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Assessment of Small Modular Reactor Suitability for Use On or Near Air Force Space Command Installations

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ABSTRACT

This is the initial milestone report of the Small Modular Reactor (SMR) Suitability study by Sandia National Laboratories and the Scitor Team (Scitor Corporation and Landrey & Company). This study reflects the intent of the memorandum of understanding between the Department of Energy (DOE) and the Department of Defense (DOD) to enhance national energy security and demonstrate leadership in transitioning to a low carbon economy. This report summarizes existing guidance and studies relating to SMRs and includes an update on light water reactor SMR technology. A key product of this phase of the study is identification of Schriever Air Force Base, Colorado and Clear Air Force Station, Alaska for detailed use case SMR suitability analyses. The final report in December 2015 will assess the feasibility of SMRs for energy security and clean energy for Air Force Space Command (AFSPC) installations.

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EXECUTIVE SUMMARY

During this first phase of the study, the team conducted broad research of existing federal and private sector policy, guidance, regulations, studies, and reports. Through this and other research the team identified major processes, potential impediments and issues, and key considerations that would affect SMR deployment on AFSPC installations. This research provided valuable information for development of use case installation selection criteria. Further, it will aid the development of recommendations for essential changes needed to facilitate successful and effective SMR deployment. With the assistance of members of the Headquarters, AFSPC staff and other DoD and Air Force representatives, the team also worked with major stakeholders to garner their inputs on factors affecting SMR deployment.

The team also gathered information from the four US companies that are developing near term light-water SMRs on the operational performance characteristics and commercialization status of their technologies. Further, the team gathered perspectives of SMR deployment scenarios from utilities that are operating nuclear power plants and some that are serving AFSPC installations. This effort also included an assessment of the Lifecycle Cost of Energy for SMRs and preliminary consideration of economic factors that are critical to realistic commercial introduction of SMRs.

The team began with the 12 AFSPC installations in the Continental United States and Alaska and applied criteria derived from research and stakeholder interactions to determine the two optimum installations for the use case studies. The AFSPC installations vary from large Air Force Bases (AFB), with multiple missions, fully mature infrastructures, and robust services to small Air Force Stations (AFS) with single missions and limited infrastructures, often in remote locations.

The selection criteria evolved into two categories: AFSPC-related criteria (mission priorities, synergistic support capabilities, and installation operations) and siting criteria (available land, seismology, hydrology, population density, proximity to hazardous activities/protected lands). For mission priorities, the team used prioritized space superiority activities approved by the Commander, AFSPC, and inputs from various subject matter experts (SME). The team determined synergistic support capabilities--installation-SMR owner/operator collaboration on key activities such as security, fire protection, and emergency response—from existing host unit documents, SME inputs, and team member familiarity with AFSPC installation capabilities. Installation operations factors were obtained through inputs from applicable Air Force agencies and SMEs. Based on Department of Energy guidance, the team developed values for a Site Selection Evaluation Criteria and submitted them to the Oak Ridge National Laboratory to apply their Oak Ridge Siting Analysis for power Generation Expansion tool. Since data for Clear AFS, AK are not currently included in the siting tool, the team used similar United States Geologic Survey data. Finally, since the study's focus is SMR feasibility versus actual siting, the team considered use case-unique considerations rather than using AFSPC and siting criteria as the only determinants in selecting the use case installations.

As a result of the selection process, the team concluded that Schriever AFB, CO and Clear AFS, AK best lend themselves to the more detailed use case feasibility analysis. This conclusion considers the higher priority missions performed on both installations and their generally favorable siting characteristics, but also enables a robust use case comparison of two installations that represent the spectrum of AFSPC installation characteristics: a fully-mature, multi-mission AFB and a more limited capability, single mission, remotely-located AFS.

The next phase of the SMR Suitability study will involve performing use case studies of Schriever AFB and Clear AFS. This includes site visits; in-depth interaction with installation SMEs; expanding interaction with DoD, Air Force, AFSPC, and private sector entities; refining commercial business models; and consideration of micro-grids and other technologies that may enhance SMR deployment on DoD installations

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APPENDIX a Nomenclature

Acronym	Definition
ACC	Air Combat Command
AETC	Air Education and Training Command
AF	Air Force
AF/A4C	HAF Directorate of Civil Engineers
AFB	Air Force Base
AFCEC	Air Force Civil Engineer Center
AFCEC/CI	AFCEC Installations Directorate
AFCEC/CN	AFCEC Energy Directorate
AFI	Air Force Instruction
AFIMSC	Air Force Installation and Mission Support Center
AFMC	Air Force Materiel Command
AFPD	Air Force Policy Directive
AFS	Air Force Station
AFSPC	Air Force Space Command
AICUZ	Air Installations Compatible Use Zones
AK	Alaska
ANG	Air National Guard
ASD(OEPP)	Assistant Secretary of Defense for Operational Energy Plans and Programs
ASD(R&E)	Assistant Secretary of Defense for Research and Engineering
ASME	American Society of Mechanical Engineers
AZ	Arizona
BRAC	Base Realignment and Closure
CA	California
CO	Colorado
COL	Construction and Operating License
CFR	Code of Federal Regulation
CNA	Center for Naval Analyses
DCA	Design Certification Application
DoD	Department of Defense
DoDD	Department of Defense Directive
DoDI	Department of Defense Instruction
DOE	Department of Energy
DSB	Defense Science Board
DUSD(I&E)	Office of the Deputy Under Secretary of Defense for Installations and Environment
ECCS	Emergency Core Cooling System
ECIP	Energy Conservation and Investment Program
EIAP	Environmental Impact Assessment Process
EMP	Electromagnetic Pulse
EO	Executive Order
EPAct	Energy Policy Act

ESP	Early Site Permit
EUL	Enhanced Use Lease
FSAR	Final Safety Analysis Report
FL	Florida
FMV	Fair Market Value
FOAK	First of a Kind
FY	Fiscal Year
GHG	Greenhouse Gas
GIS	Geographic Information Systems
GPD	Gallons Per Day
GPM	Gallons Per Minute
HAF	Headquarters, Air Force
HAF MD	Headquarters Air Force Mission Directive
HAF/SE	HAF Safety Office
HAZMAT	Hazardous Materials
HQ	Headquarters
HQ AFSPC	Headquarters, Air Force Space Command
HQ AFSPC/A2/3/6	Headquarters, Air Force Space Command Directorate of Integrated Air, Space, Cyberspace and ISR Operations
HQ AFSPC/A4	Headquarters, Air Force Space Command Directorate of Logistics, Engineering and Force Protection
HQ AFSPC/A5/8	HQ AFSPC Directorate of Strategic Plans and Requirements
IMP/S	Integrated Master Plan and Schedule
ISR	Intelligence, Surveillance, and Reconnaissance
ISFSI	Interim Spent Fuel Storage Installation
ITC	Investment Tax Credit
LCAT	Life Cycle Analysis Tool
LCOE	Lifecycle Cost of Energy
LRDR	Long Range Discrimination Radar
MA	Massachusetts
MAJCOM	Major Command
MD	Mission Directive
MWe	Megawatt Electric
MWh	Megawatt Hours
MWt	Megawatt Thermal
NASA	National Aeronautics and Space Administration
NSSS	Nuclear Steam Supply System
ND	North Dakota
NDAA	National Defense Authorization Act
NEI	Nuclear Energy Institute
NEPA	National Environmental Policy Act
NH	New Hampshire
NORAD	North American Air Defense Command

NORTHCOM	United States Northern Command
NPM	Nuclear Power Module
NPV	Net Present Value
NRC	Nuclear Regulatory Commission
NV Energy	Nevada Power Company
O&M	Operations and Maintenance
ORNL	Oak Ridge National Laboratory
OR-SAGE	Oak Ridge Siting Analysis for Power Generation Expansion
OSD	Office of the Secretary of Defense
OUSD(I&E)	Office of the Under Secretary of Defense for Installations and Environment
PPA	Power Purchase Agreement
PREIAP	Planning Requirements for the Environmental Impact Analysis Process
PSAR	Preliminary Safety Analysis Report
PTC	Production Tax Credits
REC	Renewable Energy Certificate
SAB	Scientific Advisory Board
SAF	Secretary of the Air Force Staff
SAF/AQ	Office of the Assistant Secretary of the Air Force for Acquisition
SAF/IE	Office of the Assistant Secretary of the Air Force for Installations, Environment and Energy
SAF/IEE	Office of the Assistant Secretary of the Air Force for Installations, Environment and Energy, Deputy Assistant Secretary for Environment, Safety and Occupational Health
SAF/IEI	Office of the Assistant Secretary of the Air Force for Installations, Environment and Energy, Deputy Assistant Secretary for Installations
SAF/IEN	Office of the Assistant Secretary of the Air Force for Installations, Environment and Energy, Deputy Assistant Secretary for Energy
SAF/US	Office of the Under Secretary of the Air Force
SBS	Strategic Basing Structure
SECDEF	Secretary of Defense
SME	Subject Matter Expert
SMR	Small Modular Reactor
SSEC	Site Selection and Evaluation Criteria
UAMPS	Utah Associated Municipal Power Systems
US	United States
USAF	United States Air Force
USC	United States Code
USD(AT&L)	Undersecretary of Defense for Acquisition, Technology and Logistics
UT	Utah
WACC	Weighted Average Cost of Capital

