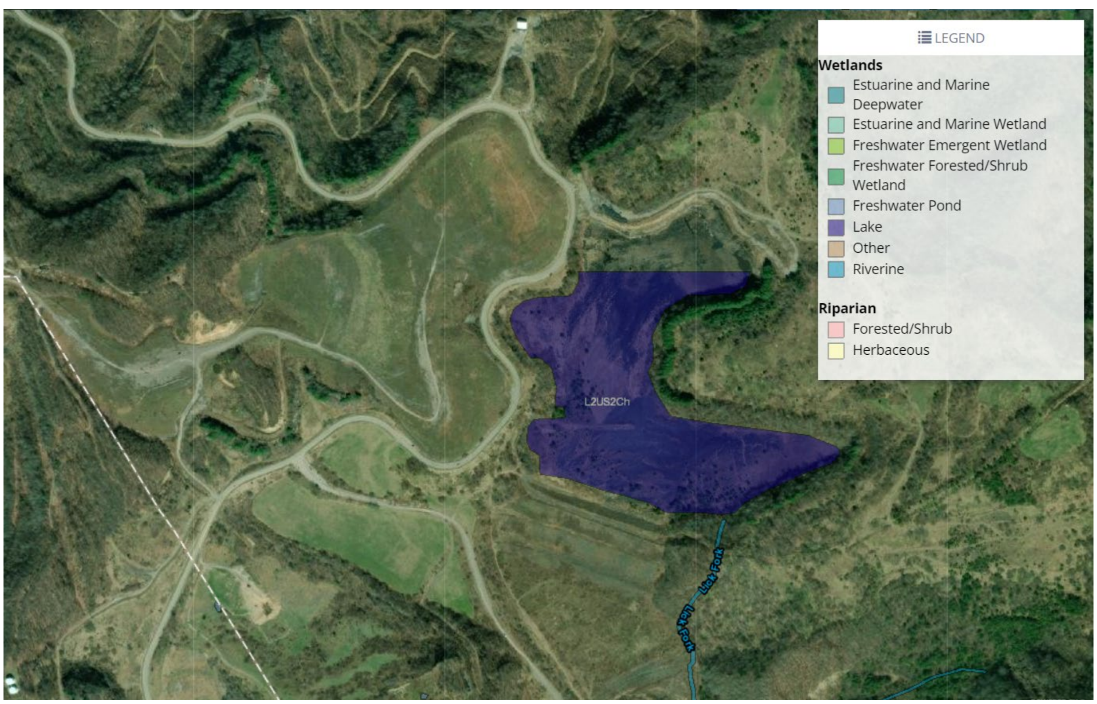

Figure 4-11 Red Onion Wetlands Map*

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* The blue shaded region noted as a wetland on this figure is not a protected wetland. It is an area filled with coal refuse, or GOB.

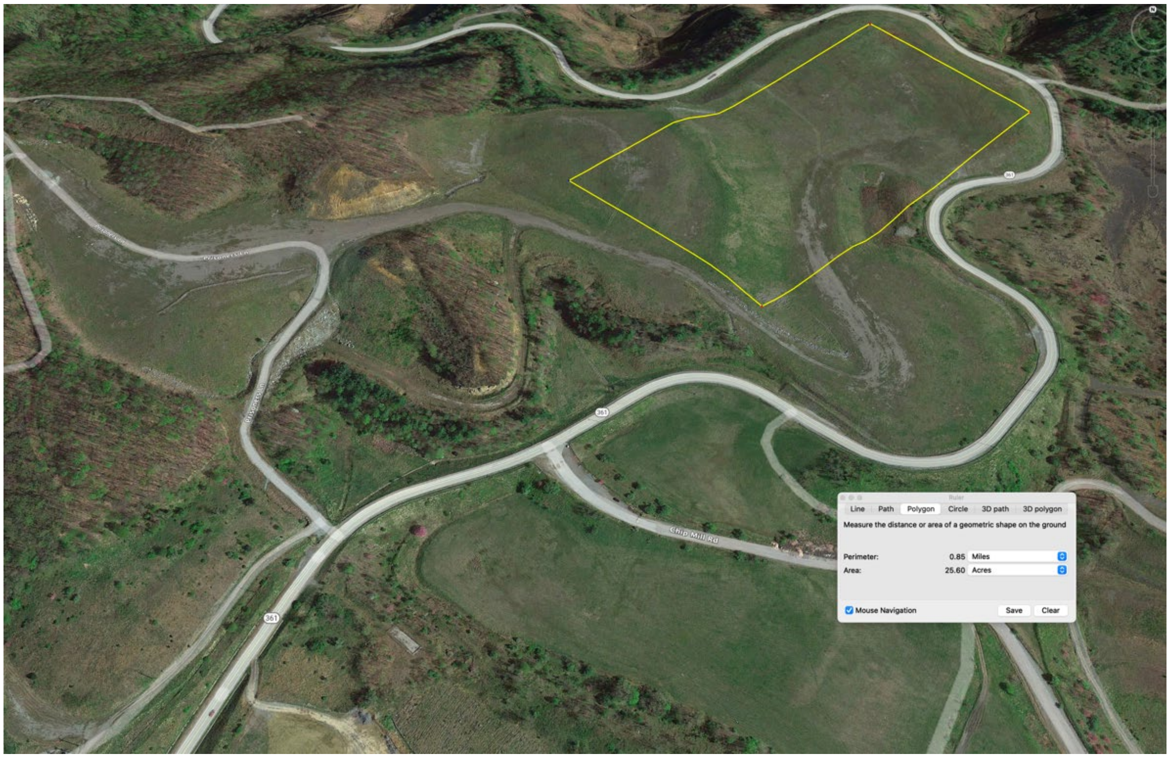

Figure 4-12 Red Onion Approximate Site Acreage

4.1.1.5 Mineral Gap

Mineral Gap is located at the coordinates 36.9753, -82.5367. The approximate location is shown in Figure 4-13 and Figure 4-14. The Mineral Gap site consists of 76 acres of currently available land in Wise County (as shown in Figure 4-15) making it potentially large enough for multiple 300 MWe units. The Mineral Gap site intersects with the Blair, Lyons, Upper Banner, and Kennedy mines. The Clintwood and Dorchester mines intersect very slightly into the Mineral Gap site.

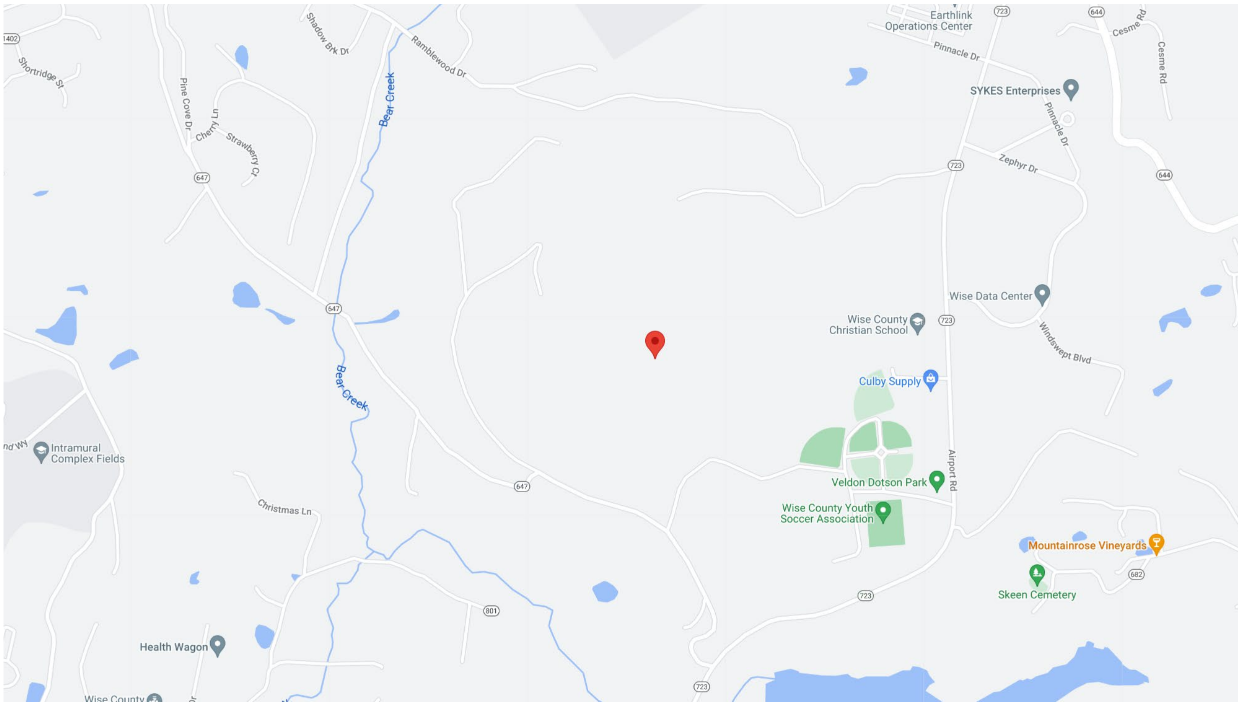

Figure 4-13 Mineral Gap Google Maps Pin

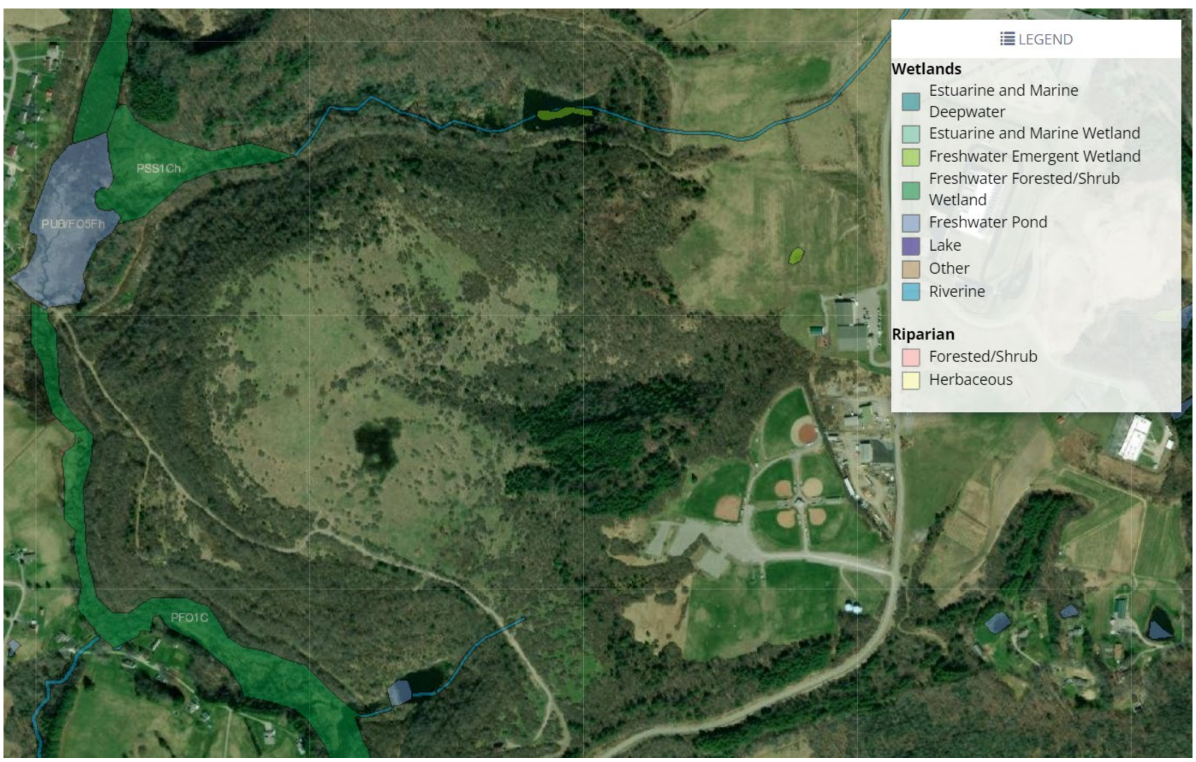

Figure 4-14 Mineral Gap Wetlands Map

Figure 4-15 Mineral Gap Expected Site Acreage

4.1.1.6 VCHEC Virginia City

VCHEC is located at the coordinates 36.9215, -82.3347. The approximate location is shown in Figure 4-16 and Figure 4-17. This site is an operating coal plant and is not available for immediate development. No specific location has been identified within this acreage. However, it has been included in this study for future reference. The Virginia City site intersects with the Jawbone and Raven mines.

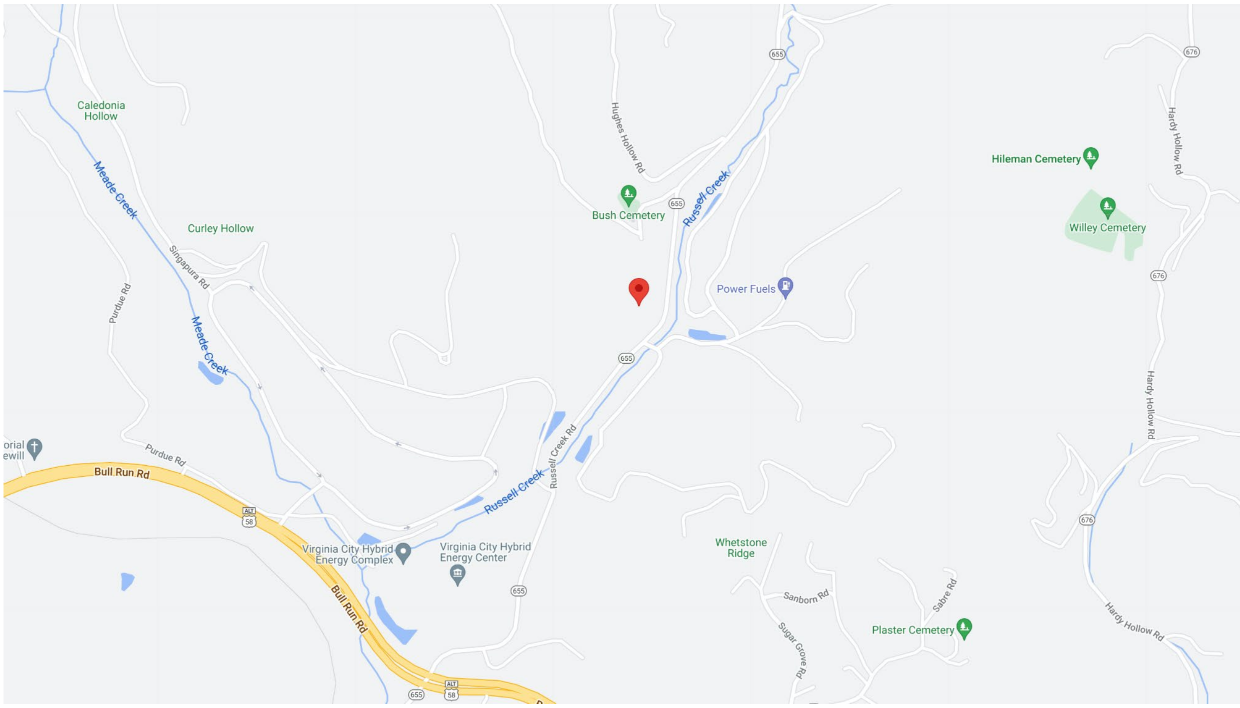

Figure 4-16 VCHEC Virginia City Google Maps Pin

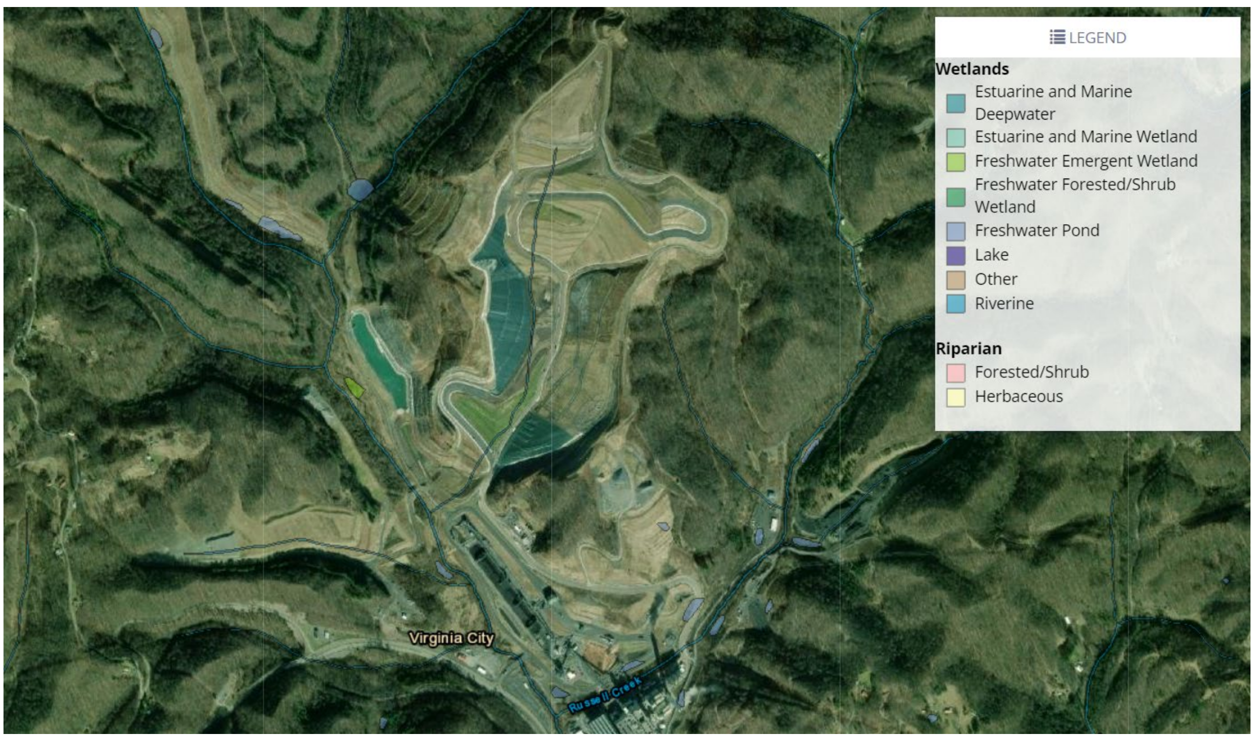

Figure 4-17 VCHEC Virginia City Wetlands Map

4.1.1.7 Project Intersection

The Project Intersection site is located at coordinates 36.9452, -82.6087 and is located within the City of Norton and being developed as an industrial park. The approximate location is shown in Figure 4-18 and Figure 4-19. This site may have sufficient acreage to support microreactors but there is likely not enough space for a larger SMR. A sub-station is located directly adjacent to Project Intersection. The site is located within the City of Norton and close to a population center, single-family homes, businesses, a school, and shopping centers which must be carefully considered during siting. It is possible that underground mined seams (Norton mine and Blair mine) could be used by SMRs and data centers for cooling.

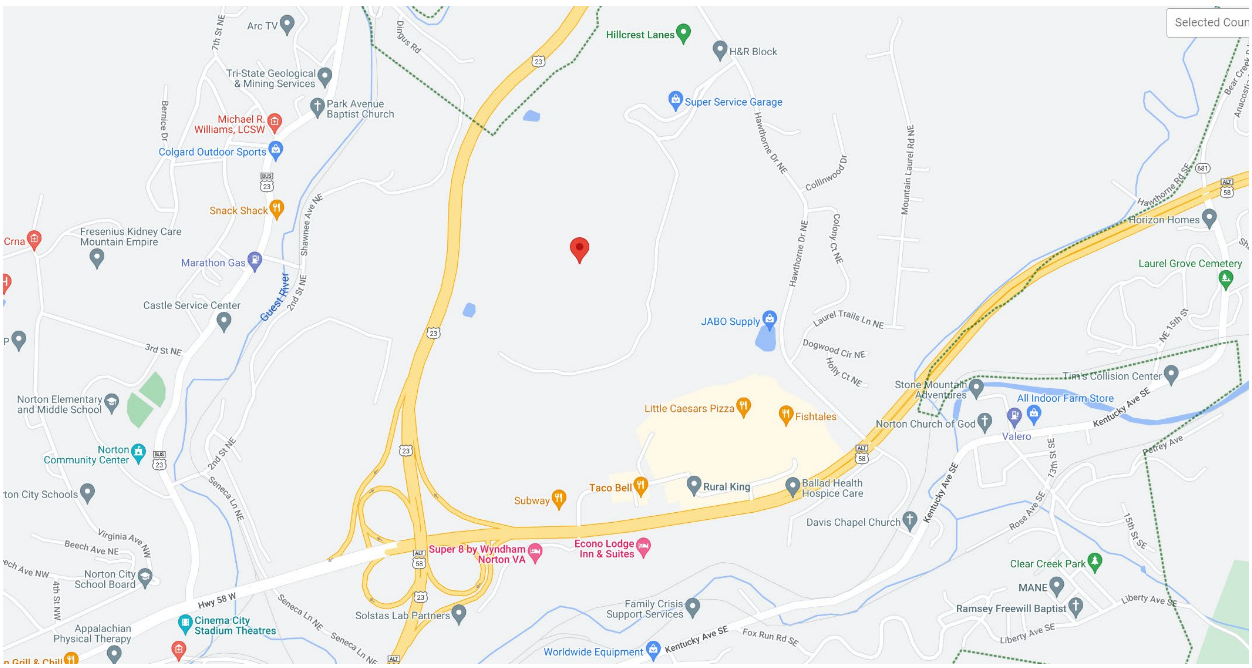

Figure 4-18 Project Intersection Google Maps Pin

Figure 4-19 Project Intersection Wetlands Map

4.1.2 Comparison Sites

Five comparison sites were selected.

