Small Modular Reactors:
Adding to Resilience at Federal Facilities

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The views and assumptions described in this report are those of the authors. This Report does not represent the views of DOE, and no official endorsement should be inferred. Additionally, this Report is not intended to provide legal advice, and readers are encouraged to consult with an attorney familiar with the applicable federal and state requirements prior to entering into any agreements for the purchase of power. TVA's decisions regarding power assets are subject to management recommendation and TVA Board of Director's approval, and are based on a number of strategic considerations, including expected power demand, least cost planning requirements, financial flexibility, and consistency with integrated resource planning.

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SMALL MODULAR REACTORS: ADDING TO RESILIENCE AT FEDERAL FACILITIES

CONTENTS

APPENDICES

FIGURES

EXECUTIVE SUMMARY

Small Modular Reactors: Adding to Resilience at Federal Facilities (this "Report") expands on the January 2017 report entitled *Purchasing Power Produced by Small Modular Reactors: Federal Agency Options* (the "Initial Report").[1] The Initial Report focused on assisting federal agencies to identify options to participate in the purchase of power produced by small modular reactors ("SMRs"), the structure and issues with financing an SMR, and the unique issues that federal agencies face when making power purchase decisions. The Initial Report identified how federal agencies can purchase SMR-produced power through long-term agreements (over thirty (30) years) by using the Utah Associated Municipal Power Systems ("UAMPS") SMR project as an example.

SMRs are designed to provide valuable resilience services as a secure, reliable, and flexible source of primary and backup power. SMRs, coupled with transmission hardening, could provide highly reliable, non-intermittent, clean, and carbon-free power. SMRs can also easily store two years' worth of fuel on-site. Certain SMR designs allow for output to be varied over days, hours, or minutes, thereby enabling the SMR to ramp up quickly in the case of a grid outage and adjust to be in line with changing load demands.

This Report identifies the need for energy resilience and how an SMR can provide such a service for federal agencies. As an illustrative example, this Report focuses on the SMR project being developed by the Tennessee Valley Authority ("TVA") in Oak Ridge, Tennessee on a site adjacent to critical U.S. Department of Energy ("DOE") and National Nuclear Security Administration ("NNSA")[2] facilities (referred to herein as the Oak Ridge Reservation).

ENERGY RESILIENCE

Energy resilience is the ability to prepare for and recover from energy disruptions such as extreme weather events, physical attacks, cyber-attacks, and electromagnetic interference. Resilient power systems minimize the effect of such failures, which DOE estimates cost U.S. businesses approximately $150 billion per year.[3] Having a resilient power source during a power outage can save billions of dollars, maintain critical services, and protect lives.

Governmental entities are increasingly focusing on energy resilience through the passage of legislation, issuance of executive directives, the purchasing of resilient energy sources, and the commissioning of research like the DOE's August 2017 Staff Report on Electricity Markets and Reliability. This year Congress is requiring that, "The Secretary of Defense shall ensure the readiness of the armed forces for their military missions by pursuing energy security and energy resilience. In fact, the Fiscal Year 2018 National

Defense Authorization Act ("NDAA") includes a new section on energy "resilience" for military bases which sets requirement for the military and defines energy resilience.[4] U.S. military and other national defense facilities (such as DOE's laboratories and weapons facilities) have made energy resilience a key operational priority and are actively procuring backup power at military bases.

The Fiscal Year 18 NDAA defines "energy resilience" as "the ability to avoid or prepare for, minimize, adapt to, and recover from anticipated and unanticipated energy disruptions in order to ensure energy availability and resiliency sufficient to provide for mission assurance and readiness, including task critical assets and other mission essential operations related to readiness and to execute and rapidly reestablish mission essential requirements"

Energy resilience for individual facilities requires power generation and delivery capabilities that can be accessed in the event of a grid outage. This typically entails investing in backup power supply systems which can be activated when the grid goes down. In some cases, backup power may be provided by installing a "behind the meter" on-site power source that provides power to the grid during normal circumstances but can also be isolated from the grid through "islanding" during grid failures. Both options incur additional costs borne by the single beneficiary of the backup power. Common methods for energy resilience include installing generators and/or microgrids, improving cybersecurity, and physical site hardening.

Investing in Energy Resilience

Investing in energy resilience can present a cost recovery challenge, since backup power is not used in normal circumstances, and, preferably, never used. Investing in resilience requires capital and maintenance expenditures for assets which may largely sit idle; thus, routes to cost recovery are not as clear as for normal power generation, which sells power on a regular basis. When making an investment decision for resilience, energy users generally seek options that provide acceptable levels of reliability for critical loads throughout the requisite time period at the least cost.

Many industries, such as large technology companies, hospitals, and universities, rely on on-site backup generation. The United States military typically buys its day-to-day power off-site (from a utility) and uses stand-alone backup generators during outages. The fact that organizations are willing to spend money on energy security implies that resilience has a value. The "resilience premium" as noted in this Report reflects the extra benefit of backup power as compared to the status quo option.

As large computer systems and data centers increase their importance to national security, the need for resilience for large facilities increases. However, it can become unrealistic to buy and maintain many diesel generators and fuel oil storage tanks at some of the facilities.

TVA's Clinch River Site SMR Project

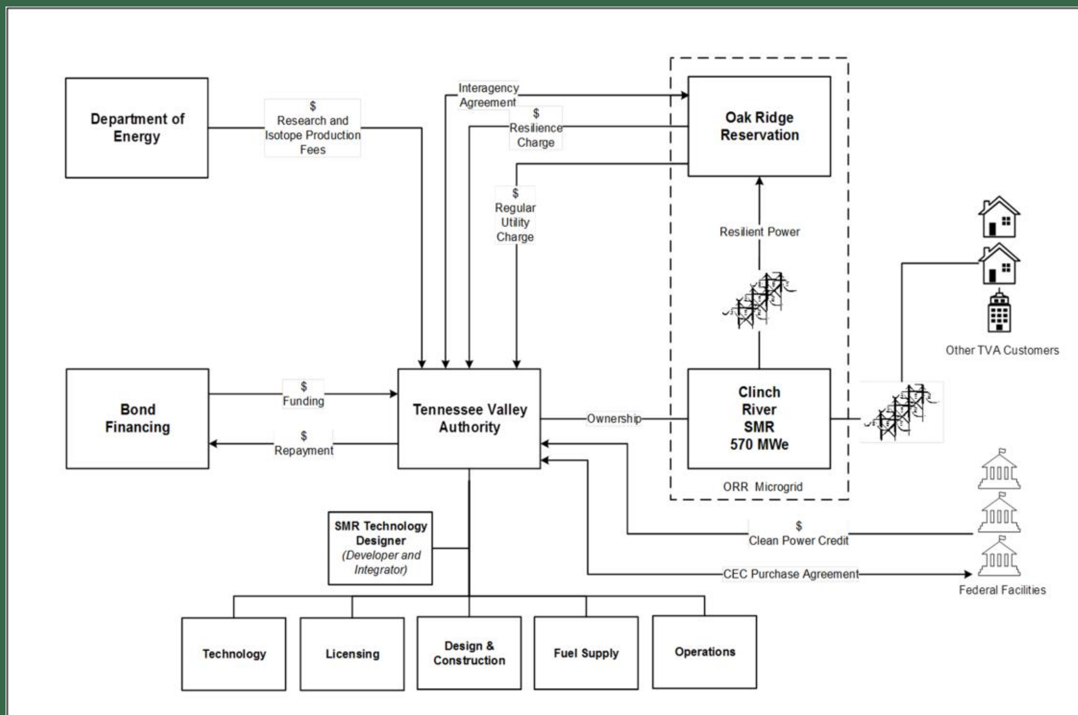
TVA is the nation's largest government-owned power provider.[5] On February 17, 2016, DOE requested TVA consider the work and potential impacts from supplying enhanced reliability to DOE's facilities through the potential deployment of SMRs and associated transmission system features to the Oak Ridge Reservation. As the largest DOE science and energy laboratory, the Oak Ridge National Laboratory ("ORNL") is the greatest consumer of electricity among the DOE's sites and has many facilities that require a continuous energy supply to safeguard analytical results and machines. The Y-12 National Security Complex has been described by DOE as one of the most important national security assets, because it houses the U.S. stockpile of highly enriched uranium, which is necessary for nuclear reactions.[6]

In response to such request, TVA is exploring the inclusion of an SMR as a power source within TVA's inventory that can be used to provide electric power resilience to the Oak Ridge Reservation and other potential uses (including research and isotope production use). TVA has identified the site for one or more SMRs on the Clinch River (the "Clinch River Site"), which is owned and controlled by TVA and is located next to ORNL in Oak Ridge, Tennessee.

TVA is currently working on the Nuclear Regulatory Commission ("NRC") permitting process for developing two or more SMRs on the Clinch River Site. In its Early Site Permit Application, TVA considered the environmental impacts associated with potential deployment of an underground transmission line from the SMR to the Bethel Valley substation at ORNL, which would make the transmission less vulnerable to weather events and intentional destructive acts. The proximity of the Clinch River Site to the Oak Ridge Reservation offers a unique opportunity to provide energy security for functions critical to national security.

DOE and TVA could use the existing Power Supply Agreement for the provision of SMR-produced power and services to the Oak Ridge Reservation. Alternatively, TVA and DOE may use the authority in the Atomic Energy Act which authorizes DOE to enter into contracts for electric services for up to 25 years; [7] however, such contract may be for a maximum of 20 years under TVA's existing authority.[8] The following figure shows an illustrative transaction structure for this Project:

Figure 1: Illustrative Transaction Structure for the Project



Given the load characteristics of the Oak Ridge Reservation and its proximity to the Clinch River Site, an SMR could be configured to allow the Oak Ridge Reservation to operate in an islanded mode during periods of grid outages. Additionally, the power plant's configuration would allow the SMR to provide black start capability.

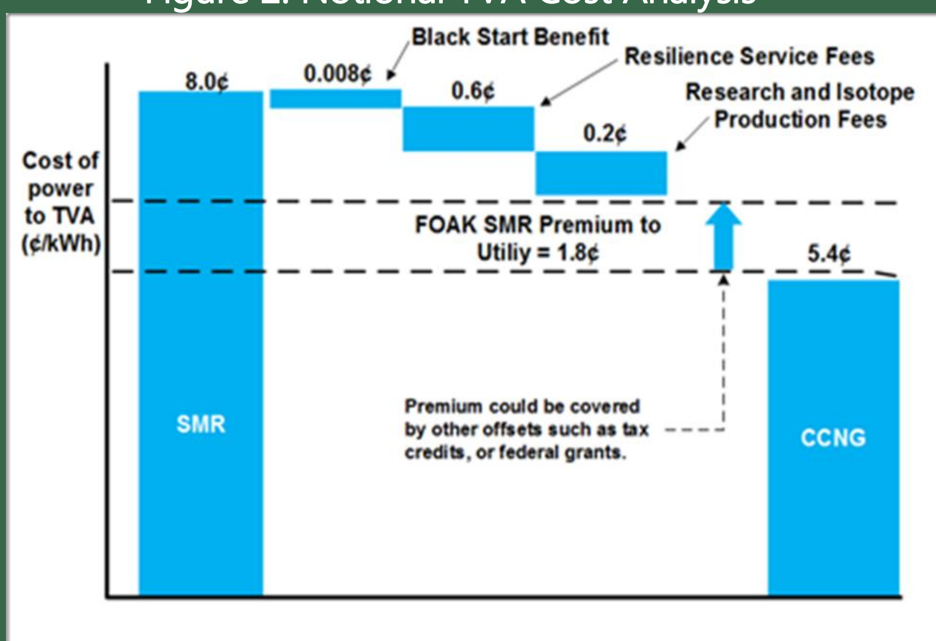
The most likely method for financing this Project is for TVA to finance the Project as a corporate undertaking. Under a corporate borrowing structure, the SMR would be one of TVA's grid assets, and their installation costs would be recovered through utility cost-of-service principles, whereby revenue requirements would reflect cost drivers specific to each class of customers.

The Project's financial structure benefits greatly from being on TVA's balance sheet. As a corporate undertaking of TVA, credit will be supported by TVA's corporate revenue and assets. TVA is a long-standing bond issuer with investment-grade ratings from the three major credit agencies. This will ease access to finance and lower interest rates (cost of borrowing), as compared to a project financing. Since TVA generates revenue from a portfolio of power plants, the technology risk inherent in the novelty of SMR technology is substantially mitigated.

Constructing an SMR at the Clinch River Site as TVA's generating asset with special resilience services to the Oak Ridge Reservation would require a contractual arrangement between TVA and DOE (acting on behalf of the Oak Ridge Reservation) that allows for costs associated with the SMRs to be assessed to DOE over a long period of time. This would serve to offset any cost premium of first-of-a-kind ("FOAK") SMRs, a key consideration for TVA as it seeks to avoid investments in generating assets that introduce added costs to its ratepayers.

As the Oak Ridge Reservation would be the predominant beneficiary of the resilience benefit of the SMR, TVA would require the federal government to fund the incremental costs associated with the plant's increased resilience (as this burden should not be borne by TVA's other ratepayers). This would include the cost of incremental transmission infrastructure, switchgear, and cost premiums associated with the SMR relative to alternative electric generation technologies. Given the extra value of resilient baseload electric service, a resilience premium paid by the Oak Ridge Reservation could help to offset the incremental additional expense of power provided by SMRs with microgrid features. Additional services may be provided by the SMR to offset the cost premium, such as setting aside one or more reactor modules for research or production of isotopes by DOE. Figure 2 includes a notional cost analysis from TVA's perspective which shows how the levelized cost of energy of the SMR could be offset in several ways.

Figure 2: Notional TVA Cost Analysis



Recommendations to Advance the Deployment of Small Modular Reactors

There are many ways the federal government can assist with making the financing and development of SMRs easier – both in its role as a customer and as a governing body – such as:

1. Permit federal agencies to enter into agreements with a term of up to 30 years to purchase power produced by SMRs;
2. Facilitate TVA's Clinch River Site project as a pilot project for SMRs, while simultaneously providing DOE with critical energy resilience and a potential opportunity to conduct research and isotope services;
3. Extend the 2005 Energy Policy Act Production Tax Credits and allow applicability to public power entities;
4. Authorize the DOE Loan Program to continue to support advanced reactors;
5. Include nuclear power in the definition of "clean power," and if EPA's Clean Power Plan continues, add a rule that encourages states to support SMRs giving them credit for the zero-carbon energy; and
6. DOE and DOD should collaborate to identify facilities that can benefit from hosting or having an SMR located near the facility to achieve added energy resilience.

Report Structure

This Report begins with an exploration of the interconnectedness of power systems, the benefits and opportunities offered by SMRs, and government actions to encourage the development of SMRs (Chapter 1). Next, the Report summarizes the many threats to the United States power systems and identifies why energy resilience is important and a focus of many governmental and private sector entities (Chapter 2). Key federal utility acquisition legal authorities that may be relied upon for purchasing power from an SMR are identified, as well as the rationale for a "Resilience Tariff" (Chapter 3). The Report then presents cost reduction tools for innovation nuclear power projects, such as tax incentives, payments for research and isotope services, and grants (Chapter 4). The Report describes the role of TVA and a potential SMR project on the Clinch River Site under consideration by TVA for the benefit of the Oak Ridge Reservation (Chapter 5). The next Chapter describes key considerations for the Clinch River Site SMR Project and identifies an illustrative transaction structure which entails DOE paying for the incremental cost of an SMR over other power sources because of certain services (black start benefit, resilience, and research and isotope production fees) that will be offered to the Oak Ridge Reservation through this Project (Chapter 6). Finally, the Report concludes with recommendations that, along with the potential solutions described elsewhere in this

Report, may be considered to assist with overcoming these challenges and advance the deployment of SMRs in the United States (Chapter 7).

CHAPTER 1:
INTRODUCTION AND BACKGROUND

1.1 Initial Report

In January 2017, Kutak Rock LLP and Scully Capital Services, Inc. published a report entitled *Purchasing Power Produced by Small Modular Reactors: Federal Agency Options* (the "Initial Report").[9]

The Initial Report provided guidance to federal agencies on procuring power generated by small modular reactors ("SMRs") in accordance with existing federal authorities. Amongst other topics, the Initial Report described power supply options for federal customers, financing considerations for energy projects, the legal authorities enabling federal agencies to purchase power, and the considerations federal agencies evaluate when making power purchase decisions. The Initial Report applied the concepts it described to the SMR project contemplated by Utah Associated Municipal Power Systems ("UAMPS") and offered a roadmap for federal agencies interested in procuring power from SMRs.

The Executive Summary of the Initial Report which outlines the issues identified above is included for reference as Appendix A.

1.2 Purpose of This Report

This Report is offered as an expansion on certain concepts presented in the Initial Report. The objectives of this Report are to:

- Identify the need for resilience and threats to the federal power systems and federal facilities;
- Identify how an SMR can add to on-site resilience and electric power reliability;
- Explore potential options for federal purchasing of power produced by the contemplated Tennessee Valley Authority ("TVA") Clinch River Site SMR project;
- Explore existing legal authorities and ways that federal agencies can "buy-down" the current cost premium associated with the commercialization of SMRs through the making of certain payments that recognize the "resilience" and "clean energy production" of SMR-produced power, as well as the ability to use an SMR to provide research reactor and isotope production; and
- Analyze the financial and financing considerations related to the siting and development of an SMR and the feasibility of leveraging federal off-take to incentivize such development.

1.3 The Small Modular Reactor Opportunity

The United States power sector will be defined in coming years by a need to increase the use of low-carbon and "clean" power while ensuring that power is provided reliably and at low cost. This is particularly relevant to baseload power. The term "baseload" refers to the minimum amount of electric power delivered or required over a given period of time at a steady rate.[10] Baseload power sources are power stations that can consistently generate the electrical power needed to satisfy this minimum demand.[11] The Energy Information Administration ("EIA") estimates that coal power output will decline by 32% from 2015 to 2040, largely due to federal targets for carbon emission reduction[12] – unless those targets are repealed. EIA expects output from nuclear generation to remain largely constant through 2040, as some older plants are retired and some new plants come online.[13] Carbon emission targets are also expected to drive growth in renewable electricity output (mostly from intermittent solar and wind plants), growing by 99% from 2015 to 2030 and by 152% from 2015 to 2040.[14]

As baseload power plants are going off-line, there is an emerging need for newly constructed power sources. Environmental considerations are driving consumers to look towards clean energy options. However, renewable power sources are not as reliable as traditional power stations, and, thus, ill-suited sources of baseload power.[15] Although natural gas power plants do release far less carbon than today's coal-heavy generation portfolio, they do nonetheless emit significant amounts.[16] Hence, there is an opportunity for an environmentally friendly, reliable, and fast-responding power source.

An SMR is defined by the International Atomic Energy Agency ("IAEA") as any reactor with an output of 300 megawatts electric ("MWe") or less,[17] comprised of components, or modules, that are factory-fabricated and transported to a nuclear power plant location for on-site assembly.[18] The definition of an SMR does not formally stipulate the design or fuel type of the reactor; light water, gas-cooled, molten salt, and liquid metal system types have appeared in different SMR designs.[19] Most SMRs share a common set of basic design characteristics that distinguish them from traditional, large-scale nuclear reactors, such as being smaller and less expensive.

Compared to certain other baseload power alternatives, SMRs may present an opportunity to reduce emissions from baseload power generation in the future, offer a more secure power source, and provide more reliable power.

1.4 Benefits Offered by Small Modular Reactors

SMRs bring certain benefits which could justify using them over other, less costly sources of baseload power in some cases. As compared to other power sources, SMRs may offer the following benefits, each of which are explained in more detail in Appendix B:

- Carbon-free baseload power
- Enhanced safety
- Modularity
- Lower total capital cost
- Scalability
- Improved energy security
- Integration of renewables
- Siting flexibility
- Small land requirements
- Process heat
- International export opportunities
- Reduced fuel risk

The following are the primary characteristics which make an SMR a resilient power source:

- Fuel Security: An SMR can easily store two years' worth of fuel on-site, and, in some cases, multiple decades' worth. Storing that much fuel on-site for a natural gas plant would be impractical and expensive, given the massive gas storage facilities which would be required. Natural gas deliveries can be subject to volatile markets and occasional shortages, especially during unusually cold winter weather.

- Ramp Up and Ramp Down: Certain SMR designs, like that of NuScale Power, LLC ("NuScale"), allow for output to be varied over days, hours, or even minutes. This feature enables an SMR to ramp up quickly in the case of a grid outage and adjust to be in line with changing load demands.

- Islanding: SMRS can operate connected to the grid or independently. If attached to a minigrid with islanding, an SMR could power a facility campus in the event of grid failure.