1.0 INTRODUCTION

1.1. This is the initial milestone report of the Small Modular Reactor (SMR) Suitability study by Sandia National Laboratories and the Scitor Team (Scitor Corporation and Landrey & Company). This study reflects the intent of the memorandum of understanding between the Department of Energy (DOE) and the Department of Defense (DOD) to enhance national energy security and demonstrate leadership in transitioning to a low carbon economy. The final report in December 2015 will assess the feasibility of SMRs for energy security and clean energy for Air Force Space Command (AFSPC) installations. The study's objectives are to:

- Facilitate understanding of SMR benefits for AFSPC and the DoD
- Identify DoD requirements for SMR on or near installations
- Identify potential partnerships with utilities/operators for notional SMR deployments
- Identify government actions needed to facilitate SMR deployment for DoD energy security
- Inform discussion of broader market potential among other critical federal installations

1.2. A focus of this phase of the study was selection of two AFSPC installations for in-depth use case studies, based on criteria developed through research, surveys, discussion with subject matter experts (SME), siting analysis, and mission prioritization. Key activities are outlined below.

- Review current policy, instructions, and regulations—including the DoD and Nuclear Regulatory Commission (NRC) guidance--to identify potential impediments and preliminary solutions to SMR deployment
- Review studies and reports to gain insights and benefits from previous assessments of SMR capabilities, financial considerations, and applicability to DoD
- Interact with DoD and AFSPC stakeholders for their inputs on mission priorities, operating characteristics, and lessons learned, as well as energy requirements, goals, management, and processes to assess SMR integration into a DoD setting
- Interact with SMR vendors for their inputs on the current state of SMR technology and timelines associated with deployment of their capabilities
- Interact with nuclear operating utilities for their inputs into the feasibility of using SMRs to serve Federal facilities
- Develop criteria to identify use case installations based on AFSPC mission priorities, potential SMR-AFSPC installation support synergy, installation operations, and specific siting requirements (seismology, hydrology, population density, etc.)

1.3. The team worked directly with representatives from Headquarters, AFSPC (HQ AFSPC), HQ Air Force (HAF), AFSPC installations, and key DOD and Air Force (AF) agencies to gain a DoD perspective on applicability of SMRs to the current installation energy environment. In a parallel effort, the team canvassed the four principal light-water SMR vendors whose technology has potential for deployment by 2025 (a study precondition) as well as key utilities associated with nuclear power and DoD installations. The team also initiated an analysis of the key factors affecting lifecycle costs as well as the incentives to encourage new nuclear and renewable energy projects. Based on guidance from the DOE, the team provided values to capitalize on the Oak Ridge Siting Analysis for Power Generation Expansion (OR-SAGE) tool as a means of streamlining review of the initial 12 AFSPC installations. We then combined these results with AFSPC-related criteria to determine the best candidate installations for the use case studies.

1.4. Since this is a “feasibility” study versus a concentrated effort to identify an AFSPC installation for actual SMR siting, the team considered broader use case considerations rather than making AFSPC and siting criteria the sole determinants in selecting the use case installations. Our rationale for the use case candidate installation selection in Section 4 addresses this consideration.

2.0 RESEARCH AND FINDINGS

2.1 Guidance and Policies

2.1.1. Purpose. The team’s intent was to review existing guidelines that would impact the concept of SMR deployment on DoD and specifically, AFSPC installations. This review would help identify considerations, factors, limitations, impediments, and potential solutions to SMR deployment feasibility. As detailed below, we sought to address laws, policies, regulations, and associated guidance that relates to energy production and management, recognizing that guidelines on nuclear reactors would be absent from DoD and especially Air Force publications.

2.1.2. Methodology: The team began by querying stakeholders (see paragraph 2.3) for inputs on their guiding documents to ensure an accurate and current index of directives and policies. Our focus was on requirements for siting, operating and sustaining AFSPC mission systems; goals and mission critical needs for clean, secure energy; management and interim storage of used fuel; and other functional areas that support and enable the potential to deploy SMRs on AFSPC installations. We ensured currency, then reviewed and archived electronic copies of pertinent documents. Since most of these documents include references to related documents, we also reviewed and archived applicable documents and did the same with references from our review of SMR-related studies (see paragraph 2.5). In addition, we conducted general internet and website searches to identify applicable policy and guidance documents (e.g., DoD: <http://www.dtic.mil/whs/directives/>, DOE: <https://www.directives.doe.gov/>, and AF publications, <http://www.e-publishing.af.mil/>). All pertinent documents are listed in the SMR Policy and Guidance Summary (Appendix B). This summary includes:

- Document title and date
- Office of primary responsibility
- A short description, and a discussion of the issues/impediments related to SMR deployment on DoD installations
- A list of potential stakeholders(where applicable)

2.1.3. AFSPC mission system siting. This section provides a high level summary of guidance documents, directives and policies related to requirements for siting, operating and sustaining AFSPC mission systems. The highest level guidance is in *Executive Order (EO) 13327, Federal Real Property Asset Management*, which sets US policy to promote efficient and economical use of Federal real property (defined as real property owned, leased, or otherwise managed by the Federal Government).

2.1.3.1. US Codes (USC) are the next category. The *10 USC § 2662, Real property transactions: reports to congressional committees* requires a Secretary of Defense (SECDEF) report to Congress on leases of real property valued in excess of \$750K. The *10 USC § 2667, Leases: non-excess property of military departments and Defense Agencies* gives military department secretaries lease authority for real property they control which is not needed for public use during the term of the lease and not excess property. The Secretary of the AF lease authority includes:

- Conditions on leases
- Types of in-kind considerations
- Enhanced Use Lease (EUL) evaluation
- Use of proceeds

Section § 2667 also provides guidelines for new facilities whose construction is accepted as in-kind consideration. The 32 Code of Federal Regulation (CFR) § 989, *Environmental Impact Analysis Process (EIAP)* provides procedures for environmental impact analysis within the US and abroad--required to place a unit, mission, etc., on an AF facility. Finally, 10 USC § 2692, *Storage, treatment, and disposal of nondefense toxic and hazardous materials*, prohibits use of a DoD installation for storage, treatment, or disposal of toxic or hazardous material not owned by DoD. There is an exception for temporary storage of nuclear materials in accordance with an agreement with the DOE Secretary.

2.1.3.2. DoD guidance is generally based on EOs and US Law. DoD Directive (DoDD) 4165.06, *Real Property*, delegates responsibilities relating to acquisition, management, and disposal of real property, consistent with EO 13327, to the Military Departments. DoD Instruction (DoDI) 4165.70, *Real Property Management* implements policy and assigns responsibility for managing real property and directs master plans for all installations, based on the operational mission and expected use of the real property. This DoDI also addresses leases, licenses, permits, and easements; provides authority for AF Instruction (AFI) 32-9003, *Granting Temporary Use of Air Force Real Property* and covers policy for Federal legislative jurisdiction on AF installations. DoDI 4165.57, *Air Installations Compatible Use Zones (AICUZ)*, establishes policy, assigns responsibilities, and prescribes procedures for the DoD AICUZ program for installations with an airfield.

2.1.3.3. Air Force policy and guidance is derived from US Law and DoD guidance. HAF Mission Directive (HAF MD) 1-18, *Assistant Secretary of the Air Force, (Installations, Environment, and Energy)* delineates SAF/IE responsibility for installation strategy and strategic basing, operational energy, and safety to ensure AF sustainability and operational readiness (stakeholders: SAF/IEI, IEIB, IEE & IEN). AF Policy Directive (AFPD) 10-5, *Basing* establishes a review process for basing actions of 1 year or longer--the AF Strategic Basing Structure (SBS), and directs EUL coordination through SBS. AFI 10-503, *Strategic Basing* applies to basing actions for non-AF entities requesting to move onto AF real property, and provides EUL guidelines (stakeholders: SAF/IEI; AF/A4C, A8P; AFIMSC, AFCEC). It details the SBS process (similar to SMR candidate site selection), which would apply in the case of an SMR deployment decision. AFI 10-504, *Overseas Force Structure Changes and Host Nation Notification* have procedures for basing actions affecting overseas installations and augments the SBS. AFPD 32-90, *Real Property Asset Management* addresses real property management. The AF will issue leases, licenses, permits, and easements when the proposed use is compatible with multiple uses and consistent with mission need and environmental criteria. Specific AF real property responsibilities, procedures, and guidelines are published in 9000 series publications. AFI 32-9003, *Granting Temporary Use of Air Force Real Property* guides the temporary use of AF owned and controlled real property (stakeholders: SAF/IEI & IEN, AFCEC/CI & CN). Temporary use may be possible if there is no current AF military purpose; no mission interference; reasonable cost; and compatibility with AF needs, security, and safety. The AF must charge fair market value in return for temporary use. AF Handbook 32-9007, *Managing*

Air Force Real Property supplements AFPD 32-90 and AFI32-9003. AF Pamphlet 32-1010, Land Use Planning is a “how to” guide for base land use planning, including factors to consider in determining location of facilities. AFI 32-7061, Environmental Impact Analysis Process addresses the specific tasks and procedures to conduct the AF EIAP. The AF EUL Playbook describes the seven phases in a typical EUL project (stakeholders: SAF/IEI, IEN; AFCEC/CI, CN). The AFCEC Guide for Submission of an Unsolicited EUL Proposal describes the unsolicited EUL process (stakeholders: SAF/IEI & IEN, AFCEC/CI & CN). EULs are discussed in greater detail in paragraph 2.3.3.