- **AEP's Clinch River Coal Station**: Appalachian Electric Power's (AEP) Fossil Clinch River Site was originally constructed as a three-unit coal station. It is located in Carbo, Virginia along the Clinch River. In 2016 two of the coal units were converted into natural gas burners, and the third was retired. Unit three is potentially available for a coal-to-nuclear transition. Access to cooling water is potentially available due to the plants position along the Clinch River. The distance to any large population area allows for safe proximity for nuclear development.
- **TVA's Kingston Fossil Plant**: The Tennessee Valley Authority's (TVA) Kingston Fossil Plant is a 9 unit coal fired power plant on a reservation of 1,255 acres. The plant is situated on a peninsula formed by the Clinch and Emory rivers in Tennessee. TVA is currently planning to retire the fossil plant. Retirement opens up an opportunity to replace the area with a nuclear plant, utilizing the existing infrastructure. Site location provides access to cooling water, as well as adequate distance from large populations [28,29].
- **North Anna Nuclear Generating Station**: Dominion Energy's North Anna Nuclear Generating Station is a 1,075-acre nuclear power plant located on the North Anna river. North Anna currently operates two Westinghouse pressurized water reactors. A 40-year operating licenses for the two units were originally issued in 1978 and 1980. A 20-year

license extension was granted in 2003 for both units, which allows the units to operate until 2038 and 2040 respectively. In 2017 North Anna received a Combined Construction and Operating License (COL) for a third reactor although construction of this unit is not currently being pursued.

- **TVA's Clinch River Nuclear Site**: This site, near Oak Ridge National Laboratory, is currently being prepared for construction of the GE Hitachi BWRX-300, a boiling water SMR. TVA is currently preparing a construction application for the BWRX-300. The BWRX-300 is still in the pre-application activities with the NRC. This site provides a good example of an undeveloped area that has already been selected for SMR development [30,31].
- **Natrium Demonstration Site**: This is a demonstration site for the TerraPower Natrium reactor located in Kemmerer, WY. The Natrium reactor is a sodium-cooled fast reactor that is currently in the pre-application activities with the NRC. This site will replace the Naughton coal fired power plant which is set to retire in 2025. This allows the Natrium team to take advantage of existing grid infrastructure already in place. This provides another good example of a site chosen for SMR development. The attributes of this site are a good point of comparison for other sites looking to house SMRs of different types [32,33,34].

4.2 Regulatory Considerations

The siting of a nuclear power plant is subject to federal regulations. These regulations stem from both the US Nuclear Regulatory Commission (NRC) through the Code of Federal Regulations (CFR) as well as various laws associated with environmental protection (e.g., The Clean Water Act and The Endangered Species Act). Section 4.2.1 and Section 4.2.2 describe the initial process to identify the Region of Interest and Candidate Areas which will be reviewed for compliance with siting criteria and regulations. Section 4.2.3 lists the regulations which form the basis for siting criteria which are discussed in Section 4.2.4.

4.2.1 Identification of the Region of Interest

The region of interest may be selected based on geographic boundaries such as state lines. The ROI is composed of the area considered for siting of the nuclear reactor (e.g., the LENOWISCO Planning District and neighboring Dickenson County). The ROI is further defined by a purpose and need which may be defined by the applicant (e.g., provide 300 MWe generation capacity within the LENOWISCO region to stimulate data center investments). The ROI should be large enough that it does not prevent the inclusion of locations where the defined project objectives can be achieved. The selection process of the ROI may include restrictions due to siting constraints, population density, or proximity to load centers or transmission lines. The selection process for the ROI will be described in the environmental report submitted with the license application.

4.2.2 Identification of Candidate Areas

Candidate areas are selected within the region of interest by excluding locations where the nuclear power plant cannot be sited due to regulatory, environmental, or business constraints (e.g., locations within national parks, upon tribal land, or with no access transportation networks). In addition to excluding areas where siting is not feasible, the candidate areas may be defined by avoiding areas which are expected to be unfavorable (e.g., areas containing wetlands, critical habitat for endangered species, or with no immediately available source of cooling water). The exclusionary and avoidance factors used to define the candidate areas from the region of interest should be documented during the siting process. Once the candidate areas have been defined, a number of discrete potential sites may be selected for further evaluation.

4.2.3 Applicable Regulations

The applicable federal regulations for siting a nuclear power plant are described in Regulatory Guide 4.7 “General Site Suitability Criteria for Nuclear Power Stations” (US NRC, 2014c) [35]. These regulations are broadly summarized as:

- Title 10, Part 50, of the *Code of Federal Regulations* (10 CFR Part 50), “Domestic Licensing of Production and Utilization Facilities,” requires that structures important to safety be designed to withstand the effects of expected natural phenomena during accident conditions without a loss of capability to perform their safety functions [36]. This requirement broadly specifies that the site must be selected with an understanding of anticipated seismic, flooding, tornado, and other environmental hazards. The power plant must be designed to ensure these hazards do not prevent safe shutdown operations.
- The National Environmental Policy Act of 1969 (NEPA) (42 U.S.C. 4321 et seq) and the Council on Environmental Quality’s regulations (40 CFR Parts 1500 – 1508) require detailed environmental statements on proposed major Federal actions that will significantly affect the quality of the human environment [37]. This requirement specifies that the Federal decision-making process considers the environmental impacts of nuclear power plant construction and operation, as well as the available alternatives (including no construction or alternative siting).
- 10 CFR Part 51, “Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions,” provides the regulations associated with the preparation of environmental impact statements pursuant to NEPA as well as the Clean Water Act (CWA) [38]. The regulations provided in 10 CFR 51.45 set forth the required contents of the environmental report submitted by the applicant.

- 10 CFR Part 52, “Licenses, Certifications, and Approvals for Nuclear Power Plants,” provides regulations on the issuance of early site permits and combined licenses for nuclear power facilities[39]. These regulations include the requirements which must be met for the NRC to issue licenses for construction. These requirements include the issuance of a final safety analysis report which provides information related to site location, population considerations, locations of nearby industrial facilities, and postulated radioactive releases in the event of an accident.
- 10 CFR Part 100, “Reactor Site Criteria” specifies the attributes required to be considered in determining a site to be acceptable for a nuclear power reactor [40]. These attributes include: seismology, meteorology, geology, hydrology, population density, etc.

The regulations above provide an overarching framework for the site selection process. These regulations are discussed in more detail in Section 4.2.4. When applying for a license to operate a nuclear reactor, an environmental report is required to be submitted as part of the application. Following the site selection process detailed in Regulatory Guide 4.7 will ensure that the environmental report generated will meet the requirements of Regulatory Guide 4.2 “Preparation of Environmental Reports for Nuclear Power Stations,” in accordance with the guidance of NUREG-1555 “Environmental Standard Review Plan.”

It is recognized that during early site selection efforts, limited information will be available. During early efforts to categorize the ROI, candidate areas, and potential sites a low level of detail is required. Early siting efforts should proceed with sufficient documentation to show the regulator that the applicant considered locations with environmental diversity and viable alternative sites were investigated for siting. Following the identification of potential sites, more detailed analysis is applied to identify the candidate sites and proposed site.

4.2.4 Regulation Review

This section provides a review of the siting constraints due to the regulations listed in Section 4.2.3. These siting constraints must be fully evaluated during the siting process but may not require evaluation during early stages of siting (i.e., most detailed investigation occurs between the identification of potential sites and the selection of a proposed site).

4.2.4.1 Health and Safety Criteria

This section describes the criteria associated with siting which may affect the health and safety of the public or reactor operators. Some criteria concern natural phenomena (e.g., earthquake or flood), an increase in the radiological consequences of accidents to people (e.g., dense populations), or an increase in the radiological consequences of accidents to the environment (e.g., local aquifers or surface waters).

4.2.4.1.1 Geology/Seismology

The proposed site must be suitable for a nuclear power plant with respect to surface faulting, potential earthquake induced ground motion, and foundation. These criteria are described in 10 CFR 100.23 and 10 CFR 52.17(a)(1)(vi). Regulatory Guide 1.206 "Combined License Application for Nuclear Power Plants" describes the geological information which will be required for licensing of the proposed site [41]. In general, regions which are expected to be subject to peak ground acceleration greater than 0.3 g during a design basis earthquake should be excluded from the candidate areas. Siting a power plant greater than 200 miles from a capable tectonic structure (seismic source) will reduce the need for detailed geological investigation. Surface faulting and deformation are evaluated within 25 miles of the proposed site. Geologically hazardous areas such as those with unstable slope, at risk of collapse, near-surface coal mined-out regions, etc. should be avoided in site selection. Areas with unstable soil due to mineralogy, water content, high groundwater table, etc. should also be avoided.

4.2.4.1.2 Cooling System Requirements

Nuclear reactors require a cooling source in order to reject waste heat. Traditional large light water reactors utilize cooling water via either direct cooling or an evaporative cooling tower. Smaller advanced reactor designs may utilize air cooling in place of water cooling. When a reactor design has been identified, the supply of cooling air or water must be evaluated. Regulatory Guide 1.27 "Ultimate Heat Sink for Nuclear Power Plants" provides guidance on water supplies for nuclear power plants [42].

If cooling water is required, the water sources within the ROI should be investigated. The use and consumption of cooling water is generally governed by state policies. If consumptive water use is planned, then the quantity of use for power plant operation will need to be specified. A reasonable assurance that the consumptive water use will be permitted by the appropriate local or state agencies should be obtained. Cooling water sources should also be screened against intake flow limits as specified in the Clean Water Act 316(b).

If thermal heat or chemical effluents are planned to be discharged from the power plant, they are governed by the Clean Water Act, 40 CFR Part 122 "EPA Administered Permit Programs: The National Pollutant Discharge Elimination System," 40 CFR Part 423 "Steam Electric Power Generating Point Source Category," as well as State water quality standards [43,44]. Upon submission of a license application, the NRC will require a certification from the state that the proposed discharges will comply with the applicable requirements and limitations.

Cooling water may be sourced from rivers or lakes (surface waters), groundwater, or reclaimed water supplies (e.g., effluent from other industrial processes). Areas without adequate cooling water supply may be excluded from the candidate areas. Water supply plans should be developed for candidate sites including an evaluation of low-flow conditions based on historical seven-day and ten-year low flows. Additionally, water supply plans will require projections of water use and consumption into the future throughout the operating period of the proposed nuclear plant. Site-specific water supply features should also be considered such as the need for pumping facilities, water treatment facilities, and reservoirs.

Fogging and icing can be a concern if cooling towers, lakes, canals, or spray ponds are planned to be used in the reactor design. The discharged water vapor may result in plumes which degrade visibility and cause challenges with routine transportation and emergency evacuation. Sites which experience natural fogging or icing may have these conditions worsened by the discharged vapor. Sites should be evaluated for the mean number of days heavy fog (<0.25-mile visibility is experienced). The potential effects of fogging and icing are described in Section 5.1.1 "The Site and Vicinity" and Section 5.3.3.1 "Heat Dissipation to Atmosphere" of NUREG-1555.

If ambient air cooling is required, general climate conditions should be evaluated, and locations with the lowest dry bulb temperature are the most preferable. Maximum, minimum, and average annual and monthly air temperatures should be evaluated based on the nearest weather station for a period of the previous 20 years.

4.2.4.1.3 Flooding

The proposed site should not be subject to flooding conditions. None of the candidate sites identified within the LENOWISCO ROI were found to fall within the 100-year nor 500-year floodplain. 10 CFR 100.20(c)(3) and 10 CFR 100.23(d)(3) require that a maximum probable flood be determined. This determination will include floods which may be seismically induced (including dam failures), localized flooding, river flooding (including blockage or diversion), tsunami, and storm surge. Regulatory Guide 1.59, "Design Basis Floods," describes an acceptable method for determining the maximum probable flood [45]. Candidate areas and potential sites should be screened against 100-year flood zone data as a basic exclusion. When identifying candidate sites, the flooding analysis is further refined in consultation with 100-year and 500-year flood zones, as well as describing proximity to flooding concerns as well as site elevation compared to the nearest body of water.

4.2.4.1.4 Local Hazardous Land Uses

The proposed site should be located away from other hazardous land uses. 10 CFR 100.21(e) requires that nearby hazardous land uses be evaluated to ensure that they do not pose an undue risk to the facility. The proposed site should be located greater than 10 miles from major airports and greater than 5 miles from hazardous facilities and activities to the extent possible. Hazardous land uses within the 5 mile area will have to be evaluated as part of the license application. Hazardous land uses are postulated to generate: missiles, shock waves, flammable vapor clouds, toxic chemicals, or incendiary fragments. Existing land uses that are considered potentially hazardous include: military bases, oil or gas wells and pipelines or storage, manufacturing facilities, chemical facilities or refineries, mining and quarrying operations involving blasting, dams, freight rail lines, highways, docks, or nearby power plants.

4.2.4.1.5 Extreme Weather Conditions

Nuclear power plants must be designed to withstand extreme weather conditions such as tornadoes, hurricanes, and excessive rainfall. However, these conditions are not expected to vary significantly between potential sites within the same region. Consequently, extreme weather conditions are not typically assessed during the identification of potential sites. When candidate sites are identified they may be assessed for peak gusts, number of tornadoes per 10,000 square miles, number of hurricanes, and maximum 24-hour precipitation (rain or snow).

4.2.4.1.6 Population Density

The proposed site must meet the population density requirements described in 10 CFR 100.21 which requires:

- An exclusion area surrounding the reactor in which the reactor licensee has the authority to determine all activities including exclusion or removal of personnel and property from the area.
- A low population zone (LPZ) surrounding the exclusion area which contains residents, the total number of density of which are such that there is a reasonable probability that protective measures could be taken on their behalf in the event of a serious accident.
- The nearest population center of more than 25,000 residents located at least 1.33 times the distance from the reactor to the outer boundary of the LPZ.

In practice, the proposed siting should be such that the population density including the transient population (migrant labor, recreational hikers, etc.) does not exceed 500 persons per square mile for a radial distance of 20 miles. The ROI may be reduced to candidate areas by applying an exclusion factor for population densities greater than 300 persons per square mile to account for future population growth. The candidate areas may also exclude regions within the following distances of population centers:

- Within 4 miles of a population center of 25,000 residents
- Within 10 miles of a population center of 100,000 residents
- Within 20 miles of a population center of 500,000 residents
- Within 30 miles of a population center of 1,000,000 residents

Deviations from the above guidance will require justification during the licensing process but may be acceptable pending other siting characteristics such as superior seismic characteristics, lower environmental impacts, or better access to transmission or transportation infrastructure.

4.2.4.1.7 Emergency Planning

The proposed site is required to be located such that adequate plans to protect the public in emergencies can be developed in accordance with 10 CFR 100.21(g) and 10 CFR 50.47(a)(1)(i). Guidance to meet these regulations can be found in NUREG-0654, "Criteria for Preparation and Evaluation of Radiological Emergency Plans and Preparedness in Support of Nuclear Power Plants: Criteria for Emergency Planning in an Early Site Permit Application" [46]. Special site characteristics such as an egress limitation from the area surrounding the site should be considered (e.g., a single roadway out of a region, bridges, etc.). Additionally, the presence of a population with special requirements for evacuation must be considered (e.g., hospitals, prisons, schools, etc.) If major differences exist between the candidate sites, the emergency planning characteristics may play a role in the selection of the candidate and proposed site. An evacuation time estimate must be conducted for the final proposed site to assess the suitability of the site with respect to emergency planning in accordance with NUREG/CR-7002 Revision 1, Criteria for Development of Evacuation Time Estimate Studies [47].

4.2.4.1.8 Atmospheric Dispersion

If an accident occurs at the proposed site, airborne radiation or other hazardous materials may be released to the environment. The effect of these releases is dependent upon atmospheric dispersion characteristics of the site. Wind speed, wind direction, and the change in air temperature with elevation will all affect the atmospheric dispersion of an airborne release. In general, higher wind speeds will result in increased atmospheric dispersion (i.e., farther spread) and lower the consequences (i.e., more dilution) of the release in any target area. Local geographic phenomena such as canyons, valleys, and mountain ranges can result in significant variations between a proposed site and the general region. Siting locations which would significantly restrict airborne dispersion such as valleys or areas surrounded by hills should be avoided. Available data such as average annual wind speeds and direction may be used to compare the suitability of candidate sites.

The proposed reactor design as well as the proposed site atmospheric dispersion characteristics will be required inputs to ensure compliance with various regulations. 10 CFR 50.34(a)(1)(ii)(D)(1), 10 CFR 52.17(a)(1)(ix)(A), and 10 CFR 52.79(a)(1)(vi)(A) require the exclusion area be large enough to limit the radiation received by a member of the public during a postulated radiation release to 25 rem total effective dose equivalent (TEDE) during a 2 hour period. 10 CFR 50.34(a)(1)(ii)(D)(2), 10 CFR 52.17(a)(1)(ix)(B), and 10 CFR 52.79(a)(1)(vi)(B) require the low population zone to be large enough to limit the radiation received by a member of the public during a postulated accident to 25 rem TEDE. The atmospheric dispersion characteristics of the proposed site are analyzed in accordance with Regulatory Guide 1.23 "Meteorological Monitoring Programs for Nuclear Power Plants" [48].

4.2.4.1.9 Groundwater Requirements

The proposed site must be analyzed for the potential of an accident or routine effluent discharge to result in ground water contamination. 10 CFR 100.20(c)(3) requires that factors important to hydrological radionuclide transport be assessed from onsite measurements. These factors include soil, sediment, and rock characteristics, ground water velocity, and adsorption coefficients, among others. The Environmental Protection Agency (EPA) has established three classes of groundwater under The Groundwater Protection Strategy. Locations containing Class I, or special groundwater, may be excluded from the candidate area. Sites located near sole source aquifers should also be excluded from the candidate area. When evaluating candidate sites, the vulnerability of each site's groundwater may be assessed using the EPA's DRASTIC model [49]. The license application will need to include a conceptual ground water site model which considers the characteristics of the nearby ground and surface waters which determines the most severe radiological impact on existing and future uses of ground and surface water resources.

4.2.4.1.10 Radionuclide Pathways

Nuclear power reactors are generally designed to allow for routine liquid and gaseous radioactive discharges. These effluents are discharged at low concentrations and low flow rates in order to limit the consequence of the release to people and the environment.

Radioactive liquid releases to surface water such as streams, rivers, or lakes, may be limited based on the potential dilution flowrate, the proximity of the discharge to consumptive users, and the baseline radioactivity of the surface water. Proposed sites with higher dilution capacity, further proximity to public water supply or recreational use, and lower baseline radioactivity are preferred.

Radioactive releases can result in the contamination of food stores via airborne or liquid pathways. Subsequent ingestion of contaminated food can result in dose to the population. Candidate sites should be screened at the county level for nearby agricultural sites. Agricultural uses of land which could be affected by airborne releases include farming and grazing. Agricultural uses of water which could be affected by liquid releases include irrigation. Food and irrigation exposure pathways are generally minimal, but site locations with lower irrigated or non-irrigated crop and pasturelands are preferred.

4.2.4.1.11 Security

10 CFR 52.17(a)(1)(x) and 10 CFR 100.21(f) specify that the characteristics of the proposed site are such that adequate security plans and measures can be developed. Guidance related to the development of security plans and measures can be found in NUREG-0800, Section 13.6.1 and 13.6.3 [50]. In general, the site must be able to show that nearby industrial, transportation, and military facilities, regional climatology, floods, ice effects, and seismology will not prevent the development of adequate controls which meet security requirements.

4.2.4.2 Ecological Criteria

This section describes the criteria associated with ecological disruption to the environment which may be affected by the proposed reactor. Criteria may result from potential effects on aquatic or terrestrial ecology caused by either the construction or operation of the proposed reactor. The effects on important species must also be considered. Important species are defined in Regulatory Guide 4.7 as any species which is:

1. Commercially or recreationally valuable
2. Endangered or threatened
3. Able to affect the well-being of some important species within criteria (1) or (2) or if it is critical to the structure and function of a valuable ecological system or is a biological indicator of radionuclides in the environment.
4. Endangered and threatened species are defined by the Endangered Species Act of 1973 (16 U.S.C. 1531 et seq.), as amended.