- Black Start: SMRs can start up from a completely de-energized state without receiving energy from the grid. This can help an electricity grid meet system requirements in terms of voltage, frequency and other attributes when recovering from an outage.

- Underground Construction: SMRs can be built underground. This would make them less vulnerable to natural phenomena, EMP, and other intentional destructive acts.

- Minimal use of Electrical Components: SMRs can be designed to minimize the use of electrically controlled and operated components (for example, using natural circulation for cooling instead of forced pumping). Using fewer electrical components reduces SMRs' vulnerability to EMP.

1.5 Government Actions to Encourage the Development of Small Modular Reactors

The federal government is supporting the development of SMRs in a number of ways. For instance, DOE has a cooperative agreement with NuScale under which NuScale will receive up to $217 million in matching funds over a five-year period to support the accelerated development of its NuScale Power Module™ SMR technology.[20] In addition, in December 2014, DOE's Title XVII loan program issued a solicitation for loan applications to finance advanced nuclear energy projects.[21] The House of Representatives passed legislation which would extend production tax credits for nuclear energy;[22] similar legislation was also introduced in the Senate.[23]

Leveraging the federal government's strong credit rating and its continual need for baseload power represents another feasible tool that could advance the development of SMRs. Federal agency purchasers can help to set the market and offer more certainty to other initial buyers. In the early stages of commercial deployment, SMRs may introduce additional costs relative to more mature technologies, and, therefore, the federal government is uniquely positioned to harness its purchasing to advance a policy objective to accelerate the commercialization of SMRs. A number of opportunities exist for the federal government to do so, such as:

- Federal Off-Take through Long-Term Purchasing Agreements: As detailed in the Initial Report, federal facilities can enter into bilateral Power Purchase Agreements ("PPAs"), Interagency Agreements, or, in the case of TVA, Power Supply Agreements, with SMR plant owners to provide assured off-take at a price sufficient to support project financing. Creditworthy commitments for off-take are an essential element of project financing, and the federal government's energy requirements and financial strength make it an ideal long-term customer of an SMR.

- Clean Energy Credits: Currently, the federal government encourages facilities to purchase Renewable Energy Certificates ("RECs") to meet clean energy requirements. Federal agencies were first ordered to use renewable energy for 7.5% of energy needs by the Energy Policy Act of 2005;[24] Executive Order 13693 later increased the requirement to 30%.[25] When direct purchases of renewable energy are impractical, RECs may present an attractive alternative for a federal agency, since RECs can be purchased from any power producer, independent of the underlying energy, and without consideration of grid constraints, state lines, or other constraints to purchases of energy.

  Clean Energy Credits ("CECs") could work in the same way – federal agencies would be required to source a percentage of their power needs from an SMR and in lieu of direct purchases could acquire CECs, the value of which would accrue to the SMR plant owner.

The State of New York recently introduced such a program and supports nuclear power through the Zero Emissions Credit ("ZEC") program. This helps subsidize the production of zero-carbon power from three nuclear power plants in New York, which would otherwise face financial challenges. The program is run by the New York State Energy Research and Development Authority ("NYSERDA") and requires utilities to purchase a specified amount of ZECs based on each utility's load.[26]

- Resilience Payments: While highly site-dependent, the operating characteristics of SMRs offer an opportunity for SMRs to be a source of highly reliable power in the event of a grid disruption. Capturing this value via a "resilience payment" represents a tool that could mobilize commercial deployment, while also addressing the existing and emerging threats to energy security.

- SMRs for Research and Isotope Production: In some instances, SMRs can be used as a research reactor for national laboratories and other federal users. In addition, isotope production can also be explored for the operation of an SMR. Each additional use would provide an additional income or funding stream to support the financing of an SMR as further explored in Section 4.2.

By pursuing one or all of the strategies summarized above, the federal government could play a critical role in facilitating the deployment of first-of-a-kind ("FOAK") SMR facilities and building the industrial ecosystem necessary to drive down costs for future users.

CHAPTER 2: THREATS TO THE FEDERAL POWER SYSTEM AND THE NEED FOR RESILIENCE

The power sector provides fundamental services for the United States government, economy, and civil society. A power grid requires many different facilities and systems to work in concert; thus, a failure in one spot can bring down the power system over a large area. Increasing recognition of the threats facing the grid, ranging from extreme weather to intentional attacks, has encouraged utility providers and users to search for ways to make the power system less vulnerable to unanticipated events.

When there is a power outage, having a resilient power source can save billions of dollars, maintain critical services, and protect lives. Energy resilience is the ability to prepare for and recover from energy disruptions. Even as technology has become more efficient and annual electricity consumption has declined,[27] the United States has been experiencing more electric outages than any other developed nation.[28] Resilient power systems minimize the effect of such failures, which DOE estimates cost U.S. businesses approximately $150 billion per year.[29]

Recognizing the importance of keeping infrastructure operational during and after emergencies, the federal government has launched various initiatives to improve energy resilience. For instance, DOE submitted a report to Congress on the value of energy resilience in January 2017, and the executive and legislative branches have taken action to protect infrastructure through measures like the 2015 Fixing America's Surface Transportation ("FAST") Act. The military is also pursuing resilience initiatives at its bases, including backup energy sources to provide power in the event of a grid outage.

This Chapter describes the interconnectedness of the United States power system, summarizes threats to the grid, identifies various resilience initiatives being undertaken by governmental and private entities, and explains how the SMR can serve as a tool for resilience.

2.1 The Interconnectedness of Power Systems

Since the earliest days of grid utilities, power systems have required that all stages of the value chain work in concert to deliver power to users. A failure in any stage of the power sector chain, whether for production or transportation, can cause the system to go down over a wide geographic area. More recently, the power system has grown increasingly interconnected, thus heightening the system's vulnerabilities. The greater integration of physical infrastructure across states and regions, which has progressed for decades to improve grid efficiency and reliability by providing additional power sources in case of spikes in demand, also increases the possibility of system failures occurring over a wider geographic area.[30]

Growth in interconnectedness has also accelerated in terms of communication and information systems from the late 1990s onwards with the advent of regional competitive markets run by Independent System Operators ("ISOs") and Regional Transmission Organizations ("RTOs").[31] ISOs and RTOs manage power markets and transmission grids and provide centralized dispatch of power plants; carrying out these activities requires interconnection of trading and control systems over large areas. ISOs and RTOs are fundamentally information technology organizations which manage communication networks between various grid stakeholders.[32]

The main stages of the power sector value chain are:

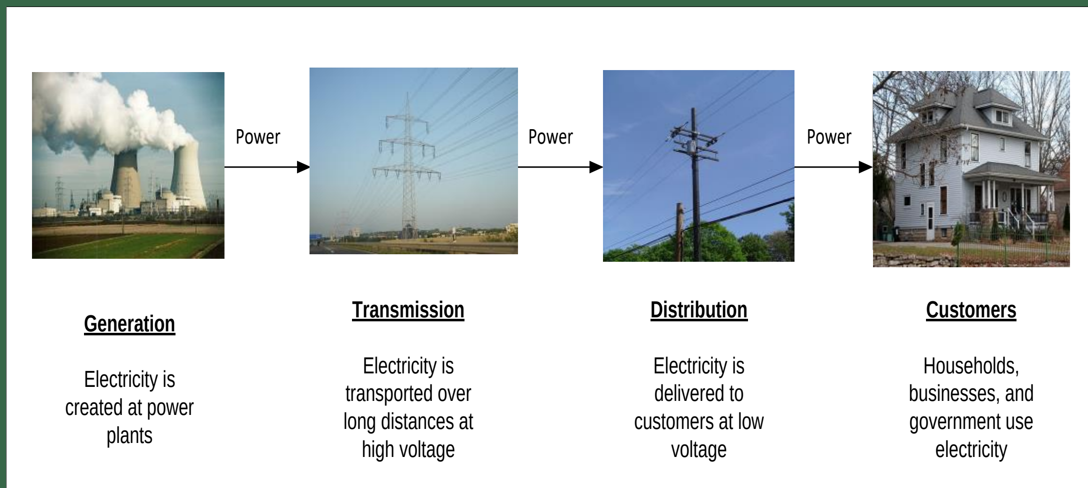
- Generation: The creation of electric power through conversion from thermal sources (such as steam or heat) or kinetic sources (such as wind or flowing water). Electricity can also be generated through electro-chemical processes, such as converting solar energy to power. Different energy sources and generation technologies have different operating characteristics which impact reliability and resilience.

- Transmission: Transmission refers to the movement of electricity over long distances through high voltage ("HV") lines. Transmission lines generally transport power from the generation sources to utilities and within and between utilities. In addition, transmission lines are important for balancing supply and demand for power, as they can be used to move power from a region with excess supply to another region with inadequate supply at a given time.

- Distribution: Distribution refers to the delivery of electricity to end users over low voltage lines. This involves the conversion of HV current to lower voltage current via transformers and the delivery of low voltage current to the end user, often referred to as a retail customer. Thus, distribution has a focus on managing billing and communications with a large group of end users.

The key components of the electricity sector are summarized in Figure 3.

Figure 3: Main Segments of the Electricity Sector



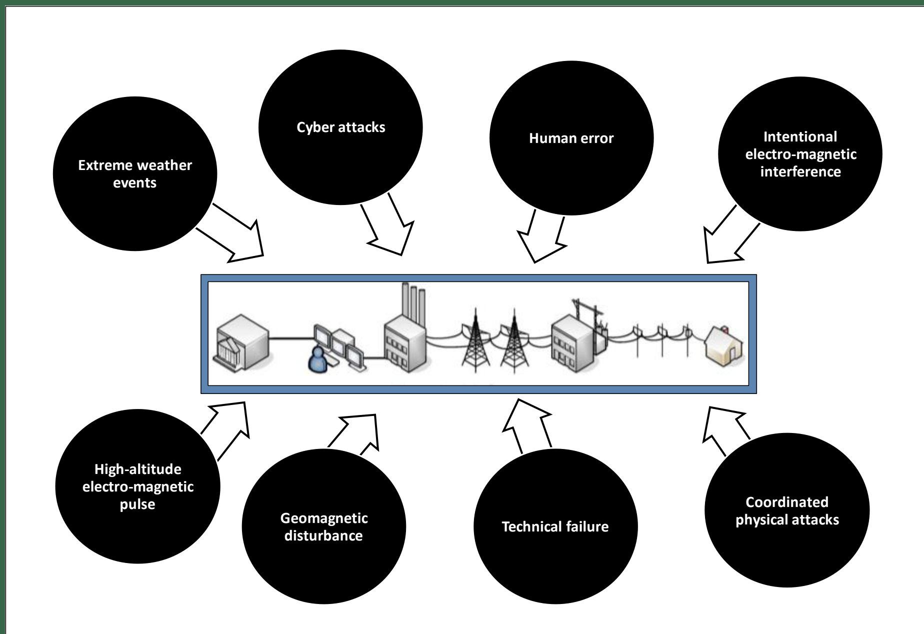
The increasing interconnectedness of the electric power system has brought added awareness of the range of threats facing the system and the need to build resilience into the system for key facilities.

2.2 Threats to United States Power Systems

While the electric grid in the United States is very reliable compared to grids in developing countries, it still experiences significant, unexpected power outages. Growing interconnectedness of the electric power sector has increased the exposure to disruptions from threats such as extreme weather events, physical attacks, cyberattacks, and electromagnetic interferences. From 2003 to 2012, an estimated 679 widespread outages occurred with costs averaging between $25 and $70 billion per year.[33] Of these outages, the cost of U.S. weather-caused outages lasting more than 5 minutes averaged $18 billion to $33 billion per year from 2003 to 2012, and those costs were dominated by 14 long-duration outages.

Potential causes of outages are shown in Figure 4 and discussed below.

Figure 4: Potential Causes of Power Outages



Extreme Weather Events

Extreme weather events are the leading cause of power outages in the United States, with weather causing 80% of all outages between 2003 and 2012.[34] Severe weather triggered an estimated 934 widespread outages between 2003 and 2016,[35] costing the U.S. economy an inflation-adjusted annual average anywhere from $13 billion to $70 billion, depending on assumptions and data.[36] These costs take various forms, including lost or delayed output and wages, spoiled inventory, and damaged infrastructure. The scientific community predicts increasingly frequent and intense hurricanes, storms, heat waves, floods, and other extreme weather events, which will lead to more frequent challenges to the power systems.[37] Already, in the decade after 2003, the average annual number of weather-related power outages has doubled,[38] and eight of the ten costliest storms in U.S. history occurred 2004 onwards.[39]

Physical Attacks

Besides natural disasters, power systems are vulnerable to attacks by deliberate malicious actors. During 2011 to 2014, 348 targeted attacks against the power grid were physical in nature.[40] There have been notable cases of domestic vandalism, theft, and tampering, such as the 2013 assault on the Metcalf substation in California which destroyed 17 transformers, costing $15.4 million worth of damages within one hour.[41] While the Metcalf attack did not cause a power outage, it did take 27 days for the substation to resume operation,[42] and the event demonstrated the grid's susceptibility to sabotage and the difficulty of replacement, particularly for components like large transformers which can take months to replace.[43]

The United States electric power grid consists of over 200,000 miles of HV transmission lines interspersed with hundreds of large electric power transformers that are potential targets.[44] Of these transformers, HV transformer units (which make up less than 3% of transformers in U.S. power substations but carry 60% to 70% of the nation's electricity) and towers are the most susceptible to attack.[45] Although damage to transmission towers and failure of individual HV transformers may not cause long-lasting outages, a coordinated attack that produces simultaneous failures of multiple HV transformers could have severe implications over a large geographic area and trigger widespread, extended blackouts with serious economic and social consequences.[46] Such physical vulnerabilities in power systems have been the target of approximately 3,000 terrorist attacks around the world from 2002 to 2012.[47]

Cyberattacks

As modernization has made the grid 'smarter,' Internet connections between the various components of the power system (such as smart power meters, synchro phasors, and appliances) have introduced new vectors for intrusions and cyberattacks. Activities that compromise the operation of sensors, communication, and control systems by spoofing, jamming, or sending improper commands could also disrupt the system, cause blackouts, and, in some cases, result in physical damage to key system components.

While thus far there have been no reports of cyberattacks in the United States that have resulted in long-term damage to power system operations, the concern is no longer entirely theoretical.[48] From 2011 to 2014, electric utilities in the United States reported 14 cyberattacks (3.9% of all directed attacks),[49] and one was reported in 2017.[50] While relatively few cyberattacks have occurred on the United States grid (at least as reported), the increasing connectedness of information systems has raised the possibility of major cyberattacks on the power grid. Centralized markets and control systems managed by RTOs and ISOs are vulnerable and may be attractive targets since they are effectively regional command centers for the power grid.[51]

Electromagnetic Interference

More immediately extensive than focused physical or virtual attacks is the potential damage of an electromagnetic pulse ("EMP"), a sudden burst of electromagnetic radiation resulting from a natural or man-made event. EMPs can occur naturally and unexpectedly as part of cyclical solar magnetic storms or be produced artificially by tools like Intentional Electromagnetic Interference or detonation of a nuclear device above the atmosphere, which would trigger a High Altitude Electromagnetic Pulse.[52] While major geomagnetic storms are rare, they are global events with widespread effects, and simulations suggest that a storm today could cause power system collapses in the Northeast, Mid-Atlantic, and Pacific Northwest that would take years to repair and interrupt power for 130 million people in the United States alone.[53] Manmade EMP events could have similar effects and set the United States economy back by decades. Since 2016, DOE has been working to develop and implement an EMP resilience strategy, but the grid currently remains highly vulnerable to EMP attacks.[54]

Others

In addition to the threats outlined above, the grid is also vulnerable to human error, technical failure, and geomagnetic disturbances.

2.3 Ways to Increase Energy Resilience

Today, developing energy resilience is more critical than ever, with outage frequency having risen 470% between 2000 and 2016.[55] Energy resilience for individual facilities requires power generation and delivery capabilities that can be accessed in the event of a grid outage. This typically entails investing in backup power supply systems (i.e. diesel generators) that can be activated when the grid goes down. In some (but not all) cases, backup power may be provided by developing a "behind the meter" on-site power source that provides power to the grid during normal circumstances but can also be isolated from the grid through "islanding." Both options incur additional costs borne by the single beneficiary of the backup power.

Several methods for achieving energy resilience are described below and are being reviewed by federal agencies.

On-Site Backup Power

A range of options exist for providing on-site backup power. A long-standing and common practice is to use diesel generators to provide power when the grid fails. Such generators require fuel to produce power; thus, running a diesel generator for a long period requires buying and storing a large amount of fuel. On-site renewable power is being increasingly used as well, although this poses challenges due to the intermittence of wind or solar power unless an energy storage option is available.[56]

When there is a power outage, most facilities currently depend on standalone generators and short-term fuel stockpiles to provide emergency power for critical loads. Large military bases, for instance, can have hundreds of generators, each attached to a single building.[57] Standalone generators offer a high degree of operator control, but there are numerous disadvantages to the existing system. Because standalone generators work independently, each must be able to supply 200% of a building's peak load per military regulation, leading to higher capital costs, fuel use, and wear and tear.[58] Maintenance, inspection, and testing of generators also require excessive time and money. In fact, only 60% of bases perform the required testing, increasing risk of generator failure.[59]

Microgrids

An alternative strategy for energy resilience that is gaining traction is to create a microgrid, which DOE defines as "a group of interconnected loads and distributed energy resources with clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid [and can] connect and disconnect from the grid to enable it to operate in both grid-connected or island mode."[60] Unlike standalone generators, microgrids are comprised of few generation units that share resources across buildings, making it more affordable and easier to maintain.

Microgrids have been tested and started to be implemented in the military. In conjunction with DOE, the Department of Homeland Security, and individual military services, the U.S. Department of Defense ("DOD") led the three-phase, four-year Smart Power Infrastructure Demonstration for Energy Reliability and Security ("SPIDERS") to establish the viability and value of installing microgrids at military bases. In the first phase, which took place in 2012 and 2013 at a Joint Base Pearl Harbor-Hickam facility in Hawaii, SPIDERS exhibited seamless transitions to and from the commercial grid with circuit-level cybersecurity and integrated renewable energy.[61] The second phase, in 2013 and 2014, had similarly positive results and demonstrated successful use of microgrid controls and an existing photovoltaic solar array to support critical operations at Fort Carson, a large 137,000-acre U.S. Army installation in Colorado with a population of approximately 14,000.[62] The third and final phase at Camp Smith, Hawaii expanded to put the whole camp, including both critical and non-critical facilities, on integrated microgrids and installed multiple large new prime power stationary generator sets for redundancy.[63] Ending in late 2015, this phase also exhibited how a base microgrid can be used by the local utility as a smart grid resource in exchange for more affordable commercial electrical rates.[64] In all three phases, the microgrids were able to keep critical base functions operational and power systems resilient.

In addition to military compounds, microgrids have become integrated into university campuses, hospitals, jails, and other large institutional facilities. One of the most notable examples is New York University, which transformed its on-site oil-fired energy generation plant into a natural-gas fired combined heat and power CHP system in 2011.[65] The new plant boasts twice the old plant's output capacity at 13.4 megawatts and supplies electricity to 22 buildings and heat to 37 buildings, and the microgrids islanding capability allowed the University to power much of the campus through Hurricane Sandy in 2012.[66] Similarly, Princeton University's gas and solar powered microgrid supported the campus buildings and operations, including the preservation of critical research projects and computing services, and aided community emergency personnel and residents through the hurricane.[67] Other facilities with critical energy needs are also utilizing microgrids.

Santa Rita Jail in California, for instance, opened a microgrid in 2012 with funding assistance from DOE's Smart Grid program to ensure dependable full service for its 4,000 inmates, incorporating solar, wind, fuel cells, storage, and diesel generators into its power sources.[68]

Community microgrids are also emerging with funding from government initiatives and grassroots projects. At the national level, DOE's Smart Grid R&D Program includes a microgrid initiative that focuses on working with national laboratories to develop more advanced designs and testing at field demonstration sites across the country.[69] Additionally, some states responded to blackouts caused by extreme weather events like Hurricane Sandy by instituting funding for microgrids, such as:

- Connecticut's Department of Energy and Environmental Protection agency has awarded a total of $18 million for nine microgrid projects, including Wesleyan University and University of Hartford, and has an additional $30 million authorized for funding.[70]

- New Jersey's Energy Resilience Bank, a public infrastructure bank which focuses on energy resilience, was created to finance the installation of affordable resilient energy systems for critical facilities like the St. Peter's University Hospital, which was the first project to receive preliminary approval in 2016.[71]

- In 2015, New York State established the NY Prize Community Microgrid competition as part of its new Reforming the Energy Vision program, with its $40 million grant budget administered by NYSERDA.[72]

The private sector has also been active in expanding microgrids, with individuals linking up their power supply sources with coordinators like Brooklyn Microgrid, a benefit corporation which is installing infrastructure to enable a small neighborhood network in New York to create a microgrid.[73] States like California are encouraging such private enterprises by requiring utilities to share planning information that could be used to set up microgrids and by adopting Community Choice Aggregation, which allows local governments to legally compete with utility companies by buying locally generated energy and selling it back to residents.[74] As energy resilience becomes increasingly more important, research into and implementation of microgrids is growing across all sectors.