2.1.4. Clean, secure energy. This section provides a high level summary of guidance documents, directives and policies related to goals and mission critical needs for clean, secure energy. In June 2013, President Obama issued “The President’s Climate Action Plan”. This is a broad-based plan to cut carbon pollution, move the US economy toward American-made clean energy sources, increase renewable electricity generation, issue permits for renewables on public lands (including military installations), and invest in a range of energy technology—including SMRs. In essence, this plan promotes the safe and secure use of nuclear power. EO 13693 *Planning for Federal Sustainability in the Next Decade*, March, 2015, has several impacts on US energy policy. It directs Federal agencies to reduce greenhouse gas (GHG) emissions by 40% over the next decade, requires 2025 goals with fiscal year (FY) 2008 as the baseline, and encourages renewable or alternative energy solutions. SMRs are specifically included as a potential alternative energy solution, and SMRs were added to the “alternative energy” definition.

2.1.4.1. Numerous US Codes impact energy use and generation on AF installations. The 10 USC § 2911, Energy performance goals and master plan for the Department of Defense requires DoD energy performance goals and a master plan, submitted annually to Congress. It includes a description of proposed investments for achievement of energy performance goals. The 40 USC § 591, Purchase of electricity requires federal (e.g., AF) purchase of electricity consistent with state law governing the provision of electric utility service—except when unusual standards of service reliability are necessary for national defense. The 10 USC § 2922, Contracts for energy or fuel for military installations allows Service secretaries, with SECDEF approval, to contract for up to 30 years for energy production facilities on property under the Service secretary’s jurisdiction or on private property, as well as the purchase of energy produced from such facilities. The 10 USC § 2809, Long-term facilities contracts for certain activities and services provides guidelines to Service secretaries to contract for construction, management, and operation of a facility on or near a military installation for utilities, and includes economic consideration for contracts not in excess of 32 years. The 10 USC § 2688, Utility systems conveyance authority provides authority to convey a utility system under AF jurisdiction to a utility company or other entity, which should facilitate linking an installation into the local power grid.

2.1.4.2. Several US Codes address renewables. The 10 USC § 2410q Multiyear contracts: purchase of electricity from renewable energy sources allows SECDEF to enter multiyear contracts up to 10 years for renewable energy. Contracts may exceed 5 years if the electricity purchase is cost effective for DoD and the source requires a 5 year contract. The 10 USC § 2916, Sale of electricity from alternate energy and cogeneration production facilities authorizes the

sale of electrical energy under the jurisdiction (or produced on land under the jurisdiction) of the Service secretary. Under EO 13693 this could apply to SMRs since they are now included as alternate energy sources.

2.1.4.3. The following US Codes address requirements for nuclear power plants. The 10 UCS § 100 Reactor Site Criteria requires the NRC to consider population density; site environs (including proximity to manmade hazards), and the physical characteristics of the site in determining its acceptability for a nuclear power reactor. The 10 USC § 50 Domestic Licensing of Production and Utilization Facilities governs the licensing of nuclear power plants. It requires two steps--a construction permit and then an operating license. The operating license could not be obtained until after plant construction was complete. This was the original licensing process and applies to all plants built, in construction, or in the licensing process before 10 USC § 52 took effect. The 10 USC § 52 Licenses, Certifications, and Approvals for Nuclear Power Plants established an alternative licensing process that essentially combines a construction permit and an operating license. It governs issuance of early site permits, standard design certifications, combined licenses, standard design approvals, and manufacturing licenses for nuclear power facilities not built, in construction, or in the licensing process before 1989.

2.1.4.4. DoD also addresses energy issues. DoDD 4140.25, DoD Management Policy for Energy Commodities and Related Services provides policy and responsibilities for energy commodity management (but does not address SMRs). DoDI 4170.11, Installation Energy Management tasks DoD components to establish energy program management structures, noting the DoD vision is to provide reliable and cost effective utility services to the warfighter. It also states “Utilities privatization is the preferred method for modernizing and recapitalizing DoD utility systems.” DoDD 5134.15, Asst. Sec of Defense for Operational Energy Plans and Programs ASD (OEPP) designates ASD (OEPP) as the principal advisor to SECDEF on operations energy plans and programs. It defines “operational energy”, which includes AFSPC’s facility-based operations. DoDI 4180.01, DoD Energy Policy defines responsibilities for DoD energy planning, use, and management. It highlights the need to improve energy performance; diversify and expand energy supplies and sources; and to include energy in requirements, acquisition, and budgeting decisions. The DoD Strategic Sustainability Performance Plan, FY2012 outlines DoD goals and sustainability expectations through FY2020. EO 13693 requires this plan to be updated. The Undersecretary of Defense for Acquisition, Technology and Logistics (USD(AT&L)) Financing of Renewable Energy Projects Policy memorandum provides guidance to DoD components to cover initial capital costs for energy projects utilizing private (‘third-party’) financing. It also addresses certification of energy related EULs and the special agreement authority found in 10 U.S.C. § 2922a.

2.1.4.5. DOE provides energy guidance across the federal spectrum. Choosing a Financing Vehicle for Energy-Efficiency Projects for Federal Sites (2009) assists acquisition teams in assessing the benefits and constraints of private-sector alternatives and site-specific issues to choose an optimum financing strategy. The intent is for project cost savings to cover the cost of project implementation. DOE-DoD memorandum of understanding, Concerning Cooperation in a Strategic Partnership to Enhance Energy Security identifies the framework for cooperation and partnership to enhance national energy security and provides the basis for SMR studies with DoD installations as test sites. Nuclear Energy Research and Development Roadmap, Report to Congress is a guide for DOE research, development, and demonstration to ensure nuclear energy

remains a viable option for the US. Its objective is to improve affordability of new reactors to meet energy security and climate change goals. *Nuclear Reactor Safety Design Criteria* establishes guidelines for design, construction, testing, and performance of nuclear reactor facilities--applicable to new and existing reactors.

2.1.4.6. The NRC provides guidance for nuclear power stations. *Nuclear Power Plant Licensing Process* provides an overview of two potential approaches to NRC licensing of commercial nuclear power plants: the traditional two-step process (10 CFR part 50) and the newer Combined Operating License Processes (10 CFR Part 52). *NRC Regulatory Guide 4.7 General Site Suitability for Nuclear Power Stations* discusses the major site characteristics related to public health and safety and environmental issues that the NRC considers in determining suitability of sites for light water-cooled nuclear power stations. NRC's *Report to Congress: Advanced Reactor Licensing* addresses NRC strategy for licensing advanced reactors and addresses anticipated licensing applications. This report provides details on licensing of advanced reactors, including SMRs.

2.1.4.7. AF guidance is derived primarily from DoD guidance but also relates to EOs and US Code. The *AF Energy Strategic Plan* (2013) incorporates energy security and operational energy into strategic energy priorities, goals, and objectives to help the AF meet federal legislative provisions, EOs and DoD directives. *AFPD 90-17, Energy Management* provides overarching structure, policies, roles, and responsibilities to enable the AF to manage its energy programs. *AFI 90-1701, Energy Management* establishes the cross-functional AF governance and management structure to execute energy policy, defines energy (includes nuclear), and sets renewable energy goals (stakeholders: SAF/US, IE, AQ; HAF/A4C, AFIMSC/AFCEC). The *AF FY2012 Implementation Plan for the DoD Strategic Sustainability Performance Plan* (2012) describes how the AF will achieve the DoD sustainability goals. *AFI 32-1061, Providing Utilities to USAF Installations* establishes guidelines for utility service contracts and management, preferred order of options to acquire electric service (number one: supplier owned), addresses computation of utility reimbursement rates, metering policy and reporting requirements (stakeholders: SAF/IEN, AF/A4C, AFIMSC/AFCEC, installation leadership). *AFI 32-1062, Electrical Systems, Power Plants and Generators* provide acquisition, operations, and maintenance requirements for power systems, individual real property installed equipment, and generators.