These effects must be understood and assessed during the siting process which will culminate in the issuance of an environmental report with the license application.

4.2.4.2.1 Aquatic Effects of Construction and Operation

In accordance with the Endangered Species Act, the proposed site should not disrupt designated critical habitat of threated or endangered species. The habitat areas (year-round or seasonal) of important species to be avoided include breeding, nursing, nesting, spawning, wintering and feeding areas. If possible, cooling waters should not be sourced from critical habitats. If no other cooling waters are available, critical habitats may be considered with significant environmental review. The proposed sites may be assessed with and without critical habitat restrictions to determine the overall impact of critical habitats. At the proposed site screening level, each site may be ranked by the overall number of protected or endangered species located in its host county. At the candidate site screening level, sites may be evaluated based on more detailed evaluations of the habitat, existing land uses surrounding the water body, water quality data, and detailed plans for construction of a water intake structure which minimizes impact to aquatic species.

An evaluation of sediment disruption during construction should also be performed. Short term effects relating to dredging and construction may disturb contaminated sediments which can then impact human health and wildlife. Sediment toxicity is of concern in areas which have been subject to mining or industrial uses. Fine-grained sediments such as muds are generally more contaminated than coarse sandy sediments, and sites with higher proportion of clays and silts are the least suitable for construction. Periodic maintenance dredging of the site during operation may also be required. The rate of sedimentation at the site may be considered to determine how often maintenance dredging may be required.

During operation, the proposed nuclear reactor will impact the cooling body of water via thermal discharge and water withdrawal. Thermal discharge of waste heat to the proposed body of water must be conducted in accordance with state and federal Clean Water Act regulations. Once-through cooling systems have more difficulty meeting relevant thermal discharge limits than evaporative (cooling tower) systems. In addition to siting the plant away from waters which compose critical habitats, the power plant should be sited with a preference for cooling water supplies of higher flow rate which will dilute the thermal discharges more efficiently.

The removal of water from the target cooling water supply will be subject to EPA regulation 316(b) of the Clean Water Act regarding impingement and entrainment. Entrainment refers to the intake of small organisms such as small fish, eggs, or plankton into the power plant along with the cooling water supply. Organisms which are entrained may be subject to high mortality when passing through plant systems. Impingement refers to the trapping of larger fish, turtles, or other wildlife against plant intake structure screens where elevated intake flow rates prevent the escape of the wildlife. In NUREG 1437 the NRC concluded that evaporative cooling towers allow for the protection of aquatic species from impingement and entrainment regardless of siting. Proposed once-through cooling systems may require additional evaluation with respect to the effects of impingement and entrainment during the siting process.

4.2.4.2.2 Terrestrial Effects of Construction and Operation

In accordance with the Endangered Species Act, the proposed site should not disrupt designated critical habitat of threated or endangered species. The habitat areas (year-round or seasonal) of important species to be avoided include breeding, nursing, nesting, spawning, wintering, and feeding areas. If possible, the proposed site should be located away from critical habitats as well as other areas of ecological interest such as national preserves, biological stations, or wildlife management areas. The proposed sites may be assessed with and without critical habitat restrictions to determine the overall impact of critical habitats. At the proposed site screening level, each site may be ranked by the overall number of protected or endangered species located in its host county. At the candidate site screening level, sites may be evaluated based on more detailed evaluations of the habitat, such as the uniqueness of the habitat within the region and the amount of the habitat which would be disturbed compared to the total amount of habitat in the area.

If connection to existing high voltage electrical distribution is planned, then the proposed transmission corridor should be evaluated. Distance from the proposed site to existing electrical power corridors or substations should be evaluated. An existing right of way is preferred compared to areas which would require the clearing of land for new transmission infrastructure. The proposed transmission corridor is subject to the same assessment of effects to species of interest as the proposed site.

Wetland disruptions due to operation or construction are to be avoided to the extent practical in accordance with Executive Order 11990, Protection of Wetlands [51]. During the screening process, wetlands should be excluded from candidate areas. If the exclusion of wetlands is too restrictive, sites may be screened based on the total acreage of wetlands which would be affected by construction and operation. If wetlands are present near the candidate site, an evaluation must be performed to determine what affect if any will occur due to construction-related dewatering.

If a cooling tower is planned for the proposed site, cooling tower drift must also be considered. Drift is the term for the carryover of liquid water within the evaporated water stream of a cooling tower. The liquid water may contain water treatment chemicals, excess salt, and other particles which will be deposited to the environment. Drift can affect terrestrial life and vegetation due to deposition. Cooling water with high salt content or dissolved solids can exacerbate the concentration of adulterants present in the liquid water drift. Proposed sites with freshwater cooling sources are preferred with respect to cooling tower drift.

4.2.4.3 Socioeconomic Criteria

Socioeconomic criteria should be investigated during the siting process and will need to be addressed as part of the license application in accordance with Regulatory Guide 4.7 [52]. Socioeconomic criteria include land use issues, public infrastructure issues, and environmental justice issues.

The proposed site of the nuclear reactor should not interfere with current or planned land uses. Parks, recreational areas, and other public land uses may conflict with the proposed siting and will require resolution through state and local agencies. Archeological or historical areas are subject to additional laws and regulations and should be avoided if their presence is known. Land devoted to specialty crop production may be displaced by the proposed siting which would require additional investigation. The proposed siting may also result in aesthetic impacts to the surrounding area which must be assessed.

The suitability of the site with respect to local communities and public infrastructure must also be assessed. Construction and operation of the proposed nuclear reactor could result in a disruption to community services such as schools, hospitals, and water or sewage infrastructure. The number of local and migrating workers attracted by the facility during construction and operation must be found to not adversely affect the local community nor disproportionately affect minority or low-income populations.

The candidate sites must be screened for any differences in environmental justice outcomes. Areas that if developed can result in adverse effects to minority or low-income populations should be avoided. If a certain site may disproportionately affect the lifestyle or food intake of a group which would be avoided if a different site was selected, that would be an environmental justice concern. This screening should take into account the desire of local citizens, who may embrace the changes brought about by the proposed nuclear reactor.

4.3 Community Involvement

The success of any large infrastructure project begins with the support of the local community. In order to assess the attitudes of local organizations, the LENOWISCO Planning District Commission sent out a questionnaire to numerous local stakeholders. This was followed up by interviews with representatives from each county and the City of Norton.

The industry questionnaire contained a total of twelve questions [53]. The full list of question and the responses are shown in Appendix A. A summary is provided below.

- All ten respondents stated that they believe energy policies should consider nuclear energy as one of many energy sources to provide electricity and that they prefer to be engaged and informed on presently published energy policies and legislation. Ninety percent of those that responded agreed that they would support additional studies to determine the feasibility of utilizing Small Modular Reactors (SMRs) in the coalfields of Southwest Virginia if the new technologies receive approvals by the United States Nuclear Regulatory Commission.
- A number of questions asked what organization would be best qualified to continue public outreach related to SMRs. The majority (80%) of respondents stated that the Commonwealth of Virginia's Department of Virginia Energy is best qualified to inform the public about presently published energy policies and legislation. Seventy percent of respondents chose Virginia Energy as the group best qualified to facilitate community informational meetings related to the development of Small Modular Reactors (SMRs) in the coalfields of Southwest Virginia. In addition to Virginia Energy, there are a number of other groups that it was suggested be stakeholders in future studies and provide the public with additional information. These include local economic developers, community colleges, SWVA Energy R&D Authority, InvestSWVA, Energy DELTA Lab, VNEC, and VNECA.
- When asked how respondents prefer to be engaged and informed pertaining to the technological development of Small Modular Reactor(s) in the coalfields of Southwest Virginia, 50% answered community forums/meetings (held in-person and/or virtually), 40% answered stakeholder panels (held in-person and/or virtually), and 10% answered community fact sheets (disseminated via email).
- When asked what future topics should be included in subsequent Small Modular Reactor feasibility reviews, respondents suggested:

– Supply chain opportunities and related workforce development/training needs
– Water use and water quality
– Land use change/compatibility with local comprehensive plans
– Land stability and siting criteria
– On-site storage and management of waste
– Safety/risk management
– Community benefits
– Environmental justice

– Long term impacts, risks, and benefits
– Public education
– Safety and fuel disposal

- When asked what additional methods of community education and involvement they would suggest be utilized throughout this process, respondents suggested:

– Community meetings, focus groups, and forums
– Digital media campaign (website and social media, including paid media)
– Public TV or radio spots with information
– Statewide Education Consultants

These responses demonstrate a high degree of engagement and interest in further work and that a number of decision makers will need to be involved in new projects in the region. Additionally multiple approaches should be used to reach the members of the community.

During the preparation of this report, representatives from Scott County, Lee County, Wise County, Dickenson County, and the City of Norton were met with (virtually) to communicate the major findings of the report and solicit feedback. In general, the representatives were eager to continue their involvement in future phases of this work. The following bullets summarize the main points that came from those discussions.

- Many of the representatives expressed interest in receiving the first SMR in their locality. The tax revenues to the host county are expected to be a significant boon to the local community. However, it is expected that the localities would be eager to work together. What benefits one locality, benefits the entire region.
- Many representatives noted a lack of public knowledge regarding nuclear power in their county (or city). Public outreach campaigns will be necessary in order to reach community members. Multiple methods of outreach were suggested in order to reach different groups of people. Some proposed outreach campaigns included youth education (e.g., sessions education in K-12 schools, boy and girl scout sessions), town hall meetings hosted by industry experts, and training for local leaders and politicians who would go on to interface with their constituents.
- Some representatives wanted to know how the plant would be staffed. There was a general interest in a mixture of an inflow of new workers to the area, employment opportunities for current residents, and opportunities for residents that pursued higher education and would be interested in returning to the area for a high paying job where they grew up.

4.4 Factors Affecting Siting

Along with regulatory considerations, there are specific factors that affect the sites proposed for nuclear plant construction. This section will discuss the three main categories of factors that affect nuclear siting, and the sub factors within those categories. These categories include socioeconomic factors, proximity factors, and safety factors. These factors are collected and used by the NRC to help define what sites are viable, as well as compare multiple potential sites. The STAND tool described in Section 4.5 is used to rank potential sites using the subfactors described in Sections 4.4.1, 4.4.2, and 4.4.3.

4.4.1 Socioeconomic Factors

Socioeconomic factors include the social acceptance of nuclear power as well as the economic factors that could affect a nuclear power plant in the siting area. These factors aim to quantify how the population around the area feels about nuclear power, what policies the local government has in place regarding nuclear power, and the current power market in the area. The sub factors affecting socioeconomic factors in reference to nuclear siting are as follows:

- Nuclear Restrictions
- Energy Price
- Net Electricity Imports
- Nuclear Sentiment
- Nuclear Inclusive Policy
- Market Regulation
- Construction Labor Rate

These are discussed in the following subsections.

4.4.1.1 Nuclear Restrictions

Nuclear reactor restrictions at the state level can prevent the construction of new nuclear reactors and be difficult to overcome. Some restrictions include requirements for approval by state legislature or the state commission on environmental protection. Other laws such as moratoriums on nuclear development, requirements for voter approval, or successful demonstration of technology for waste disposal can take a considerable amount of time and resources to overcome. These issues affect the ability of a site to be approved by the state it is being proposed in, regardless of whether NRC approval is granted. Currently no such laws or restrictions are in place for the Commonwealth of Virginia.

4.4.1.2 Energy Prices

Average energy prices vary throughout the country in accordance with market forces and laws regarding the mix of energy sources. Populations in areas with high energy prices may be more receptive to adding new nuclear generation as a way to lower household electricity prices. Owner-operators in areas with high energy prices may be more willing to invest in new nuclear generation.

4.4.1.3 Net Electricity Imports

Depending on existing load profiles, some states are required to import electricity from other states or countries over the course of the day. States that are currently importing electricity are more likely to prioritize the development of new electrical generation facilities in order to ensure self-sufficiency or better control the electrical generation mix in accordance with state energy mandates.

4.4.1.4 Nuclear Sentiment

Public attitudes toward nuclear power are an issue for many regions that already contain or seek to develop nuclear power plants. Understanding the sentiment toward nuclear power in the immediate surrounding area, and the state as whole is important to determine what actions are needed to ensure public support of the proposed reactor. Community outreach developments can be a useful tool to help the public better understand nuclear energy, and the benefits a proposed reactor can bring to the region. The NRC collects information on nuclear sentiment based on 10 years of public polling data. Factors at the individual level (race, gender, age, etc.) as well as county level factors (partisanship, distance to existing facilities, social vulnerability scores, etc.) are used in compiling this data into percentiles describing every county in the nation. This standardized set is used in judging a potential site.

4.4.1.5 Nuclear Inclusive Policy

Policies that aim to reduce the environmental impact of carbon emissions or uphold clean energy standards can support nuclear development. These policies often include incentives for generation technologies which frequently include new nuclear energy production. Some states have enacted policies based on achieving certain percentages of clean energy in the future and, as long as nuclear energy is not excluded from these policies, nuclear energy can be a viable option to meet these goals.

4.4.1.6 Market Regulation

Market regulation refers to whether a utility controls the flow of electricity from the generator to meter or not, depending on if they are regulated or deregulated, respectively. Deregulated markets consist of multiple energy producers in competition which sell electricity onto the grid at market prices. A market maker ensures that enough electricity is transmitted to the grid to meet demand at any time. Regulated markets operate vertically, with a single energy producer generating and transmitting the energy according to a public regulator. More information on regulated and deregulated markets can be found in Section 7. Both regulated and deregulated markets have a complex history of use in the United States. Currently there is a mix of both regulated and deregulated markets in the US and in local regions. Historically, nuclear power plants were financed and developed in regulated energy markets, due to the guaranteed rate of return from the rate payers. Deregulated markets create a greater risk for long term construction investments due to the fluctuation of electricity prices over time. The market structure is a factor that needs to be considered by the owner-operator when proposing the business case of nuclear reactors including financing and expected rate of return. The market structure is predominantly determined by the siting of the reactor and the proposed grid connections.

4.4.1.7 Construction Labor Rate

This siting factor refers to the five-year average labor rates at the state level and is used to estimate the potential construction and operating costs of a nuclear facility. This varies from state to state and is not considered on a county basis. Labor rates affect the amount of financing necessary for the construction of a nuclear plant.

4.4.2 Proximity Factors

Proximity factors affecting nuclear reactor siting refer to the area around the potential site. These factors are concerned with facilities or natural features within a certain radius of the planned site. Some of the siting requirements in this section refer directly to regulations set forth by the NRC as described in Section 4.2.4. The subfactors affecting the proximity factors are as follows:

- Population
- Operating Nuclear Facilities
- Nuclear Research and Development
- Substations
- Generator Retirement

- Transportation
- Streamflow

4.4.2.1 Population

As described in Section 4.2.4.1.6, proposed reactors should be sited away from areas with a population density greater than 500 persons per square mile. This siting factor assesses the population density of nearby areas as well as the nearest population center of greater than 25,000 people.

4.4.2.2 Operating Nuclear Facilities

This siting factor refers to the distance between the proposed site and an existing nuclear facility. Communities with existing nuclear power facilities are generally more amenable to the addition of new nuclear facilities. These communities generally perceive lower risks associated with nuclear power and have experienced the benefits of the existing nuclear power facility within their community.

4.4.2.3 Nuclear Research and Development

Access to nearby nuclear research and development can aid in the development of advanced nuclear facilities. Technical support provided by international labs or universities with research reactors can be a useful tool in the siting, construction, and maintenance of advanced reactors. For siting purposes, national labs with robust support for advanced reactors or universities with active research reactors and/or nuclear programs are considered within a 100-mile radius of the proposed site as nuclear research and development support.

Efforts spearheaded by the Energy DELTA Lab are underway in Southwest Virginia to create public and private partnerships that will facilitate the necessary licensing and deployment of SMR designs. This is further discussed in Section 4.6.

4.4.2.4 Substations

The distance from the proposed site to an electrical substation can have significant monetary impacts on the proposed reactor. An existing, nearby substation can significantly reduce construction costs of new transmission lines which can exceed $3 M/mile (see Section 7.1). A substation and transmission lines with excess amperage capacity may also be desired if the proposed site will potentially be expanded with additional SMRs following initial construction.

4.4.2.5 Generator Retirement

Retiring fossil plant generation and electrical power facilities provide an opportunity for cost savings when siting nuclear plants. Reactor construction at a site that is already connected to the grid with transmission and other infrastructure preinstalled may provide an enticing starting point for a nuclear plant. The reuse of existing electrical generation infrastructure is referred to as coal-to-nuclear conversion and is described in Section 7.4. The Kemmerer site in Wyoming is being pursued by TerraPower, where a demonstration reactor has been proposed at a retired coal plant.

4.4.2.6 Transportation

Access to transportation infrastructure is a factor which can affect the proposed siting. SMR designs are planned to be pre-built in large modules and shipped to the site for construction making access to adequate transportation infrastructure important. Large loads will need to be transported to the site requiring coordination with local departments of transportation and the use of major roads, railways, or navigable waterways. Access to these modes of transportation is a necessary concern in site evaluation, especially for advanced SMR designs.

4.4.2.7 Streamflow

Streamflow refers to the availability of sufficient cooling water makeup sources for closed cycle cooling applications. This siting factor varies between the different designs available for reactors. Some SMR designs do not require water anywhere in their cooling system and will not require a freshwater source for cooling operations. For plants that require cooling water sources the siting tools limit makeup water removal by the power plant to less than 10% of the available flow.

4.4.3 Safety Factors

Safety factors affecting nuclear siting refer to the surrounding area and include how local industry, nature, and society would incorporate the presence of the proposed nuclear power plant. Some industries can pose potential hazards if located near nuclear plants, for example large airports or chemical manufacturing. The local area must support safe evacuation routes in case of a nuclear emergency. Naturally occurring hazards must also be assessed for the proposed reactor site, such as earthquake potential due to proximity to fault lines, flooding, and landslide threats. Most of the siting requirements in this section are set forth directly by the NRC. The subfactors affecting the safety factors are as follows:

- Social Vulnerability Index

- Protected Lands
- Hazardous Facilities
- Fault Lines
- Landslide Hazard
- Safe Shutdown Earthquake
- 100 Year Flood
- Open Waters and Wetlands
- Slope

4.4.3.1 Social Vulnerability Index

The social vulnerability index (SVI) is used to determine how well a community can deal with disasters. Situations like natural disasters, human caused events, and disease outbreaks are considered for this category. The SVI is measured by the centers for disease control (CDC) through 15 social factors, including poverty, lack of vehicle access, and crowded housing. These are analyzed at a county level to determine how well a community could deal with a potential accident scenario at the local level. A high SVI index number means that an area is more socially vulnerable and may not be able to adequately respond to potential accident scenarios.

4.4.3.2 Protected Lands

Protected land categories such as public lands, lands with restricted uses, or access restrictions are excluded from nuclear site selection. The NRC Regulatory Guide 4.7 states that reactor siting adjacent to protected lands may not be suitable to the local jurisdiction. However, allowances may be made for certain situations and protected lands do not always mean a potential site is immediately discarded. Federal land, as an example, has the potential to be used to nuclear reactor siting, however further proposals will have to be made to use the federal land for this purpose.

4.4.3.3 Hazardous Facilities

Hazardous facilities refer to any nearby industrial facilities that could have accidents that might produce "missiles, shock waves, flammable vapor clouds, toxic chemicals, or incendiary fragments," according to NRC Regulatory Guide 4.7. These types of industrial facilities are described in Section 4.2.4.1.4. These facilities should be considered during site evaluation for their current proximity. These facilities do not rule out nuclear power plant siting as some industrial uses, such as chemical processing, require large amounts of readily available local power and heat to operate. Additional engineering analysis is required to ensure safety when considering a site near hazardous facilities.

4.4.3.4 Fault Lines

The existence of known geological faults within 200 miles of the site must be considered as described in Section 4.2.4.1.1. Earthquakes are an environmental hazard which must be evaluated by all reactor designs, due to the earthquake's ability to disrupt normal equipment operation. Proposed reactor siting near geological faults increases the geological characterization requirements and engineering controls required for design approval.

4.4.3.5 Landslide Hazard

Proposed siting should be avoided for areas with a moderate to high risk of landslide or sinkhole activity as determined by the USGS. These hazards are mitigated by siting of the proposed reactor in areas with suitable foundation conditions as described in Section 4.2.4.1.1. Formal onsite geology inspections and characterization are required prior to licensing, but excess costs can be avoided with proper site selection.