Improved Cybersecurity

Given frequent changes in technology used by the power sector and the types of cyber threats, protecting against cyber threats requires an ongoing process of assessing risks, identifying threats, and developing and improving security practices.[75] This includes technological improvements and changes to staff behavior. As with many other industries, the power sector has to protect against a range of cyberattack delivery methods.[76, 77]

Physical Site Hardening

Facilities' resistance to physical harm can be improved in a variety of ways depending upon the threat being addressed. Intentional attacks can be protected against through defenses like strong walls, armor over transformers, and buried transmission and distribution lines. In the case of natural disasters, power providers can take some proactive actions to mitigate the effects. For instance, some utilities in flood-prone areas are locating substations and other critical equipment above the flood plain or building dams to protect equipment.[78] However, given the large number of power facilities scattered across the country, it is unlikely that the entire system will ever receive a sufficiently high degree of hardening.[79]

2.4 Governmental Focus on Resilience

The federal government is increasingly focused on energy security and has created policies to support resilience in the power sector nationwide and mandates for federal agencies to improve their own energy resilience.

DOE is designated as the federal agency responsible for energy security. DOE's foundational law, the DOE Organization Act of 1977, initially limited DOE's energy security functions to the oil sector only.[80] However, the federal government now recognizes the importance of electricity to energy security, and various policy directives encourage DOE to broaden its purview with an increased focus on electricity. Presidential Policy Directive 21 (2013) orders agencies to develop ways to protect critical infrastructure, including calling on the Nuclear Regulatory Commission ("NRC") to collaborate with DOE and other agencies to strengthen the resilience of nuclear power facilities, reactors used for research, fuel storage facilities, and other nuclear sites.[81] DOE's electricity resilience mandate is further delineated in Emergency Support Function #12, a Federal Emergency Management Agency document which outlines emergency interagency coordination structures. DOE is tasked with serving as "the primary agency [which] assists government and private sector stakeholders…with reestablishment of the energy system."[82] This specifically includes the power grid, as well as delivery of oil and other energy sources. Emergency Support Function #12 also directly calls on TVA to provide surplus power to the grid and assess damage and related repair requirements in its service area.

Since September 11, 2001, emergency management has increasingly focused on ways to keep infrastructure operating during and after an emergency. Given the importance of electricity services to federal operations and the wider economy, the federal government has begun developing a framework for analyzing and responding to risks in the power sector, as captured in DOE's January 2017 report to Congress, "Valuation of Energy Security for the United States." That report to Congress differentiates between reliability, which is related to maintaining service during routine circumstances, and resilience, which applies to extreme circumstances. Resilience is defined in that report as "the ability of the electric power sector to withstand and recover from any disruptions created by extreme weather, cyberattack, terrorism, or other unanticipated event[s]."[83] Additionally, in response to Energy Secretary Rick Perry's request for "concrete policy recommendations and solutions" regarding energy reliability, resilience, and affordability, DOE released a staff report in August 2017 that provides an overview of power system trends, current status, and policy recommendations.[84]

On December 4, 2015, President Obama signed the FAST Act into law. The FAST Act mostly focuses on transportation issues, while also addressing the need to improve the security of energy infrastructure in the following ways:

- Emergency Protection: DOE is authorized to mandate specific actions to protect energy infrastructure in response to a grid security emergency, as identified by the President.[85]

- Critical Information Protection and Sharing: The Federal Energy Regulatory Commission ("FERC") and DOE are directed to develop and implement processes and tools to protect and facilitate needed sharing of critical electric infrastructure information among stakeholders to ensure security and resilience of energy infrastructure during emergencies.[86]

2.5 Department of Defense Resilience Initiatives

Military installations, both in the United States and abroad, operate as small cities and need to maintain operations to support their defense mission. Historically, critical energy loads have been supported with backup generation equipment. However, DOD is taking steps to increase the resilience of its installations, including assessing the specific needs of and threats facing domestic and international facilities and considering construction projects. Such projects will require up-front investment and may need careful financial consideration to identify the financial resources required to build infrastructure which is essential in emergencies, but otherwise is not used.

DOD has issued several mandates as part of its energy resilience initiative. A 2009 DOD directive entitled "Installation Energy Management" orders the military to focus on energy management at its installations.[87] The directive states that, among other objectives, utility infrastructure should be "secure, safe, reliable, and efficient." According to the February 2017 Army directive on energy security, "vulnerabilities in the interdependent electric power grids, natural gas pipelines, and water resources supporting Army installations jeopardize mission capabilities and installation security and the Army's ability to project power and support global operations."[88] Specifically, the Army is required to reduce risk to critical missions by providing backup energy (and water) for a minimum of 14 days. The directive also identifies that the Army should improve resilience at installations for all missions (including non-critical ones) by:

- Assuring access to resource supply;
- Utilizing infrastructure capable of storing energy on-site, with flexible and redundant distribution networks; and
- Having trained personnel available for planning, operations, and sustainment of energy and water security.

DOD has been particularly active in improving the resilience of its electricity services. Military facilities typically buy power off-site from a utility and use standalone backup generators during outages. Besides generators, renewable power and microgrids are increasingly being considered for energy resilience at military bases.

Generators

Currently the most prevalent source of backup power, diesel-powered generators have the advantages of relatively low capital costs (about $100,000 for a 250 kW generator plus about $6,500 per year in maintenance) and ease of installation.[89] According to a study written by Noblis for the Pew Charitable Trusts, a military installation with 20 MW of critical loads will spend approximately $16 million to buy the 40 MW of standalone generator capacity it needs and $1 million a year to maintain it.[90] Additionally, backup generators can be linked to individual buildings, rather than powering an entire base, and installation of building-specific generators also does not require interaction with utilities or considerations of the electric distribution system within a site.[91]

However, standalone generators have limitations and drawbacks, including fuel requirements, efficient sizing, maintainability, reliability, flexibility, coverage, and overall cost. Diesel generators are not designed to run for long periods, and the amount of fuel available limits how long a diesel generator can run. Furthermore, preventative maintenance for diesel generators does not always prepare the generators for 100% availability. Assuming 75% reliability for diesel generators, a study by the Center for Naval Analyses estimates that the full cost of providing energy security at military facilities via a backup generator over its lifetime to be nearly $50 per kW of capacity per year.[92] In comparison, the standalone generators for hospitals, which would need comparably larger capacity, could cost as much as $400 per kWh including the cost of installation, warranties, and service agreements.[93]

Additionally, since each generator has to be sized to the load of the building it is supporting, a base may buy generators equal to double estimated peak load for their respective buildings, or more. This tends to result in excessive capital costs across a base, as well as excessive fuel use and unnecessary wear and tear. While maintenance requirements for generators are well known, military bases have often failed to maintain them properly in practice; this leads to reliability issues. Even if maintenance were properly executed, N+1 reliability would require installing a second generator for each building, in case the first one fails.[94] Generators also force installations to make "all or nothing" decisions on a building-by-building basis; this may not be the best way to link backup power plans to needs and changing circumstances.[95] An interconnected microgrid eliminates much of these inefficiencies.

Renewable Sources

On-site renewable power plants can provide an independent energy source for critical facilities. These projects typically sell power to the host installation and into the grid during normal circumstances. However, they do provide intermittent power which depends entirely on the availability of the energy resource (typically the sun or wind), absent the ability to store energy for use when the resource is not available. At this time, storage technologies are still expensive and not widely commercialized; combining renewables with storage is generally not cost competitive with diesel generators.[96] Biomass projects provide non-intermittent power, although they, like diesel generators, require storage of fuel on-site.

An example of renewable power for installation energy resilience can be found at Fort Drum in New York. Fort Drum is the largest single-site employer in New York State and supports mobilization of more than 30,000 Army troops annually. The power project has 60 MW of installed capacity and has been using wood biomass to generate power since November 2014; contracts have been signed with some tree growers to facilitate access to fuel.[97] The project generates energy in excess of Fort Drum's peak load and sells excess power into the grid. The power plant is owned and financed by ReEnergy Holdings LLC, a biomass power project developer which sells power to Fort Drum through a PPA.[98]

Some installations prefer to combine renewable and non-renewable sources of power to obtain greater resilience capability. For example, Schofield Barracks is part of the Army's Installation Management Command and is responsible for operations at Army facilities in the islands of Oahu and Hawaii. A 50 MW project is under construction which will be able to generate power from biofuels or fossil fuels. The project is owned and financed by Hawaii Electric Company, the local utility, on land which the utility is leasing from Schofield Barracks.[99] The power plant will be the only baseload generation facility situated above the tsunami strike zone in the island of Oahu. The plant will be able to operate in islanded mode, thus enhancing resilience for the military base. The plant also provides added grid benefits by being able to provide black start power.[100]

Microgrids

Microgrids provide the key benefit of allowing power to be distributed across multiple facilities at an installation. This creates flexibility, as backup power is not linked to any one building. Additionally, microgrids are designed to separate from the larger transmission grid in the event of power disruptions. Microgrids are still a relatively new technology, with only several dozen operating in the United States as of early 2016.[101] Most microgrids are relatively small—serving loads of under 1 MW—and have relied on smaller distributed energy resources.[102] Because the key benefit of a microgrid is the ability to operate independently of the grid, a large campus could benefit from a microgrid if generation is sufficient and paired with switching and control technologies to enable islanded operation.

The military has an active microgrid at the Twenty-nine Palms Marine Corps Air Station and is building another at the Air Station in Miramar (both sites are in California).

Military Resilience Legislation

The Fiscal Year 18 NDAA,, requires that, "The Secretary of Defense shall ensure the readiness of the armed forces for their military missions by pursuing energy security and energy resilience."[103] The Fiscal Year 18 NDAA defines energy resilience as "the ability to avoid or prepare for minimize, adapt to, and recover from anticipated and unanticipated energy disruptions in order to ensure energy availability and resiliency sufficient to provide for mission assurance and reediness, including task critical assets and other mission essential operations related to readiness and to execute and rapidly reestablish mission essential requirements." [104]

In its report for the National Defense Authorization Act for Fiscal Year 2018, the House Armed Services Committee acknowledged that several efforts, including the Security Management Improvement Program, the Security Infrastructure Revitalization Program and associated 10-Year Revitalization Plan, and the Center for Security Technology, Analysis, Response, and Testing are encouraging steps toward resolving longstanding deficiencies in NNSA's physical security program.[105] The committee called on NNSA and DOE to continue efforts to bring greater effectiveness, clarity, and consistency to oversight and management practices, requirements, standards, and policies for physical security. The Administrator for National Security is urged to brief the House Committee on Armed Services on these efforts by December 1, 2017. The committee recommended $720 million for Defense Nuclear Security.[106]

CHAPTER 3: BUYING RESILIENCE - SMALL MODULAR REACTOR SOLUTION

This Chapter begins with a summary of the key federal utility acquisition legal authorities for purchasing power. Agencies can opt to use these authorities and request that the power be provided from a source that will support the agency's energy resilience. This Chapter then explains the costs associated with energy resilience and potential ways that federal agencies can make "resilience payments" in order to assist power providers with the high up-front costs associated with the construction of an SMR.

3.1 Summary of Key Federal Utility Acquisition Legal Authorities

As described in detail in Chapter 4 of the Initial Report, there are several authorities that federal agencies may use to purchase power through a PPA (a long-term contract to sell electricity between a producer of electricity and a buyer), which, in certain instances involving two federal agencies, may be referred to as an Interagency Agreement or, in the case of TVA, Power Supply Agreements. Federal agencies enter into PPAs to satisfy their power needs. PPAs are executed under a range of legal authorities.

Most federal agency power purchases are made through "area wide" or direct purchase contracts under the authority of the General Services Administration ("GSA"). These contracts are executed under the authority of 40 U.S.C. § 501 and carry terms of five (5) to ten (10) years. The area wide contracts authorize the purchase of specified quantities of electricity at a specified price or tariff for a specified period of time at specific negotiated or regulatory determined rates. The authority is delegated to specific federal agencies (DOD and DOE), and GSA arranges for or delegates the authority to other federal agencies.

Certain other federal agencies, such as DOD, DOE, the Western Area Power Administration ("WAPA"), and TVA, have additional (sometimes longer-term) legal authorities. Additionally, as renewable energy projects have developed, additional legal authorities have been enacted to permit longer contract terms in certain instances.

Below is a list of key legal authorities that federal agencies use to purchase power. See Chapter 4 of the Initial Report for additional detail relating to each of these authorities.

Key Utility Acquisition Authorities Used by Federal Agencies	
GSA	• 40 U.S.C. § 501 (and FAR Part 41) authorizes GSA to prescribe policies and methods governing the acquisition and supply of utility services for federal agencies
DOD	• GSA delegated its authority under 40 U.S.C. § 501 to DOD to enable DOD to enter into utility service contracts not exceeding 10 years • 10 U.S.C. § 2304 and 40 U.S.C. § 113(e)(3) authorize DOD to acquire utility services for military facilities • 10 U.S.C. § 2922a authorizes DOD to purchase power generated on military bases or private property (but not other federal agency or governmental land) for a term not exceeding 30 years
DOE	• GSA delegated its authority under 40 U.S.C. § 501 to DOE to enable DOE to enter into utility service contracts not exceeding 10 years • 42 U.S.C. § 7251, *et seq.* (the Department of Energy Organization Act) authorizes DOE to acquire utility services • 42 U.S.C. § 2204 (the Atomic Energy Act of 1954) authorizes DOE to enter into new contracts or modify existing contracts for electric services for periods not exceeding 25 years for the Oak Ridge, Paducah, and Portsmouth installations
Department of Veterans Affairs	• GSA delegated its authority under 40 U.S.C. § 501 to the Department of Veterans Affairs *for connection charges only*
Other Federal Agencies	• If utility services are required for over one year, federal agencies can request a delegation of authority from GSA under 40 U.S.C. § 501 in accordance with FAR Part 41.103(c)

Federal agencies must comply with the requirements of FAR Part 41 when acquiring utility services (except for utility services produced, distributed, or sold by another federal agency – which follow the rules for interagency agreements – and several other exceptions not directly related to this Report).[107] Federal agencies use interagency agreements (e.g. power purchase, consolidated purchase, joint use, or cross-service agreements) when acquiring utility services or facilities from other federal government agencies.[108] Such agreements must be in accordance with the procedures of FAR Part 17.502-2 and the Economy Act (31 U.S.C. § 1535), and, in the case of TVA, 16 U.S.C. § 831i.

A Power Supply Agreement between TVA and DOE would be limited to 20 years, as 20 years is TVA's maximum authority under 16 U.S.C. § 831i.

Federal agencies typically pay for utility services through annually appropriated operation and maintenance funds. The term of any federal government contractual commitment varies based upon the legal authority used to enter into the contract, and most follow the FAR. Such contracts will be subject to cancellation and termination due to lack of appropriation, utility provider default, and the government's convenience. With certain limited exceptions, federal agencies are required to comply with state law governing the provision of electric utility service, including state utility commission rulings and electric utility franchises or service territories established pursuant to state statute, state regulation, or state-approved territorial agreements.[109]

The utility rate that a federal agency pays is either set by a regulatory body or is a negotiated rate. The negotiated rate can be based on federal agency demand and other factors. A stand-alone contract to purchase power only from an SMR will likely require the federal agency to negotiate a rate for the power delivered to the federal agency. A contract to purchase power from a utility where there is mix of power sources, and an SMR is one of the sources, will provide an agency with a "blended rate" for all of the types of power, and the agency will either negotiate a rate or, in the case of a regulated utility, will likely pay a regulated rate that is set by the utility based on the blended costs of the power sources plus the cost of specific services, such as power for a microgrid to provide resilience.

3.2 Most Likely Legal Authorities to Use for Federal Agency Power Purchases from a Small Modular Reactor

The most likely legal authorities that will be relied upon by federal agencies to purchase power from an SMR are as follows:

- GSA's 40 U.S.C. § 501, which will allow for a contract up to a 10 year term;
- Interagency Agreements, coupled with a PPA, which will allow federal agencies to take advantage of the authorities or power sources of other federal agencies or departments (i.e. DOE may enter into an Interagency Agreement with WAPA (up to 40 years) to take advantage of WAPA's ability to enter into long-term PPAs with the SMR power producer, which may also be dependent on the counterparty's authority if such counterparty is a governmental entity);
- Power Supply Agreement or Interagency Agreements with another federal agency that produces power. The term of such Power Supply Agreement (in the case of TVA) or Interagency Agreement (in the case of WAPA) would be limited by the underlying legal authorities of the participating federal agencies. For example, a

Power Supply Agreement between TVA and DOE would be limited to 20 years, as 20 years is TVA's maximum authority under 16 U.S.C. § 831i, despite DOE's authority for 10 years under 40 U.S.C. § 501 and up to 25 years under 42 U.S.C. § 2204;

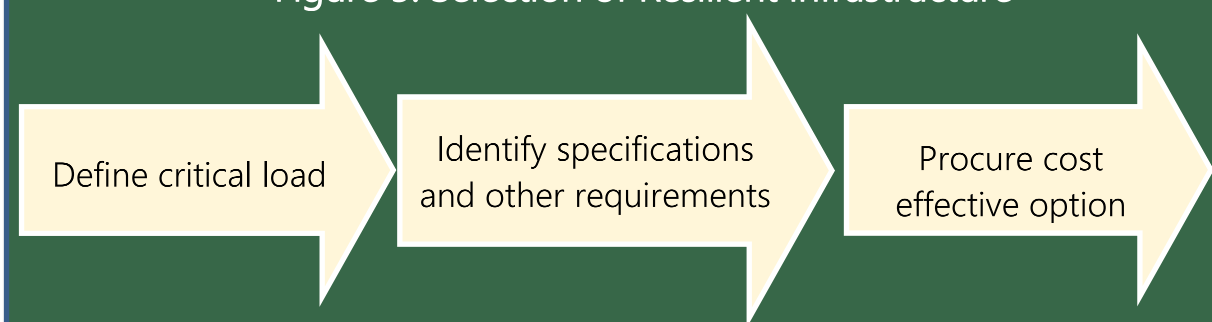
- 10 U.S.C. § 2922a (for DOD only), which will allow for up to a 30 year term assuming the project is constructed on DOD or privately owned land; and
- 42 U.S.C. § 2204 (for DOE at the Oak Ridge, Paducah, and Portsmouth installations only), which will allow for electric service contracts up to 25 years.

DOD components may also have the opportunity to take advantage of additional authorities depending upon the location of the SMR.

3.3 The Challenge of Investing in Energy Resilience

Providing energy resilience requires investment in the appropriate infrastructure and systems. This can present a cost recovery challenge, since backup power is not used in normal circumstances, and, preferably, never used. Investing in energy resilience requires capital and maintenance expenditures for assets which may largely sit idle; thus, routes to cost recovery are not as clear as for normal power generation, which sells power on a regular basis. When making an investment decision for resilience, energy users generally seek options that provide acceptable levels of reliability for critical loads throughout the requisite time period at the least cost. An overview of this process is summarized in Figure 5.

Figure 5: Selection of Resilient Infrastructure



Common considerations in choosing a backup power source in line with the steps in Figure 5 are summarized below:

- Define Critical Load: Since backup power generally costs more than routine power services, it is important to identify which activities at a given facility are critical and should be sustained during an outage; only a subset of activities at a facility may be critical. For example, a military base may need to maintain perimeter security activities at all times, but it may not need to process accounts payable during an outage. Therefore, the definition of critical load should consider the nature of threat (i.e., the adverse events a facility intends to protect itself from) and the potential duration of an outage caused by the threats. Critical functions may extend beyond key activities to include those that keep a facility operational over a long period of time, such as electricity for water and wastewater conveyance and treatment. Once the critical activities are chosen, the power required to sustain those activities can be defined; the aggregate of critical activities defines the critical load for a facility. Importantly, isolating critical activities and connecting them can be costly. In some cases, it may be more economical to serve some non-essential loads as part of a larger microgrid rather than only install the equipment and capability to isolate and supply only critical loads.