2.1.4.8. AFI 91-202, The *US Air Force Mishap Prevention Program* establishes mishap prevention program requirements, assigns responsibilities, and provides program management information. It cites the HAF Chief of Safety's role in safety study groups for "terrestrial nuclear reactors" (stakeholder: HAF/SE). *AFI 10-2501, AF Emergency Management Program Planning & Operations* establishes responsibilities and procedures for mitigation and emergency response to threats from major accidents; natural disasters; conventional attacks; and terrorist use of chemical, biological, radioactive and nuclear materials. *AFI 10-211, Civil Engineering Contingency Response Planning* provides requirements for base civil engineer initial responses to major accidents, natural disasters, and other contingencies.

2.1.5. Potential Considerations/Impediments. Based on our policy and guidance review, the items below are potential considerations or impediments that must be taken into account if siting an SMR on an AFSPC installation. NRC-related considerations are provided in paragraph 2.4.

- 10 USC § 2692 prohibits on DoD installations: storage, treatment, or disposal of any material that is a toxic or hazardous material and that is not owned by DoD except for temporary storage of nuclear materials in accordance with an agreement with the Secretary of Energy.
- DoDI 4165.57 restricts facilities and use within the Air Installations Compatible Use Zones.
- AFI 32-9003 reinforces DoD policy that prohibits storage or disposal of non-DoD-owned hazardous or toxic materials on AF real property. The Deputy Assistant Secretary of Defense (Environment) may grant exceptions.
- 10 USC §2916 states that the applicable Service secretary will set the price and receive the proceeds for sale of energy from alternate energy or cogeneration facilities which are under the secretary's jurisdiction (or produced on land which is under that jurisdiction). This would impact partnering with a utility or nuclear industry company to build, own and operate an SMR on an AF installation.
- The DOE *Nuclear Energy Research and Development Roadmap, Report to Congress* notes impediments to new plant development as capital cost and uncertainties in time required for licensing and construction.
- Several policy and guidance documents overlap or are inconsistent in their guidance for timeframes of utility service contracts:
 - 10 USC § 2688 – not to exceed 10 years, unless SECDEF determines that a contract for a longer term (not to exceed 50 years) will be cost effective.
 - 10 USC § 24' 10q – not to exceed 10 years for purchase from a renewable source, but SECDEF must determine if the contract is cost effective and would not be economical without a contract > 5 years.
 - 10 USC § 2922 – after SECDEF approval, the department Secretary may enter into contracts for up to 30 years for the provision and operation of energy production facilities on real property under the Secretary's jurisdiction or on private property and the purchase of energy produced from such facilities.
 - 10 USC § 2809 – not in excess of 32 years, excluding the construction period
 - DoD *Strategic Sustainability Performance Plan, FY2012* – Under a 20-year power purchase agreement (PPA), a financier purchased the solar system that a private solar company will design, build, operate and maintain. The role of the installation is to provide the land for the project and purchase electricity from it, at a rate that is locked in for 20 years below the current retail utility rate.
 - AFI 32-1061 – GSA area-wide utility contracts for a period not to exceed 10 years.

The variations in contract terms are open to interpretation requiring legal review. It appears that EUL guidance has been taken from 10 USC § 2688 as the maximum term is 50 years (see 2.3.2 below).

2.1.6. Preliminary assessment of required changes. The actions below would need to be considered to facilitate SMR deployment on AFSPC or DoD installations.

- 10 USC § 2692 and AFI 32-9003 need to be amended to allow storage of SMR used fuel, or the SECDEF and DOE Secretary need to co-sign an agreement for long term storage
- 10 USC § 2410q should be amended to include alternate energy
- 10 USC §2916 should be amended to allow for partnering with a utility or nuclear industry company to build, own and operate an SMR on an AF installation and sell the generated power.
- DoDD 4140.25 should be updated to address SMRs
- AFIs 10-211 and 10-2501 should be updated to include actions for SMR

2.2 Base Missions and Operating Characteristics

Energy availability and management is critical to Air Force readiness. Energy enables the Air Force to deliver its designed capabilities without unacceptable delay, and is essential for successful accomplishment of the mission. Energy availability and security impacts all Air Force missions, operations, and organizations and supports the Air Force’s priorities. The Air Force must have reliable energy supplies. AFI 90-1701, *Energy Management*, 8 May 2014

2.2.1. AFSPC Study Participation. AFSPC involvement in the SMR study began in April 2013 when General William Shelton, the Commander, AFSPC committed to partnering with Sandia National Laboratories to share information and support development of technical solutions to meet AFSPC facility power and energy security requirements. Due to the command’s facility-centric space missions, relatively high energy densities, reliability requirements, and diverse locations, AFSPC was a logical choice to participate in this study.

2.2.2. AFSPC Installations. As illustrated to the right and in Table 1, AFSPC installations are dispersed across the US and have a broad range of characteristics and missions. Although AFSPC is also responsible for the AF cyberspace mission, the installations considered in this study are primarily focused on the space domain; the cyberspace units are predominately located on installations owned by other AF Major Commands (MAJCOMs). We used the definition of “United States” provided in EO 13693, “...the fifty States, the District of Columbia, the Commonwealth of Puerto Rico, Guam, American Samoa, the United States Virgin Islands, and the Northern Mariana Islands, and associated territorial waters and airspace”. Given this definition of “United States”, Thule Air Base, Greenland was not included among the installations in our assessment, although Thule’s unique energy requirements, remote location, weather extremes, Danish governance, and critical mission make it a reasonable choice for a separate study.

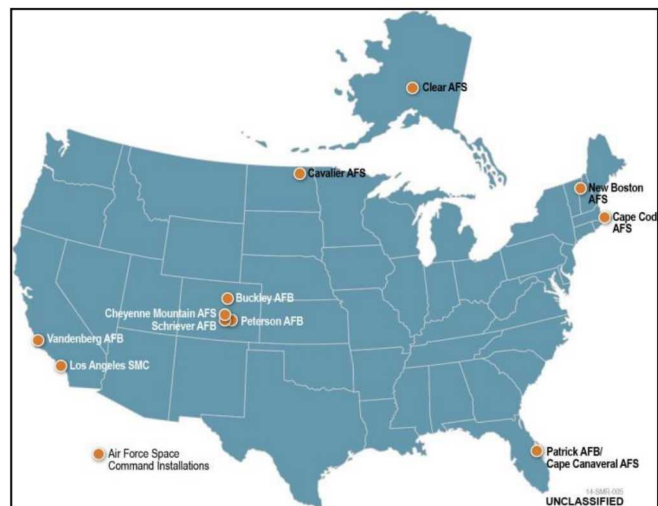


Table 1. AFSPC Installations Overview

Installation, Unit	Mission(s), Major Tenants	Operating Characteristics	Energy Supplier
Buckley AFB, CO 460th Space Wing (SW)	<u>Missile Warning/Space Surveillance, Intelligence</u> <i>Aerospace Data Facility-Colorado</i> <i>Navy Operational Support Center</i> <i>Colorado ANG</i> <i>Army Aviation Support Facility</i> <i>Air Reserve Personnel Center</i>	- 11,006' runway - Multiple radomes (line of sight) - F-16, helicopter operations - Urban setting	Public Service of Colorado
Los Angeles AFB, CA	<u>Space systems acquisition</u> Space and Missile Systems Center	- No runway - Urban setting	Southern California Edison
Patrick AFB, Cape Canaveral AFS, FL 45 SW (considered as separate installations)	<u>Space launch operations</u> <i>NASA operations</i> <i>Naval Ordnance Test Unit</i> <i>Commercial space activities</i>	- PAFB: 3993' runway - CCAFS: 10,000' runway - NASA, AFSPC, and commercial launches	Florida Power and Light
Peterson AFB, CO 21 SW	<u>Missile Warning/Space Surveillance</u> <i>302 Air Wing (AFRC)</i> <i>HQ AFSPC</i> <i>NORAD/NORTHCOM</i> <i>Army Space and Missile Defense Command</i>	- Co-located with Colorado Springs Municipal Airport - 13,501', 11022', 8270' runways - C-130 operations	Colorado Springs Utilities
Schriever AFB, CO 50 SW	<u>Satellite Operations</u> <i>57 Adversary Tactics Group (ACC)</i> <i>310 SW (AFRC)</i> <i>Missile Defense Agency</i>	- No runway - Multiple radomes (line of sight)	Mountain View Electric Association
Vandenberg AFB, CA 30 SW	<u>Space launch operations</u> <i>Joint Space Operations Center</i> <i>HQ Fourteenth Air Force</i> <i>381 Training Group (AETC)</i> <i>576 Flight Test Squadron (ACC)</i>	- 8,500' runway - NASA and AFSPC launches - Emerging commercial launch operations	Pacific Gas and Electric
Cape Cod AFS, MA 21 SW	<u>Missile warning</u>	- No runway	Cape Light and N-Star
Cavalier AFS, ND 21 SW	<u>Missile warning/space surveillance</u>	- No runway	Minkota
Cheyenne Mountain AFS, CO 21 SW	<u>Integrated Tactical Warning and Attack Assessment operations</u>	- No runway - Majority is within Cheyenne Mountain	Colorado Springs Utilities
Clear AFS, AK 21 SW	<u>Missile warning</u> <i>Missile Defense Agency</i>	- No runway	Golden Valley Electric Association (fall 2015)
New Boston AFS, NH 50 SW	<u>Satellite command and control</u>	- No runway	Public Service of New Hampshire
ACC: Air Combat Command AETC: Air Education and Training Command AFRC: Air Force Reserve Command ANG: Air National Guard		NASA: National Aeronautics and Space Administration NORAD/NORTHCOM: North American Aerospace Defense Command/US Northern Command	

2.2.3. AFSPC Energy Priorities. As is the case throughout the DoD, AFSPC faces distinct and often conflicting challenges in the energy arena. The major priorities impacting AFSPC energy requirements are listed below (not prioritized) and discussed in the following paragraphs.