4.4.3.6 Safe Shutdown Earthquake

Regional areas which can be subjected to earthquakes resulting in peak ground acceleration of greater than 0.3 g should be avoided as described in Section 4.2.4.1.1. This guidance is based on currently operating large light water reactor technology. Some SMR designs are more resilient to earthquakes and may be sited in areas with approximately 0.5 peak ground acceleration. Earthquake mitigating design features of SMRs include smaller piping systems, passive safety systems, underground installations, and improved seismic isolation.

4.4.3.7 100-Year Flood

100-year floodplains are assessed to ensure that the proposed site in not located within floodplains as described in Section 4.2.4.1.3. Other flooding risks will need to be assessed for the candidate site further in the process.

4.4.3.8 Open Waters and Wetlands

This siting criteria is concerned with avoiding sensitive and protected ecological areas as described in Section 4.2.4.2. This includes bodies of water such as drinking water sources, recreational areas, or navigable waterways. Protected land such as wetlands are also included. Wetlands and protected waters should be heavily discouraged from potential site selection in order to avoid environmental and ecological disruption as well as legal siting challenges.

4.4.3.9 Slope

Areas with slopes in excess of 12% can be costly to develop and are not recommended for reactor siting based on current large LWR designs. This value can be relaxed for SMR siting as the footprint for these plants is smaller. However, areas with an excessive slope may still result in additional construction costs for SMRs during site preparation.

4.5 Results from STAND

The Siting Tool for Advanced Nuclear Development (STAND) is used to identify, compare, and analyze potential sites for nuclear plant development. STAND was developed by the National Reactor Innovation Center (NRIC), which is a Department of Energy program lead by Idaho National Laboratory in conjunction with the University of Michigan, Oak Ridge National Lab, and Argonne National Lab. This tool is used to identify and examine potential nuclear sites, while providing comparisons between potential sites. STAND is not a replacement for a rigorous analysis of candidate areas and proposed sites during the siting process but does provide an efficient way to analyze multiple sites for initial suitability. STAND aggregates data from many sources, including socioeconomic sources like the US Census, the Bureau of Labor Statistics, and the EIA, safety sources like the NRC, the CDC, and EPRI, and geographical and geological sources like the USGS, the EPA, and the Oak Ridge Siting Analysis for Power Generation Expansion (OR-SAGE) tool. The user may determine what siting factors are most important to site decision-making and weight them accordingly. This weighting is used along with the data collected from the various sources, to give each location a relative value. The proposed sites are then ranked based on this value. The STAND tool uses attribute relevance and range significance as two separate variables for ranking calculations.

Attribute relevance refers to the importance of each attribute in the choice of an optimal site. If the optimal site is to be contained in low population area, then the significance of surrounding population should be set to high or very high. This will lead to it population density being a more heavily weighted factor for the siting evaluation. Setting any attribute to not relevant removes them from consideration in site ranking. Siting factors were only rated as not relevant when all of the analyzed sites were not affected by the criteria. For example, in this analysis, this occurred when all sites were identified as being outside of the 200 mile range for capable tectonic structures.

Range significance refers to how the sites relate to each other for each attribute. The best and worst measures from all considered sites is listed, as well as the difference between them. The user then selects how significant the difference between the best and worst measurement is to the siting process. For example, a measure of proximity to operating nuclear facilities is siting factor which can affect the surrounding community's sentiment. However, if the surrounding community is sparse or non-existent there may be no significant difference between a 3-mile distance and an 80-mile distance. Three methods may remove a range from the consideration in site ranking; setting the attribute to not relevant, the best and worst site measures are equal, or the best and worst site measures are outside of the range of consideration.

The STAND tool was used to evaluate proposed sites in the LENOWISCO ROI. Figure 4-20 shows a map of the LENOWISCO sites. Additional sites from outside the LENOWISCO region were also evaluated to provide a comparison against sites which have already been proposed for reactor siting. Some site selection factors did not affect the site selection results. For example, all of the evaluated sites were located in states without nuclear construction bans or moratoriums. This resulted in the nuclear restrictions siting factor (Section 4.4.1.1) having no effect on site rankings. Likewise, all the evaluated sites were located away from large population centers and fault lines. These factors were removed from the site comparison analysis.

Five sites were selected for comparison with the proposed LENOWISCO sites:

- AEP's Clinch River Coal Station in Virginia
- TVA's Clinch River Nuclear Site in Tennessee
- The North Anna Nuclear Plant in Virginia
- TVA's Kingston Fossil Plant in Tennessee
- The Natrium Demonstration Site in Wyoming

TVA's Clinch River Nuclear Site is a proposed site that has been granted an Early Site Permit (ESP) by the NRC for two or more small modular reactors. It is located in Oak Ridge, Tennessee at the former location of the Clinch River Breeder Reactor Project. This site provides a valuable comparison to LENOWISCO as it represents an SMR site that has already been accepted by the NRC.

The North Anna Nuclear Generating Station in Virginia provides a comparison between an existing nuclear power plant and the proposed sites in the LENOWISCO ROI. The two currently operating reactors at North Anna are large LWRs and require much more infrastructure including land and cooling water than a SMR site would require. Additionally, North Anna is currently in possession of an approved Combined Construction and Operating License for a 3rd large LWR. Due to these factors the North Anna site ranks highly during STAND evaluations. North Anna exceeds the siting requirements of SMRs which represents a valuable comparison point to the proposed sites in the LENOWISCO ROI.

The TVA Kingston Fossil Plant in Tennessee and the AEP Clinch River Coal Station in Virginia represent coal-to-nuclear transition sites. Reuse of retired coal plant infrastructure can result in significant reactor construction savings which are further discussed in Section 7.4. AEP's Clinch River Coal Station has transitioned two units to natural gas fired operation and retired a third unit. AEP's Clinch River Coal Station provides an example of coal-to-nuclear transition site in the Southwest Virginia region near the LENOWISCO planning district. TVA's Kingston Fossil Plant represents a coal-to-nuclear transition in the same region as TVA's Clinch River Nuclear site. Taken together, they provide a comparison against the proposed brownfield sites in the LENOWISCO region.

The Natrium Demonstration Site in Wyoming provides a representative example of an advanced reactor site that is commensurate with the proposed LENOWISCO sites. The Natrium Demonstration Site is to be built on a retiring coal plant. While the Natrium site is similar to the proposed LENOWISCO sites, it is located in a different area of the country which allows for a comparison with Southwest Virginia.

The STAND tool was used for three different evaluations. A baseline evaluationwhere all site selection factors discussed in Section 4.4 were given an equal, medium weighting. The factors were then adjusted to be representative of the needs of a microreactor. Finally the factors were adjusted to represent the needs of a 300 MWe SMR.

In each of these evaluations, the LENOWISCO sites were averaged together to compared with the sites outside of LENOWISCO. This allows for an understanding of how the LENOWISCO ROI compares with approved SMR sites, conversion sites from coal to nuclear, and current nuclear power plants. In all of the evaluations, the LENOWISCO sites showed that they are capable sites for further review in the pursuit of nuclear plants. The LENOWISCO sites differed in their viability when compared using microreactor and 300 MWe SMR adjustments, but all sites remained viable for further review.

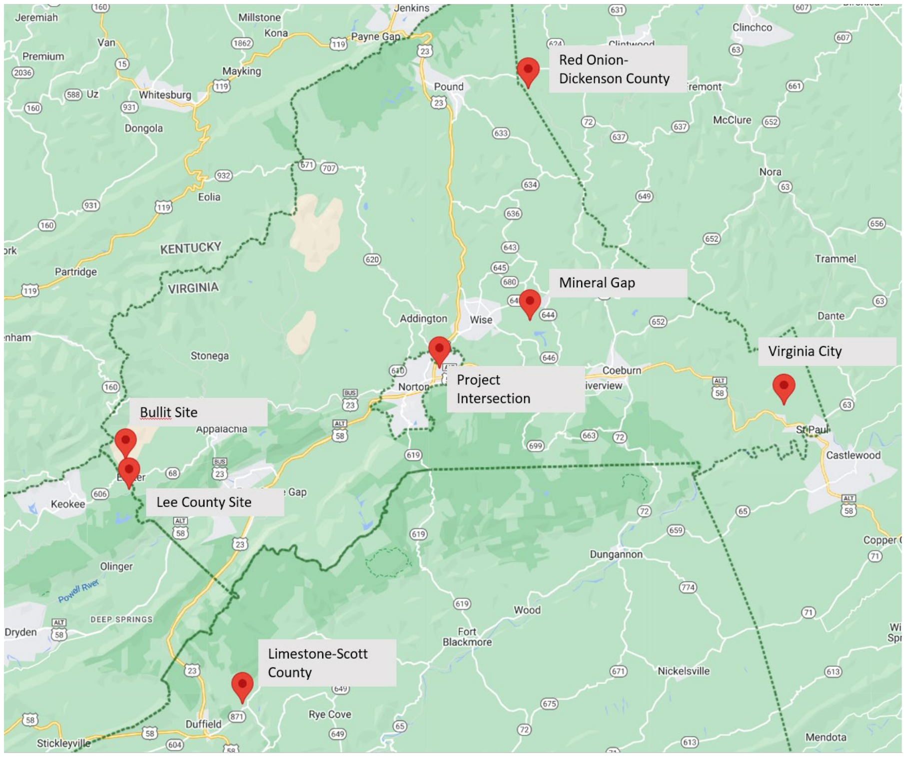

Figure 4-20 Map of the LENOWISCO ROI sites

4.5.1 Baseline Analysis

For the purpose of this section, all sites were evaluated by setting all factors available in the STAND tool to medium. This allows for each factor to have an even field of influence on the relative value of the site. This resulted in a suitability comparison between the LENOWISCO ROI and the external sites based on relative value score. The relative value score for each site is a composite of their scores for safety, proximity, and socioeconomic factors. These scores are affected by the relevance and range significance values which are selected for the case. For the baseline case where all attributes were set to medium, Figure 4-21 shows the relative values. The green bars correspond to the socioeconomic factors described in Section 4.4.1. The black bars correspond to the proximity factors described in Section 4.4.2. The blue bars correspond to the safety factors described in Section 4.4.3.

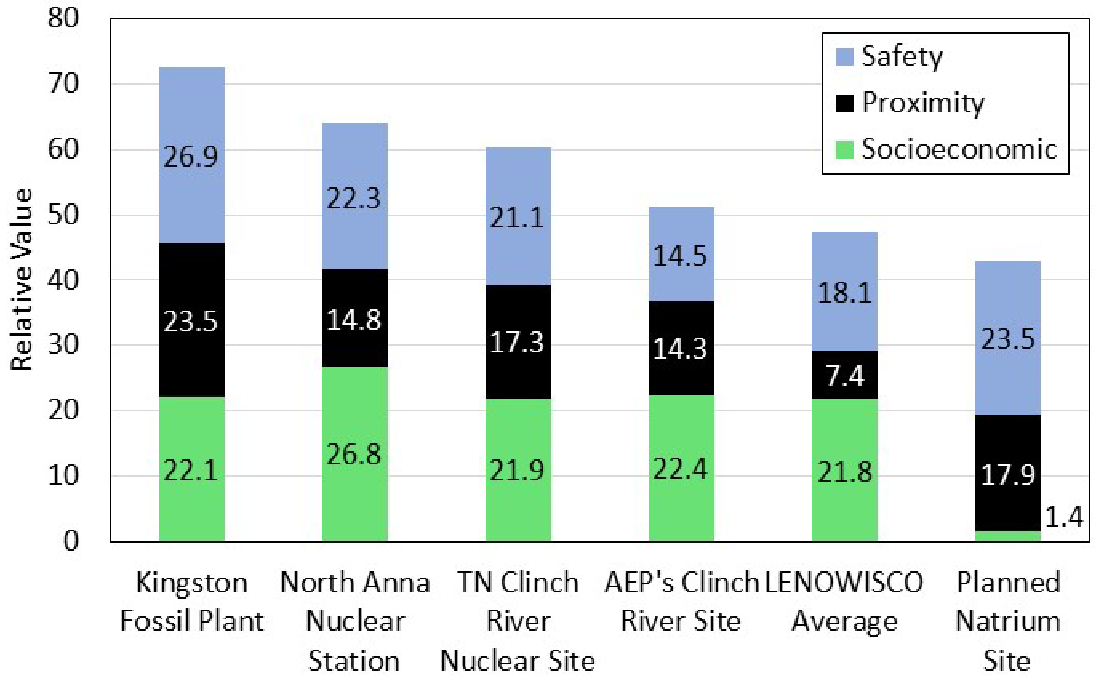

Figure 4-21 The Contribution of Each Primary Objectives Score to the Comparison of the Sites

Among the siting factors modeled, some were marked as irrelevant due to each modeled site having results which were either the same or outside of the bounds of consideration. The irrelevant factors were nuclear restrictions, nuclear inclusive policy, fault lines, safe shutdown earthquake, 100-year flood, and population.

This analysis ranks the Clinch River Nuclear Site (TVA), North Anna Nuclear Generating Station (Dominion Energy), and Kingston Fossil Plant (TVA) as the first three positions on this list. However, those comparison areas are already constructed power plants with existing infrastructure and known suitability. This does not indicate that the LENOWISCO ROI is unacceptable or not within consideration. The STAND tool acquires information on the current state of the location and its surroundings from multiple sources, so a developed site, in many cases, is expected to score higher than a proposed undeveloped site.

The LENOWISCO ROI scores favorably compared to the proposed Natrium demonstration site. The Natrium demonstration site is scheduled to apply for a construction permit in 2023. This is an indication that the LENOWISCO ROI is generally suitable for nuclear development compared to other advanced reactor sites.

4.5.2 Microreactor Analysis

The STAND analysis was also performed to evaluate proposed microreactors. Due to the small size of the reactor and plant, microreactors can employ more effective safety measures on smaller scales. Seismic and other natural hazard phenomena are much less of a concern for microreactors compared to conventional light water reactors if an issue at all [54]. Microreactors may be suitable for deployment in populated areas as a local energy source due to their reduced size and ability to be housed underground with a small site footprint and limited employees. These reactors may also be placed in remote locations. This could lead to changes in siting requirements for microreactors compared to conventional reactors and other SMRs.

The siting attributes relevance and range significance in the STAND tool were modified to represent microreactor siting as shown in Figure 4-22. These changes resulted in the change to the LNENOWISCO ROI's comparison of relative value with the comparison sites in Figure 4-23.

Range Significance \ Measure Relevance	Very High	High	Medium	Low	Very Low	Not Relevant
Very High						
High		Electrical Substations 7.739 Energy Price 7.739	Labor Rate 6.721	Generator Retirement 5.703 Hazardous Facilities 5.703 Streamflow 5.703		
Medium		Net Electricity Imports 6.721 Open Water And Wetlands 6.721	Landslide Hazard 5.703 Market Regulation 5.703 Nuclear R And D 5.703 Nuclear Sentiment 5.703 Protected Lands 5.703 Transportation 5.703	Slope 4.684		
Low			Operating Nuclear 4.684	Cdc Svi 3.666		
Very Low						
Not Significant						Fault Lines 0.000 Nuclear Inclusive Policy 0.000 Nuclear Restrictions 0.000 One Hundred Year Flood 0.000 Population 0.000 Safe Shutdown Earthquake 0.000

Figure 4-22 Attribute Relevance – Range Significance Matrix for Microreactor Analysis

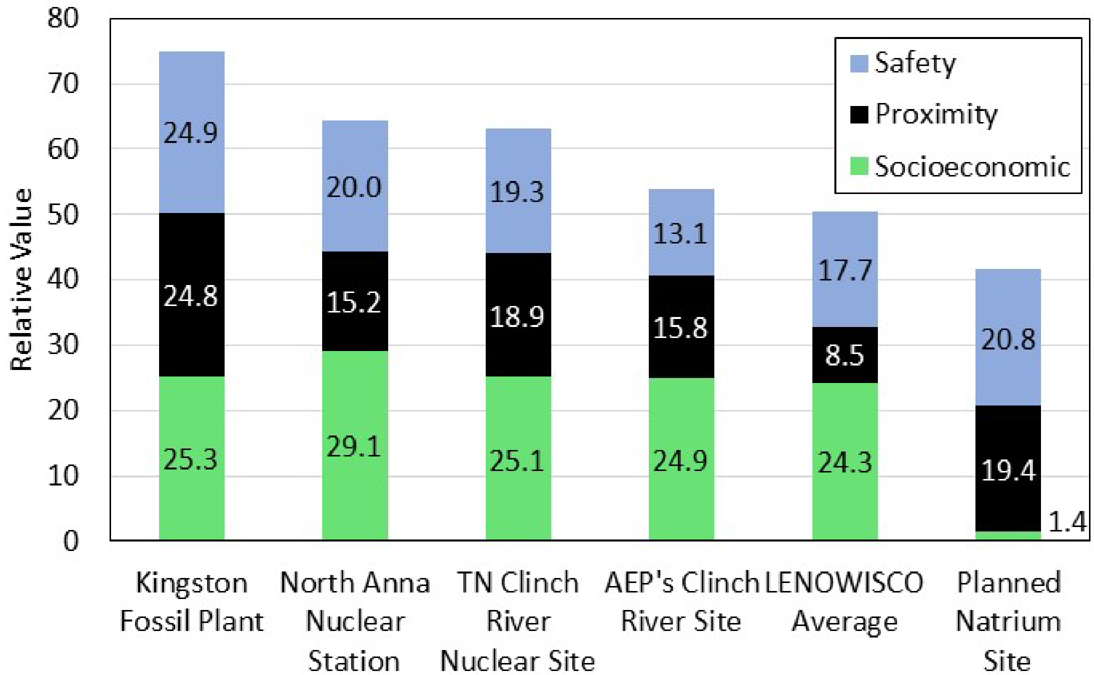

Figure 4-23 The Contribution of Each Primary Objectives Score to the Comparison of the Sites for Microreactors

The LENOWISCO ROI scores similarly with respect to microreactor siting compared to the baseline case. It is noted that the Project Intersection site represents a potential option for a microreactor. Project Intersection (described in Section 4.1.1.7) is located in an area with residential and commercial energy demands in the direct vicinity which represent potential challenges to the Emergency Planning Zone as described in Section 4.2.4.1.7. The City of Norton approaches the population density limit of 500 persons/square mile which would preclude LWR siting. A microreactor may be able to be licensed in spite of the nearby population, although the regulatory path forward is unclear. A microreactor would take up less than 1% of the area of other reactor types, allowing for the existing site to include industrial electricity users.

All sites within the LENOWISCO ROI increased in their relative site value compared to the baseline case. This indicates that a microreactor is a viable option for all of the proposed sites within the LENOWISCO ROI.

4.5.3 300 MWe SMR Analysis

The STAND analysis was also performed to evaluate proposed 300 MWe SMRs. Larger SMR designs, like the BWRX-300, have siting requirements which are closer to those of conventional large LWRs, on a smaller scale. SMR plants at the 300 MWe scale will require larger amounts of land, with a greater emphasis on proximity and safety of the surrounding area and industries. These plants will also require emergency planning zones and low population zones preventing siting in population centers as envisioned for microreactors. A 300 MWe SMR will have higher construction costs and supply a much larger amount of electricity than a microreactor. Consequently a 300 MWe SMR will need to have a stronger business case for future demand of electricity than a microreactor. Substation proximity, labor rate, and the current energy price are more heavily weighted factors in determining the viability of the proposed site.

The attributes relevance and range significance in the STAND tool were modified to represent 300 MWe SMR siting as shown in Figure 4-24. These changes resulted in the change to the LNENOWISCO ROI's comparison of relative value with the comparison sites in Figure 4-25.