- Identify Specifications and Other Requirements: Having identified the critical load, a facility should determine the specifications for the facility including the amount of time for which backup power is needed. This may be a function of the expected time required for grid power to be restored in relatively dire circumstances. Certain facilities have already established such guidelines, like the DOD's 14-day requirement.[110] .[111] The choice of duration of backup power should consider the types of threats a facility is likely to face, and the expected duration of outages from those threats. Other requirements must also be considered, such as power quality and characteristics (frequency, voltages, response time, ability to be resilient in the face of certain threats, etc.).

- Procure Cost Effective Option: The options available at a given facility's site will be partly determined by the site's location. For example, if a large amount of land is available, a facility could develop a backup power plant. This may depend partly on access to fuel (such as natural gas for a large power plant or diesel for a smaller generator), which may be influenced by proximity to pipelines and regional fuel market pricing; furthermore, large fuel storage facilities may be required. In some areas, a facility may be faced with standby charges to recover the cost of grid services when needed, even if the grid is seldom used due to large on-site generation; these charges may significantly impact costs.

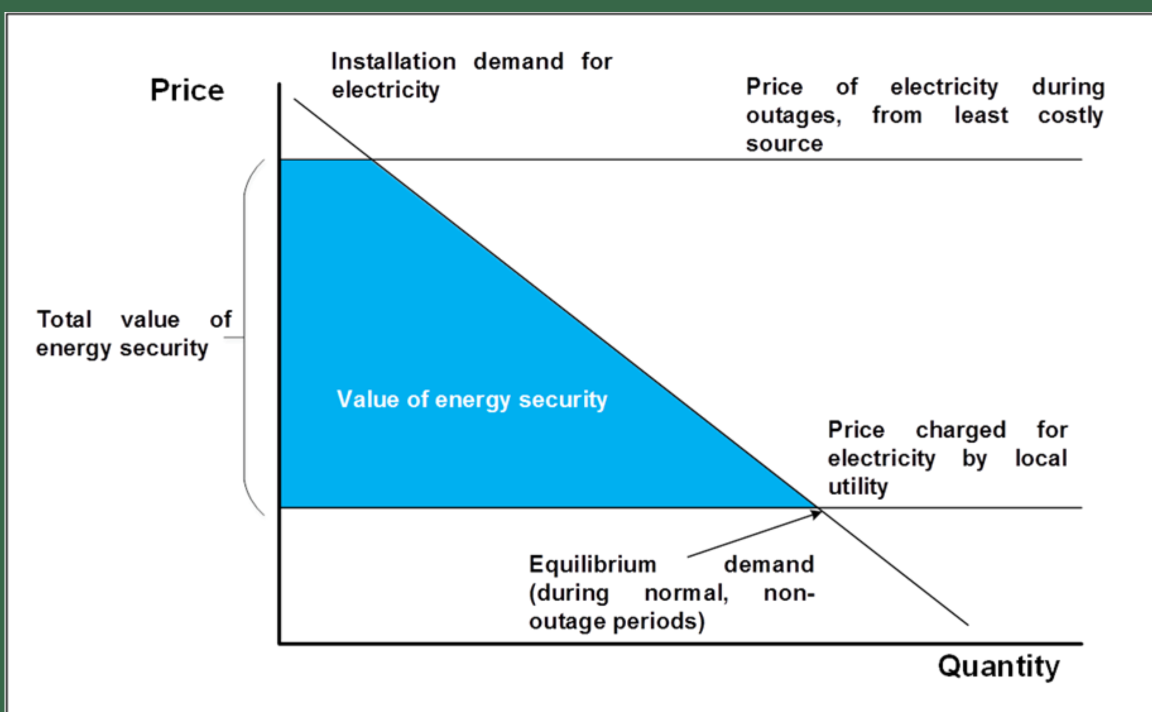
3.4 Valuing Energy Security for Critical Activities

Many industries, such as large technology companies, hospitals, and universities, rely on on-site backup generation. The United States military typically buys its day-to-day power off-site (from a utility) and uses stand-alone backup generators during outages. The fact that organizations are willing to spend money on energy security implies that resilience has a value. For most civilian activities, the cost of an outage can be estimated in terms of lost economic activity, which helps inform spending decisions on resilience.[112] DOD also carries out critical functions for national security, which can greatly affect the short-term and long-term welfare and security of the nation. While lost economic activity is relatively easy to measure, the value of national security is harder to quantify. The cost of an outage for defense facilities may be much higher than for civilian activities, since mission failure is not an acceptable option.[113]

The cost of electricity from backup sources reflects the value of energy security – if those sources can ramp up quickly to avoid harm from an outage.[114, 115] Absent any form of backup power, the cost of energy during normal periods in which there is no outage would be the total charge paid to a utility to meet a facility's load. The value of energy security is the total spending on backup power from the least-costly source of backup power during an outage. For a critical function, this would be the cost of on-site backup power supply sized to the critical load (and perhaps linked to a microgrid). When making investment decisions about energy security, stakeholders may consider other practical considerations, such as carbon emissions, gaps in supply when transitioning to backup power during an outage, and other issues.

This concept is illustrated in Figure 6; the value of energy security is shown by the shaded areas.

Figure 6: Value of Energy Security[116]



3.5 Potential Imposition of "Resilience Tariffs"

Resilience is a useful electrical service beyond provision of power in routine circumstances; it is appropriate to impose a tariff for this service. United States power markets already have established systems for procuring and selling a range of services. One example is ancillary services, which help keep the transmission system balanced as it delivers power. Ancillary services include synchronized reserves, which provide power if the grid faces unexpected need for more power due to power plant failures or other events; and regulation, which helps match generation to load to keep the grid within the desired electrical frequency.[117] Another example of services beyond routine provision of power can be found in capacity markets, which incentivize investment in generation capacity in the future to help meet forecasted needs.[118] Capacity is paid for separately from energy which may be produced by that capacity. Besides additional power plants, capacity can also be purchased through energy efficiency initiatives, temporary termination of users, or other means which help align future supply with demand.[119]

Some more usual precedents for recovery of the cost of backup power generation can be found in other resilience services. Utilities and generators already recover the cost of some resilience services which are generally unused by incorporating those costs into tariffs charged to customers. Examples include:

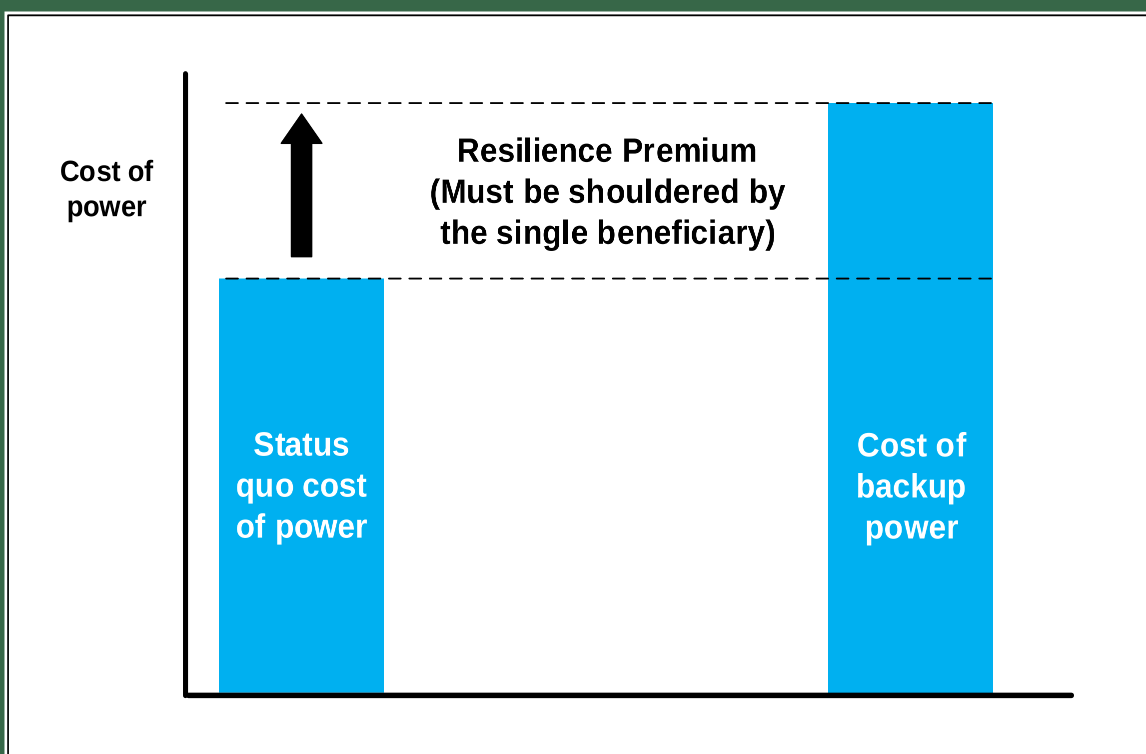
- Black Start Power: Black start generators are able to start generation from zero output without receipt of any additional energy from the grid. Thus, black start generators are the first to come online in the event of a grid outage and facilitate resumption of normal operations by providing energy required for the transmission grid and other generators to resume regular operations. Black start capabilities typically increase the capital cost of a power plant. The capital cost premium has been estimated at 0.4% or 1% of capital expenditures without black start for different thermal plants.[120] Black start tariffs allow generators to recover the additional cost of building a black start plant, even if black start services are seldom provided.
- Standby Tariffs: These charges recover costs incurred by a load-serving utility for potential demands by customers who produce power on-site, but may need to draw additional power from the grid when on-site power is not adequate to meet load. In this context, the grid electricity provider is providing energy resilience to the power-producing customer.
- Transmission Equipment Reserves: Grid Assurance LLC ("Grid Assurance") maintains an inventory of backup transmission equipment which can be used by utilities if their existing equipment is damaged. Utilities pay fees to Grid Assurance to have access to inventory when needed; in regular circumstances, the transmission equipment held by Grid Assurance is not used. Pooling costs through Grid Assurance should result in lower costs of utilities than if each maintained an inventory of backup equipment on its own. In March 2016, FERC issued a decision allowing transmission utilities to incorporate the cost of Grid Assurance fees into rates charged to transmission customers. DOE recently published a report to

Congress on the importance of a strategic transformer reserve (one type of transmission equipment).[121]

- Resilience as a Service (Air Force): The Air Force has stated an interest in contracting with service providers to procure resilience; the providers are expected to bundle all the capital works and services required to gain access to backup power.[122] This could be based on the model of energy service companies ("ESCOs"), which help implement energy efficiency projects. ESCOs bundle financing, design, installation, and operating services for energy efficiency through multi-year contracts.[123]

As shown by the examples above, resilience has value and can be measured in terms of a "resilience premium," which reflects the extra benefit of backup power as compared to the status quo option. This premium could be applied to backup power from an SMR. Typically, the status quo options will be continuing to use the existing electric utility service. The value of resilience should then be captured in the difference between the cost paid for resilience and the lower amount that would be paid by continuing the status quo. This is illustrated in Figure 7.

Figure 7: Buy Down of SMR Charges



Given the extra value of backup power over conventional utility service, a resilience premium can help off-set the expense of power from an SMR. When combined with incentives such as DOE grants and production tax credits, basic power charges and resilience charges can cover the whole cost of power from an SMR. The whole resilience premium should be paid by the single beneficiary of backup power services, even if the project sells much of its power into the general customer base during normal circumstances.

After an SMR-powered micogrid is established that produces more power than the federal agency customer utilizes, there could be societal and commercial economic development benefits. For example, facilities that rely on high reliability electricity may choose to locate or relocate in the vicinity of the SMR, such as hospitals or internet data server facilities. Eventually, there could be a commercial resilience market.

CHAPTER 4: COST REDUCTION TOOLS FOR INNOVATIVE NUCLEAR POWER PROJECTS

This Chapter presents options for narrowing the cost gap between existing power generation technologies and innovative nuclear technologies, such as SMRs. Federal tax incentives may help lower the costs of SMRs. DOE could also help defray costs by paying for research services provided by an SMR, sharing costs through technology development grants, or by providing a loan guarantee. Utility rates could be also be structured to accelerate recovery of SMR capital costs. A combination of options could make an SMR economically attractive for an SMR owner or off taker.

4.1 Tax Incentives

There are federal tax incentives for power production, some of which have been used for nuclear power. These incentives take the form of tax credits or deductions and include:

- Investment Tax Credits ("ITC"): ITCs give a tax credit equal to a defined percentage of qualifying investment costs. The qualifying costs vary for different technologies. If a project does not use its entire credit in a given year, it can carry unused tax credits forward; tax equity financing is another way that a renewable project can benefit from the full value of a tax credit.[124] ITCs for renewable energy projects were first established by the 2005 Energy Policy Act ("EPACT 2005"), and then modified by several subsequent laws, the most recent being the Consolidated Appropriations Act of December 2015. ITCs have been available for a wide range of generation technologies, but have not yet been offered for nuclear power. Previously, credits were set as high as 30% of qualifying investment costs. Credits for some technologies expired in 2016; other technologies' credits will expire in 2019; and still others have credits which scale down to 10% and remain there for the future.[125] Current law would have to be modified to allow ITCs to apply to nuclear power.
- Production Tax Credits ("PTC"): A PTC is a tax credit generated by production of a certain good; in the case of power generation, tax credits are typically allocated per kWh of production, and reduce the project's total lax liability. Federal PTCs are currently provided for clean power produced by nuclear power plants, at the rate of $0.018 per kWh as established in EPACT 2005.[126] That legislation would only provide PTCs for nuclear power plants which enter service by December 31, 2020. However, the House of Representatives passed a bill in June 2017 which would lift the 2020 deadline, and allow non-taxpaying owners to pass benefits on to eligible

project participants with tax liabilities (to lower total project cost),[127]thereby allowing SMR projects entering service after 2020 to benefit from PTCs. The bill would need to pass the Senate and be signed by the President to become law. Other changes to PTCs could further help SMRs, such as increasing the value of PTCs to better account for inflation and more closely match renewable PTCs.

- Accelerated Depreciation Deduction: This incentive allows qualifying projects to increase their depreciation expense in the earlier years of an asset's life, thus reducing net income and the related tax liability in those years.[128] The total depreciation, however, remains unchanged. This contrasts with conventional straight-line depreciation in which depreciation is the same each year of an asset's life.[129] Accelerated depreciation has been offered for various renewable technologies since 1986. The depreciation schedule has been modified by several laws since then, the most recent being the Consolidated Appropriations Act of December 2015.[130] This law extended bonus depreciation offerings through 2019 (bonus depreciation was established by the American Recovery and Reinvestment Act of 2009, which allowed for up to 100% depreciation in the first year; the allowable amount of bonus depreciation has been scaled down since then). Current laws would have to be modified to allow accelerated depreciation to apply to nuclear power, and the deadline would have to be extended past 2019 to allow SMRs to benefit.

As noted in Chapter 7, the extension of the PTCs for nuclear power would provide meaningful incentives for SMRs and would be consistent with the original intent of EPACT 2005.

4.2 Payments for Research and Isotope Services

DOE currently has limited access to nuclear test reactors to conduct research needed to improve reactor designs, capabilities, and commercialization potential and to reactors for producing isotopes (variants of natural elements created through deliberate intervention).[131] DOE views having a commercial, multi-unit SMR sited on or next to national laboratory property as an opportunity to conduct research in a number of areas, including power generation, process heat, materials testing, and production of radioisotopes or other nuclear material for DOE.

The modular design of an SMR could enable a Joint Use Modular Plant ("JUMP"), in which most reactor modules support the generation of electricity, and one or more are devoted to other activities when not used for electricity generation. Reserving a reactor for non-generation activities could also facilitate a new revenue stream, which is clearly aligned to the costs of one or more modules. DOE, a major user of reactors for non-generation activities, could effectively lease or purchase one or more modules of an SMR. Research uses for a reactor module include testing of process heat production (steam) and testing of technical issues of regulatory concern.[132]

DOE could defray a portion of the cost of the operation of a commercial reactor sited on or next to laboratory property in exchange for access to one or more units of an SMR for several research areas, including:

- Operations: Examination of issues such as control room human factors, improvement of plant procedures, safeguards and securities development, refueling capabilities, and more.

- Technical Optimization: Use of the operating plant to conduct research and optimization of components and systems such as unique sensors, instrumentation, control systems, and on-line monitoring. This could also include demonstration and validation of code cases associated with components manufactured using advanced techniques, such as additive-manufactured components.

- Grid Uses: Evaluation of grid reliability and SMR impacts on grid stability through connections to microgrids and operations within microgrids with other generation sources.

- Hybrid Energy: Connections with other generating technologies as a hybrid energy system.

- Process Heat: Use of process heat for industrial processes and systems, such as desalination systems.

- Irradiation Testing: Use of the low enriched commercial core to conduct irradiation testing on materials, parts, components, and specialized fuels.

DOE already manages the production and sale of isotopes for government and commercial use through the National Isotope Development Center ("NIDC"), which produces isotopes at several DOE facilities (including ORNL, Y-12, and INL) and universities. NIDC was expected to generate approximately $36 million in revenue in the 2015 fiscal year.[133] NIDC's small revenue share relative to the market implies that NIDC has significant potential for increasing its share of the market. Radioisotopes (radioactive isotopes) are commonly used in medicine, including imaging and cancer treatment. The international market for radioisotopes was estimated to be worth $9.6 billion, with medical uses comprising 80% of the market ($7.7 billion); diagnostic uses predominate, using 90% of medical radioisotopes. North America alone represents a huge market for medical radioisotopes, as the region consumes about half the market for diagnostic radioisotopes.[134]

SMRs present an opportunity to supply the domestic and international isotope market, which faces potential supply shortages over the long-term without investment in new production facilities. Major production facilities have reduced or ceased production globally in recent years, including the National Research Universal reactor in Canada in

2016 and the OSIRSIS reactor in France in 2015. The market for isotopes experienced several short-term supply shortages from 2013-2015. Several projects which were expected to come online by 2022 have been delayed, raising long-term concerns about adequacy of supply.[135]

DOE also recognizes that a number of regulatory challenges will need to be addressed to conduct research using an operating commercial reactor system. It is likely that the initial Combined Operating License Application ("COLA") will be for the standard designs and that subsequent amendments would include evaluations of specific tests, which could be requested years before commercial operations but after NRC issues the Combined Operating License. The agreement would need to account for lost opportunity as reactor units are used for testing and not electricity production, which can easily be financially modeled as a change in the capacity factor of the SMR plant.

Isotope production and research represent potential revenue streams outside of power generation. However, for these revenue streams to reduce the cost of an SMR, they must either generate more revenue than the power production they displace or utilize reactor capacity which would otherwise sit idle. Further, DOE's policy and practice is to refrain from competing with private suppliers of isotopes when such isotopes are reasonably available commercially.