- Mission
- Energy security
- Safety
- Security
- Reduced energy costs
- Clean energy, greenhouse gas goals

2.2.3.1. Mission assurance is a process to protect or ensure the continued function and resilience of capabilities and assets--including personnel, equipment, facilities, networks, information and information systems, infrastructure, and supply chains-- critical to the performance of DoD Mission Essential Functions in any operating environment or condition. (AFPD 16-14, *Security Enterprise Governance*, 2014). Mission is a major consideration in any assessment of installation operations, and mission priority was factored into our use case installation selection.

2.2.3.2. Energy security can be defined as having assured access to reliable supplies of energy and the ability to protect and deliver sufficient energy to meet operational needs. Energy is critical to the AF's national defense mission, but it is also vulnerability as the AF attempts to confront today's global and increasingly complex challenges. This makes energy security a central element of strategic policies and plans. (*U.S. Air Force Energy Strategic Plan*, 2013)

2.2.3.3. Safety. Safety programs preserve resources to maximize combat capability by eliminating mishaps through proactive hazard identification and risk management. (AFPD 91-2, *Safety Programs*, 2012)

2.2.3.4. Security involves measures taken by a military unit, activity, or installation to protect against all acts which may impair its effectiveness. It is the result of establishment and maintenance of protective measures that ensure a state of inviolability from hostile acts or influences. (AFPD 16-14)

2.2.3.5. Reduced energy costs. As the DoD's largest energy consumer, the AF has established a comprehensive management structure to enhance energy use and supply, including specific goals to decrease energy costs. In the effort to reduce energy demand, the AF has increased its focus on life cycle cost-effectiveness, optimizing energy procurement, and improving efficiency. This includes identification of best financing approaches, based on the following goals that are applicable to SMRs: (AFI 90-1701, *Energy Management*, 2009)

- Explore other methods of funding for energy initiatives
- Review energy economic and cost models
- Explore government and private sector best practices for energy purchases

- Engage the Office of the Secretary of Defense (OSD) to influence DoD financial regulations pertaining to energy as laws and policies change; update or develop requisite AF policies
- Gain Congressional support for energy legislative initiatives/ proposals with financial impact

2.2.3.6. Clean energy, GHG goals. As part of the effort to increase energy supply, the AF incorporates clean energy and GHG goals. These goals will be updated to reflect the latest guidance in response to the EO 13693. For example:

- Overarching Goal. Increase available energy supplies to become more energy independent... reduce the amount of energy from foreign sources, use renewable or green energy where possible to reduce GHG emissions. Focus: aviation fuel, ground fuels, and installation energy.
- Sustainability Goal. By FY25, 25% of building electric and thermal energy shall be clean energy, accounted for by renewable electric energy and alternative energy.
- Implementation Objective. Develop renewable energy resources on base. Procure commercially-produced alternative/renewable energy. Identify/develop privately financed/operated energy production on bases.

2.2.3.7. AFI 90-1701 also highlights a specific role for EULs in energy management. The EUL program studies underutilized assets and real estate to determine if they can be used to facilitate development of alternative/renewable energy projects. These projects must not hinder the installation's mission; negatively impact the environment; comply with applicable local, state, and federal laws and regulations governing energy development; and return a net positive value to the AF. (See paragraph 2.3.2.)

2.2.3.8 To gain insight into the current energy demands on AFSPC installations, the team requested energy use data for the most recent fiscal year, FY14, from the HQ AFSPC Energy Office (HQ AFSPC/A7OE). Table 2 below is a recap of the data provided

Table 2. AFSPC Installation Energy Requirements

Installation	Electric					Heat (MBTUs)			
	Base Average Demand (MWe)	Annual Use (MWh)	Annual Cost (in \$1,000)	Peak Demand (MWe)	Highest Peak Month	Annual	Annual Cost (in \$1,000)	Max	Month occurred
Buckley AFB, CO	16.28373	142646	\$9,157	5.58	July	129729	\$1,028	23036	Dec
Cape Canaveral AFS, FL	16.69509	146249	\$9,301	21.74	Apr-14	51449	\$433	4635	Oct
Cape Cod AFS, MA	1.27989	11212	\$653	1.52	July	10737	\$282	2094	Feb
Cavalier AFS, ND	5.76610	50511	\$2,429	7.00	14-Feb	56545	\$793	5723	May
Cheyenne MT AFS, CO	2.70000	26369	\$1,423	3.20	July	2162	\$30	352	Dec
Clear AFS, AK CALCULATED (loads/costs)	4.50685	39480	\$4,343	5.89	Mar	206916	\$4,476	76386	Mar
Los Angeles AFB, CA	2.63550	23087	\$2,893	4.56	Sep	28145	\$207	3526	Dec
New Boston AFS, NH	0.57534	5040	\$516	0.70	Feb	12953	\$327	1916	Feb
Patrick AFB, FL	10.42021	91281	\$5,673	17.21	May-14	39181	\$334	4855	Jan
Peterson AFB, CO	10.29276	90165	\$5,084	15.99	July	192578	\$1,367	30879	Dec
Schriever AFB, CO	9.20464	80633	\$5,874	10.70	14-Oct	155595	\$836	19651	Dec
Vandenberg AFB, CA	18.72146	164000	\$17,035	25.46	May-14	280623	\$2,391	35804	Nov

2.3 Stakeholders

2.3.1. Methodology: We capitalized on our Base Realignment and Closure (BRAC) experience to identify DoD and AF offices that were BRAC stakeholders. Since BRAC is the congressionally authorized process DoD has used to reorganize its installation structure, we recognized many of the BRAC stakeholders would also have interests in installation-level discussions such as SMR deployment. We also reviewed our personal points of contact within the Office of the Secretary of the Air Force (SAF), HAF, HQ AFSPC, utility companies and the SMR vendor community. During our research for applicable guidance and policy documents (see paragraph 2.1), we identified additional stakeholders by cross-referencing offices responsible for the primary and related documents. Our review of existing SMR studies (paragraph 2.5) also provided possible stakeholders. We followed up with possible stakeholders by phone or e-mail to provide details on our study and confirm their office’s interest or official affiliation with our study. Finally, we solicited inputs from installation-level stakeholders using

an “Installation SMR Questionnaire” (Appendix C) to gather first-hand data on energy requirements and characteristics.

2.3.1.1. DoD stakeholders:

- Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics (USD(AT&L))
- Office of the Deputy Under Secretary of Defense for Installations and Environment (DUSD(I&E))
- Office of the Assistant Secretary of Defense for Operational Energy (ASD(OEPP))
- Assistant Secretary of Defense for Research and Engineering (ASD(R&E))

2.3.1.2. SAF stakeholders:

- Office of the Under Secretary of the Air Force (SAF/US)
- Office of the Assistant Secretary of the Air Force for Installations, Environment and Energy (SAF/IE)
 - Deputy Assistant Secretary for Installations (SAF/IEI)
 - Deputy Assistant Secretary for Environment, Safety and Occupational Health (SAF/IEE)
 - Deputy Assistant Secretary for Energy (SAF/IEN)
- Office of the Assistant Secretary of the Air Force for Acquisition (SAF/AQ)

2.3.1.3. HAF stakeholders:

- Safety Office (HAF/SE)
- Directorate of Civil Engineers (AF/A4C)

2.3.1.4. MAJCOM stakeholders:

- Air Force Materiel Command (AFMC), Air Force Installation and Mission Support Center (AFMC)
 - Air Force Civil Engineer Center (AFCEC)
 - Energy Directorate (AFCEC/CN)
 - Installations Directorate (AFCEC/CI)
- HQ Air Force Space Command (HQ AFSPC)
 - Directorate of Integrated Air, Space, Cyberspace and Intelligence Operations (A2/3/6)
 - Directorate of Logistics, Installations and Force Protection (A4)
 - Directorate of Strategic Plans and Requirements (A5/8)