Range Significance \ Measure Relevance	Very High	High	Medium	Low	Very Low	Not Relevant
Very High	Generator Retirement 8.406	Electrical Substations 7.531				
High	Cdc Svi 7.531	Energy Price 6.655 Labor Rate 6.655 Transportation 6.655	Market Regulation 5.779			
Medium		Hazardous Facilities 5.779 Landslide Hazard 5.779 Open Water And Wetlands 5.779 Slope 5.779	Net Electricity Imports 4.904 Nuclear R And D 4.904 Protected Lands 4.904 Streamflow 4.904			
Low		Nuclear Sentiment 4.904				
Very Low			Operating Nuclear 3.152			
Not Significant						Fault Lines 0.000 Nuclear Inclusive Policy 0.000 Nuclear Restrictions 0.000 One Hundred Year Flood 0.000 Population 0.000 Safe Shutdown Earthquake 0.000

Figure 4-24 Attribute Relevance – Range Significance Matrix for Larger SMRs Analysis

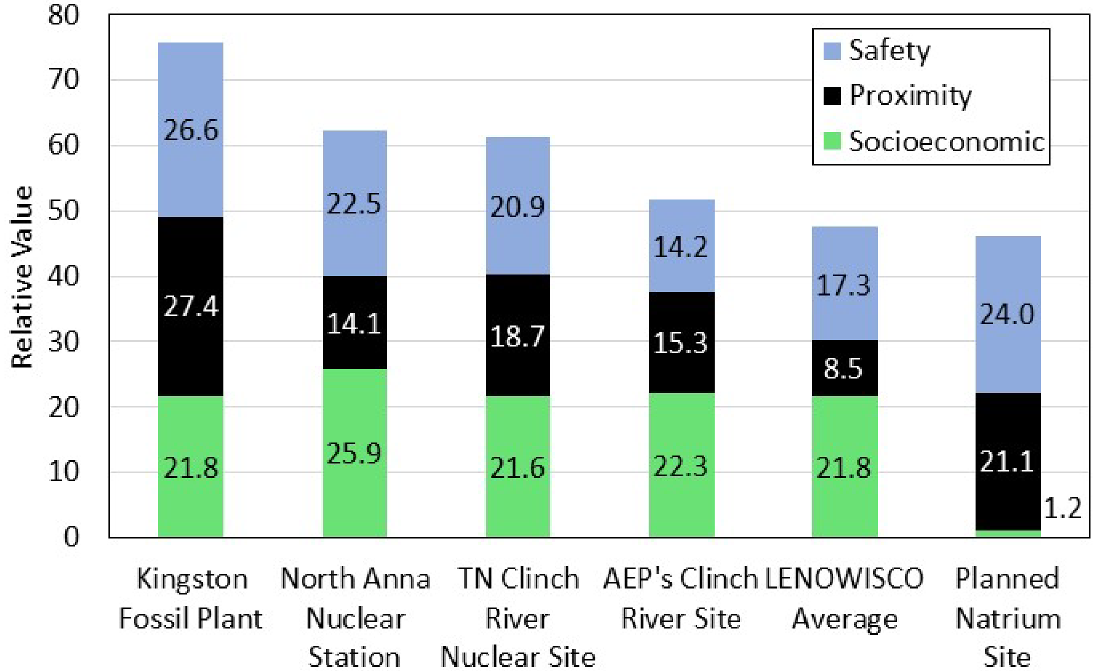

Figure 4-25 The Contribution of Each Primary Objectives Score to the Comparison of the Sites for Larger SMRs

The relative values from the baseline evaluation and the 300 MWe SMR evaluation, shows very little change in the relative scoring of the LENOWISCO region and comparison sites. The similarity between scores for the LENOWISCO region in both microreactor and 300 MWe SMR evaluations is expected as the evaluated sites are in similar geographic areas, with similar population densities. The suggested LENOWISCO sites score well against established nuclear sites and proposed nuclear sites, especially the Planned Natrium Site. This indicates that the suggested LENOWISCO sites are options for increased characterization and nuclear development.

4.6 LENOWISCO Differentiators

As illustrated in Figure 4-21, Figure 4-23, and Figure 4-25, the results from the STAND evaluation show that example sites in the LENOWISCO ROI compare favorably to sites that have already been identified for new nuclear projects (and in the case of TVA's Clinch River Nuclear site already qualified). This indicates that LENOWISCO would have numerous sites that are feasible for nuclear reactors and each of the example sites considered as part of this evaluation are worthy of further consideration. In itself, the number of sites that are favorable for deployment is a significant differentiator for the LENOWISCO region.

Although ranking more favorably in safety and socioeconomic considerations, the example LENOWISCO sites rank slightly less favorably with respect to proximity.

The following individual components of the STAND socioeconomic considerations have LENOWISCO-specific implications:

- Energy Prices: The STAND tool indicates that energy prices in LENOWISCO are low compared to other locations. Therefore, it is expected that an emphasis on *future* energy consumption and resulting prices should be considered when evaluating LENOWISCO for SMR siting. Specifically, the projected growth of data centers in the region should be emphasized when considering energy pricing and comparison of LENOWISCO sites to other potential sites.
- Net Electricity Imports: The STAND tool indicates that the LENOWISCO sites imports 100% of their electricity. Because this is also indicated to be the case at the Virginia City Site, this may indicate that the tool does not have sufficient resolution. Regardless, the lack of generating capacity within LENOWISCO should be considered a positive differentiator, i.e., a feature making LENOWISCO more attractive as a location for SMRs.
- Nuclear Sentiment: The STAND results indicate that LENOWISCO scores relatively low on nuclear sentiment (40 on a scale of 0 to 100, with 100 being the most amenable to siting a nuclear power plant in the region of interest). As discussed in Section 4.4.1.4, this ranking is based on polling performed by the NRC and represents a 10-year average. Future actions in support of SMR siting could include more detailed analysis of the raw polling data and, if warranted, efforts to increase public acceptance of nuclear in LENOWISCO. This is further discussed in Section 4.3.

The following individual components of the STAND proximity considerations have LENOWISCO-specific implications:

- Nuclear Research and Development: There are no nuclear research and development facilities within 100 miles of LENOWISCO. Therefore, STAND ranks LENOWISCO low in this metric. However, there are multiple sites that are just outside of this distance. Oak Ridge is approximately 120 miles away. Virginia Polytechnical Institute is just over 100 miles away. The attractiveness of LENOWISCO per this metric would be improved if the Energy DELTA Lab were included as a nuclear research and development organization in the screening process. The Energy DELTA (Discovery, Education, Learning & Technology Accelerator) Lab is a collaborative effort by the Virginia Department of Energy, the Southwest Virginia Energy Research and Development Authority and its business development partner InvestSWVA. DELTA Lab's lead private industry partners include Appalachian Power (discussed in Section 7.3.1) and Dominion Energy Virginia (discussed in Section 7.3.2). It is an energy testbed located in Southwest Virginia focused on leveraging previously-mined land as a proving ground for the commercialization and deployment of innovative energy technologies. The Energy DELTA Lab has the capacity to bring together the region's utilities, the SMR vendors, and their supply-chain manufacturers in public and private partnerships to facilitate the necessary licensing and deployment of SMR designs. The Energy DELTA is a signficant differentiator for the LENOWISCO ROI because it has the potential to support any research and development necessary to site SMRs in the region. It also serves as a facilitator for the numerous partnerships that will be needed in order to ensure the project's success. The growth of the DELTA Lab will result in significant proximity benefits for the LENOWISCO ROI which are not captured by the current STAND analysis.

- Substations: Although the LENOWISCO sites generally compare favorably with other locations with respect to the distance to substations, some sites scored lower on this metric. Specifically, the Bullit, Mineral Gap, and Lee County sites scored low by this metric.
- Generator Retirement: The STAND database indicates that none of the LENOWISCO sites are within 20 miles of a retiring coal plant, thus ranking them low in this regard. However, the advantages of being near a retiring coal plant are not likely to be different from being near a recently retired coal plant (AEP's Clinch River site) or near a hybrid energy center that includes coal in the fuel mix (Virginia City site).
- Transportation: The STAND database indicates that none of the LENOWISCO sites are, on average, about 30 miles away from a major transportation route. This obviously does not include the many active or semi-active rail lines that have serviced the sites under consideration. In further assessments of specific sites, additional work to include existing rail lines should be considered.

The following individual components of the STAND safety considerations have LENOWISCO-specific implications:

- Hazardous Facilities: There is significant differentiation among the LENOWISCO sites with respect to the proximity of hazardous facilities. When further site refinement is desired, identification of these facilities will be necessary.
- Protected Lands: There is significant differentiation among the LENOWISCO sites with respect to the proximity to protected lands. When further site refinement is desired, identification of these areas will be necessary.

Overall, the results of the STAND analyses indicate that deployment of SMRs to LENOWISCO is quite feasible and compares well with deployments already planned for outside of the LENOWISCO ROI. Further, there are several factors not accounted for by the STAND tool which make the LENOWISCO ROI more desirable. These include, among others, the presence of the Energy DELTA Lab, the human exertise of the region, the numerous sources of cooling water, the potential for load growth, the presence of numerous brownfield sites, and existing right of way to transmission infrastructure. Within LENOWISCO, there are many potential sites, which would favor multiple deployments. This is an advantage of LENOWISCO that is not fully captured by the tool.

5 GOVERNMENT INCENTIVES FOR NUCLEAR

The following subsections provide a description of the relevant legislation that can provide government incentives for a nuclear project in LENOWISCO.

5.1 Infrastructure Investment and Jobs Act

In 2021, the Infrastructure Investment and Jobs Act (IIJA), also known as the "bipartisan infrastructure bill" was passed containing several types of investments in the nuclear power industry [55]. Funding has been allotted to keep currently operating plants open and for the DOE's Advanced Reactor Demonstration Program (ARDP). These programs would not be useful to future nuclear projects in LENOWISCO. The third major provision related to nuclear power mandates that at least one of the four newly created clean hydrogen hubs have hydrogen that is produced by nuclear power. If hydrogen production were to be considered for LENOWISCO then this funding could be pursued.

Section 40321, Infrastructure Planning for Micro and Small Nuclear Reactors, provides funding for feasibility studies for the purpose of identifying suitable locations for the deployment of microreactors, small modular reactors, and advanced nuclear reactors in isolated communities. The term isolated community was previously defined in Section 8011(a) of the Energy Act of 2020 (42 U.S.C. 17392(a) [56]). An isolated community is defined as a community that is powered by a stand-alone electric generation and distribution system without the economic and reliability benefits of connection to a regional electric grid. This provision likely disqualifies LENOWISCO. This funding is distinct from the ARDP as 50% of this budget must be spent outside of the national labs.

Section 40342 pertains to clean energy demonstration programs on current and former mine land. Under this section advanced nuclear projects are considered clean energy projects. LENOWISCO certainly applies as having mine land. Two of the five projects funded under this section are mandated to be solar projects. Competition for the other three projects will be in part based on job creation both directly at the clean energy site and created in the vicinity of the project. When applying for this funding, LENOWISCO should stress the economic development expected as a result of the industry partners brought to the region. In total, $500 million is allocated for projects in the fiscal years of 2022 through 2026.

5.2 Inflation Reduction Act

The Inflation Reduction Act (IRA), passed in August 2022, contains numerous benefits that could be applicable to nuclear projects in LENOWISCO [57]. Several aspects of this legislation are discussed below.

The existing Production Tax Credit (PTC) and Investment Tax Credit (ITC) were extended through the end of 2024. After 2024, they are being replaced by technology neutral emissions based credits which can be applied to nuclear projects [58]. A project must choose between the PTC and the ITC (both cannot be captured on the same project). The PTC (as part of IRA provision 45Y) provides an inflation adjusted $25/MWh in tax credits for every MWh of power produced by a nuclear plant. The IRA (as part of IRA provision 48E) provides 30% of the capital cost for a nuclear plant back in tax credits. Both the PTC and the IRA provide an additional 10% booster for siting in energy communities (which LENOWISCO certainly qualifies as) and another additional 10% booster for use of domestic content. Domestic content is broken into two categories (1) iron and steel products and (2) manufactured products. To qualify for use of domestic content, it is understood that 100% of any iron/steel products must be produced in the United States and 40% of the total cost of all manufactured products that are components of the facility must be produced in the United States. When selecting a plant vendor, this condition should be taken into account. If both boosters are captured, the total benefit of the ITC is 50% of capital cost and the PTC is $30/MWh. It is expected that NuScale will receive nearly $2.8 billion in funds from the IRA (through the ITC) for the 462-MWe Carbon-Free Power Project (CFPP) at Idaho National Laboratory (INL) [59].

The IRA also provides $40 billion in loan authority to guarantee loans for innovative clean energy projects. The Inflation Reduction Act provides the Department of Energy Loan Programs Office with $40 billion in loan authority supported by $3.6 billion in credit subsidy for loan guarantees under section 1703 of the Energy Policy Act for innovative clean energy technologies, including renewable energy systems, carbon capture, nuclear energy, and critical minerals processing, manufacturing, and recycling.

The Hydrogen Production Tax Credit (part of the IRA) is eligible for direct pay meaning that these tax benefits can be received in the form of direct payments. The credit is for hydrogen facilities placed in service before January 1, 2033, for their first 10 years in service. The credit value is for $0.60/kg of hydrogen produced multiplied by an applicable percentage. The applicable percentage ranges from 20% to 100% depending on lifecycle greenhouse gas emissions. The credit value of $0.60/kg is adjusted for inflation. Additionally, there is a bonus credit amount of up to five times the base credit if the facility meets prevailing wage and registered apprenticeship requirements. Initial guidance on the labor provisions is available from the federal register [60].

The Bipartisan Infrastructure Law also included $9.5 billion for clean hydrogen initiatives including $8 billion for regional clean hydrogen hubs

5.3 Abandoned Mine Land Economic Revitalization Program

Congress has appropriated funding to the Abandoned Mine Land Economic Revitalization (AMLER) Program on an annual basis since 2016 [61]. In FY2023, VA was allotted $11.739 million. Projects in the state of Virginia can be proposed through Virginia Energy [62]. In 2020, the largest grant of $5.5 Million was received by the City of Norton for Project Intersection Phase IV. This project has received funding in other fiscal years as well. It is possible and likely that the nuclear project could receive several million dollars from this project if certain features of the selected site qualify as abandoned mine land.

5.4 Opportunity Zones

The opportunity zone program is a federal program that was created by Congress as part of the Tax Cuts and Jobs Act (TCJA). The tax incentive offers three benefits; tax deferral, tax reduction through long-term investment, and exclusion of certain capital gains tax. Aspects of the original legislation are expected to expire December 31, 2026. This opportunity should be re-examined when the investment timeline is better understood. However, this could be seen as an advantage for certain sites that fall within zones as they are currently defined.

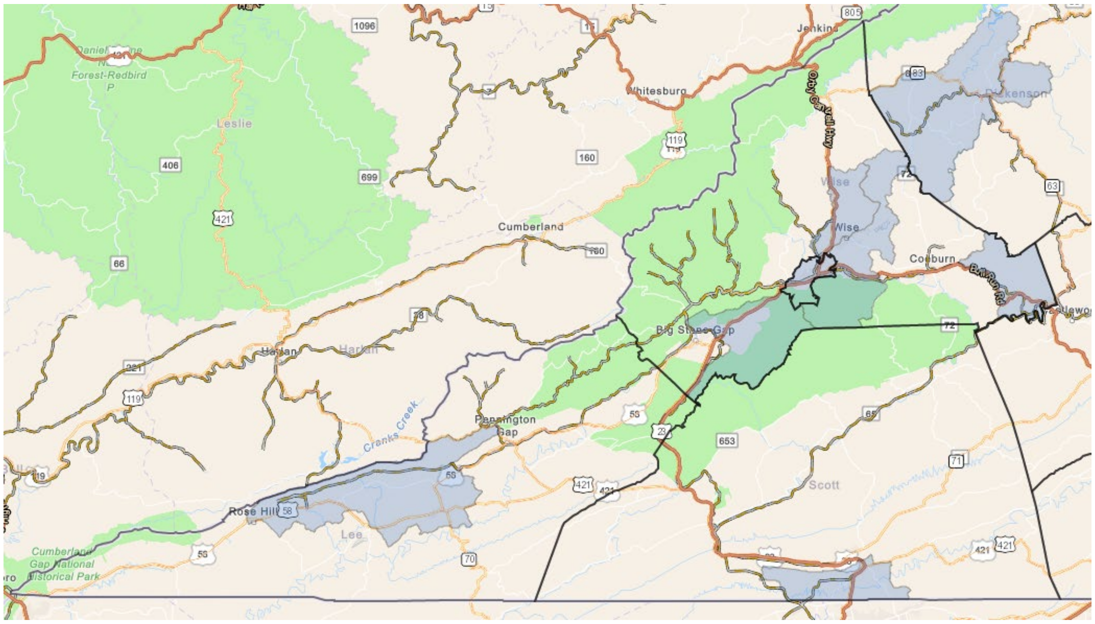

Figure 5-1 Opportunity Zones (Grey Shaded Regions) in LENOWISCO [63]

5.5 Tobacco Region Opportunity Fund

The Tobacco Region Opportunity Fund (TROF) provides funding for economic development projects in GO Virginia Region One. The award has a maximum value of $3 million dollars. Funds are delivered at the front end and can be used for site development, access roads, and infrastructure expansion that would reduce the cost of acquiring and developing sites [64]. It is likely that a portion of this funding could be available to either the nuclear plant or the co-located business(es).

5.6 Commonwealth Opportunity Fund

The Commonwealth Opportunity Fund is a “deal closing” fund administered by the virginia Economic Development Partnership (VEDP) and approved by the Governor. The goal of the fund is to help secure projects in Virginia that are receiving competition from outside the state. Given the focus of this project on co-location of nuclear and other projects on specific sites within LENOWISCO ROI, it is likely that this funding could be used to secure the co-located energy consumer but not the nuclear plant itself. Further, several other requirements of this funding pool likely make the nuclear plant not an ideal fit [65].

- Fifty One Percent (51%) or more of the facility’s revenue must be generated outside the Commonwealth. This is not the objective of the nuclear plant and thus would be a disqualifying criteria.

- The project must also bring in 50 new jobs and $5 million capital investment or 25 new jobs and $100 million capital investment. These targets are possible for some but not all plant designs under consideration.

This fund is not a likely source for the nuclear plant at LENOWISCO because it is intended for projects for which there is competition between VA and another state and it is for projects where the revenue is generated outside of the state.

5.7 LENOWISCO Differentiators

Several pieces of federal legislation were reviewed to determine their applicability to LENOWISCO's project. The following aspects of these legislation could be useful.

- Section 40342 of the IIJA provides a pool of $500 million for clean energy demonstration programs on current and former mine land that will be allocated for projects in the fiscal years of 2022 through 2026. LENOWISCO certainly qualifies for this funding pool.
- The Inflation Reduction Act provides the Production Tax Credit (PTC) and Investment Tax Credit (ITC) one of which may be selected for the LENOWISCO site. It is likely that the ITC would be chosen over the PTC because the nuclear projects have not yet been built. LENOWISCO is well positioned to access these funds, because one of the two 10% boosters applies for siting in energy communities (which LENOWISCO certainly qualifies as). Along with the other 10% booster that can be captured if enough of the components of the project are manufactured domestically, LENOWISCO can take full advantage of the funds available. With the boosters, the IRA provides 50% of the capital cost for a plant back in tax credits. Further, the IRA also provides $40 billion in loan guarantees.
- The Abandoned Mine Land Economic Revitalization Program (AMLER) could provide several million dollars in funding depending on the site that is selected. In FY2023, VA was allotted $11.739 million of this funding. In years past some of this funding has been used at Project Intersection.
- Although the current version of the Opportunity Zones funding will most likely expire before it can be fully utilized, it may be available to certain sites if it is renewed.
- The Tobacco Region Opportunity Fund may provide funding to nuclear plant or the co-located business(es).

When considering what public funding may be available, LENOWISCO must first determine if it is more advantageous to take advantage of the IRA's PTC or ITC. The other funding sources may provide some beneficial contributions but are likely to be only a small fraction of the funding the IRA can provide.

6 USE OF NUCLEAR POWER FOR DEDICATED NEW FACILITIES

Nuclear power has several advantages when compared to other generation technologies that make it an ideal fit for some of the proposed new facilities.

6.1 Energy Production and Utilization

Electrical generation and consumption are measured in units of watts, often in terms of kilowatts (1,000 watts), megawatts (1 million watts), and gigawatts (1 billion watts). Watts are units of power expressed in terms of energy per time, also known as an instantaneous rate. When discussing electrical power on a grid-scale using units of watts is often convenient because the supply and demand of electricity must be in balance.

When discussing a particular generator or consumer of electricity, units of watt-hours (energy) per time period are often used instead (see Equation [3]). For example, residential or commercial billing is often performed based on kilowatt-hours (kWh) of electricity consumed during the billing cycle. This is convenient because the consumption or generation of electricity may not be the same for all periods of the day. For example, during the summer a building's air conditioner may be consuming much more electricity during the afternoon then it does in the evening. The air conditioner itself may be turning on and off altering the building's consumption of electricity minute by minute. The outside temperature may affect the number of minutes each hour the air conditioner is running, altering the building's consumption of electricity hour by hour.

$$Energy\ Consumed\ (Wh) = Power\ Consumed\ (W) * Time(h) \qquad [3]$$

Because electrical generation and consumption is described over 9 orders of magnitude between watts and gigawatts, it can be helpful to benchmark electrical capacity in terms of more familiar scales.

At the residential scale, the average US home uses approximately 10.5 MWh each year. This equates to approximately 875 kWh each month, or approximately 1.2 kW continuously. A hairdryer or a 2 ton air conditioner each require between 1 and 2 kW while running. Hyperscale data centers have power requirements between 30 and 300 MWe.

At the utility scale, in 2021 Kentucky Utilities Co provided 667,000 MWh to VA (primarily in the LENOWISCO region, and approximately 18,140,000 MWh to their total customer base [66]. This results in a yearly average generation capacity of 76 MWe in VA and 2,070 MWe total.

At the grid scale, the PJM Interconnection is forecasting peak Summer 2023 load demand to be 149,059 MWe for their service territory [67].