4.3 DOE Grants, Cooperative Agreements and Other Arrangements

DOE has offered a range of grants, cooperative agreements and other arrangements to help defray costs related to the development of new reactor technologies such as:

SMR Licensing Technical Support: Grants have been offered through the SMR Licensing Technical Support ("LTS") program.[136] TVA has benefited from cost-sharing through LTS, which was used to defray the costs of the early site permit application for an SMR at the Clinch River Site. TVA will also receive cost-sharing support in preparing the subsequent COLA. Under this program NuScale was awarded $217 million in matching funds to cover costs related to design and licensing of its SMR. It is further used to support UAMPS with siting and licensing activities.[137]

- Advanced Nuclear Technologies Funding: On August 8, 2017, DOE announced a new cost-sharing funding opportunity for advanced nuclear technologies, which can support SMRs; full details are not available at this time.[138]

- Grants: DOE has also supported other nuclear technologies, including a grant to Southern Company for molten chloride fast reactors and to X-energy for an SMR design using thousands of small fuel pellets which can be inserted into, or removed from, a reactor without shutting it down.[139]

4.4 Credit Incentives

DOE's Loan Programs Office ("LPO") offers loan guarantees for advanced nuclear technology through the Title XVII program. Four advanced technology areas are supported by the nuclear part of the program, including SMRs. The loan guarantees aim to facilitate affordable financing from private sector sources. By guaranteeing a loan (offering to pay the lender in the event of a default by the borrower), LPO aims to lower interest rates or enable financing which would not otherwise be provided at all. LPO has provided three nuclear loan guarantees through Title XVII totaling $8.3 billion to support the construction of new reactors at the Vogtle power plant in Georgia.[140] LPO currently has an open solicitation for support for advanced projects, which could benefit SMRs.[141]

While LPO guarantees could be used to support the development of SMRs generally, by statute a project which benefits from a DOE loan guarantee cannot be supported by federal off-takers. This limitation presents an important consideration in developing a project with a DOE laboratory buying power.[142]

4.5 Ratemaking

Cost recovery for nuclear projects can be accelerated through utility rate structures. Most utilities set rates which are approved by state utility regulators; the regulators aim for rates which allow all costs, including large capital expenditure and debt repayment, to be recovered over time while providing a reasonable return to investors and charging reasonable prices to customers. Construction Work in Progress ("CWIP") is a rate setting approach which has been used to support cost recovery for nuclear power projects. CWIP allows a utility to charge customers to deliver a return on capital while a project is partially built but not yet completed, which can reduce the total financing costs over the long run. Otherwise, regulators do not typically allow utilities to collect return on capital for a project until it passes a "used and useful" test. CWIP was commonly used in the 1970s to support the construction of large nuclear projects.[143]

TVA uses many of the same economic principles in setting rates that state regulators use, although TVA, as a federal agency, is not subject to typical state regulation of rates. Thus, CWIP would have to be authorized by TVA's board, which has authority over TVA's rates. Rate proposals are developed by the board's Finance, Rates, and Portfolio Committee of the board, for final approval by the board.[144]

CHAPTER 5: TENNESSEE VALLEY AUTHORITY AND MODEL CLINCH RIVER SITE PROJECT

5.1 Tennessee Valley Authority

TVA was created by Congress in 1933 to:

> improve the navigability and to provide for the flood control of the Tennessee River; to provide for reforestation and the proper use of marginal lands in the Tennessee Valley; to provide for the agricultural and industrial development of said valley; to provide for the national defense by the creation of a corporation for the operation of Government properties at and near Muscle Shoals in the State of Alabama, and for other purposes.[145]

Today, TVA is the nation's largest government-owned power provider.[146] TVA focuses on three key areas – energy, environment, and economic development – and is fully self-financing.[147]

5.2 Tennessee Valley Authority Power Sales

In accordance with 16 U.S.C. § 831i, the TVA Board of Directors is authorized to sell surplus power not used by TVA for its operations (and for operations of locks and other works generated by it) to states, counties, municipalities, corporations, partnerships, or individuals.[148] The term of any such contracts cannot exceed twenty (20) years.[149]

Additionally, TVA sells power to federal agencies (including DOE) through the use of Interagency Agreements, which contain similar content as the PPAs described elsewhere in this Report, but are between two instrumentalities of the United States. Such agreements are entered into in accordance with the procedures of FAR Part 17.502-2 and the Economy Act (31 U.S.C. § 1535).

DOE, through the DOE Business Services Division, and TVA entered into a Power Supply Agreement. Under the authority of 16 U.S.C. § 831i the Power Supply Agreement identifies that TVA will provide DOE certain power services, and DOE agrees to pay TVA for the cost of providing such services, as described in detail in the Power Supply Agreement.

5.3 Potential TVA SMR Project

On February 17, 2016, DOE requested TVA consider the work and potential impacts from supplying enhanced reliability to DOE's facilities through the potential deployment of SMRs and associated transmission system features to the Oak Ridge Reservation. In response to such request, TVA is exploring the inclusion of an SMR as a power source within TVA's inventory that can be used to provide electric power resilience and other potential uses (including research and isotope production use) to all or a portion of ORNL, Y-12 National Security Complex and the East Tennessee Technology Park (collectively referred to herein as the "Oak Ridge Reservation"). TVA has identified the site for one or more SMRs on the Clinch River Site which is owned and controlled by TVA and is located next to ORNL in Oak Ridge, Tennessee (Roane County, Tennessee) (see Figure 8), west-southwest of downtown Knoxville, Tennessee.

Figure 8: Clinch River SMR Project Site

Source: TVA

The proximity of the Clinch River Site to the Oak Ridge Reservation offers a unique opportunity to provide energy security for functions critical to national security. The ORNL site (including the Y-12 National Security Complex) consumes approximately 724,000 MWh of power annually and, as identified above, performs several important and energy dependent research and nuclear security initiatives. Additionally, the Knoxville area has a substantial workforce skilled in nuclear power generation and other aspects of the nuclear sector, due partly to the presence of the Oak Ridge Reservation and TVA.

Besides proximity, the Clinch River Site has several features which make it favorable for building an SMR. These include:

- Proximity to Water Supply: The Clinch River Site borders the Clinch River, which could provide a steady source of water for SMR operations.

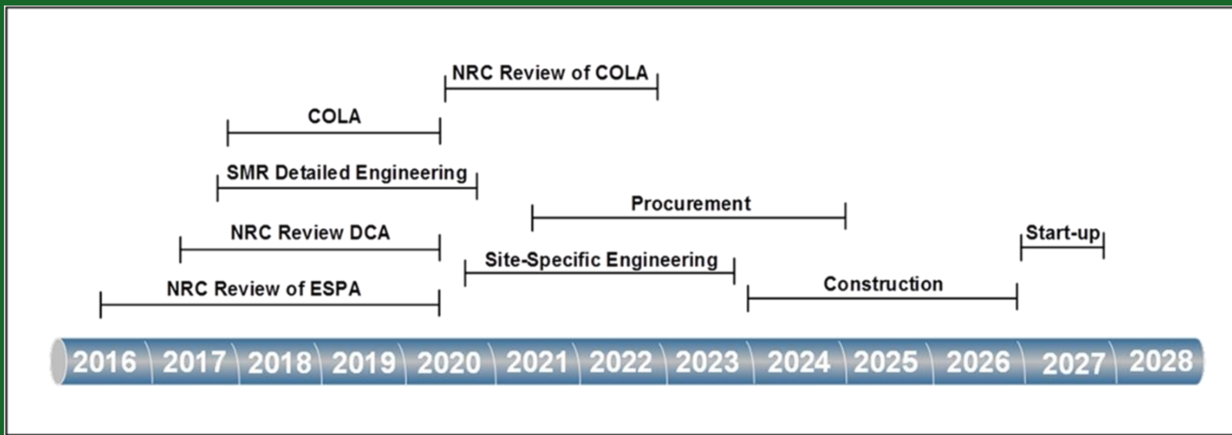
- Proximity to Existing Transmission Lines: Transmission lines pass through the Clinch River Site, providing convenient access to 500 KV and 161 KV transmission lines, thereby facilitating the sale of power from the SMR to TVA's wider customer base during routine operations.

- Underground Transmission: An underground transmission line is being considered for the Clinch River Site, which could link an SMR located there to the Bethel Valley Substation on the Oak Ridge Reservation. This would enhance resilience by hardening the route through which power would be delivered to the Oak Ridge Reservation in event of an outage to the power grid.

- Progress on Permitting: TVA is working on the NRC permitting process for developing two or more SMRs at the Clinch River Site. In May 2016, TVA submitted an Early Site Permit ("ESP") Application to the NRC. ESPs are site permits which are valid for 10-20 years from the date of issuance. Obtaining an ESP reduces risk relating to the COLA process with the NRC, as the ESP Application covers some of the requirements for COLA. The proposed timeline for permitting and completing the SMR at the Clinch River Site is summarized in Figure 9. If the project remains on schedule, it will start operations in 2027 or 2028. The site had been previously cleared and prepared for the potential construction of a separate nuclear energy facility which did not proceed.

If TVA were to decide to build a 570 MWe (net) nuclear power plant, TVA would likely finance any such SMR project through the issuance of debt on TVA's balance sheet. If DOE was to contract for 120 MW of capacity for the Oak Ridge Reservation, TVA could potentially sell the remaining 450 MW of capacity generated from the SMR to TVA's other customers (the current plan is for DOE to use the remaining power for other uses as noted below).

Figure 9: Potential Deployment Schedule[150]



5.4 Description of DOE Oak Ridge Sites

During World War II, President Franklin Roosevelt authorized research into the possibility of developing the world's first nuclear weapon.[151] By 1942, the secret U.S. government research and engineering project code-named the Manhattan Project had begun.[152] As part of this project, the Army Corps of Engineers designated a 59,000 acre region below Oak Ridge, Tennessee a federal reserve, one of three nationwide sites for the development of the atomic bomb.[153] On this reservation, K-25, a gaseous diffusion plant, and Y-12 both worked on separating uranium isotopes while the smaller X-10 plant used neutrons emitted in the fission of uranium-235 to convert uranium-238 into a new element, plutonium-239.[154]

As demolition and environmental cleanup began in the early 1990s at K-25, it became the 'East Tennessee Technology Park' to recognize its transition to a private industrial park. Similarly, in 1990, the NNSA facility Y-12 expanded its mission to include weapons reduction and disassembly.[155] Further, ORNL evolved from the former X-10, which was known as the Clinton Laboratories during World War II, and expanded its research into supercomputing, biomedical engineering, environmental health, and nuclear physics.[156]

5.4.1. Oak Ridge National Laboratory

As one of the largest DOE science and energy laboratory, ORNL is comprised of 196 buildings on 4,421 acres with 4,559 staff members and a current budget of approximately \$1.5 billion.[157] ORNL primarily researches neutrons, high-performance computing, advanced materials for energy applications, and nuclear fission and fusion.[158] The majority of its work, except some projects under its national security programs, is not classified and is published in the open literature.[159] Many of its world-class and often unique facilities are used by researchers from other organizations, including the Spallation Neutron Source (which produces the world's most intense pulsed neutron beams), the High Flux Isotope Reactor (the provider of the highest steady-state neutron fluxes for research in the United States and the only one of the ORNL's 13 nuclear reactors still active today), and the Computational Sciences Building (which houses systems like Titan, the country's most powerful supercomputer for open science).[160, 161, 162]

Not only do such resources require significant amounts of energy, but also the facilities need a continuous energy supply to safeguard project results and machines.[163] As such, the ORNL campus showcases advanced strategies to improve grid monitoring and resilience. One such project is the Distributed Energy Communication & Controls facility, which is connected to the electric distribution utility owned and operated by ORNL and contains 50 kW and 13.5 kW photovoltaic systems, batteries, a 30 kW microturbine, two smart inverters, a power flow controller, several load banks, synchronous and induction machines, and programmable power system protection relays, all of which allow researchers to fully test the power distribution system through load changes, dynamic load startup, feeder reconfiguration, and relaxed capacitor compensation.[164] The campus also operates a microgrid which is powered by a combination of buses, photovoltaic inverter, and battery inverter and controlled by the Complete System-level Efficient and Interoperable Solution for Microgrid Integrated Controls, an ORNL-designed program that uses communication links to monitor and manage microgrid components and interface between the microgrid and the power system.[165]

5.4.2. Y-12 National Security Complex

Spanning 811 acres, the Y-12 National Security Complex has been described by DOE as one of the most important national security assets, because it houses the U.S. stockpile of highly enriched uranium, which is necessary for nuclear reactions.[166] As part of the NNSA, Y-12 not only processes and stores uranium, but it also produces and refurbishes nuclear weapon components, performs surveillance testing to determine how weapons are aging, and dismantles retired weapons to recover nuclear materials.[167] Additionally, Y-12 supports NNSA's Office of Radiological Security and other federal agencies in reducing the risk posed by nuclear proliferation by detecting, removing, and securing nuclear material as well as reconfiguring weapons components into peaceful functions, like fueling energy reactors.[168] Y-12, as a source of highly enriched uranium, supports the Navy, which requires highly enriched uranium as fuel for its nuclear-powered aircraft carriers and submarines.[169] For national security purposes, it is essential that the Navy have secure access to an entirely domestic supply chain for its fuel source, which makes the resilience of Y-12 particularly important.[170]

5.4.3. East Tennessee Technology Park

In 1987, two years after DOE terminated K-25's uranium enrichment operations, the Office of Environmental Management ("EM") began to clean up the 2,200 acre site's contaminated buildings, soil, sediment, and groundwater.[171] EM removed the site's five former gaseous diffusion plant buildings, marking the first cleanup and removal of a former uranium enrichment complex in the world.[172] DOE aims to complete cleanup by the end of 2020 by demolishing remaining structures, such as the Central Neutralization Facility, Poplar Creek Facilities, and the TSCA Incinerator, and remediating soil and groundwater contamination.[173] While cleaning up the site, EM has leased and transferred portions of the site for private development with the goal of transferring the full site for private development.[174]

CHAPTER 6: KEY CONSIDERATIONS FOR THE TVA SMR CLINCH RIVER SITE PROJECT

This Chapter identifies the likely legal authorities that would be used by DOE to purchase power for the Oak Ridge Reservation from an SMR sited at the Clinch River Site (the "Project"). This Chapter then explores the financing considerations associated with an SMR sited in TVA's service territory, including a discussion of the issues, terms, and conditions that would need to be addressed and negotiated. As noted previously, the proximity of the Clinch River Site provides a unique opportunity to generate baseload power while also offering energy resilience to the Oak Ridge Reservation. The Sections below review a potential financing approach and transaction structure for the Project.

6.1 Potential Legal Authorities for the Sale of Power from the Project

DOE and TVA currently have an existing Power Supply Agreement to provide power to the Oak Ridge Reservation for a term of 10 years. The provision of power and services from an SMR to the Oak Ridge Reservation may be authorized by an amendment or by a new Power Supply Agreement to include specific components of the resilience-based rate or tariff (potentially along with other services) which would enable TVA to recover through the rate some of the up-front costs associated with the licensing, design, and construction of the SMR (based on the service being provided to DOE).

In entering the Power Supply Agreement, in addition to 16 U.S.C. § 831i, TVA and DOE may utilize the legal authority of the Atomic Energy Act (42 U.S.C. § 2204) which authorizes DOE to enter into contracts for electric services for up to 25 years for the Oak Ridge installation; however, TVA will be limited to a term of 20 years under its legal authority (16 U.S.C. § 831i).

6.2 TVA's Financing of the Small Modular Reactor

As noted in the Initial Report, the approaches to financing power projects vary based on the needs of the project sponsor, the risks presented by the project, and the availability of capital. Potential financing approaches generally fall into one of the following three categories:

1. Non-recourse or limited-recourse project financing;
2. Corporate/balance sheet borrowing; or
3. Public power financing.

As a large baseload generation asset owned by TVA, the Project would operate in the TVA service territory. While it is possible that the plant could secure sale of power or off-take from customers outside of the TVA region, TVA would rely on TVA transmission and another transmission line owner to deliver power, incurring wheeling charges and line losses to transport power to customers outside of the TVA service territory. TVA has the statutory authority to set rates for electricity sales within its territory. Therefore, unlike plants sited in deregulated markets, a financing plan associated with the Project would rely less on the terms and conditions of a PPA and more on the economics of the SMR relative to other sources of baseload power.

Given these circumstances, the Project would represent a generation resource serving all customers in TVA's service territory. The Project could be financed either through a project finance approach or, more likely, by TVA issuing debt. These approaches are described below.

Assumptions Regarding TVA Financing and Project Timing:

It is most likely that this Project would be financed by TVA as a corporate undertaking. In order to do so, the transaction would need to address the following considerations:

- TVA Generating Asset: The plant would be part of TVA's power plant portfolio, providing energy to the grid in TVA's service territory.
- Cost Neutrality: TVA's commitment to building the plant would reflect careful analysis of alternatives and would need to be cost neutral when compared to alternatives.
- Risk Sharing: In addition to cost neutrality, TVA would seek to shelter its ratepayers from unique risks associated with deploying an SMR given the limited track record of SMRs. Therefore, a sharing of risks associated with design, permits, and construction would be required between TVA and DOE.
- Appropriate Risk Profile: It is unlikely that TVA would pursue development of the plant if it exposed TVA and its ratepayers to an unacceptable risk profile. Therefore, the development and completion risk of the SMR would need to be addressed such that risk of completion delays or cost overruns would not be fully borne by TVA ratepayers.
- Timing of Commercial Operations: According to TVA, recent and planned capacity replacements obviate the need for a new baseload generation source until the year 2030, although, given the schedule risk of nuclear builds and DOE objectives, TVA may target initial operation as early as 2027. The commissioning of an SMR by 2027 would be eased by DOE providing adequate support to narrow the cost premium of an SMR versus likely alternative generation, thus avoiding a rate

increase for TVA's customers. In either case, it is possible that this would not be the first commercial development of an SMR in the United States.

Based on the above considerations, it is reasonable to assume that an SMR sited in TVA's service territory would be financed like other TVA generation assets: on TVA's balance sheet and backed by power system and net power proceeds. Thus, the debt will be repaid through TVA's total revenue and not be limited to revenue from the Project itself. This provides many advantages over project financing; chief among them is that TVA has a relatively low cost of capital as a long-standing corporate borrower in the bond markets. TVA is rated well above the threshold for investment grade, with stable outlook, by the three major rating agencies. The ratings are "AA+" by S&P, "Aaa" by Moody's, and "AAA" by Fitch. Accordingly, access to long-term debt financing at low interest rates would not be a concern.

Under a corporate borrowing, the SMR will be one of TVA's grid assets, and its costs would be recovered through utility cost-of-service principles, whereby revenue requirements reflect cost drivers specific to each class of customers.

Project Finance Approach:

Alternatively, though less likely, the Project could be accomplished under a project finance approach (which would potentially require the ownership by a special purpose entity controlled by TVA of the Project for financing). Such an approach would require addressing the following key considerations:

- Off-taker(s): The key to project financing is the revenue source or the purchasers of the power. DOE would be an off-taker for the power produced at the Clinch River Site. Other off-takers could include (i) federal customers inside and outside the TVA region, assuming their willingness to support the likely additional costs associated with transmission, and (ii) TVA if the project is owned by a special purpose entity (or other TVA customers). We note that the customers would be the key to a successful financing and other TVA customers may already be scheduled to be supplied by power through long-term electric generation resources owned by TVA.
- Project Development and Completion: For potential off-takers of the SMR power, the development and completion risk present difficult challenges that must be overcome. In particular, customer resource planning requires capacity to come online within anticipated timeframes. Delays in commercial operations would require off-takers to procure power on short notice, potentially exposing them to higher than expected costs. Typically, this risk is assumed by the power producer via performance security; however, this could be challenging due to the unique risks of developing and financing an SMR.

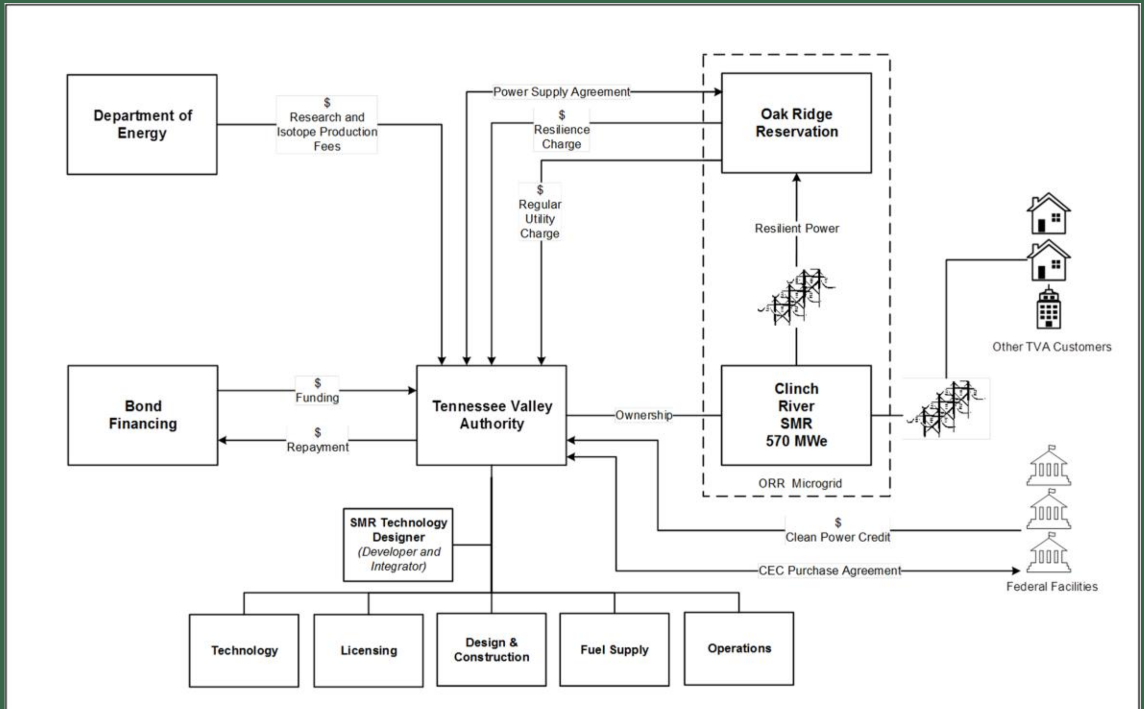
- PPA Term: Ideally, any PPA term (Power Supply Agreement or Interagency Agreement) would extend for the useful life of the asset (assumed to be 40 years). However, it is more likely that the term will be limited by TVA (20 year authority) and federal contract authorities (typically 10 years and in Oak Ridge up to 25 year authority) and by lender underwriting criteria related to acceptable loan terms. Pricing under the PPA would be directly influenced by the term of the PPA(s). For this Project, lenders would structure repayments to fully amortize the debt before PPA expiration. Accordingly, PPA pricing may be high in the early years as the investment in the new plant would be recovered over approximately the first half of the useful life of the SMR unless the non-recourse financing party is comfortable that DOE would purchase the power upon the initial PPA or interagency agreement expiration.
- Source of Debt Financing: Under the structure, substantially all power off-take would be sold to federal entities – either to TVA or to other federal off-takers outside of the TVA region. Accordingly, debt would need to be sourced from the taxable public debt or bank markets. The Project would not be eligible to access the lower-cost tax exempt municipal bond market (due to tax rules related to the federal off-take) or the DOE loan guarantee program (federal appropriations cannot secure repayment of a federal loan).
- Other Terms that Affect Financing: The financing of the Project would be directly affected by the terms of the off-take agreement(s). For example, FAR-based contracts typically carry termination for convenience provisions. Absent a termination payment schedule, project financing could present challenges.
- Step-Up Provisions: If there is more than one PPA, lenders will seek to be insulated from the termination of one PPA through a step-up provision that requires other off-takers to increase their minimum purchase in the event a PPA is canceled.