2.3.1.5. Wing/installation stakeholders will be determined during the use case studies.

2.3.1.6. Utility Companies

- Ameren Corporation, St. Louis, MO

- Blue Castle Holdings, Inc., Provo, UT
- Colorado Springs Utilities, Colorado Springs, CO
- Duke Energy, Charlotte, NC
- Energy Northwest, Richland, WA
- Exelon Corporation, Chicago, IL
- Mountain View Electric Association, Falcon, CO
- Public Service Electric and Gas Company, Newark, NJ
- Tennessee Valley Authority, Knoxville, TN
- Tri-State Generation and Transmission Association, Inc., Westminster, CO
- Xcel Energy, Inc., Minneapolis, MN

2.3.1.7. SMR vendors

- BWX Technologies, Inc. (BWXT) mPower, Inc., Charlotte, NC
- Holtec International, Marlton, NJ
- NuScale Power, LLC, Portland, OR
- Westinghouse Electric Company, Pittsburgh, PA

2.3.2. Enhanced Use Leases. The Air Force Civil Engineer Center (AFCEC) of the Air Force Installation Mission Support Center (AFIMSC) has primary responsibility for all AF EULs. As defined in AFCEC’s *Guide for Submission of an Unsolicited Enhanced Use Lease Proposal*, 24 Feb 15), an AF EUL is a lease:

...of an exclusive, possessory interest, in real or personal property under the control of the Secretary of the AF to a public or private-sector lessee and is offered in exchange for consideration at least equal to the property’s fair market value. Consideration for a EUL may be either cash or in-kind. Such a lease is limited to a 5 year term unless the Secretary of the AF determines that a lease for a longer period will promote the national defense or be in the public interest. In no event shall the term exceed a period of 50 years.

AFCEC provided additional guidance relating to SMRs and the maximum 50 year period:

- Construction phase is incorporated within the 50 year EUL
- Decommissioning is included in the 50 year EUL
- EULs can be extended beyond 50 years; this process starts approximately 5 years before the termination date
- The EUL can be renewed prior to 50 year termination for a specific technology lifespan

2.3.2.1. Potential EUL properties must comply with “non-excess” and “mission compatible” criteria in 10 USC § 2667 and AFI 32-9003, *Granting Temporary Use of Air Force Real Property*. “Non-excess” property includes assets not anticipated to be needed for the duration of the lease, but which the AF may need in the future. Operational and force protection issues should have primary consideration. (*AF EUL Playbook*)

2.3.2.2. The AF has two tracks for EULs, a Full and Open competition (generally internal to the AF) and an unsolicited EUL proposal (generally nongovernmental). The Full and Open Competition EUL is a collaborative effort that includes installations, MAJCOMs, AFCEC and other internal and external stakeholders, including public and private sector interests. Guidance for Full and Open Competition EULs is contained in the *AF EUL Playbook* and the *AFCEC/CIM Playbook*, (currently in revision). In the case of an Unsolicited EUL Proposal, the AF encourages innovative and unique ideas in response to AFCEC EUL solicitations or programs. Unsolicited EULs are addressed in the *AFCEC Guide for Submission of an Unsolicited EUL Proposal*. These guides do not supersede EOs, USC, and National Environmental Policy Act (NEPA), DoD or AF directives/policies.

2.3.2.3. The AFCEC Guide for Submission of an Unsolicited EUL Proposal states that an unsolicited EUL proposal must:

- Be innovative and unique
- Be independently originated and developed by the offer or
- Be prepared without AF direct involvement
- Include sufficient detail to determine that AFCEC support could be worthwhile and the proposed EUL could benefit the AF's mission
- Not be an advance proposal for a known AF requirement that can be achieved through competition and
- Not address a published AF requirement

2.3.2.4. The EUL process has seven phases. The phases 0-3 are managed by AFCEC/CIU and follow the guidance in the *AF EUL Playbook*. Phases 4-6 are managed by AFCEC/CIM and follow the guidance in the *AFCEC/CIM Playbook*. (Since the CIM playbook is in revision, no current version or a copy of the revision were available, therefore Phases 4-6 are briefly summarized).

Phase 0 – Project Identification. Potential projects are identified in several ways. Stakeholders may identify EUL opportunities that are consistent with statutory, regulatory, and installation requirements, authorities, and limitations. AFCEC studies real estate and energy markets' demand, looking for EUL opportunities and markets the EUL program to developers, installations, and communities. A site visit may occur including a meeting with stakeholders to explain the opportunity, stakeholder roles, costs/benefits, and issues/challenges. An Opportunity Assessment is conducted, which includes; market analysis; financial analysis; strengths, weaknesses, opportunities, and threats analysis; and risk analysis (for energy projects, this also addresses interconnection/off-take issues and additional regulatory concerns). The decision to proceed to Phase 1 includes a review of lifecycle cost estimates and the strengths and weaknesses of the proposed EUL.

Phase 1 – Project Definition – This phase includes more detailed market research, economic, and technical analysis. AFCEC outlines the most advantageous plan, milestones, and schedule. For energy EULs, AFCEC briefs the Renewable Energy Project Development panel, which determines if the energy project qualifies as a EUL, PPA, or a combination of both.

The environmental planning process is critical to any EUL project and achieving project success. The NEPA of 1969 establishes a national environmental policy which impacts a “proposed action” such as a EUL. EUL energy opportunities must not impact current or future installation mission performance. The HAF Encroachment Management Working Group approves EUL energy projects. Approved projects go to AF leadership through the Strategic Basing Process (AFI 10-503, *Strategic Basing*).

“Legislative jurisdiction”--the authority to enact or pass laws, regulations, or ordinances and exercise executive and judicial enforcement powers over enacted legislation within that land area--must be clarified. Law enforcement resources and criminal jurisdiction may drive a change in land area jurisdiction, which can be a lengthy process.

Phase 2 Project Acquisition documents AF requirements, solicits the EUL, and evaluates offers for the proposed EUL. In this phase, market research is finalized and industry inputs are incorporated into a final solicitation. The Source Selection Decision Authority approves progression to Phase 3. (*AF EUL Playbook*).

A basic premise of a EUL is that the installation will receive “in kind consideration” from the lessee, as determined by AFCEC and the installation. Possible considerations include services (e.g., electrical power at reduced rates). The objective is to ensure the consideration is equal to or exceeds the fair market value (FMV) of the leasehold interest. The preferred in kind consideration is included in project-specific solicitations and lease documents. If the FMV of the lease is in excess of \$100K or the lease exceeds 1 year, 10 U.S.C. § 2667 requires competitive procedures.

The AFCEC *EUL Playbook* notes that energy EULs must comply with the 9 November 2012 Office of the Under Secretary of Defense for Installations and Environment (OUSD (I&E)), *Financing of Renewable Energy Projects Policy Memorandum*. Although this memorandum is for renewable energy projects, it addresses certification of energy-related EULs and the special agreement authority found in 10 USC § 2922a. This USC section applies to any type of energy production facility, allows for a contract up to 30 years for energy production facilities on DoD real property and the purchase of energy produced from these facilities, and requires contract approval by DUSD (I&E). For an SMR EUL, compliance with the OUSD (I&E) memo would be through the installation’s procurement of generated power from the SMR, the added energy security capabilities of on base generation and in-kind considerations.

Phase 3 – Lease Negotiations & Closing includes the negotiate lease terms and obtain SAF/IEI approval on the final lease, and negotiate unresolved project-specific terms and conditions, site control requirements, and development agreements. The goal is to ensure the AF receives FMV as a minimum. Key areas include site control issues, designs and plans, compliance with AF missions, constraints, and requirements and compliance with Strategic Basing and/or Encroachment Management assumptions. Upon completion, AFCEC submits the lease execution package to SAF/IEI.

Phase 4 – Design and Construction includes design and construction of the actual facility/plant including the utility interconnection and final approvals. Phase 4 ends with the project entering its operational phase. Design must comply with AF standards and base guidelines

Phase 5 – Sustainment is the long-term operation and maintenance of the project and managing the portfolio to include; tracking cash or in-kind consideration, monitoring lease compliance and managing the portfolio.

Phase 6 – Termination includes the decommissioning and removal of the plant and restoration and return of the property to the AF. Key steps are: determine continuing AF mission requirements and termination or renegotiation of the lease.

2.3.2.5. For an Unsolicited EUL Proposal, AFCEC determines if the proposal is valid, meets the definition of a EUL, and complies with statutory authorities. If so, AFCEC evaluates the proposal, looking for unique and innovative methods, approaches, or concepts; the qualifications/experience of the offeror; potential value to the AF; offeror's capabilities, experience and financing; whether the EUL is feasible and legally permissible; and if the proposal provides the AF with a best solution. Under certain conditions, AFCEC will bypass full and open competition and begin EUL negotiations.