The peak and average consumption of electricity by a load should be considered when determining the suitability of an electrical generator to supply the load. If the load is connected to a large power grid, the effect of load changes is reduced. If the load is connected directly to the generator, or within a microgrid, load changes can require the generator to change power or voltage to ensure electrical system stability.

Generators and loads can also be described by capacity factor. The capacity factor is the percent of electrical generation or consumption compared to the maximum over a period of time. For example, if a nuclear power plant has a nameplate capacity of 100 MWe over a 1 day period it would be expected to provide 2,400 MWh of power (per Equation [3]). If the power plant only generated 2,200 MWh of power during the day, it would have exhibited a capacity factor of 91.6% (per Equation [4]).

$$Capacity\ Factor\ (\%) = Actual\ Energy\ Provided\ (MWh)\ /\ Max\ Capacity (MWh) \qquad [4]$$

The power production history, load profile, or capacity factor of a generation source must accommodate the needs of the load. The 2021 yearly average capacity factor for various methods of electrical generation are included in Table 6-1. Nuclear power plants typically operate reliably at full power for extended durations. The currently operating fleet of nuclear power plants shutdown, producing no electrical output, every 18 to 24 months for a period of a few weeks to refuel the core and perform maintenance. These maintenance outages result in an annual average capacity factor of >90%. During these periods of maintenance supplied loads will require power from the wider electrical grid or temporary electrical generators*.

* One example is diesel generators.

Table 6-1 2021 Average Annual Capacity Factors [68]

Generation Class	Capacity Factor
Hydroelectric	37.4%
Nuclear	92.6%
Photovoltaic Solar	24.8%
Thermal Solar	23.1%
Wind	36.1%

6.2 Data Centers

One of the primary potential customers of interest for nuclear power projects in LENOWISCO are data centers. Northern Virginia has over 13 million square feet of data center space requiring more than a gigawatt of power. According to the Loudon County Economic Development Authority, over 70% of the world's internet traffic passes through Northern Virginia each day [69]. The state of Virginia has heavily invested in data centers to promote this growth including sales tax exemptions and construction employment tax credits. About 70% of Virginia's datacenters are in Northern VA. In order to promote this growth in other areas of the state, Project Oasis (Reference [69]) specifically looked at the challenges and opportunities associated with building these projects in Southwestern Virginia. It provides several benchmarks for the relative sizes of data centers which are shown in Table 6-2. In general, from this study it can be assumed that there is a general power requirement of 1 MWe per 7,000-10,000 ft^2 of facility space.

Data centers are a particularly good match for nuclear power plants because they have a constant baseload power requirement and nuclear plants provide baseload power. Renewable energy sources are intermittent generators and there are unplanned or cyclic periods of time where they do not produce electricity. As a result, a data center powered by renewables would require an alternate energy supply or a large energy storage solution to supply continuous power during time periods of low renewable generation. Fossil fuels, in addition to emitting greenhouse gases, are subject to fluctuating fuel prices. Nuclear plants stand apart as an energy source that provides a constant amount of energy at a constant price. Nuclear plants do have periodic outages, but these are typically planned and relatively brief (as shown in Table 6-1, nuclear has a capacity factor of >90%).

Data centers are a particularly good match for sites in the LENOWISCO ROI because of the ample supply of 51°F mine water available at many sites. This water supply can be used to cool the servers or to make the nuclear power plant more energy efficient.

Table 6-2 Relative Size of Data Centers

Size	Size (ft^2)	Power Requirement (MWe)
Hyper	350,000	30-300
Model*	250,000	36
Large	100,000-200,000	10-50
Small	<100,000	-
Micro	10	-

*This model was carried through to example scenarios used throughout the Oasis report.

6.3 Hydrogen Generation

Hydrogen generation is considered a technologically compatible technology with nuclear power. The high operating temperatures of nuclear power plants (>500°F and up to 1600°F for some advanced reactor designs) provide an excellent heat source for the efficient production of hydrogen. At these high temperatures, hydrogen can be formed more efficiently making it less expensive to produce. Hydrogen is transported in gas lines, although it is noted that some of these may need to be refurbished to accommodate hydrogen transport (the IRA provides funding for such projects). LENOWISCO's close proximity to existing gas lines may make them ideal sites for hydrogen production.

More generally, nuclear is an excellent source of nonintermittent process heat. Around the world, nuclear is being actively considered for heat to be used for hydrogen generation, chemical manufacturing, desalination, and district heating in addition to electricity generation.

6.4 Industrial Park

Low wholesale electricity prices can be an attractive way to incentivize new business development and investment in a region. Behind the meter industrial parks would perform synergistically with nuclear power plants to allow for reliable and affordable power, and district heating, if desired. Locating the nuclear power plant behind the meter of an industrial park would reduce transmission costs and line losses, potentially resulting in lower electricity prices for the businesses, and higher sales prices for the generator than would normally be available.

Once constructed, nuclear power plants offer benefits with respect to energy cost stability. Nuclear plants are characterized as having significant fuel reserves on site (on the order of years) compared to coal plants which may have weeks of fuel reserves or natural gas plants which require continuous resupply from pipelines. These fuel reserves minimize interruptions to electrical generation associated with disruptions from weather, supply chain, and other external factors. The cost to generate electricity via nuclear power is also relatively insensitive to the price of fuel compared to coal or natural gas powered generators. For example, doubling the price of uranium is reported to increase the cost of generation by only 10% [70]. These factors result in high confidence in the projected future cost of generation and may allow for long-term contracts for fixed rate power production.

In contrast to the low price of nuclear fuel, the levelized cost of electricity generation at nuclear facilities is dominated by the initial capital costs of power plant construction. Recent nuclear deployment in the United States has been characterized by cost overruns and schedule delays associated with construction. SMR vendors are proposing to address these issues with factory manufactured components and onsite assembly. To date, no SMR vendors have placed an SMR in service, so uncertainty in construction costs and schedule remains a concern.

Attracting business development prior to reactor operation may be difficult due to these uncertainties. For example, in January of 2023 NuScale increased their target price point of power produced from a proposed site from a 2016 estimate of $55/MWh to $89/MWh [71]. This increase was primarily driven by an increase in projected construction costs from $5.3 billion to $9.3 billion. The increase is driven by increased costs of construction commodities such as piping, steel, and cable as well as higher interest rates.

Once constructed, the reactor will benefit from low fuel costs and high availability which will make co-located industrial uses financially attractive options. It may be difficult to broker commitments between a reactor owner/operator and industrial customers such that each entity is willing to commit to the long term construction project. Instead, it may be easier to deploy a reactor with a standalone business case such as electrical sales to the grid detailed in Section 7 which can then attract industrial users once constructed.

6.5 LENOWISCO Differentiators

LENOWISCO is proposing the construction of a Small Modular Reactor to provide power to new developments. This co-location arrangement provides many benefits. Primarily, co-location provides a guaranteed wholesale power rate for the development and a guaranteed customer for the power plant. Cutting out transmission costs and losses may result in a lower price for customer and a higher price for the plant.

Nuclear is well suited for a customer like a data center where the need for power is constant. This is because nuclear plants are designed to operate at full power continuously for an extended period of time (generally 18-24 months) and then are refueled for a short period (generally several weeks). The length (or existence because some plants do not require this) of the refueling window is dependent on the plant design. LENOWISCO's access to mine water also makes it an ideal location for future data center projects that require cooling water.

Nuclear is also well suited to provide process heat for industrial parks or chemical manufacturing, one example of which is hydrogen production. Although hydrogen production is not currently a technology being evaluated specifically by this study, it is worth noting due to the federal funding being devoted to hydrogen production and the proximity of natural gas lines to the LENOWISCO region, which could be used to transport hydrogen once it is produced.

One noteworthy drawback of co-location is shared commercial vulnerability. If one of the businesses fails, the other will need to find a new partner. As it relates to the nuclear plant, if the data center or other industrial partner fails, the plant will need to begin supplying to the grid. This will likely result in a lower price of electricity and overall decrease in revenue.

7 USE OF NUCLEAR POWER FOR SALE TO THE GRID

In order to ensure grid reliability (electrical voltage and frequency remain within limits) the supply of electricity must match the demand for electricity at all times. However, due to daily and seasonal variations in load (e.g., many air conditioners hit their peak loads on summer afternoons), electricity demand is always changing. Generators which produce electricity can be broadly defined as [72]:

- Baseload power plants which run continuously at full power
- Seasonal baseload power plants which run continuously at full power in winter and/or summer but may vary their output with demand in spring and fall
- Intermediate power plants (or load following plants) which vary power output throughout the day depending on demand
- Peaking power plants which may only run for the hottest or coldest weeks of the year and otherwise maintain readiness for demand

In general, an electrical plant's status between baseload and peaking is determined by its variable cost of production. Traditional large light water nuclear power plants have high fixed costs due to their extensive staff but low variable (fuel) costs to produce electricity. This results in their use as baseload or seasonal baseload power. Nuclear plants also require continuous small power adjustments following load changes due to inherent feedback loops, which makes continuous full power operation more attractive. The price of electricity produced by coal and natural gas plants is heavily dependent on the price of fuel, which results in their variable status from baseload to peaking. Small <100 MWe gas and diesel fired power plants are typically the most expensive way to produce electricity and are often used as peaking plants.

It is necessary to 'overbuild' electrical generating capacity to ensure that sufficient peaking capacity exists for the highest demand periods of the year. When insufficient generating capacity exists compared to demand, rolling blackouts may occur. Rolling blackouts reduce the demand on the electrical grid by purposefully shutting off the supply of electricity to some consumers. This ensures electrical equipment at critical locations such as hospitals continues to remain available.

The sale of electricity in the US can broadly be divided into two categories, regulated and deregulated.

In a regulated environment, a public service commission (PSC) establishes the price of electricity for all generators. In addition to the price of electricity the PSC is in charge of ensuring sufficient electricity supply compared to projected peak demand, determining when new generation should be constructed, and authorizing reinvestment in transmission infrastructure. Louisville Gas & Electric and Kentucky Utilities Energy (LG&E and KU Energy) as well as their subsidiary Old Dominion Power (ODP) are regulated utilities. (Some utilities, for example Powell Valley, are only distributors and purchase all of their electricity from other providers.)

In a deregulated environment, generators supply electricity to the grid at a variable price which is determined by the supply and demand of electricity at any given time. If too much generation is available, the price of power falls, and more expensive generators shutdown for a period of hours to months until there is enough demand to facilitate bringing them back online. If not enough generation exists, the price of power rises which causes generators to start up and begin producing power for the grid. Because peaking plants are necessary, but only operate a fraction of the year, generators may be paid both for the actual electricity they provide to the grid as well for their standby capacity. PJM is a regional transmission organization (RTO) that coordinates the movement and sale of electricity on the deregulated PJM grid.

7.1 PJM Summary

The LENOWISCO region is not fully served by the PJM grid. The LENOWISCO region is currently served by three separate generating utilities Appalachian Power Co., Kentucky Utilities Co., and the Tennessee Valley Authority. Appalachian Power company does participate in the PJM and some areas within Northern Wise county are part of the PJM. Kentucky Utilities Co. and TVA are not part of the PJM.

Connection to the PJM grid requires study and analysis to ensure reliability criteria are met in accordance with federal and regional standards. Upgrades, expansions, and enhancements to PJM transmission lines and interconnection of new generation is governed by PJM's Regional Transmission Expansion Plan (RTEP). The process for interconnection must be followed in order to participate in the sale of electricity on the PJM grid and is described in Section 7.2.

Connection to the PJM grid will require connection to an electrical substation which is already connected to the PJM grid. Three substations located near LENOWISCO were identified as potential candidates for interconnection: Pocket, Hill, and Nagel.

The Pocket substation is located approximately 1 mile north of Pennington gap off of State Route 606. The Pocket substation is connected via 500 kV lines to the Nagel substation (TN), and via 161 kV lines to the Dorchester substation (VA) and the Harlan substation (KY). The Pocket substation and its highlines are owned by Kentucky Utilities Co.

The Hill substation is located approximately 5 miles southwest of Fort Blackmore off of the Clinch River Highway. The Hill substation is connected via 138 kV lines to the Nagel substation (TN) and to Clinch River (VA) substation by way of the Copper Ridge substation. The Hill substation and its transmission lines are owned by Appalachian Power Co.

The Nagel substation is located approximately 6 miles northwest of Kingsport TN off of Virginia State Route 713 and is connected to the wider PJM via 138 kV transmission lines owned by Appalachian Power Co. as well as 500 kV transmission lines owned by the Tennessee Valley Authority.

In addition to existing substation infrastructure, new substation development has been proposed within the LENOWISCO region. The Virginia Department of Energy has proposed Project WiseLink in conjunction with other regional development partners. The scope of Project WiseLink includes the construction of new transmission lines in Wise County. The transmission expansion is proposed to be connected to the existing PJM grid near Pound and terminate approximately 1 mile southwest of Appalachia, Va. Project WiseLink, if completed, would provide a substation in close proximity to the Bullit and Lee County sites.

PJM supplemental project S2774 has been proposed to construct a greenfield 138/12 kV substation (Salmon) connected to the Broadford (Smith) and Claypool Hill (Tazewell) substations which are NE of Saltville, Virginia. Due to its location near the LENOWISCO region, this supplemental project provides a budgetary reference for greenfield substation and transmission lines. The construction of Salmon station in addition to 2.3 miles of double circuit 138 kV line is estimated to cost $8.5M. The cost is noted to be high per mile due to new access road requirements and environmental surveying. 4.1 miles of fiber network connection are also proposed to be installed below the 138 kV transmission lines with an estimated cost of $0.8M. This project is in the scoping phase and was submitted by American Electric Power in October 2022 with a proposed in service date of September 2024 [73,74].

7.2 Grid Connection Requirements

The RTEP process for grid connection is described by the PJM 14 series of manuals (A-G). PJM Manual 14A New Services Request Process outlines the process used to initiate a new service request [75]. The new service customer initiates the interconnection process by processing a New Service Queue Request due by either March 10th or September 10th for the first or second queue of the year. New generation service requests are subdivided into interconnection requests of 20 MWe or less, or interconnection requests greater than 20 MWe. This process must be followed in order to obtain a Wholesale Market Participant Agreement from the PJM.

Interconnection to the PJM grid is analyzed under a 3-phased study approach. These phases are an initial feasibility study, a system impact study, and an interconnection facilities study. This process allows the new service customer to receive tiered feedback on a proposed project, with the option to withdraw from the expenditure of additional analysis if the business case is altered by study results. For each phase of study, the new service customer is responsible for funding the study and providing an initial deposit. Pricing and estimated cost of study information is provided in PJM Manual 14A, for example the expected cost of a feasibility study for a large generator in the AEP transmission zone is $26,000.

The feasibility study examines the practicality and cost of incorporating the additional generation into the PJM system. The study is limited to basic analyses assuming summer peak load. The study focuses on identifying estimates of the scope, cost, and lead time required for interconnection of the proposed generation facility. As part of the feasibility study, the new service customer defines a primary interconnection and a secondary point of interconnection (if desired). Following the feasibility study the new service customer may determine whether or not to proceed with a system impact study.

The system impact study is a more comprehensive regional analysis of the effects of adding the new generation facility to the system. The study identifies the necessary upgrades which will be required to support the new generation facility and provides comprehensive time and cost estimates for the construction of those upgrades. Following the completion of the system impact study the new service customer may determine whether or not to proceed with the final facilities study.

For generation connection requests greater than 20 MWe, a stability analysis is required during the facilities study phase. The facilities study identifies all control equipment required for the new generator interconnection, and the necessary engineering design required to begin construction of required facilities. A good-faith estimate is provided to the developer for the costs of the work required.

7.3 Utility Comments

It is reasonable to assume that most customers would want a grid connection as a backup power source to what is provided by the nuclear plant. The plant itself would also benefit from the security of having a grid connection to sell electricity to if the commercial partner were to decrease its electricity demand. Interviews were conducted with nearby utilities in order to assess their interest in nuclear power.

7.3.1 AEP

AEP is engaged with many of the advanced reactor vendors and continues to stay informed of their developments. Consistent with the Governor Youngkin's energy plan, AEP considers nuclear to be an important part of Virginia's energy portfolio and supports the development of SMR technology for deployment. AEP is unlikely to be a first adopter of new nuclear technologies but plans to increase their involvement in the space as the technology becomes more mature. AEP's interest in the nuclear space is currently focused on larger SMRs (>300 MW) because AEP is most interested in grid scale generation. AEP is open to working with other utilities and regional stakeholders to ensure the success of new nuclear projects in Southwest Virginia.

7.3.2 Dominion Energy

Driven by the construction of datacenters in Northern Virginia, Dominion Energy Virginia has some of the largest forecasted load growth of any utility on the PJM grid. Additionally, Dominion Energy Virginia recognizes the Commonwealth’s plans to have 100% of energy needs met by carbon free resources within the next few decades. To support this increasing demand and the need to ensure reliability, while also decarbonizing the grid, Dominion Energy Virginia is evaluating options to significantly expand its nuclear power generation fleet. Dominion Energy Virginia has initiated outreach with SMR vendors and has increased engagement steadily through today, culminating in the scoping of new SMRs into their future generation plans. The continued evaluation of SMRs as a potential future energy supply resource led to SMRs being listed as a supply side resource as soon as the early 2030s in Dominion Energy Virginia’s 2022 Update to its 2020 Integrated Resource Plan (IRP, Reference [76]).

As of 2022, nearly all of Dominion Energy Virginia’s potential portfolios that involve decarbonization assume significant deployment of SMRs. The most recent IRP update assumes that one 285 MW SMR could be built per year starting in 2034. Dominion representatives noted that the 2023 comprehensive IRP, which is filed every three years, is expected to be published in early May 2023..

Across its fleet, Dominion Energy Virginia and its affiliates currently operate seven nuclear power reactors in Connecticut, Virginia, and South Carolina, with four units that serve Dominion Energy Virginia customers. Dominion Energy Virginia has NRC approval to extend the operating license of the two units at Surry Power Station for an additional 20 years to a total of 80 operating years (through May 2052 and January 2053). The company is also pursuing operating license extensions for North Anna Power Station and V.C. Summer Power Station, and is evaluating operating license extensions for Millstone Power Station [77]. Additionally, in 2007, Dominion Energy applied for a Combined Construction and Operating License for the construction and operation of an Economic Simplified Boiling Water Reactor, which was granted by the NRC in 2017. Thus, Dominion Energy has invaluable recent experience with the licensing process for new nuclear reactors which can be leveraged for new SMR development.

This current experience with operating plants, relicensing with the NRC, and the licensing of new reactors makes Dominion Energy Virginia well positioned to be the first adopter of SMR technology in the state of Virginia.

7.4 Coal to Nuclear

The equipment used to generate electricity and distribute it to the power grid is not inherently unique to nuclear power plants. All steam cycle plants boil water to create high pressure steam via a heat source (e.g., coal, natural gas, nuclear) which creates electricity by spinning a turbine connected to an electrical generator. Upon exiting the turbine, the steam is condensed into water by rejecting heat to a heat sink. Recent studies have focused on the economic benefits of reusing steam cycle components of retired coal plants to reduce capital construction costs of new nuclear power plants [78]. This coal-to-nuclear (C2N) conversion is expected to lower capital costs in certain scenarios. Three different subsets of coal plant equipment are potentially able to be reused during a C2N transition:

- Transmission, switchyards, and office buildings (Section 7.4.1)
- Ultimate heat sink infrastructure (Section 7.4.2)
- Steam cycle components (Section 7.4.3)

This section also provides a review of the DOE's C2N study (Section 7.4.4) and a review of power plants near LENOWISCO that have recently closed (Section 7.4.5).

7.4.1 Transmission, Switchyards, and Office Buildings

The preexisting site infrastructure for electricity transmission as well as related office buildings are the most easily repurposed infrastructure for a new nuclear power plant. The power lines from the switchyard to the grid can be reused provided amperage (current) limitations are met. Switchyard components such as breakers and relays must also meet amperage limitations. Generator step up transformers function to increase the output voltage of the generator to grid voltages, and may be reused if the new generator output voltage is the same as the output voltage of the retired generator. This represents substantial cost savings as the cost/mile of new transmission lines can exceed $3M/mile [79].

Preexisting land and office facilities can also be reused. This includes physical land and yard work, office buildings, roads and parking, cafeterias, and other infrastructure necessary for workers and offices unrelated to the industrial activity.

7.4.2 Ultimate Heat Sink Infrastructure

Steam cycle plants require an ultimate heat sink to condense exhausted steam into water after it exits the turbine as described in Section 3.2.5. Approximately two thirds of the energy produced by the heat source is exhausted to the ultimate heat sink during electricity production. The heat sink may be a body of water used for direct cooling of a condenser, a water source used for evaporative cooling in conjunction with cooling towers, or direct atmospheric cooling. The reuse of existing cooling structures within the envelope of the previous coal plant's thermal discharges is feasible to reduce capital expenditures and provide for reduced uncertainty during permit applications. Thermal discharges or consumptive water usage which is within the envelope of the coal plant's previous operation may be easier to permit. The new nuclear power plant can utilize the cooling structures already present if supported by the plant design.