Given the location and scale of the potential Project, financing the SMR on a project finance basis would present significant challenges, the solutions to which would likely increase costs and render the Project financially unfeasible.

6.3 Illustrative Transaction Structure for the Project

The transaction structure for the development and financing of an SMR at the Clinch River Site would introduce a limited number of changes in the way the Oak Ridge Reservation procures power. Key elements of the development of financing and ownership are described in Figure 10 below:

Figure 10: Illustrative Transaction Structure for the Project



- Tennessee Valley Authority: TVA would be the Sponsor of the Project, as well as the Project's owner. TVA would operate and maintain the Project over its operating life. As currently envisioned, the SMR would be owned by TVA and would be a generation asset in TVA's portfolio. This would allow the Project to be financed on TVA's balance sheet and for costs to be recovered as part of TVA's rate base.
- DOE/Oak Ridge Reservation: DOE, on behalf of the Oak Ridge Reservation, would purchase power from the Project under a large industrial user tariff under the TVA rate structure. The Oak Ridge Reservation's load represents approximately 21% of the Project's output during normal operations. During grid outages, the Project could remain operational and provide power to the Oak Ridge Reservation sufficient to satisfy all requirements.
- SMR Technology Designer: The technology designer will integrate the roles of technology supply, engineering, construction, and fuel supply for the SMR. Several companies are developing potential SMR designs, including NuScale, which is supporting the development of the SMR at Idaho National Laboratory. These roles will be undertaken under subcontract agreements, the most important of which will be the Engineering, Procurement, and Construction Agreement. Under this Agreement, the contractor will commit to design and build the SMR on time, within budget, and to expected performance standards. The specific risk allocation is currently not known.

- Bondholders: The Project will be capitalized on TVA's balance sheet and funded through the issuance of long-term taxable bonds. Accessing financing at attractive terms should not represent a challenge as repayment would be a corporate obligation of TVA, an established bond market participant with investment-grade credit ratings.

  Key agreements in the transaction structure in Figure 10 include the following:

1. PPA: TVA and DOE (on behalf of the Oak Ridge Reservation) would amend the existing PPA or enter into a new agreement setting forth the terms and conditions under which TVA would provide power, and the Oak Ridge Reservation would receive power. Key elements of this arrangement would include:
   - DOE (on behalf of the Oak Ridge Reservation) would be responsible for paying rates charged by TVA in the customer class applicable to its generation of electricity.
   - Payments for the resilience benefits provided by the SMR and associated transmission/distribution charges and enhancements as part of the utility services bill. This "resilience premium" would be payable over the term of the Power Supply Agreement either as a component of the electric bill rate or separated out to account for a potentially different funding source and accounting.
   - To provide the benefit of resilience, the Project would need to be capable of islanding, so that it can supply power to the Oak Ridge Reservation while isolated from the wider grid.
   - Mechanisms could be included in the Power Supply Agreement to protect each party, appropriately sharing risks/rewards as actual conditions on the project differ from the planning basis used on entering the Power Supply Agreement.
   - If DOE is utilizing the SMR for research and/or isotope services, the availability of the SMR for such purpose will be specified, as well as parameters for DOE's use and the payment of fees by DOE to TVA for such purpose.
2. CEC Purchase Agreements: As has recently been implemented in New York, CECs (as identified in Section 1.5) can be implemented to provide incentives for nuclear energy. Federal facilities may pay a premium for nuclear energy in markets where CECs are implemented or could purchase CECs if mandated to do so. The market for CECs could be facilitated by DOE aggregating CEC purchasers on behalf of DOE sites, DOD, or other federal agencies. TVA does not currently use such agreements.

6.4 Resilience Benefit

As noted above, the development of an SMR at the Clinch River Site would bring the benefit of energy resilience to the Oak Ridge Reservation. Given the load characteristics of the Oak Ridge Reservation and the proximity of the Clinch River Site, an SMR could be configured to allow the Oak Ridge Reservation to operate in an islanded mode during periods of grid outages. Additionally, the power plant's configuration could allow the SMR to provide black start capability.

Importantly, the Oak Ridge Reservation would be the primary and potentially the exclusive beneficiary of the resilience benefit of the SMR, and, as such, would need to support the incremental costs associated with the plant. This would include the cost of incremental transmission infrastructure, switchgear, and any cost premium associated with the SMR relative to alternative technologies. Given the extra value of backup power over conventional utility service, a resilience premium paid by DOE (on behalf of the Oak Ridge Reservation) could help to off-set the expense of power from an SMR. The size of an SMR relative to the Oak Ridge Reservation's load would require the Project's output is consumed partially by the Oak Ridge Reservation and partially by TVA's general customer base.

As further discussed below, siting an SMR at the Clinch River Site as a TVA generating asset with special resilience services to the Oak Ridge Reservation would require a contractual arrangement between TVA and DOE that allows compensation for services associated with the SMR to be assessed to the Oak Ridge Reservation ideally over a long period of time. This would serve to off-set the cost premium of the FOAK SMR, a key consideration for TVA as it would seek to avoid investments in generating assets that introduce added costs to its ratepayers.

6.5 Clean Energy Credits for Nuclear Power

As the use of federal off-take in the TVA service territory will be limited, an alternative incentive could be a CEC instrument which is used by federal facilities to meet clean energy purchase mandates (much like RECs are used to meet clean energy requirements as described in Section 1.5). This would create an additional revenue stream for TVA as owner of the SMR and would potentially create a federal revenue stream beyond TVA's typical customer base. Federal facilities in the TVA service territory could purchase CECs without incurring transmission charges and without entering into a PPA.

6.6 Research and Isotope Production Revenue

Setting aside one or more reactor modules for research or production of isotopes could provide an alternative revenue stream for the Project, in line with the JUMP concept (see Section 4.2. A reactor module used for research or isotope production would necessarily not be used for power production. DOE could pay TVA an annual fee for access to one or more reactor modules for these uses, effectively reserving a share of the SMR's capacity. ORNL is already an isotope producer, and thus has the facilities required for preparing material inputs for isotope production and for processing isotopes after removal from a reactor.[175]

Devoting reactor modules exclusively to power production or to other activities should minimize the possibility of having unexpected outages of power-producing reactor modules due to issues related to other activities. If a research or isotope-producing module has to be shut down, then power supply from other modules should continue uninterrupted.[176] An arrangement could also identify certain reactor modules with priority to support DOE missions, but allowing also for electricity production.

6.7 Financial Analysis

Developing and financing an SMR at the Clinch River Site would need to balance the competing interests of Oak Ridge Reservation (the "Customer") and TVA (the "Utility"). This Section explores these perspectives and provides rough order of magnitude estimates of cost implications to Oak Ridge Reservation and TVA. The analysis first considers the requirements of each party, and then presents an analysis of the costs of an SMR option compared to a combined-cycle natural gas ("CCNG") option as a likely alternative and ways to increase value from an SMR or reduce cost differentials.

For the Customer, the alternative would be an on-site, privately-financed, PPA-supported CCNG plant providing resilient power. The analysis compares the SMR option against the development of a baseload power plant on-site and financed by a third party under a power purchase agreement. The financial analysis from the customer's perspective focuses on the cost of energy and certain energy services. A more detailed analysis would consider costs of transmission, demand charges, the cost of delivering islanding capability for the Oak Ridge Reservation, and other economic inputs as individual billable line items.

For the Utility, the alternative would be a CCNG plant financed on TVA's balance sheet. The analysis from the Utility's perspective assumes TVA is developing a generation asset for the grid, is contemplating siting a plant at the Clinch River Site, and is considering an SMR or a CCNG plant. The analysis identifies financial gaps facing TVA that would need to be addressed through financial incentives such as production tax credits, clean energy emission credits, or other opportunities to improve the economics associated with commercially deploying SMRs.

Costs are determined by the estimated Levelized Cost of Energy ("LCOE") of each technology and are influenced by a number of factors, each of which is subject to considerable uncertainty at this time. This includes the cost of development, construction, and O&M, as well as the cost of fuel over the life of the asset. This analysis is notional and is intended to illustrate the tradeoffs which would be faced by the Oak Ridge Reservation and TVA (if the Oak Ridge Reservation is interested in pursuing an SMR for energy resilience).

Customer Requirements: Oak Ridge Reservation

This Section is premised on the assumption that the Oak Ridge Reservation will be seeking energy resilience over the next decade and would seek backup generation for loads deemed critical at the site. For analysis purposes, it is assumed that the entire Oak Ridge Reservation would seek energy resilience through backup generation, as it may be easier and cheaper to supply all of the load than to carve out and serve selected loads. While this represents an option, it is recognized that the site may, as an alternative, seek to identify critical loads and determine courses of action that could isolate these loads and have them served by distributed backup generation. Nevertheless, this analysis assumes that all loads at the Oak Ridge Reservation are deemed mission-critical, requiring the supply of backup power during grid outage.[177]

The analysis of Oak Ridge considers the costs facing Oak Ridge Reservation resulting from two resilient power options:

- On-site CCNG: A "behind the meter" CCNG baseload plant with private financing and a PPA selling power to Oak Ridge Reservation; and,
- Off-site SMR: An "in front of the meter" SMR at the Clinch River Site which TVA would own and finance, and could be isolated from the grid to supply Oak Ridge Reservation.

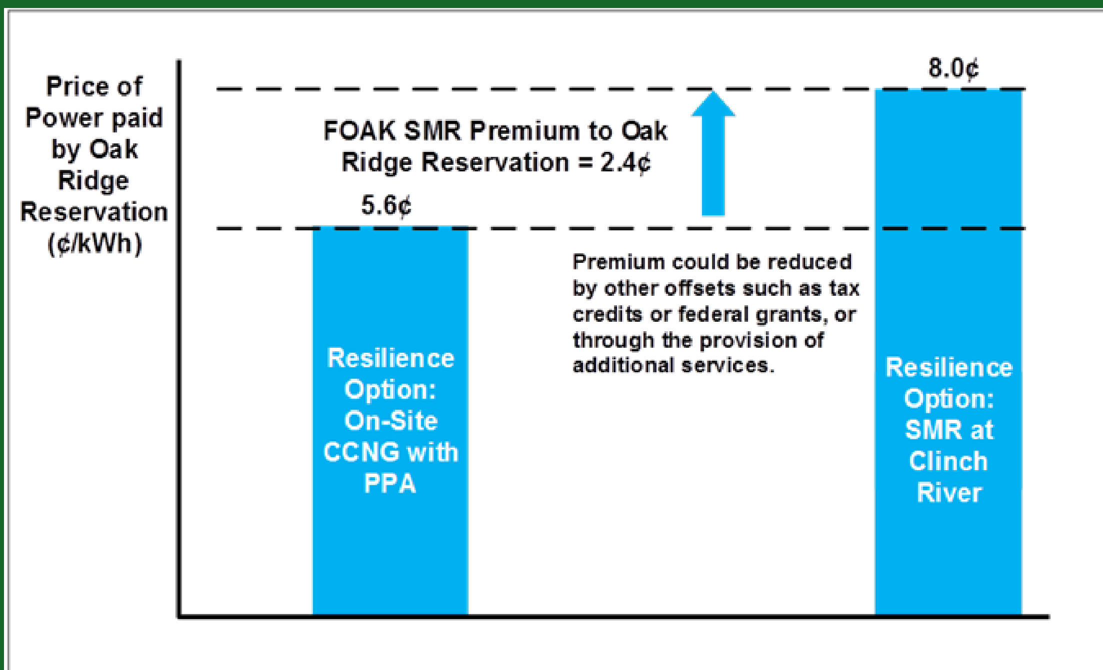
Notional Customer Cost Analysis: Oak Ridge Reservation

The cost of energy resilience for the Oak Ridge Reservation is examined by considering two different options for resilience. One option – the basis of comparison – is a baseload generation facility capable of meeting all of the Oak Ridge Reservation's energy requirements and capable of continued operations in the event of a grid outage. This is broadly comparable to an SMR, in that it is a non-intermittent power source which could support all of the Oak Ridge Reservation's lands. While using on-site baseload power would probably incur standby charges to be paid to TVA for providing generation capacity to serve the Oak Ridge Reservation through the grid as needed, these charges are not considered in the financial analysis.

The analysis assumes that an on-site CCNG power plant – would be third-party financed under a long-term PPA (and not an Interagency Agreement between DOE and TVA). This is broadly similar to how federal entities such as the Army and Navy use PPAs for on-site energy production. The LCOE for the on-site CCNG plant was calculated using a LCOE calculator made by the University of Texas Energy Institute, set to consider a CCNG plant in the Knoxville area.[178] The LCOE was estimated at $0.056 per kWh.[179]

The second option for energy resilience is an off-site SMR at Clinch River. The costs of the likely alternatives can be compared to the cost of a FOAK SMR. Based on industry estimates, the LCOE of an SMR for a public power producer falls near $0.080 per kWh. The challenge in developing an SMR to serve Oak Ridge Reservation is in narrowing the SMR's price premium. As noted in Figure 11, the LCOE for an SMR exceeds the CCNG alternative by 2.4¢ per kWh. By comparison, the value of energy resilience has been estimated to fall in the range of 0.6¢ per kWh, which would leave an approximate gap of 1.8¢ per kWh.[180] This is well within the range of financial incentives that have been implemented in the past, namely production tax credits for renewables and nuclear power. Additionally, this gap could be further closed through research and isotope production fees, as described further below in the analysis from TVA's perspective.

Figure 11: Notional Analysis: Customer[181]



Utility Requirements: TVA

The analysis from the Utility's perspective assumes that TVA will be seeking to invest in a baseload generation asset with commercial operations beginning in the 2027 – 2030 timeframe. Consistent with its utility cost allocation policies, TVA would need to determine whether the SMR would introduce a cost premium over other comparable technologies available. Further, the analysis also considers the value of useful services besides basic power supply, such as resilience, black start, and research capabilities of an SMR. These services are assumed to be paid for by their beneficiaries, thus generating revenue for the SMR.

It remains possible that sources of clean power may command a financial premium or benefit from a credit such as the ZECs recently implemented in the State of New York.

Further, other policies (i.e., production tax credits) or programs (i.e., DOE cost share) may be available to narrow the LCOE gap between a FOAK SMR and a new combined cycle natural gas plant, which would be the likely alternative power source if an SMR is not pursued.

To the extent a cost premium associated with the SMR is identified, TVA would look to other revenue streams to cover such costs in order to avoid ratepayer impacts. The analysis from TVA's perspective considers two power options:

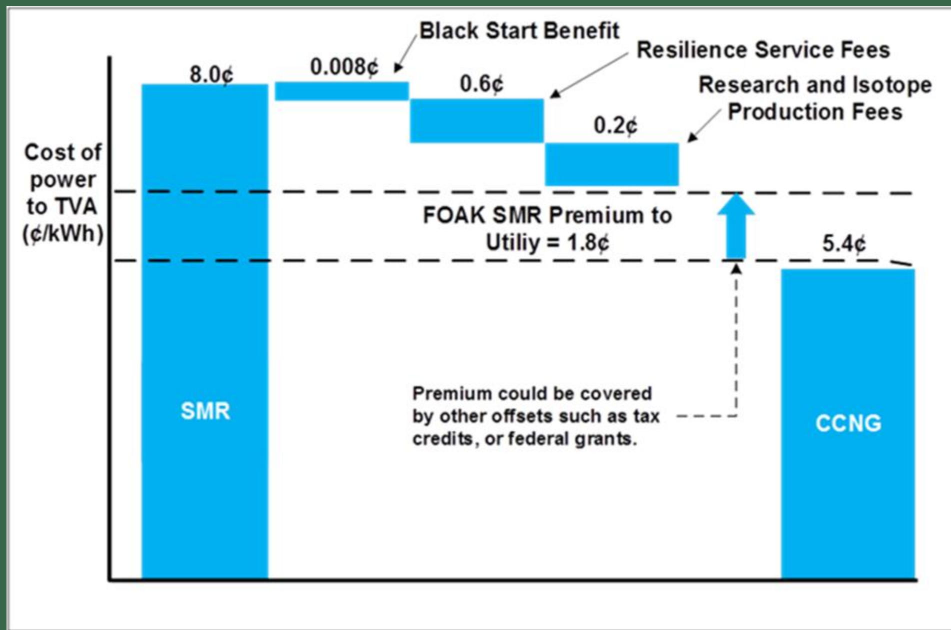
- CCNG: A CCNG baseload plant which TVA would own and finance on its balance sheet; and,
- SMR: An SMR at Clinch River which TVA would own and finance on its balance sheet.

Notional Utility Cost Analysis: TVA

For TVA, it is assumed that the decision to invest in an SMR at the Clinch River Site will be based on the cost of service measured by LCOE relative to the comparable baseload alternative and the value of other useful services provided by the SMR. In present conditions, the basis for comparison is assumed to be a CCNG plant of comparable size to the SMR. The CCNG plant financed by TVA has an estimated LCOE of 5.4¢ per kWh, which is slightly lower than the LCOE for the PPA-supported CCNG plant sited at Oak Ridge Reservation due to differences in cost of capital.

Figure 12 includes a notional cost analysis for TVA, which shows how the LCOE of the SMR could be offset in several ways.

Figure 12: Notional Analysis: Utility



The notional analysis in Figure 12 indicates that several pathways exist for reducing the estimated premium of 33% in LCOE for the SMR over the CCNG plant. The financial analysis assumes that the SMR can provide black start capability, which provides a valuable benefit to TVA, which will lead to DOE paying a resilience service charge to TVA. The value of black start was based on a federal study estimating the value of black start from natural gas power plants.[182] The value of the resilience charge was based on estimates of the LCOE of backup power through diesel generators at military facilities.[183] The value of the research and isotope production fees was calculated assuming that one reactor module of 12 would be used for those activities; and that a reactor module devoted to those activities would generate $10 million additional revenue per year over its revenue requirement (annual revenue with power priced at LCOE). That additional revenue would then help pay down costs for the 11 power-producing reactor modules. These three benefits help reduce the cost premium of the SMR, as illustrated in Figure 12. Future analyses of the value of energy resilience to critical sites could help better justify a premium for energy resilience. The remaining premium represents a potential cost gap that would need to be closed through various incentives.

Possible incentives may include government-sponsored financial initiatives, such as upfront grants for development and deployment or tax incentives for investment or production. The use of investment or production tax incentives for a TVA project will necessarily affect the financial structure or require legislative change, as TVA generation projects typically are not taxed due to TVA's federal ownership. The premium could be further reduced if the federal government chooses to incentivize carbon-free power production by allowing CECs from an SMR to meet clean energy requirements as described earlier in this Chapter.

CHAPTER 7: RECOMMENDATIONS

SMRs are designed to provide valuable resilience services as a secure, reliable, and flexible source of primary and backup power. SMRs, coupled with transmission hardening, could provide highly reliable, non-intermittent, clean, and carbon-free power. SMRs can also easily store two years' worth of fuel on-site. Certain SMR designs allow for output to be varied over days, hours, or minutes, thereby enabling the SMR to adjust to be in line with changing load demands.