2.3.2.6. EUL Lessons Learned. In an effort to develop lessons learned, the Scitor Team contacted personnel involved in recent EUL projects to obtain their inputs. These projects included:

- Luke AFB, AZ, 10 MWe solar development EUL with Arizona Public Service
- Eglin AFB, FL, resort development EUL with Emerald Breeze Resort Group and Innisfree Hotels, Inc.
- Hill AFB, UT, research park EUL with Sunset Ridge Development Partners LLC
- Nellis AFB, UT, wastewater treatment plant EUL with the City of North Las Vegas

The team gleaned these lessons learned from the EUL projects above:

- In-kind considerations vary considerably. While cash is always beneficial, it may not be the best incentive for granting a EUL. In the resort development EUL at Eglin AFB, in-kind consideration included cash as well as setting aside several rooms at a reduced rate for military personnel. At Hill AFB, construction of new administrative facilities and the subsequent demolition of World War II era facilities were included. At Nellis AFB, a new fitness center, a supply of reclaimed water, and water supply infrastructure were in-kind considerations.
- Strong teamwork is essential. Establish weekly meetings and communication processes early. When issues arise the communications framework will already be in place.
- Patience is required. The EUL process is still fairly new and subject to change as the AF procedures mature. For example, the Eglin AFB resort development EUL took 7 years from Industry Day to Opening Day. The whole concept of a EUL is new to industry partners so the learning curve can be steep.
- The NEPA process will always be a major factor. This should be one of the earliest considerations and needs to have strong emphasis throughout the process. Open lines of communication are essential.
- Never assume. Archeological issues were known to exist at Luke AFB. Prior construction and surveys indicated that only surface artifacts would be found. However, exploratory trenching discovered features 12-18 inches below the surface and expanded

trenching found sub-surface artifacts on 45% of the solar site. Mitigation efforts significantly delayed the project.

- Be innovative. During the Eglin AFB resort project, the lessee needed to demolish an AF facility with a receiver that tracked AF maneuvers along the Florida coast. Rather than building a new facility they negotiated an innovative design which would allow the receiver to remain in use from a new location on top of the resort.
- Review state laws/recommended changes. Utah passed a law establishing a special economic development authority to assist development in connection with military installations such as Hill AFB. Utah appropriated \$10M in grants for infrastructure costs and relocation of a base gate.
- Look for flexibility in financing. Consider securing equity investments and debt financing by leveraging the projected cash flows and community buy-in when seeking investors. The Eglin resort project received capital investment from the Poarch Band of Creek Indians and additional financing from Navy Federal Credit Union and Pen Air Federal Credit Union.
- Pay attention to local property tax laws. If leased land was and remains “Federal Jurisdiction” the lessee may not have to pay property taxes.
- Get a good land and boundary survey early and utilities survey. “Finding” below-ground utility lines with a backhoe or trencher can cause significant delays (revising easements boundaries) as well as unexpected expense and aggravation repairing the utility lines.
- Make sure the government understands the “land valuation process” (normally done by the Army Corps of Engineers). It is highly unlikely that their process is the same as the lessee’s. Differences in process result in different valuations which will compound negotiations.
- Last, but most important, take advantage of AFCEC staff capabilities. They can help solve issues much faster and they understand the leasing particulars much better than either the installation or the lessee. Always get their advice first and last.

2.3.2.7. The team also reviewed several other energy projects on DoD facilities for insight into other options than EULs.

- Ft Carson, CO, developed a direct land lease with a PPA for a 2 MWe solar array on the installation. If an installation expects to use all or almost all of the plant’s production, a simple land lease with a PPA can be accomplished. This offers a significantly shorter timeline and fewer man-hours for the military and the power provider. The base receives credit for the renewable energy they purchase from the local utility.
- Vandenberg AFB, CA, is developing a direct land lease and PPA for a contractor-owned and operated 20 MWe solar array. Renewable credits are being negotiated.
- Buckley AFB, CO, has a 1 MWe solar array and additional solar PV heat for selected facilities purchased by Buckley through the Energy Conservation and Investment Program (ECIP). There is no PPA since the base uses all the power; they receive the renewable credits.
- Cape Cod, MA, has a 3.2 MWe wind field purchased through ECIP. They have net metering rather than a PPA. The power goes to the utility’s grid and the base receives credit for their energy bill. The unit receives the renewable credits.

- Nellis AFB, UT, developed a 15 MWe solar array with Nevada Power Company (NV Energy). This is not a EUL but a hybrid. Nellis uses a direct land lease, but there is no PPA since they do not use all the power produced, yet they receive in-kind services (distribution lines and a secondary substation). NV Energy owns, operates and maintains the array but the base receives credit for the renewable energy they purchase from NV Energy.

2.3.2.8. Due to the unique nature of SMRs and the fact that they are not currently on AF bases, the benefits to the AF mission (energy security/surety) are unproven; and there is no known current AF requirement. Determination of the appropriate EUL approach (open competition vs. unsolicited) will be a focus area during the use case studies.

2.4 Small Modular Reactors

2.4.1. US SMR Technology Characteristics. All four light water SMR vendors provided information about each technology's requirements and performance capabilities (Table 3). To meet the mission critical needs of an AFSPC installation following an abnormal event such as an earthquake or failure of the electrical grid, the SMR might need to achieve a black start, operate in "island" mode, and generate electricity at less than full power. Each of the SMR respondents stated that its design is capable of achieving black start, provided it has a source of on-site, back-up power to run certain components. The respondents also stated the nuclear power plants can operate in island mode. Both black start and island mode, however, might require license exemptions from NRC regulations, or other approvals from the NRC. The NRC, for example, currently requires that nuclear power plants have two sources of off-site AC power. With their smaller scale and use of passive safety systems, the SMRs might receive exemptions from this and other requirements. While it is not the cost-effective way to operate the SMR, each vendor stated its SMR could operate at low power levels, some as low as 5 MWe, using steam bypass directly to the condenser. In addition, the site layout for three of the four designs includes an Independent Spent Fuel Storage Installation (ISFSI) to hold spent fuel for the life of the plant. None of the technologies are designed for protection against electromagnetic pulse (EMP), although companies believe it is feasible. One respondent noted that EMP protection would need to extend to the plant's switchyard and the electrical grid and distribution serving the DoD installation.

Table 3. SMR Technology Comparison

SMR Characteristic	BWXT mPower	Holtec SMR-160	NuScale NPM	Westinghouse SMR
MWe / Nuclear Steam Supply System (NSSS)	180 MWe nominal	160 MWe	50 MWe (gross)	≥ 225 MWe
MWt / NSSS	530 MWt	525 MWt	160 MWt	800 MWt
Units per site	2 reactors per module	1 - 2	1 - 12	1
Total Output	360 MWe nominal	160-320 MWe	570 MWe (net)	≥ 225 MWe
Site Size	<40 acres	5 -7.5 acres	40 acres	15 acres
Coping time	> 7 days passive cooling with ECCS and passive containment cooling	Unlimited	Indefinite	≥ 7 days
Overnight Cost per kw	Not available*	\$4,062	\$5,078	Not available*
Overnight Cost per Net Primary Production	Not available*	\$650 million	\$3.046 billion	Not available*
Lifecycle Cost of Energy (LCOE)	Not available*	\$81.50/MWh	\$72 - \$106/MWh	Not available*
Projected Capacity Factor	95%	95%	95%	95%
Cooling Options	Water cooling. Air cooling option	Wet or dry	Wet or dry	Wet or dry
Gallons per day (gpd) consumption for conventional cooling(e.g., mechanical draft)	10.37 million (two reactors)	4.5 million	13.1 million	7.5 million
Design Life	60 years	60 years	60 years	60 years
Refueling Interval	4 years	24 months	24 months	24 months
Refueling Outage Duration	< 30 days	12 days	10 days	17 days
Spent Fuel Pool storage / cores / years	10 cores/20 years	3 full cores plus one full offload	≥ 10 years	14 years
On site ISFSI in plans	Yes	Yes	Yes	No
<i>* proprietary information</i>				

2.4.2. Highlights from SMR vendors. Key points from the inputs provided by the four SMR vendors in response to the team’s request for information (Appendix D) are provided below. Since the information below is based on the content of the vendors’ responses, the length and scope may vary.

BWXT Generation mPower

- ISFSI space can either be within or outside the main plant protected area. Flexibility necessary and costs somewhat unknown due to changing ISFSI regulations.
- Spent Fuel Pool design uses un-poisoned low density storage racks. Use of high density racks would increase capacity.
- Progress toward Design Certification includes 4 years of interaction with the NRC and 30 information and report submittals. NRC has established a Design Specific Review Standard.
- BWXT could submit a DCA in 2017 to support a mid-2020s COD.
- Black start requires additional equipment to supply energy to start the plant and is not currently part of the DCA configuration.
- Overnight capital cost and LCOE comparable to a LLWR

- Plant designed to meet EPRI URD minimum of 20%, or 36 MWe.
- SMR designed to withstand a loss of all off-site power by transitioning to island mode with 100% steam turbine bypass. Once on island mode, mPower can operate indefinitely to support house loads and mission critical needs up to 100% stated output power.