7.4.3 Steam Cycle Components

Reusing steam cycle components such as turbine generators, steam generators, feedwater heaters, and feedwater pumps would result in significant potential savings but also significant challenges when performing a C2N transition. These components work together in an integral system along with the heat source in order to produce electricity. These components are also designed for specific temperature and pressure ranges based on the heat source of the original plant. The reuse of existing systems would require careful selection of a nuclear reactor design which can match the operating profile of the existing equipment. Many LWR designs cannot reach the operational temperatures and pressures of critical or supercritical coal plants and would be unable to reuse steam cycle components, although some AR designs may be able to. Further, there may not be a regulatory pathway for reuse of some components such as steam generators, as many nuclear related components are required to be purchased and installed as Safety-Related components which requires significant quality control requirements. One potential solution is to install an intermediate heat storage system between the nuclear reactor and the reused steam cycle components which interfaces with both.

7.4.4 C2N Study Results

Two different scopes of C2N conversion have been studied as potentially feasible. The reuse of only transmission and ultimate heat sink infrastructure was estimated to save approximately 25% compared to greenfield siting. If steam cycle components were to be reused in addition to transmission and ultimate heat sink infrastructure, a savings of approximately 35% was estimated.

7.4.5 Shuttered Power Plants

The LENOWISCO planning district does not contain any retired power plants. However, AEP's Clinch River power plant is located in Russel County in the unincorporated community of Carbo. AEP's Clinch River was initially designed as a three unit 705 MWe coal plant. Units 1 and 2 were converted into a 484 MWe natural gas fired power plant. Unit 3 has been retired since 2015 and may be a candidate for a C2N transition with additional study.

7.5 LENOWISCO Differentiators

The LENOWISCO region is uniquely served by three different electrical power providers, Kentucky Utilities Co., Tennessee Valley Authority, and Appalachian Power Co. These utilities represent a mix of regulated and deregulated. Access to the PJM regional transmission organization is also available in certain areas within the region.

This has the potential to complicate or ease the reactor siting process. The existence of multiple utilities provides multiple options for siting of the power plant. A single noncommittal utility will not prevent reactor siting in the LENOWISCO ROI if other utilities have interest in their own service area.

Additionally, a consortium approach between the utilities could be a path forward for a larger 300 MWe SMR site. It is not uncommon for multiple utilities to provide a stake in large construction projects resulting in joint ownership which lowers the capital barriers to entry for each stakeholder. The Utah Association of Municipal Power Systems (UAMPS) is composed of 50 member utilities and is currently proceeding with license application activities for a NuScale reactor near Idaho Falls. A similar joint venture between interested utilities in the LENOWISCO region may be possible.

8 ECONOMIC EFFECTS OF NUCLEAR INFRASTRUCTURE

The existing fleet of nuclear power plants (e.g., large LWRs like Surry and North Anna) are massive sites that cost billions of dollars (inflation adjusted) to construct and have employed hundreds of full time staff for more than 40 years. The SMR designs being considered for this effort are smaller but are still expected to cost hundreds of millions or billions of dollars to construct, employ up to 100 people and provide electricity and tax revenues for the community for decades. The remainder of this section is structured as follows.

- Section 8.1 provides a discussion regarding the amount expected to be spent during construction.
- Section 8.2 provides a discussion of the different cost accounting methods which may be used to report the costs of nuclear power plant construction and electricity.
- Section 8.3 provides a discussion of the direct jobs available at the plant once it is built.
- Section 8.4 provides a discussion of the indirect and induced jobs that are expected to be created as a result of the plant.
- Section 8.5 provides a discussion of the tax revenue expected to be generated from the power plant.

8.1 Local Spending during Construction

All large construction projects result in the creation of numerous temporary jobs and subsequent spending within the local community. The residents of LENOWISCO already possess many of the skills (e.g., general construction, heavy machinery operation) needed to staff the expected roles. It is likely that compared to other areas, a project in LENOWISCO could provide much of the required skilled construction labor locally.

One useful reference point is the Virginia City Hybrid Energy Center (VCHEC) in Wise County. Although fossil plants have different levels of complexity compared to nuclear plants, many aspects of construction are similar. VCHEC currently employees 121 direct employees and employed 2,000 people during construction [80].

8.2 Total Project Cost

The project costs for new SMR construction are currently unknown. A primary reason that the costs are difficult to estimate is because previously constructed nuclear plants in the U.S. have taken several years to build. This has resulted in compounding financing costs when construction delays occur. SMRs intend to solve this problem with factory manufactured components and short construction schedules, but that ability has not yet been demonstrated. Electricity and revenue are generated by the facility for decades after construction is complete, which makes costs sensitive to the operating life of the power plant. During electricity generation, operating and maintenance costs are incurred. Therefore, many assumptions are needed to determine what the cost of the electricity generated by the facility will be. Several methods of estimating project costs are described below and shown visually in Figure 8-1 [81].

- Direct Costs - Direct costs include the costs of equipment and materials needed to build the plant. This includes costs incurred to produce equipment in offsite factories (the reactor vessel, the turbine, etc.), labor onsite to construct the plant or install the equipment, and the cost of all materials consumed onsite (concrete, steel, formwork, scaffolding, etc.). These costs are not expected to significantly change if the time to construct the plant increases.
- Indirect Costs - Indirect costs include construction services, engineering, and field supervision required for the overall project execution but not assignable to any one piece of equipment. These costs are expected to increase as the time to construct the plant increases.
- Base Cost – Base cost is the sum of the direct and indirect costs.
- Overnight Construction Cost (OCC) – OCC is the cost of construction if all costs were incurred at once. In addition to the base costs, this OCC includes contingency costs (i.e., additional or unexpected costs during construction) and owner’s costs. Owner’s costs are the costs borne by the owner (exclusive of financing) including land, permitting, operator training, and taxes. This is expected to be roughly 60% of the levelized cost of electricity.
- Total Capital Investment Cost (TCIC) – TCIC is the amount of capital needed for a project to proceed. This is the sum total of all the costs (including financing) incurred throughout a project schedule up until the plant begins operation and begins producing revenue.
- Levelized Cost of Electricity (LCOE) – LCOE is a metric used to determine the cost to produce electricity over the lifetime of the plant. This metric time weights all costs incurred during construction and during operation.

The Carbon Free Power Project (CFPP) is the first six module NuScale plant and provides a useful reference point for SMR construction. It is reported that the project is expected to cost between 5.1 and 9.24 billion dollars (this estimate is likely the TCIC because it includes interest rate assumptions and owner’s costs). The LCOE for this project is currently projected to be $89/MWh. The costs for this project should be viewed as a ceiling for future NuScale projects. The first of a kind (FOAK) project cost is often significantly higher than future projects (sometimes referred to as the Nth of a kind (NOAK) project). It is not unreasonable to assume that if a NuScale six module plant were built in LENOWISCO ten years from now, it would be the third such plant in the United States and the project costs would be 50-75% of what they were for the CFPP. This concept is illustrated by Figure 8-2 which shows the expected cost savings to construct a second or third unit at Sizewell (a nuclear power plant in the United Kingdom).

Estimating the total project cost at this junction are difficult and require numerous assumptions. Several of these are listed below.

- Government Incentives – As discussed in Section 5, the available government incentives could be used to reduce the capital costs of the project by 50%. Further, government subsidies could be used to secure a favorable interest rate and significantly reduce the cost of financing the project. The actual cost of any future projects is highly dependent on what government incentives are available.
- Financing Costs – As noted above, OCC are expected to be roughly 60% of LCOE. The discount rates used to consider the cost of financing form a significant cost in any large construction project.
- NOAK benefits – As briefly described here, the costs to first adopters of new plant designs are significantly greater than the costs of later plants. Part of the promise of small modular reactors is that their largest components will be able to be manufactured in a factory and several of each part will be needed for each plant. This means that NOAK benefits may be realized much earlier in the lifetime of the product.

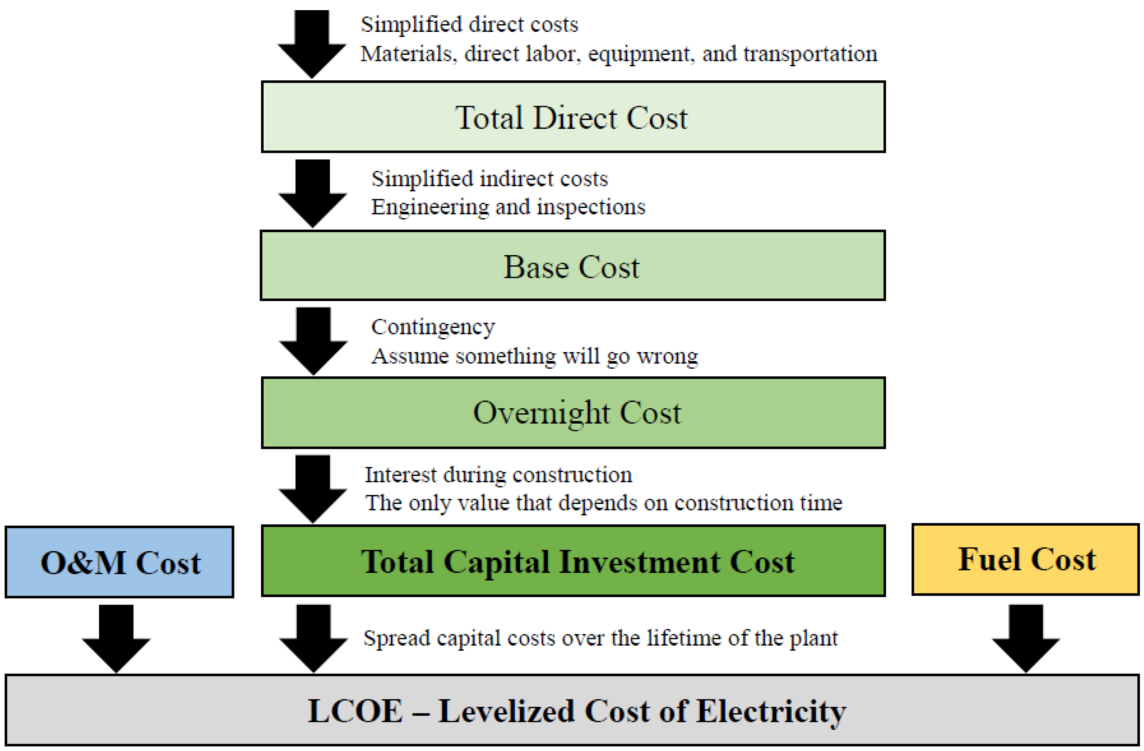

Figure 8-1 A Visualization of the Factors that Affect LCOE [82]

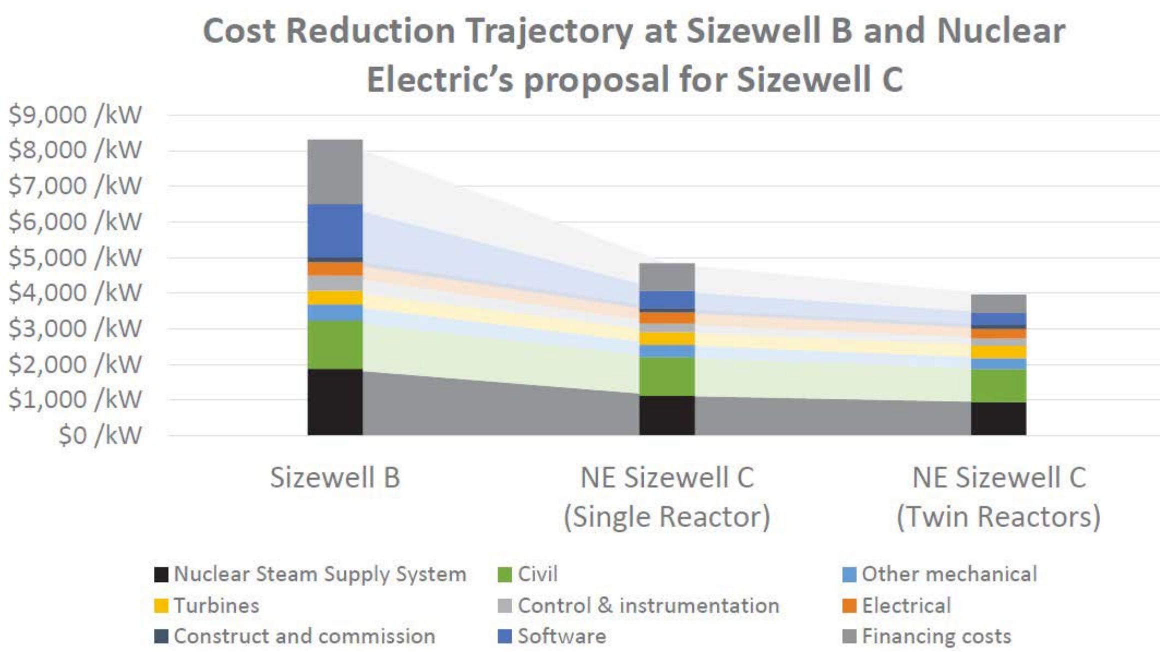

Figure 8-2 Cost Reduction Trajectory of Proposals for Sizewell C [83]

8.3 Direct Jobs

SMRs are designed to have reduced operating costs compared to current plant designs. One way in which this is achieved, is designing the plants such that fewer full-time staff are needed. Table 3-1 (and repeated in Table 8-1) shows the number of employees expected for each of the plant designs. These range from 10-300 direct employees. This is significantly less than the roughly 900 that work at Surry Nuclear Power Plant [84]. Although a SMR will bring direct jobs to the region, it is expected that the primary benefits will be tax revenues and reliable and affordable electricity which will encourage other businesses to come to the region.

The jobs created by a nuclear power plant require varied levels of qualification, training, and education. A college degree is required for some engineering jobs at the nuclear power plant. However, many of the jobs at the facility will require skilled and specialized craft work requiring an Associate's degree, certifications, or a high school diploma with relevant work experience. Power plants require day to day operation and maintenance workers to ensure the facility operates reliably. Skilled craft workers positions do not require nuclear experience. Training in the trades may come from prior work experience or be provided by a community college, such as Mountain Empire Community College. The nuclear industry recognizes the need to train the workforce and has implemented the Nuclear Uniform Curriculum Project in partnerships with community colleges to prepare students for careers in the nuclear industry [85].

The following types of jobs at nuclear power plants do not require a Bachelor's degree:

- Mechanics and welders perform mechanical maintenance tasks such as lubrication of rotating equipment, changing of filters, and overhauling pumps or valves.
- Electricians perform maintenance on motors, circuit breakers, and transformers.
- Instrumentation and control technicians maintain the performance of valves and operating systems.
- Security officers are required to protect the power plant and often comprised of individuals with prior military or police experience.
- Plant operators are required to monitor the power plant's operation and are trained to provide fire fighting and emergency first aid response.
- Control room operators are senior operators which are trained by the power plant to monitor and control the reactor.

Jobs which require college degrees may be fulfilled by employees with related engineering degrees, or other technical degrees such as biology, biochemistry, or chemistry which are offered locally from UVA Wise. Engineering roles may also be performed by experienced technicians from the navy, fossil power generation industries, or the plant itself who have developed extensive knowledge of plant components and systems over their career but do not necessarily hold a degree.

The DOE's coal to nuclear report estimates that roughly 50% of direct jobs at an SMR require a Bachelor's degree or extensive work experience and the other half require a high school diploma or a high school diploma plus a post-secondary certificate, some college courses, or an Associate's degree [78]. It is expected that these jobs would be filled by the current residents of LENOWISCO and remain in the community for the decades-long lifetime of the plant.

Table 8-1 Expected Number of Employees from Each Plant Design

Vendor	Reactor Type	Power Output (MWe)	Direct Employees	Induced and Indirect Employees	Site Footprint
GE-Hitachi BWRX-300	BWR	300	75	300	26,300 m^2 (6.5 acres)
TerraPower Natrium	SFR	345	250	1000	180,000 m^2 (44 acres)
NuScale VOYGR 6	PWR	720 (12 60 MWe modules)	270	1080	140,000 m^2 (35 acres)
X-energy XE-100	HTGR	320 (4 80 MWe modules)	3	12	130,000 m^2 (32 acres)
BWXT Project Pele	HTGR	1-5	2	8	<2,000 m^2 (< 0.5 acres)
Ultrasafe Micro-Modular Reactor	HTGR	10 (2 5 MWe modules)	0	0	< 20,000 m^2 (< 5 acres) [4]
Westinghouse eVinci	SFR	5	2	0	<2,000 m^2 (< 0.5 acres) [5]

8.4 Indirect and Induced Jobs

The presence of the plant would also create indirect jobs, or positions created to supply the goods and services consumed by the workers that take the direct jobs. These are jobs in the surrounding community as a result of new jobs that were directly created. For a nuclear plant these would include contracted laborers and other employees that support the plant but do not work for the plant. It is also possible to estimate jobs induced by the plant. These are jobs in the local economy such as teachers and cashiers that would support the personal needs and spending of the direct and indirect jobs. The Coal to Nuclear report estimates that roughly 4 times as many direct and induced jobs will be created as there are direct jobs (roughly one indirect job and two induced jobs per direct job).

It is also important to consider that the collocated industry is expected to be a creator of jobs. The estimates provided here do not include the economic impact of any new electricity consuming industry.

One useful reference point is the Virginia City Hybrid Energy Center (VCHEC) in Wise County. This facility provides 121 direct jobs, and it is estimated to have generated 180 indirect jobs [80].

8.5 Tax Revenues

One of the primary benefits of energy production facilities, nuclear or otherwise, is the tax revenues generated by them. Tax revenues generated are highly variable and depend both on local taxation and local rules for depreciating assets. The DOE's coal to nuclear report estimates that a 12 module NuScale plant (924 MWe employing 360 workers*) in a representative county would provide a peak of over $7 million in taxes in a single year and a total of 97.2 million in taxes over 18 years [78]. This is approximately $100,000 in total revenue per MWe. This estimate does not account for the additional taxes which would be generated as a result of income taxes paid from the salaries of plant workers.

One useful reference point is the Virginia City Hybrid Energy Center (VCHEC) in Wise County. This facility has generated 22 million MWh of electricity in the last ten years. VCHEC has a nameplate capacity of 610 MWe, but does not operate continuously. VCHEC's production is equivalent to 251 MWe at a 100% capacity factor and is therefore similar in annual generation to a 300 MWe SMR. This facility paid $11.2 million in personal and real property taxes to Wise County in 2022 [80].

* Since that report was published, NuScale has adjusted their staffing expectations from 360 to 270.