However, implementing SMR projects around the country are difficult due to the FOAK technology, construction challenges, and licensing requirements. SMRs introduce significant expenses and risks that may be challenging for a project to bear without any financial support from the intended end user. The recommendations offered in this Chapter, along with the potential solutions described elsewhere in this Report, may be considered to assist with overcoming these challenges and advance the deployment of SMRs in the United States while improving grid resiliency at the Oak Ridge Reservation.

More specifically, this Chapter identifies how the federal government can assist with making the financing and development of SMRs easier – both in its role as a customer and as a governing body.

7.1 Permit federal agencies to enter into agreements for a term of up to 30 years to purchase power produced by small modular reactors.

Congress may wish to consider enacting legislation which would permit federal agencies to share in the risks associated with the construction of SMRs. Leveraging the federal government's strong credit standing as a purchaser of the power and its continual need for baseload power is important in the development of SMRs. Federal agency purchasers can help to set the market and offer more certainty to other initial buyers. While there are a range of legal authorities federal agencies may use to purchase power, most often GSA's 40 U.S.C. § 501 is used, limiting PPA terms to 10 years. This 10 year limitation impacts a party's ability to take advantage of government purchasing for financing.

Federal agencies should be able to purchase power produced by an SMR for a term of up to 30 years. Currently, only DOD (pursuant to 10 U.S.C. § 2922a) has the authority to purchase power for a term of up to 30 years in limited circumstances. By creating an authority that permits federal agencies to purchase power for up to 30 years, SMR developers will be able to use traditional financing to repay a project financed project or a long-term bond over an up to 30 year term, making the financing more affordable. Depending upon the size of the federal agency's off-take, as compared to the size of the power source being funded, this discrepancy may make it difficult for financing.

The goal can be accomplished by three potential legislative actions:

Potential Legislative Actions to Extend Contracting Term for Power Produced by SMRs	
Extend GSA Authority for Certain Types of Power Sources	• Amend 40 U.S.C. § 501 to permit longer contract terms (i.e. 30 years) for nuclear or other types of energy that require more regulatory approvals or where it is in the interest of the Secretary of the federal agency to develop longer term power for grid stability or national defense
Amend 10 U.S.C. § 2922a	• Amend 10 U.S.C. § 2922a to apply to a broader federal audience than only DOD and permit federal agencies to purchase the power produced on all federal properties
Create a New Legal Authority	• Similar to amending 40 U.S.C. § 501, create a new legal authority that permits federal agencies to purchase SMR or nuclear produced power for a term of 30 years

By enacting one or more of the legal authorities set forth in the above chart, Congress would provide federal agencies with access to power for critical national defense infrastructure and allow the federal agencies to have the tools to consider the integration of SMRs into their power purchase determinations. Specifically, there are several defense facilities around the world that rely on old technology and power plants located far from the facilities to power the facilities in the case of grid outage for any reason. An SMR located in the correct area can provide a significant benefit to secure the facility and ensure long-term operation without refueling (SMRs easily store two years' worth of fuel on-site). Similar to aircraft carriers and submarines that are powered by nuclear power, no other power source can provide that much certainty to a land-based defense facility.

7.2 Facilitate TVA's Clinch River Site Project as a pilot project for SMRs, while simultaneously providing DOE with critical energy resilience and a potential opportunity to conduct research and isotope services.

The Clinch River Site SMR project has several benefits that can be a catalyst for other SMR projects around the country and assist DOE to accomplish several missions at the site. First and foremost, the SMR will produce power that can be used by the Oak Ridge Reservation. Second, the power can be delivered to the Oak Ridge Reservation in a secure manner that will provide valuable NNSA and DOE facilities with reliable power in the case of a grid outage or interruption. This will also be a pilot project and a model for federal agencies and defense facility resilience when integrated into the existing microgrid at ORNL. Some agencies may wish to consider either resilience or isotope uses of SMRs separately, depending on the agencies' missions.

DOE currently has limited access to nuclear test reactors to conduct research needed to improve reactor designs, capabilities, and commercialization potential. DOE views having a commercial, multi-unit SMR sited on or next to national laboratory property as a potential opportunity to conduct research in a number of areas, including power generation, process heat, materials testing, and production of radioisotopes or other nuclear material for DOE. DOE could defray a portion of the cost of the operation of a commercial reactor sited on or next to laboratory property in exchange for access to one or more units of an SMR for several research areas, including:

- Operations: Examination of issues such as control room human factors, improvement of plant procedures, safeguards and securities development, refueling capabilities, and more.
- Technical Optimization: Use of the operating plant to conduct research and optimization of components and systems such as unique sensors, instrumentation, control systems, and on-line monitoring. This could also include demonstration and validation of code cases associated with components manufactured using advanced techniques, such as additive-manufactured components.
- Grid Uses: Evaluation of grid reliability and SMR impacts on grid stability through connections to microgrids and operations within microgrids with other generation sources.
- Hybrid Energy: Connections with other generating technologies as a hybrid energy system.
- Process Heat: Use of process heat for industrial processes and systems, such as desalination systems or heat storage.

- Irradiation Testing: Use of the low enriched commercial core to conduct irradiation testing on materials, parts, components, and specialized fuels.
- Material Production: Potential for the manufacture of saleable radioisotopes or other nuclear material needs of the Department (e.g. tritium program support).

As described in Chapter 6 and illustrated in Figure 12, there are many benefits that can be provided to DOE (such as black start capability, resilience, and research and isotope production) which can off-set the differential between the cost of an SMR and other power sources.

7.3 Extend the EPACT 2005 Production Tax Credits.

Existing PTCs for nuclear power are set to expire in 2020. A PTC is a tax credit generated by production of a certain good; in the case of power generation, tax credits are typically allocated per kWh of production and reduce the project's total lax liability. Federal PTCs are currently provided for clean power produced by nuclear power plants at the rate of $0.018 per kWh as established in EPACT 2005.184. That legislation would only provide PTCs for nuclear power plants which enter service by December 31, 2020. However, the House of Representatives passed a bill in June 2017 which would lift the 2020 deadline and allow non-taxpaying public project owners to pass along PTC benefits to eligible taxpaying project participants,[185] thereby allowing SMR projects entering service after 2020 to benefit from PTCs. The bill would need to pass the Senate and be signed by the President to become law. Other changes to PTCs could further help SMRs: (1) increasing the value of PTCs to better account for inflation and more closely match renewable.

7.4 Continue to authorize the DOE Loan Program to support advanced reactors.

DOE's Loan Programs Office ("LPO") offers loan guarantees for advanced nuclear technology through the Title XVII program. Four advanced technology areas are supported by the nuclear part of the program, including SMRs. The loan guarantees aim to facilitate affordable financing from private sector sources. By guaranteeing a loan (offering to pay the lender in the event of a default by the borrower), LPO aims to lower interest rates or enable financing which would not otherwise be provided at all. LPO has provided three nuclear loan guarantees through Title XVII totaling $8.3 billion to support the construction of new reactors at the Vogtle power plant in Georgia.[186]

While LPO guarantees could be used to support the development of SMRs generally, by statute a project which benefits from a DOE loan guarantee cannot be supported by federal off-takers. This limitation presents an important consideration in developing a project with a DOE laboratory buying power.[187] Congress can amend this to permit federal agencies to purchase power from facilities that benefit from the loan guaranty to the extent the power purchase benefits a defense related facility or, more generally, to the extent the power is produced by an SMR.

7.5 Include nuclear power in the definition of "clean power" in federal policies. If EPA's Clean Power Plan continues, add a rule that encourages states to support SMRs giving them credit for the zero-carbon energy.

In August 2015, the U.S. Environmental Protection Agency ("EPA") released the final Clean Power Plan ("CPP") in order to develop a plan for decreasing global greenhouse gas ("GHG") emissions.[188] President Trump's Administration is currently reviewing the CPP to determine whether to amend or terminate the CPP.[189] The information below is recommended to be included if the CPP is amended. This information could be also be included in other policies that aim to support clean power or renewables, such as DoD directives or executive orders on procurement of renewable energy.

The current CPP focuses on promoting renewable energy sources. Traditional renewables like wind and solar power are variable energy sources that cannot be dispatched like baseload power such as nuclear energy. The CPP states that "Existing nuclear generation helps make existing CO_2 emissions lower than they would otherwise be."[190]

Nuclear energy is a zero-carbon energy source, and approximately 100 nuclear power plants in the United States generate about 20% of our nation's electricity.[191] As more nuclear power plants reach retirement, the CPP assumptions include the prediction that nuclear power will retain its current market share through 2030,[192] which does not seem likely at this point with a small number of large nuclear power plants being constructed.

However, SMRs can provide the same benefits without the large footprint or investment once the FOAK plants are constructed. By adding nuclear power to the CPP, states and others can begin to rely on nuclear power as a baseload power source to provide more stability to the electric grid while remaining carbon-free.

This will also assist the United States if it elects to renegotiate any climate agreements. By having a path toward additional zero-carbon power produced by SMRs, it will assist the country to meet future climate agreements while providing more stability to the electric power production.

7.6 DOE and DOD should collaborate to identify facilities that can benefit from hosting or having an SMR located near the facility to achieve added energy resilience.

DOE and DOD should meet to determine what facilities can benefit the most by locating an SMR at or near such a facility. As described in this Report, the benefits attributable to an SMR are significant and can provide additional certainty that is needed by the facilities to achieve energy resilience.

DOE can request that NNSA and DOE offices identify its most critical facilities, while DOD can work with the military services to identify domestically and abroad where the facilities can benefit from having a hardened SMR on or near the base to provide a long-term reliable (and carbon-free) power source. After such needs are identified, the entities should evaluate whether an SMR may be a good solution to assisting the facility to achieve energy resilience.

APPENDIX A
EXECUTIVE SUMMARY OF *PURCHASING POWER PRODUCED BY SMALL MODULAR REACTORS: FEDERAL AGENCY OPTIONS*

Below is the Executive Summary contained in the January 2017 report entitled Purchasing Power Produced by Small Modular Reactors: Federal Agency Options. The complete report is available for download at: https://www.energy.gov/ne/downloads/purchasing-power-produced-small-modular-reactors-federal-agency-options.

The purpose of this Report is to provide guidance to federal agencies on procuring power generated by small modular reactors ("SMRs") in accordance with existing federal authorities. By following this guidance, federal agencies can take advantage of the opportunity to purchase highly reliable carbon-free power and provide support for financing the development of the initial SMRs.

After years of development, SMRs are close to obtaining Nuclear Regulatory Commission ("NRC") regulatory approval. DOE has identified that these small nuclear power plants will "play an important role in addressing the energy security, economic and climate goals of the U.S. if they can be commercially deployed within the next decade," making it a primary element of the DOE Office of Nuclear Energy's Nuclear Energy Research and Development Roadmap.[193]

Private industry is leading the development of SMRs. There is wide-spread recognition that the risks presented by introducing this new technology in the electric power sector will require public-private risk sharing to achieve commercial deployment. In October 2016, the Nuclear Energy Institute introduced "SMR Start," an advocacy program calling for public-private partnerships to advance commercial deployment of SMRs.[194] Key elements of SMR Start include the extension of production tax credits ("PTCs") established under the Energy Policy Act of 2005 ("EPACT"), DOE loan guarantees established under Title XVII of EPACT, and Power Purchase Agreements ("PPAs").

Given the magnitude of power purchases by federal users, federal PPAs have long been cited as a meaningful method to spur the siting and development of power projects using innovative technologies. By providing a contractual commitment to purchase power from a plant, certain business risks associated with the project are reduced, thereby improving the financial profile of the project for private investors. PPAs may be attractive from a public policy perspective because: (i) power supply is essential to the day-to-day operations of federal facilities and represents an expense that will be funded regardless of the source of supply, and (ii) purchases under a PPA would align the federal government's energy expenditures with federal policy objectives under a near budget neutral profile. However, PPAs have been difficult to implement in practice. Federal legal authorities for entering into long-term contracts, along with budget scoring rules, have made PPAs an appealing yet elusive option for advancing policy objectives.

Several federal agencies have expressed interest in purchasing electric power produced by an SMR. However, there is a myriad of complex regulations and processes to navigate, making it very challenging to implement PPAs on a broad scale to support a policy outcome. Generally, federal agencies can enter into PPAs to obtain power from an SMR (either from a utility purchasing power from an SMR developer or from an SMR developer directly) under the United States General Services Administration's ("GSA") authority set forth in 40 U.S.C. § 501 (subject to applicable federal and state requirements relating to the provision of electricity). However, this GSA authority is currently limited to a maximum of ten (10) years, and given the high up-front costs associated with the development of SMRs, a longer-term power purchase contract would better facilitate financing of the SMR. Longer term PPAs are challenging for federal agencies and, unless new legislation is enacted, longer term PPAs are only an option in limited circumstances for those federal agencies located within the service territory of certain Power Marketing Administrations ("PMAs"), such as the Western Area Power Administration ("WAPA") (which can purchase power for up to 40 years under certain circumstances), and under certain Department of Defense ("DOD") authorities (such as 10 U.S.C. § 2922a which permits DOD to purchase power for up to 30 years under certain circumstances).

This Report begins with background information intended to familiarize the reader with the benefits and challenges offered by SMRs (Chapter 1) and the current state of the United States power sector (Chapter 2). Next, this Report identifies the primary financing considerations for energy projects (Chapter 3). An overview of current legal authorities federal agencies utilize to purchase power, including those legal authorities that are most applicable to power purchases from an SMR, are identified (Chapter 4). This Report next identifies considerations federal agencies evaluate when making power purchase decisions (Chapter 5). Finally, this Report concludes by applying the principles outlined in the first five chapters to a notional project (Chapter 6) and offers a roadmap of key decision points for federal agencies exploring purchasing power from an SMR (Chapter 7).

Generally, developing SMRs will likely require long-term financing for terms of 30 years or more; accordingly, the SMR project developer (the borrower) and any lenders will want to know that any high volume purchasers of the power that will be produced will continue purchasing the power for the duration of the loan term. Thus, the sellers of the power (utilities and SMR developers) are exploring how to enter into contracts with a term longer than ten (10) years with federal agencies and other large power purchasers.

As compared to other power sources, SMRs may offer the following benefits, each of which are explained in more detail in Appendix A:

- Carbon-free baseload power
- Enhanced safety
- Modularity
- Lower cost
- Scalability
- Improved energy security
- Integration of renewables
- Siting flexibility
- Small land requirements
- Process heat
- International export opportunities
- Reduced fuel risk

In regions of the country serviced by WAPA, WAPA and a federal agency that wants to purchase power generated by an SMR can negotiate an Interagency Agreement under which WAPA, using its legal authorities, agrees to enter into a PPA with the seller of the power (utility or SMR developer) for a maximum term of 40 years. WAPA's contract with the seller of the power will require the seller of the power to deliver the power to the federal agency, which will then be required under the Interagency Agreement to pay for the power during the duration of the PPA term. Additionally, federal agencies in other regions of the United States may be able to access alternate authorities under other PMAs; however, a discussion of their authorities are outside the scope of this Report. In other areas of the country not served by a PMA or by a PMA with extended contracting authority, legislation would need to be enacted to permit longer term power purchases (except in limited circumstances where DOD authorities may apply).

Power purchase decisions are complicated and important choices. When evaluating whether to purchase power from an SMR, federal off-takers will want to consider its demand profile, understand performance risks of its power source, and perform a financial impact analysis. Likewise, investors will evaluate elements applicable to all power projects (such as technology stability, contract term, and tax advantages), as well as additional concerns raised by the unique and new technology offered by SMRs (such as regulatory approvals, safety, and reliability).

Federal agencies can purchase power from a power producer or from a utility, subject to applicable federal and state requirements. Most federal agencies purchase power from the local utility in the area or through arrangements directly with power producers or PMAs, such as WAPA. In accordance with 40 U.S.C. § 591(a), federal agencies cannot purchase electricity in a manner inconsistent with state law governing the provision of electric utility service.

The Utah Associated Municipal Power Systems ("UAMPS") Carbon Free Power Project (the "Idaho SMR Project" or "CFPP") involves an SMR being developed by NuScale Power, LLC ("NuScale"), which is currently planned to be developed on land owned by the Department of Energy ("DOE") at the Idaho National Laboratory ("INL"). UAMPS has 45 members which are municipal and other public power utilities in eight states. Currently, the Idaho SMR Project structure contemplates that the power from the SMR will be sold to UAMPS' member utilities, as well as other power purchasers (non-members). Thus, subject to applicable federal and state laws, federal agencies could purchase the power produced by the SMR directly from UAMPS or one of the member or non-member utilities purchasing power from UAMPS.

As further detailed in Chapter 6, for the Idaho SMR Project, scenarios exist for federal agency customers to directly enter into a 10 year PPA under the GSA authority with UAMPS or a utility purchasing power from UAMPS, or enter into an Interagency Agreement with WAPA and for WAPA, in turn, to enter into a longer term PPA with UAMPS or a utility purchasing power from UAMPS.

As depicted in Figure 1, there are several different scenarios through which a federal agency could contract to purchase power produced by the SMR in the Idaho SMR Project. These scenarios are as follows:

Most Likely Options Contracting Between a Federal Agency and a Utility:

1. Option 1: Federal Agency Uses GSA Authority to Contract with a Utility. Either directly (if DOD or DOE), through GSA, or with delegated authority obtained from GSA, a federal agency can enter into a direct agreement with a utility (either a member of UAMPS or a non-member purchasing power produced by the SMR from UAMPS) to purchase power produced by the SMR for a maximum of ten (10) years. This is likely the most typical method of contracting that will be used by federal agencies, but utilities will likely prefer longer-term agreements outlined below.

2. Option 2: Federal Agency Collaborates with WAPA to Enter into a Longer-Term PPA with a Utility. For those federal agencies located within WAPA's service territory, the federal agency and WAPA could enter into an Interagency Agreement. Pursuant to the Interagency Agreement, the federal agency would pay a negotiated charge to WAPA for WAPA to develop a PPA with the utility (either a member of UAMPS or a non-member purchasing power produced by the SMR from UAMPS) on behalf of the federal agency. The Interagency Agreement would identify that the federal agency is responsible for all costs charged under the PPA, as well as a negotiated annual charge for contract administration. WAPA would also enter into a PPA with the utility with a maximum term of 40 years. For federal agencies located in other PMA jurisdictions, this option can be explored.

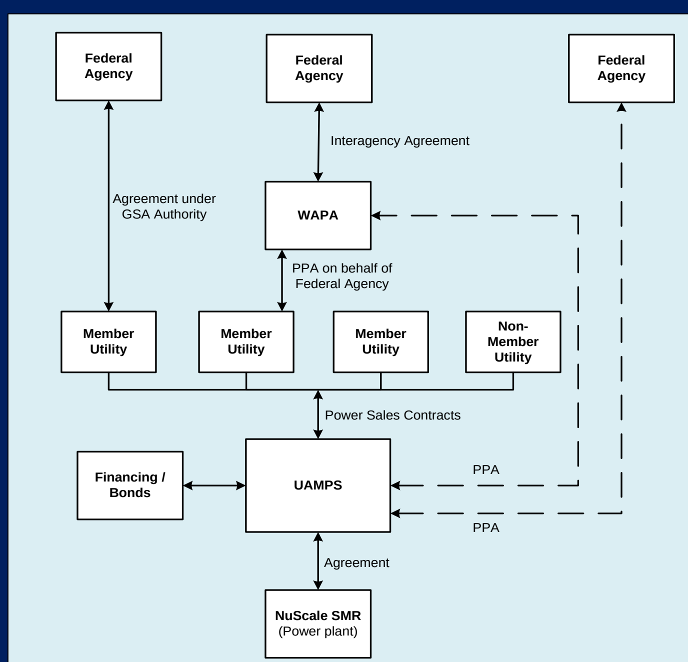
Additional Options Contracting Between a Federal Agency and UAMPS:

3. Option 3: Federal Agency Uses GSA Authority to Contract with UAMPS. Either directly (if DOD or DOE), through GSA, or with delegated authority obtained from GSA, a federal agency can enter into a direct agreement with UAMPS to purchase power produced by the SMR for a maximum of ten (10) years.

4. Option 4: Federal Agency Collaborates with WAPA to Enter into a Longer-Term PPA with UAMPS. For those federal agencies located within WAPA's service territory, the federal agency and WAPA could enter into an Interagency Agreement. Pursuant to the Interagency Agreement, the federal agency would pay a negotiated charge to WAPA for WAPA to develop a PPA with UAMPS on behalf of the federal agency. The Interagency Agreement would identify that the federal agency is responsible for all costs charged under the PPA, as well as a negotiated annual charge for contract administration. WAPA would also enter into a PPA with UAMPS with a maximum term of 40 years. For federal agencies located in other PMA jurisdictions, this option can be explored.