9 REFERENCES

1. *Cooling Power Plants*. World Nuclear. Updated September 2020. https://world-nuclear.org/information-library/current-and-future-generation/cooling-power-plants.aspx

2. *Small Nuclear Power Reactors*. World Nuclear. Updated March 2023. https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/small-nuclear-power-reactors.aspx

3. *Natrium Infrastructure Reuse: Meteorological Tower and Water Supply*. TerraPower. 2022. https://www.nrc.gov/docs/ML2208/ML22082A222.pdf

4. *MMR Energy System*. Ultra Safe Nuclear. 2023. https://www.usnc.com/mmr/

5. *Executive Summary of the Evinci Micro-Reactor Deployment in Mining and Remote Canadian Communities Feasibility Study.* Westinhouse and Bruce Power. October 2021. http://brucepower.com/wp-content/uploads/2021/10/210283A_WestinghouseBPMicroReactor_ExecutiveSummary_R000.pdf

6. *ARIS*. International Atomic Energy Agency. https://aris.iaea.org/sites/overview.html

7. *BWRX-300*. GE Hitachi. 2023. https://nuclear.gepower.com/build-a-plant/products/nuclear-power-plants-overview/bwrx-300

8. D. Yurman "TerraPower and Pacific Corp Lay in Plans for Five New Natrium Reactors to Replace Fossil Fuel Power Plants." Neutron Bytes. October 30, 2022. https://neutronbytes.com/2022/10/30/terrapower-and-pacific-corp-lay-in-plans-for-five-new-natrium-reactors-to-replace-fossil-fuel-power-plants/

9. *Natrium*. U.S. Nuclear Regulatory Comission. Updated April 06, 2023. https://www.nrc.gov/reactors/new-reactors/advanced/licensing-activities/pre-application-activities/natrium.html

10. *Demonstrating the Natrium Reactor and Integrated Energy System.* TerraPower. 2023. https://www.terrapower.com/wp-content/uploads/2023/03/TP_2023_Natrium_Technology-0215.pdf

11. *NRC Certifies First U.S. Small Modular Reactor Design*. Office of Nuclear Energy. January 20, 2023. https://www.energy.gov/ne/articles/nrc-certifies-first-us-small-modular-reactor-design

12. *NuScale Projects*. NuScale. https://www.nuscalepower.com/en/projects

13. *Reactor: XE-100*. X-Energy. 2023. https://x-energy.com/reactors/xe-100

14. *X-Energy Completes $40 Million Project to Further Develop High-Temperature Gas Reactor*. Office of Nuclear Energy. August 23, 2022. https://www.energy.gov/ne/articles/x-energy-completes-40-million-project-further-develop-high-temperature-gas-reactor

15. *Xe-100*. U.S. Nuclear Regulatory Comission. Updated March 27, 2023. https://www.nrc.gov/reactors/new-reactors/advanced/licensing-activities/pre-application-activities/xe-100.html

16. *BWXT to Build First Advanced Microreactor in United States*. BWXT Technologies. June 9, 2022. https://www.bwxt.com/news/2022/06/09/BWXT-to-Build-First-Advanced-Microreactor-in-United-States

17. J. Waksmanm, "*Project Pele Overview: Mobile Nuclear Power for Future DoD Needs.*" March 2020. https://gain.inl.gov/GAINEPRINEI_MicroreactorProgramVirtualWorkshopPres/Day-2%20Presentations/Day-2-am.02-Nichols_PeleProgOverviewPublicMarch2020,19Aug2020.pdf

18. D. Dalton, "Urenco to Provide Enriched Uranium for Ultra Safe's MMR." Nucnet. March 3, 2023. https://www.nucnet.org/news/urenco-to-provide-enriched-uranium-for-ultra-safe-s-mmr-3-5-2023

19. "Illinois Microreactor Demonstration Project." University of Illinois Urbana-Champaign. https://npre.illinois.edu/about/illinois-microreactor-project?ref=usnc.com

20. *MMR Energy System*. Ultra Safe Nuclear. 2023. https://www.usnc.com/mmr/

21. *eVinci Microreactor Team Closes Out 2022 with Milestone Achievement*. Westinghouse Electric Company. January 27, 2023. https://info.westinghousenuclear.com/blog/evinci-microreactor-team-closes-out-2022-with-milestone-achievement

22. *eVinci*. U.S. Nuclear Regulatory Comission. Updated April 10, 2023. https://www.nrc.gov/reactors/new-reactors/advanced/licensing-activities/pre-application-activities/evinci.html

23. A, Maioli, H. Detar, R. Haessler, B. Friedman, C. Belovesick, J. Scobel, S. Kinnas, M. Smith, J. van Wyk, K. Fleming. *Modernization of Technical Requirements for Licensing of Advanced Non-Light Water Reactors: Westinghouse eVinci Micro-Reactor Licensing Modernization Project Demonstration.* August 2019. https://www.nrc.gov/docs/ML1922/ML19227A322.pdf

24. *eVinci Microreactor*, Westinghouse, 2023. https://www.westinghousenuclear.com/energy-systems/evinci-microreactor

25. A. W. Herron. "Westinghouse and Penn State to Explore Advancing Sustainable Micro-Reactors." Pennsylvania State University. May 19, 2022.

26. *NUREG-1555, Draft Revision 1, Standard Review Plans for Environmental Reviews for Nuclear Power Plants: Environmental Standard Review Plan*. U.S. Nuclear Regulatory Comission. July 2007. Retrieved from US NRC Web site: https://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1555/updates.html

27. *Regulatory Guide 4.2, Revision 3, Preparation of Environmental Reports*. U.S. Nuclear Regulatory Comission. September 2018. Retrieved from US NRC Web site: https://www.nrc.gov/docs/ML1807/ML18071A400.pdf

28. *Environmental Impact Statement for Kingston Fossil Plant Retirement*. Federal Register The Daily Journal of The United States Government. June 15, 2021. https://www.federalregister.gov/documents/2021/06/15/2021-12693/environmental-impact-statement-for-kingston-fossil-plant-retirement

29. *Kingston Fossil Plant*. Tennessee Valley Authority. https://www.tva.com/energy/our-power-system/coal/kingston-fossil-plant

30. *GEH BWRX-300*. U.S. Nuclear Regulatory Comission. Updated September 21, 2022. https://www.nrc.gov/reactors/new-reactors/smr/licensing-activities/pre-application-activities/bwrx-300.html

31. *Tennessee Valley Authority, Ontario Power Generation, and Synthos Green Energy Invest in Development of GE Hitachi Small Modular Reactor Technology*. Tennassee Valley Authority. March 23, 2023. https://www.tva.com/newsroom/press-releases/tennessee-valley-authority-ontario-power-generation-and-synthos-green-energy-invest-in-development-of-ge-hitachi-small-modular-reactor-technology

32. *Wyoming Site Chosen for Natrium Plant*. World Nuclear News. November 17, 2021. https://www.world-nuclear-news.org/Articles/Wyoming-site-chosen-for-Natrium-plant

33. *Natrium*. U.S. Nuclear Regulatory Comission. Updated April 06, 2023 https://www.nrc.gov/reactors/new-reactors/advanced/licensing-activities/pre-application-activities/natrium.html

34. *The Demonstration Project*. Natrium. https://natriumpower.com/wyoming/#:~:text=TerraPower%20is%20working%20to%20advance,coal%20plant%20in%20Kemmerer%2C%20Wyoming.

35. *Regulatory Guide 4.7, Revision 3, General Site Suitability Criteria for Nuclear Power Stations*. U.S. Nuclear Regulatory Comission. March 2014. Retrieved from US NRC Web site: https://www.nrc.gov/docs/ML1218/ML12188A053.pdf

36. *US Code of Federal Regulations*, "Domestic Licensing of Production and Utilization Facilities," Appendix A, "General Design Criteria for Nuclear Power Plants," Part 50, Title 10, "Energy."

37. *US Code of Federal Regulations*, Title 40, "Protection of the Environment," Parts 1500–1508, "Regulations for Implementing NEPA," Council on Environmental Quality, Washington DC.

38. *US Code of Federal Regulations*, "Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions," Part 51, Title 10, "Energy.

39. *US Code of Federal Regulations*, "Licenses, Certifications, and Approvals for Nuclear Power Plants," Part 52, Title 10, "Energy."

40. *US Code of Federal Regulations*, "Reactor Site Criteria," Part 100, Title 10 "Energy."

41. *Regulatory Guide 1.206, Combined License Applications for Nuclear Power Plants*. U.S. Nuclear Regulatory Commission. June 2007. Retrieved from US NRC Web site: https://www.nrc.gov/reading-rm/doc-collections/reg-guides/power-reactors/rg/01-206/index.html

42. *Ultimate Heat Sink for Nuclear Power Plants*, Washington, DC. U.S. Nuclear Regulatory Commission. November 2015. Retrieved from US NRC Web site: https://www.nrc.gov/docs/ML1410/ML14107A411.pdf

43. *US Code of Federal Regulations*, Title 40, "Protection of the Environment Part 122, "EPA Administered Permit Programs: The National Pollutant Discharge Elimination System," US Environmental Protection Agency, Washington, DC.

44. *US Code of Federal Regulations*, Title 40, "Protection of the Environment, Part 423, "Steam Electric Power Generating Point Source Category," US Environmental Protection Agency, Washington, DC.

45. *Design Basis Floods for Nuclear Power Plants*. U.S. Nuclear Regulatory Commission. February 2022. https://www.nrc.gov/docs/ML1928/ML19289E561.pdf

46. *Criteria for Preparation and Evaluation of Radiological Emergency Plans and Preparedness in Support of Nuclear Power Plants: Criteria for Emergency Planning in an Early Site Permit Application*. NRC, NUREG-0654, Supplement 2, ADAMS Accession No. ML050130188. https://www.nrc.gov/docs/ML0501/ML050130188.pdf

47. *Criteria for Development of Evacuation Time Estimate Studies*. U.S. Nuclear Regulatory Commission. February 2021. NUREG/CR-7002, Revision 1, Retrieved from NRC Web site: https://www.nrc.gov/docs/ML2101/ML21013A504.pdf

48. *Regulatory Guide 1.23: Meteorological Monitoring Programs for Nuclear Power Plants*. U.S. Nuclear Regulatory Commission, Washington, DC.

49. L. Aller T. Bennet, J. H. Lehr, R. J. Petty, G. Hackett. "DRASTIC: A Standardized System for Evaluating Ground Water Pollution Potential Using Hydrogeologic Settings," US EPA Report 600/287/035, US Environmental Protection Agency. 1987. https://cfpub.epa.gov/si/si_public_record_Report.cfm?Lab=ORD&dirEntryID=35474

50. *Standard Review Plan (SRP) for the review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition*. U.S. Nuclear Regulatory Commission, NUREG-0800. Washington, DC.

51. *Executive Order 11990--Protection of wetlands*. Office of the Federal Register (OFR). Reviewed August 15, 2016. https://www.archives.gov/federal-register/codification/executive-order/11990.html

52. *Regulatory Guide 4.7: General Site Suitability Criteria For Nuclear Power Plants*. US NRC. November 1975 Rev 1. https://www.nrc.gov/docs/ML1303/ML13038A109.pdf

53. T. Lawson (LENOWISCO) email to J. Koza-Reinders (DEI) on March 31, 2023. IC-203-2301-00-03.

54. *Regulatory Review of Micro-Reactors – Initial Considerations*. U.S. Nuclear Regulatory Commission. February 5, 2020. https://www.nrc.gov/docs/ML2004/ML20044E249.pdf

55. Pub. L. 117–58, 117th Congress. H.R. 3684. 135 STAT. 429. November 15, 2021. https://www.congress.gov/117/plaws/publ58/PLAW-117publ58.pdf

56. Pub. L. 116–260, div. Z, title VIII, § 8011, Dec. 27, 2020, 134 Stat. 2589. https://www.law.cornell.edu/uscode/text/42/17392

57. *Building a Clean Energy Economy: A Guidebook to the Inflation Reduction Act's Investments in Clean Energy and Climate Action, Version 2*. The White House. cleanenergy.gov. January 2023.

58. *Pathways to Commercial Liftoff: Advanced Nuclear*. Department of Energy. March 2023. https://liftoff.energy.gov/

59. S. Patel, "Novel UAMPS-NuScale SMR Nuclear Project Gains Participant Approval to Proceed to Next Phase." Power Magazine. March 2, 2023. https://www.powermag.com/novel-uamps-nuscale-smr-nuclear-project-gains-participant-approval-to-proceed-to-next-phase/?oly_enc_id=0674A8248356A9J

60. *Prevailing Wage and Apprenticeship Initial Guidance Under Section 45(b)(6)(B)(ii) and Other Substantially Similar Provisions*. Internal Revenue Service. November 30, 2022. https://www.federalregister.gov/documents/2022/11/30/2022-26108/prevailing-wage-and-apprenticeship-initial-guidance-under-section-45b6bii-and-other-substantially

61. *Abandoned Mine Land Economic Revitalization (AMLER) Program*. US Department of the Interior Office of Surface Mining Reclamation and Enforcement. https://www.osmre.gov/programs/reclaiming-abandoned-mine-lands/amler

62. *Abandoned Mine Land Economic Revitalization Program*. Virginia Energy. https://energy.virginia.gov/coal/mined-land-repurposing/AMLER.shtml

63. *Opportunity Zones*. Virginia DHCD. https://www.dhcd.virginia.gov/opportunity-zones-oz

64. *Regional & Local Assistance Tobacco Region Opportunity Fund (TROF)*. VEDP Virginia Economic Development Partnership. https://www.vedp.org/incentive/tobacco-region-opportunity-fund-trof

65. *Discretionary Incentives: Commonwealth's Development Opportunity Fund (COF)*. VEDP, Virginia Economic Development Partnership. https://www.vedp.org/incentive/commonwealths-development-opportunity-fund-cof

66. *Electric Sales, Revenue, and Average Price*. U.S. Energy Information Administration. October 6, 2022. https://www.eia.gov/electricity/sales_revenue_price/index.php https://www.eia.gov/electricity/sales_revenue_price/pdf/table10.pdf

67. PJM Load Forecast Report, January 2023. https://www.pjm.com/-/media/library/reports-notices/load-forecast/2023-load-report.ashx

68. *US Energy Information Administration, Form EIA-923, Power Plant Operations Report; US Energy Information Administration, Form EIA-860, 'Annual Electric Generator Report' and Form EIA-860M, 'Monthly Update to the Annual Electric Generator Report.'* Retrieved from EIA Web site: https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_6_07_b

69. R. K. Hill, OnPoint Development Strategies LLC. "Project Oasis Market Analysis for Data Center Investment in Southwest Virginia." September 2020.

70. *Economics of Nuclear Power*. World Nuclear Association. August 2022. https://world-nuclear.org/information-library/economic-aspects/economics-of-nuclear-power.aspx

71. D. Schlissel, "Eye-popping new cost estimates released for NuScale small modular reactor." Institute for Energy Economics and Financial Analysis. January 11, 2023. https://ieefa.org/resources/eye-popping-new-cost-estimates-released-nuscale-small-modular-reactor#:~:text=Key%20Findings,(SMR)%20have%20risen%20dramatically.&text=As%20recently%20as%20mid-2021,MWh%2C%20a%2053%25%20increase.

72. *Electric generators' Roles Vary Due to Daily and Seasonal Variation in Demand*. EIA. June 8, 2011. https://www.eia.gov/todayinenergy/detail.php?id=1710#:~:text=As%20demand%20varies%20over%20the,electricity%20systems%20meet%20peak%20demand

73. *PJM 2022 Regional Transmission Expansion Plan.* March 14, 2023. https://www.pjm.com/-/media/library/reports-notices/2022-rtep/2022-rtep-report.ashx

74. *Submission of Supplemental Projects for Inclusion in the Local Plan*. American Electric Power. February 2, 2023. https://pjm.com/-/media/committees-groups/committees/srrtep-w/postings/2022/aep-local-plan-submission-of-the-supplemental-projects-for-2022-rtep.ashx

75. *PJM Manual 14A: New Services Request Process Revision: 29*. PJM Interconnections Project Department. August 24, 2021. https://www.pjm.com/-/media/documents/manuals/m14a.ashx

76. *Virginia Electric and Power Company 2022 Update to the 2020 Integrated Resource Plan. Dominion Energy*. Case No. PUR-2022-00147 and Docket No. E-100, Sub 182. September 1, 2022.

77. *Nuclear Energy: Clean, reliable energy available 24/7*. Dominion Energy. https://www.dominionenergy.com/projects-and-facilities/nuclear-facilities/nuclear-energy

78. J. K. Hansen, W. D. Jenson, A. M. Wrobel, K. Biegel, T.K. Kim, R. Belles & F. Omitaomu. *Investigating Benefits and Challenges of Converting Retiring Coal Plants Into Nuclear Plants*. United States. https://doi.org/10.2172/1886660

79. G. W. Griffith, "Transitioning Coal Power Plants to Nuclear Power." 2021. Retrieved from United States: https://www.osti.gov/biblio/1843924

80. *Application of Virginia Electric and Power Company, for revision of rate adjustment clause: Rider s, Virginia city Hybrid Energy Center for the Rate Years Commencing April 1, 2022 and April 1, 2023*. Virginia State Corporation Commission Case Number PUR-2021-00114. November 9, 2022.

81. *Advanced Nuclear Technology: Economic-Based Research and Development Roadmap for Nuclear Power Plant Construction.* EPRI, Palo Alto, CA: 2019. 3002015935.

82. P. A. Chaplin, "Techno-Economic Evaluation of Cross-Cutting Technologies for Cost Reduction in Nuclear Power Plants", Master's Thesis Massachusetts Institute of Technology. June 2018. https://dspace.mit.edu/bitstream/handle/1721.1/119044/1059517934-MIT.pdf?sequence=1

83. E. Ingersoll, "Economic Perspective – UK ETI Nuclear Cost Drivers Project. Presentation at EPRI/GAIN/NEI Workshop on Economics-Based R&D for Nuclear Power Construction." Washington, D.C. January 2019.

84. G. Harki. "Surry Nuclear Power Plant: A Look Inside." The Virginian Pilot, 8 Aug. 2019, https://www.pilotonline.com/news/environment/article_c6e8b31b-0db7-537c-ba96-7f93957265d8.html.

85. Nuclear Education and Training: From Concern to Capability. Nuclear Energy Agency, 2012. https://www.oecd-nea.org/upload/docs/application/pdf/2019-12/6979-nuclear-education.pdf

A COMMUNITY ENGAGEMENT QUESTIONNAIRE RESULTS

The industry questionnaire contained a total of twelve questions [53]. The results of the survey are listed below. In total, there were ten respondents.

1. Do you believe that energy policies should consider nuclear energy as one of many energy sources to provide electricity?

– Yes 100%
– No
– Unsure

2. How familiar are you with presently published energy policies and legislation?

– Not familiar 10%
– Somewhat Familiar 50%
– Very Familiar 40%

3. Would you prefer to be engaged and informed on presently published energy policies and legislation?

– Yes 100%
– No 0%

4. If you answered yes to the above, who do you feel could/would best provide the public information related to presently published energy policies and legislation?

– Commonwealth of Virginia's Department of Virginia Energy 80%
– Independent 3rd Party Consultants 10%
– Other Governmental Agencies 0%
– Utilities or Nuclear Energy Developers 0%
– Other (please specify whom) 10%
– Other responses: Nuclear Regulatory Commission; National Academies of Science and Engineering- Committee on Advanced Nuclear Technologies

5. Would you support additional studies to determine the feasibility of utilizing Small Modular Reactors (SMRs) in the coalfields of Southwest Virginia if the new technologies receive approvals by the United States Nuclear Regulatory Commission?

– Yes 90%
– No 0%
– Unsure 10%

6. Do you have suggestions as to other community leaders and organizations whose input should be sought for future input? If so, please specify whom:

– Local economic developers, community colleges, SWVA Energy R&D Authority, InvestSWVA and Energy DELTA Lab
– Local Economic Developers, Invest SWVA, other stakeholders
– The possible siting, development, and operation of smrs will have very long-term implications for the citizens of southwest Virginia. As such, it is critical to solicit meaningful input from a diverse spectrum of organized stakeholder groups as well as individual citizens. The overall goal should be to share information equitably and solicit input from diverse people, voices, and ideas. This can help lay the groundwork for creating a well informed and engaged community that understands the issue and can have a meaningful degree of influence on decisions made.
– Recommend broad public outreach including presentations to Kiwanis, Rotary, etc.
– InvestSWVA/SWVA R&D Energy Authority
– VNEC and VNECA

7. Who do you feel could/would best provide public information related to Small Modular Reactor development in the coalfields of Southwest Virginia? Please check all that apply:

– Independent 3rd Party Consultants	22%
– Commonwealth of Virginia's Department of Virginia Energy	44%
– Other Governmental Agencies	11%
– Other (please specify whom)	22%

– Other responses:
· Nuclear Regulatory Commission; National Academies of Science and Engineering-Committee on Advanced Nuclear Technologies
· Those advancing SMRs and related technologies in other countries
· InvestSWVA/SWVA R&D Energy Authority
· VNEC

8. How would you prefer to be engaged and informed pertaining to the technological development of Small Modular Reactor(s) in the coalfields of Southwest Virginia?"

– Community Forums/Meetings (Held In-Person and/or virtually)	50%
– Stakeholder Panels (Held In-Person and/or virtually)	40%
– Community Fact Sheets (Disseminated via Email)	10%

9. Who do you feel would best be positioned to facilitate community informational meetings related to the development of Small Modular Reactors (SMRs) in the coalfields of Southwest Virginia?

– Commonwealth of Virginia's Department of Virginia Energy	70%
– Independent 3rd Party Consultants	10%
– Other Governmental Agencies	0%
– Utilities or Nuclear Energy Developers	0%
– Other (please specify whom)	20%

– Other responses:

- A professional and unbiased facilitation group from academia or elsewhere that does not have a stake in the outcome of the decision regarding whether or not to pursue SMR technologies in Southwest VA.
- VNEC

10. What future topics should be included in subsequent Small Modular Reactor feasibility reviews? Please provide responses below:

- Supply chain opportunities and related workforce development/training needs
- Water use and water quality, land use change/compatibility with local comprehensive plans, land stability and siting criteria, on-site storage and management of waste, safety/risk management, community benefits, environmental justice.
- Long term impacts, risks, benefits
- The public education component is the most important
- Safety and fuel disposal (SNF)

11. What additional methods of community education and involvement would you suggest be utilized throughout this process?

- Community meetings where information is presented by someone other than the local reps from the county.
- Aggressive digital media campaign (website and social media, including paid media)
- We encourage utilization of a variety of tools in the effort to share information and solicit meaningful public input including but not limited to phone and mail surveys, community focus groups, facilitated community input sessions, public forums, etc. speakers, public awareness campaigns.
- Public tv or radio spots with information
- Statewide Education Consultants

12. What other comments might you wish to include below:

- Agree that to have reliant affordable energy we must look at all options