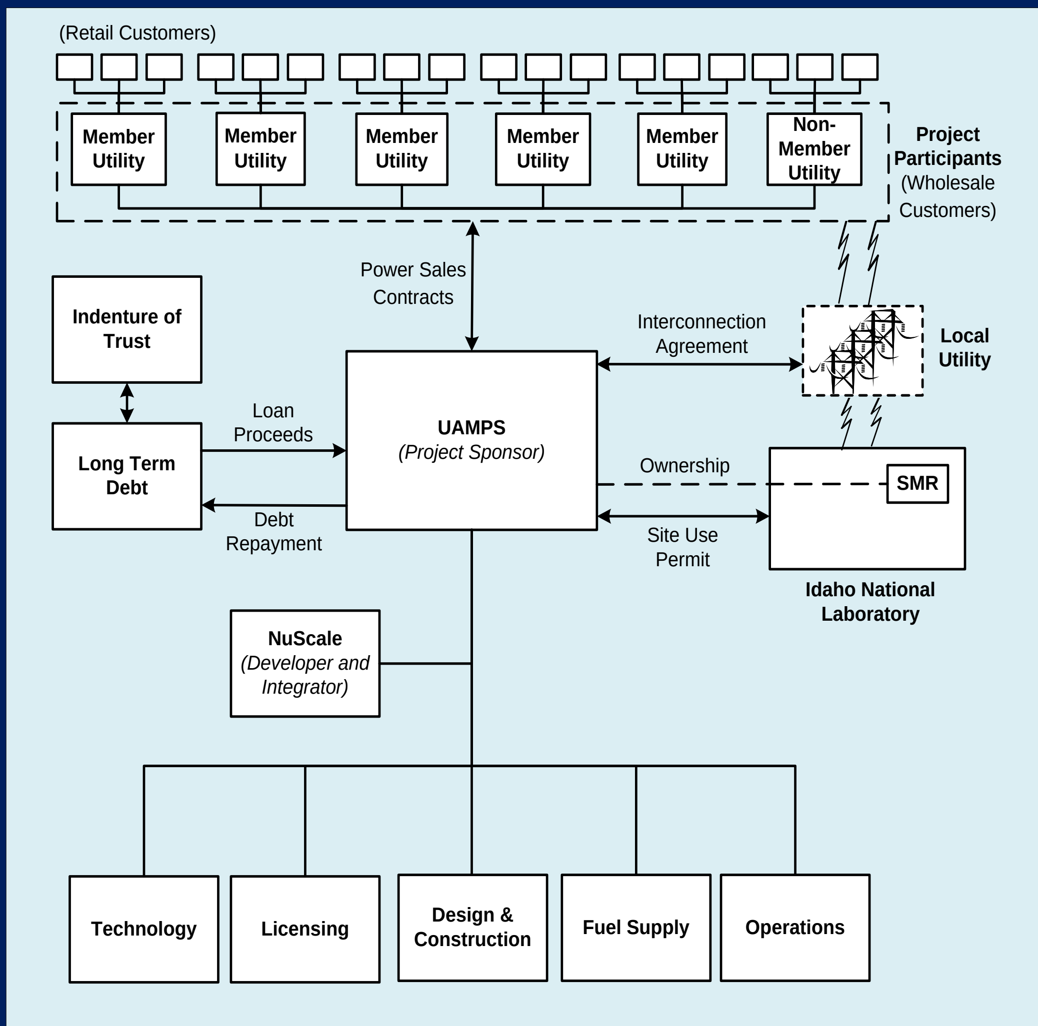
Figure 1

Potential Ways to Involve Federal Customers in the Idaho SMR Project



As further detailed in Chapter 6 and depicted in Figure 2, there are many agreements and parties involved in a potential financing structure for the Idaho SMR Project.

Figure 2
Potential Financing Structure for the Idaho SMR Project



As contemplated, the financing structure of the Idaho SMR Project provides strong credit fundamentals and should facilitate the development and financing of the Idaho SMR Project at a long-term fixed interest rate. Importantly, this structure should improve the competitiveness of the Idaho SMR Project relative to other sources of baseload power. However, a number of challenges are introduced by this first of a kind project:

- Licensing Risk: Early in the Idaho SMR Project development process, the Idaho SMR Project will need to obtain a Combined Construction and Operating License ("COL") from the NRC. In order to receive a COL, the Idaho SMR Project will have to invest millions of dollars in early stage development cost. Under the plan, these expenditures will not commence until the Power Sales Contracts have been executed. Therefore, the risk from the COL Application ("COLA") process will fall upon the participating members of UAMPS. Failure to receive a COLA will result in financial losses for UAMPS, and such losses will be incurred prior to plant construction. There is also uncertainty of completion, because the NRC will need to provide approvals before the facility can begin operations. At this stage, the Idaho SMR Project could experience delays in production, adding expense to UAMPS and its subscribers.

- Technology Risk: If implemented, the Idaho SMR Project will be the first SMR sited and constructed in the United States. The technology risk associated with this first-of-a-kind project represents a key challenge for the project sponsor to overcome. Idaho SMR Project lenders will need to become comfortable with the Idaho SMR Project's engineering and construction plans, as well as plans for long-term operations. In addition, the licensing risk introduced by an untested regulatory process could introduce delays in the initiation of commercial operations. These considerations will need to be addressed in the Idaho SMR Project's financing plan to ensure adequate protection to Idaho SMR Project lenders.
- First of a Kind Costs: A key benefit of SMRs is that component parts and assemblies could be manufactured in a factory and shipped to the Idaho SMR Project site. Over time, this could introduce significant economies of scale into the plant construction process. However, the Idaho SMR Project will not benefit from these economies as it is the first SMR to be built, and thus faces First of a Kind ("FOAK") costs, which are higher than would be expected over the long run as costs decrease.[195]
- Uncertainty in Long-Term Energy Markets: While it is widely recognized that the aging fleet of coal fired power projects and nuclear generating stations will need to be replaced over the next decade, the current conditions in the energy markets have introduced long-term uncertainties. In particular, the current low-cost of natural gas makes it challenging for other sources of baseload power to be competitive on price alone. While the historic volatility of natural gas is well recognized, the abundant supply of natural gas and its current cost profile make it the most economic option at this time. There is considerable uncertainty over the changes in demand for natural gas and the market equilibrium that will be achieved over the long-term.
- Development Timeline: Given the need to find replacement sources of baseload power, the uncertainty over the Idaho SMR Project's development timeline may introduce challenges to Project Participants. Specifically, Project Participants require a new source of baseload power to be commissioned by 2025, and thus require a precise estimate of the expected commercial operation date of the Idaho SMR Project. Since the Idaho SMR Project is subject to considerable uncertainly in respect to licensing, financing, and construction, this presents a challenge for all involved.
- Production Tax Credits: According to the Project Sponsor, the production tax credits that were introduced in EPACT are essential to making the Idaho SMR Project cost-competitive. However, for the Idaho SMR Project to benefit from the tax credits, the sunset date on the production task credits must be extended, and the Idaho SMR

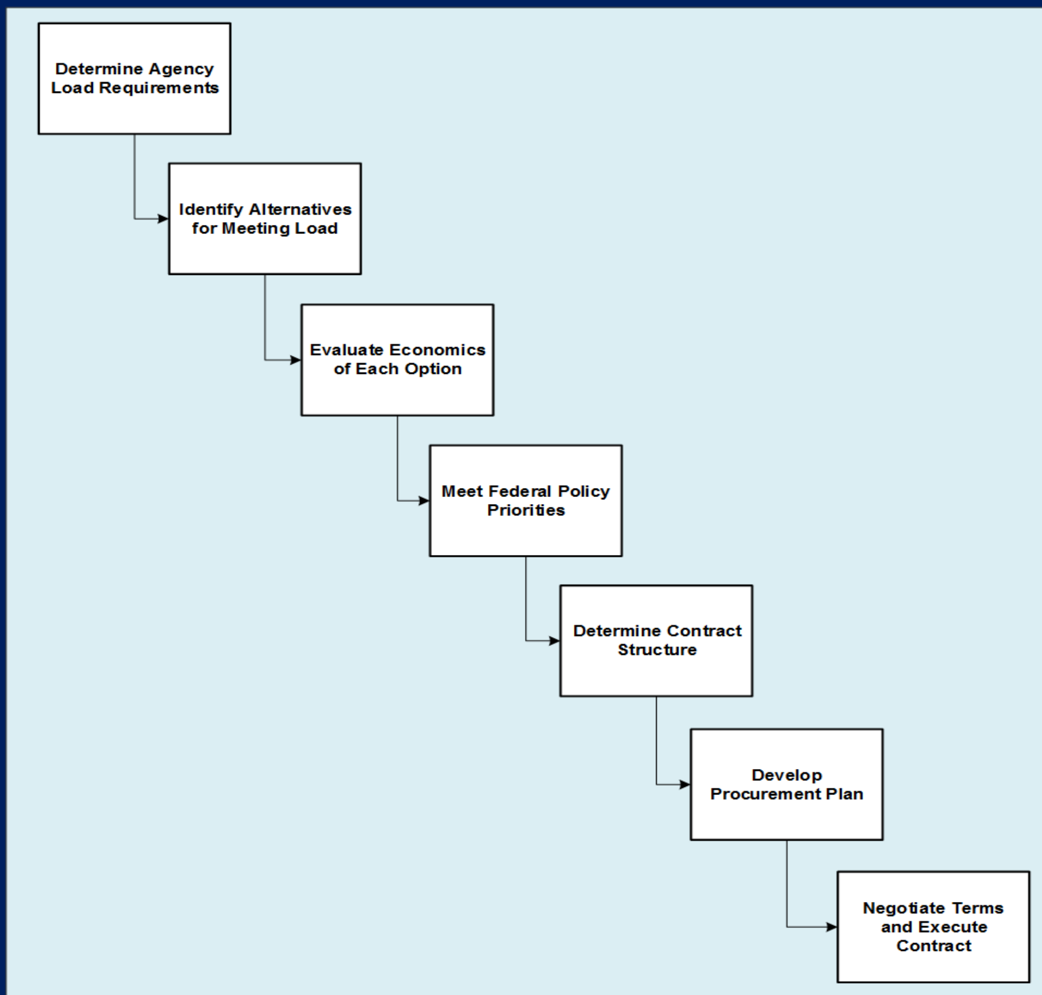
Project will need to be structured such that it can benefit financially from the tax credits. To do so, the Project Sponsor will need to allow private ownership of the plant or the amended legislation will need to allow the tax credits to benefit public power producers. Under either scenario, the Idaho SMR Project will require legislative actions.

- DOE Loan Guarantee: According to the Project Sponsor, the Idaho SMR Project may seek a DOE loan guarantee for part or all of the Idaho SMR Project financing. Given the new technology risk identified above, the DOE Title XVII Loan Guarantee Program represents an attractive and well-suited source of financing for the Idaho SMR Project. However, by statute, the DOE loan guarantee cannot benefit directly or indirectly from support provided by federal off-takers.[196] Therefore, the purchase of power from the Idaho SMR Project by a federal agency, such as a DOE laboratory, could impair the Idaho SMR Project's ability to obtain a DOE loan guarantee or limit the amount of the loan guarantee. This issue represents an important consideration in designing the Idaho SMR Project's financial structure.

This Report concludes with a roadmap federal agencies may wish to follow when making power purchase decisions that may involve an SMR. Key steps in the decision process are summarized in Figure 3 and described in Chapter 7.

Figure 3

Federal Agency SMR Purchasing Roadmap



APPENDIX B
POTENTIAL BENEFITS OFFERED BY SMALL MODULAR REACTORS

Potential Benefits Offered by SMRs	
Carbon-Free Baseload Power	• SMRs provide carbon-free baseload power.
Enhanced Safety	• SMRs may be safer than conventional reactors since they will be built below ground, thus making them better protected from human and natural risks. • Passive safety systems allow for improved accident avoidance and tolerance.[197, 198] • Transportation of fuel may be minimized since the reactors can be fueled when manufactured in a factory.
Modularity	• As major components can be manufactured off-site and shipped to the point of use, SMRs allow for the centralization of manufacturing expertise.[199] • Limited on-site construction is required, as work is concentrated in the manufacturing stage. • Individual factories could fabricate components for multiple SMRs, increasing fleet-wide design consistency and standardization. By manufacturing multiple reactors of smaller size at centralized facilities, manufacturers are likely to experience rapid learning curves.[200] • Modularity and standardized designs can also increase the safety and efficiency of plant operations, as they eliminate idiosyncratic design features between plants and streamline operating and maintenance procedures.[201]
Lower Cost	• The cost of an SMR has been estimated to be between \$800 million and \$3 billion per unit, whereas a large reactor typically costs between \$10 billion and \$12 billion per unit.[202] • The smaller size of SMRs should translate to each reactor being less capital intensive; costs associated with manufacturing and construction are reduced as less material is required. Factory fabrication can mean quicker on-site construction, which reduces the cost of labor and shortens the interval between construction of the reactor and when the reactor begins to generate electricity.[203]

Potential Benefits Offered by SMRs	
Scalability	• SMRs have a responsive, adaptable site capacity and can provide power for a range of applications. • In developing countries or rural communities that lack the transmission infrastructure to support a large nuclear plant, SMRs provide a way for utilities to still have baseload power on the grid.[204] • Nuclear plant operators can gradually scale up the number of SMRs at a single plant location as demand grows, distributing cost evenly throughout the lifetime of a nuclear power plant.[205] • Utilities could use SMRs as on-site replacement for aging fossil fuel plants – taking advantage of existing transmission infrastructure.[206]
Improved Energy Security	• Having an SMR located on-site may provide long-term energy security to the federal agency, rather than relying on a separate grid that is outside the control of the federal agency. • By providing two years of fuel on-site, vulnerabilities relating to fuel transportation disruptions are minimized.
Integration of Renewables	• NuScale's SMR design allows for output to be varied over days, hours, or minutes. This can allow SMRs to adjust their output in response to changes in electricity output from intermittent renewable generation.
Siting Flexibility	• The small size of SMRs may allow them to be sited in places where a large baseload plant is not feasible or not needed. For example, SMRs have been considered as a power source for remote mines in Canada which cannot access the grid.[207]
Small Land Requirements	• SMRs require significant less land than would power plants with the same output which use wind, solar, biomass, or hydropower. NuScale estimates that SMRs require only 1% of the land area required for similar generation by other technologies.
Process Heat	• SMRs heat water in the process of producing electricity. Some SMR designs may be useful for producing process heat for desalination and other industrial activities.
International Export Opportunities	• United States companies that produce SMRs or sell related goods or services may have opportunities to sell to foreign markets. EIA estimates that global electricity generation will increase by 69% from 2012 to 2040.[208]
Reduced Fuel Risk	• SMRs can help diversify a generation portfolio and reduce fuel risk. The price of electricity from SMRs, especially under a long-term contract, should be relatively stable and predictable. • Natural gas prices have historically been very volatile, although

Potential Benefits Offered by SMRs	
	they have been low in recent years. Higher natural gas prices would significantly increase the price of electricity produced from natural gas.

APPENDIX C
LIST OF ABBREVIATIONS

CCNG	Combined Cycle Natural Gas
CEC	Clean Energy Credit
COL	Combined Operating License
COLA	Combined Operating License Application
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
EIA	Energy Information Administration
EM	Environmental Management
EMP	Electromagnetic Pulse
EPA	U.S. Environmental Protection Agency
ESCO	Energy Service Company
ESP	Early Site Permit
FAST	Fixing America's Surface Transportation
FERC	Federal Energy Regulatory Commission
FOAK	First-of-a-kind
GSA	General Services Administration
HV	High Voltage
ISO	Independent System Operator
LCOE	Levelized Cost of Electricity
MACRS	Modified Accelerated Cost-Recovery System
MWe	Megawatt Electric
NNSA	National Nuclear Security Agency
NRC	Nuclear Regulatory Commission
NYSERDA	New York State Energy Research and Development Authority
ORNL	Oak Ridge National Laboratory
PPA	Power Purchase Agreement
REC	Renewable Energy Certificate
RTO	Regional Transmission Organization
SMR	Small Modular Reactor
SPIDERS	Smart Power Infrastructure Demonstration for Energy Reliability and Security
TVA	Tennessee Valley Authority
UAMPS	Utah Associated Municipal Power Systems
WAPA	Western Area Power Administration
ZEC	Zero Emissions Credit

APPENDIX D
ENDNOTES

[1] The Initial Report was prepared pursuant to a contract with Allegheny Science & Technology Corporation with funding from DOE, Office of Nuclear Energy, under Small Modular Reactor Report, MSA No. DOE0638-1022-11, Prime Contract No. DE-NE0000638. The Initial Report does not represent the views of DOE, and no official endorsement should be inferred. The Initial Report is available for downloading at https://www.energy.gov/ne/downloads/purchasing-power-produced-small-modular-reactors-federal-agency-options.

[2] Collectively for ease of reference in this Report, DOE and NNSA at the Oak Ridge Reservation are referred to as "DOE."

[3] "Distributed Generation: Cleaner, Cheaper, Stronger - Industrial Efficiency in the Changing Utility Landscape," *Pew Charitable Trusts*, October 2015, p. 6, http://www.pewtrusts.org/~/media/assets/2015/10/cleanercheaperstronger_finalweb.pdf?la=en.

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[7] "Electric Utility Contracts; Authority to Enter Into; Cancellation; Submission to Energy Committees," *42 U.S. Code § 2204*, 1954, https://www.gpo.gov/fdsys/pkg/USCODE-2015-title42/pdf/USCODE-2015-title42-chap23-divsnA-subchapXIII-sec2204.pdf.

[8] "Conservation," *16 U.S. Code § 831i.*

[9] Ibid.

[10] "Glossary," *U.S. Energy Information Administration*, https://www.eia.gov/tools/glossary/index.cfm?id=B.

[11] Historically, baseload plants (typically nuclear or coal powered) generally cost more to build but supply electricity at a lower hourly cost. Peaker plants, such as natural gas facilities, can be built relatively cheaply and generally operate at a higher hourly cost, and they can rapidly be brought on- or off-line in response to changes in electricity demand. Some renewable energy sources, such as solar and wind power, are intermittent and are prioritized as electricity sources by grid operators because of green energy usage requirements and their near-zero operating costs when that energy source is available. The intermittent nature of electricity generated by these renewable energy sources can be a challenge for baseload plant operators – including nuclear power plants operators –

because the operators cannot increase and decrease their power production to balance it with that of intermittent electricity sources without additional wear on their equipment or less economic power generation.

[12] Laura Martin and Jeffrey Jones, "Effects of the Clean Power Plan," *U.S. Energy Information Administration*, 20 June 2016.

[13] Ibid.

[14] Ibid.

[15] Electricity is sent through the electric grid, which consists of high-voltage, high-capacity transmission systems, to areas where it is transformed to a lower voltage and sent through the local distribution system for use by commercial and residential consumers. During this process, a grid operator must constantly balance the generation and consumption of electricity. To do so, grid operators monitor electricity consumption from a centralized location using computerized systems and send minute-by-minute signals to power plants to adjust their output – to the extent possible for each type of electric production plant – to match changes in the demand for electricity. Electricity demand can vary throughout a day, as well as seasonally, so grid operators use baseload plants, intermittent renewable energy, and peaker plants.

[16] Ibid.

[17] "Advances in Small Modular Reactor Technology Developments," *International Atomic Energy Agency*, September 2014, https://www.iaea.org/NuclearPower/Downloadable/SMR/files/IAEA_SMR_Booklet_2014.pdf.

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[22] "H.R. 1551," *U.S. House of Representatives*, 21 June 2017, https://www.congress.gov/115/bills/hr1551/BILLS-115hr1551rds.pdf.

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[26] Each ZEC reflects a specified amount of zero-carbon power which was produced by a nuclear power plant. Owners of nuclear power plants receive ZECs for producing carbon-free nuclear power and sell the ZECs to NYSERDA. Thus, the state government subsidizes nuclear power to support zero-carbon electricity. Utilities then buy ZECs from NYSERDA to meet zero-carbon power compliance requirements (which are separate from requirements related to RECs). Utilities may also meet ZEC requirements by purchasing energy plus ZEC contracts directly from power producers or by contracting for capacity from nuclear power plants.

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[29] Ibid.

[30] "Energy Primer: A Handbook of Energy Market Basics," *U.S. Federal Energy Regulatory Commission*, November 2015, https://www.ferc.gov/market-oversight/guide/energy-primer.pdf.

[31] Ibid, p. 40.

[32] Paul Feldman, "Presentation to the U.S. Association for Energy Economics: Cybersecurity and the Grid," 18 November 2016, http://www.ncac-usaee.org/pdfs/2016_11Feldman.pdf.

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