Holtec

- Holtec is using a 10 CFR Part 50 licensing process. It can submit a Construction Permit Preliminary Safety Analysis Report (PSAR) in 2017, start construction in 2020, with Commercial Operation in 2024.
- The Holtec SMR can load follow between 60% and 100% power (~95MWe – 160 MWe). It can operate at less than 60% power using steam dump directly to the condenser.
- Holtec states its SMR-160 can operate indefinitely off the grid at reduced power.
- “Operational performance of the turbine island for low power demands (5 – 25 MWe) is feasible.”
- If black start is needed, “With non-safety related diesel power used to energize one startup pump, the reactor coolant system can be brought to natural circulation, control rods pulled, and the plant brought back to full operation.”
- “SMR-160 is substantially smaller than existing nuclear plants, both in physical size and source term. The smaller source term and limited leakage paths translate into a credible case for reducing emergency planning zones, simplifying emergency planning measures and providing improved protection of public health and safety.”
- The site layout includes the HI-STORM UMAX underground storage ISFSI.
- The first ISFSI utilization takes place 8 years after the first outage.
- The ISFSI is designed to accommodate all spent fuel for the life of the plant.

NuScale Power

- Each module is rated at 50 MWe, gross. The plant requires 30 MWe for station load. It is unclear how much is required for station load from the first module.
- “Each NuScale Power Module (NPM) has 100% steam bypass capability and can be configured to continue operation when the area AC grid is unavailable. This allows ... for a black startup...”
- NuScale reactors are refueled sequentially with only one reactor out of service for refueling at a time.
- NuScale is in the pre-application phase with the NRC under 10 CFR Part 52. It expects to submit its Design Certification Application (DCA) in December 2016.
- The Utah Associated Municipal Power Systems (UAMPS) has announced that it will submit a Construction & Operating License (COL) application to the NRC in 2017.
- The target commercial operation date for the UAMPS Carbon Free Power Project is 2023.
- NuScale projects a security force of 70 personnel and sees savings if that number can be reduced by siting an SMR on a DoD installation.
- Fluor Corporation, which owns NuScale, conducted a detailed, bottoms-up cost estimate in 2015. It projects an overnight capital cost of \$5,078 per kilowatt of capacity in 2014 dollars.
- Owner’s costs are estimated at an additional \$300 million.

- LCOE for the first plant is estimated at \$72/MWh (7.2 cents/KWh) if the plant is owned by a municipal utility.
- LCOE is estimated at \$106/MWh for an investor-owned utility.
- Minimum output per NSSS is 5 MWe.
- The system has a 40% per hour ramp rate and 20% per hour step change.
- The plant can operate in island mode.
- If only one reactor and turbine generator is in operation, house loads require 60-70% of its output leaving 15-20 MWe.
- The ISFSI has capacity for all spent fuel produced the 60 year design life of a 12-module plant.
- NuScale's timeline serves as a representative breakout of required actions (Appendix E)

Westinghouse

- Estimates 1 year to prepare DCA, 39 months for review, 36 months to construct the First of a Kind (FOAK) plant, 18 months for the Nth of a Kind plants.
- Daily load follow can be performed from 100% to 20% power at a rate of 5% change per minute; in continuous load follow, the plant can perform load changes of $\pm 10\%$ power at a rate of 2% per minute.
- The system is able to island and operate at a self-sustaining power level with zero output to the grid for more than 72 hours.
- The system is able to operate at power outputs between 0 and 100% power.
- A black start requires ~ 20 MWe of power for 10-15 hours.
- The site layout does not include an ISFSI.

2.4.3. Deployment scenarios. The team also sent requests for information to 10 utilities (Appendix F), eight with operating nuclear power plants and two that serve AFSPC installations in Colorado. All were asked what they perceived to be the preferred deployment scenario for an SMR that would serve an AFSPC installation:

1. A generic location on the grid providing power to the AFSPC installation through a PPA.
2. Immediately adjacent to the AFSPC installation, with the opportunity to enhance energy surety through the use of a micro-grid.
3. Within the AFSPC installation with possible service support from installation personnel and enhanced energy surety through a micro-grid.

The SMR technology developers and the nuclear operating utilities differed in their perspectives regarding Scenarios 2 and 3. The SMR companies favored Scenario 3 in the expectation that installation personnel might provide services and support--e.g., security, emergency response, fire protection--that would lower operating costs. Scenario 3, however, raised concerns with some of the nuclear utilities. The principal concerns were whether it would complicate NRC licensing and constrain access to the site. One nuclear utility said they would prefer to "buy 100 acres adjacent to the installation" and use a micro-grid and a possible underground feed to enhance energy surety. The next phase of this study will evaluate the extent to which an installation can provide services to an SMR, quantify the potential benefits, and highlight regulatory concerns with siting an SMR on an installation.

2.4.4. Impediments to SMR Commercialization. Development of new nuclear power plants in the US is challenged by two principal impediments: high capital cost compared to alternatives such as natural gas, and licensing risks. Measured in dollars per kilowatt of generating capacity, a new nuclear power plant will cost three to four times as much to build as a new power plant that operates on natural gas. By choosing natural gas over nuclear, a utility has far less up-front money at risk for a shorter period of time. And although the price of natural gas can vary significantly, the cost of fuel is an operating expense that is passed along to customers, insulating the owner from the risk of fuel price volatility. Nuclear power from the existing fleet and new plants is currently the only option if the US is to meet its goals for clean energy. The existing nuclear fleet provides almost 70% of the carbon-free energy produced in the US, but the fleet is aging and without additional license extensions all plants will retire before 2050. Although a highly efficient combined cycle gas-fired plant emits less than half the carbon of a coal-fired plant, its emissions still have an adverse impact on attaining clean energy goals. For example, if a natural gas plant produces as much electricity as a 1,000 MWe nuclear plant operating at a 90% capacity factor, the gas plant will emit more than 3.5 million tons of carbon over 1 year.

2.4.4.1. Financial Impediments. The US government has provided financial incentives to encourage the development of carbon-free energy resources, including nuclear. However, the Federal and state incentives for new nuclear were significantly less than the incentives for other carbon-free energy. The Energy Policy Act of 2005 (EPAct 2005) provided three types of support for new nuclear: production tax credits (PTCs), loan guarantees, and risk insurance.

- The PTCs provided \$18/MWh--up to a maximum of \$125M/year for 8 years per reactor--for the first 6,000 MWe of new nuclear. Based on projected capacity factors for new nuclear plants, this is the equivalent of 800 MWe of a 1,000 GWe AP1000 reactor. To qualify, a new plant had to be under construction by 2014--only four plants, in South Carolina and Georgia, will qualify for the PTC incentive. In essence, the PTC incentive for new nuclear has expired; only about 3,200 MWe of the available 6,000 MWe will be utilized. Interestingly, the unused 2,800 MWe is more than sufficient to cover two each of the four SMR technologies evaluated in this study – Holtec (160), mPower (360), NuScale (570), and Westinghouse (225).
- The EPAct 2005 also offered Federal loan guarantees as an incentive--designed to lower the cost of borrowing. The results are mixed. Examples: Southern Company secured loan guarantees to support the construction of Vogtle 3 & 4, thereby lowering the cost of debt service by an estimated \$250M over the life of the plant. Constellation Energy was offered loan guarantees for the Calvert Cliffs 3, but the guarantees came with a risk premium payment requirement that essentially offset the potential benefit. This was one of several reasons the project was canceled. SCANA Corporation decided to not pursue loan guarantees for Summer units 2 & 3.
- EPAct 2005 incentives for renewables, especially wind and solar, overshadowed the development incentives for new nuclear. These incentives included an inflation-adjusted PTC now equal to \$23/MWh, which is generally available for 10 years. As an alternative, developers could take an Investment Tax Credit (ITC) equal to 30% of the project cost and convert it to a cash grant from the Federal government at the time of commercial operation. Most developers took the cash grant. The program did not include a cap on total payments for PTCs, ITCs, or cash grants. Most renewable energy

projects also were able to accelerate depreciation over 5 years and take a bonus depreciation of as much as 50% in the first year.

- Renewable energy projects also received Renewable Energy Certificates (REC) for the power they produced--each MWh produced resulted in one REC. Some solar projects received as many as three RECs/MWh. The project owner or power purchaser who received the REC could trade it on the market to help others meet their Renewable Portfolio Standards or clean energy standards.
- A reality impacting new nuclear power in the US, which is frustrating to the nuclear industry, is that 31 states excluded carbon-free nuclear energy from their Renewable Portfolio Standards. The failure to include nuclear energy in the RPS removed one of the key drivers for its development as a clean energy resource and excluded nuclear from state-level incentives. In addition, nuclear power was not included in the EO 13514 (2009) clean energy goals. This was rectified somewhat in EO 13693 (March 2015), which increased the goals for Federal facilities for renewable and “clean or alternative” energy. The 2015 EO specifically included SMRs as “alternative.” However, the EO wording is difficult to interpret; additional guidance is required to clarify if SMRs are receiving credit for thermal energy or will also receive credit for electrical energy.

2.4.4.2. 10 CFR Part 50 and Part 52 Regulatory Costs and Uncertainty. Another impediment hindering construction of new nuclear power plants is the uncertainty associated with the time and cost of the NRC approval process. Financial analysts and investors view it as “binary” process with a yes or no outcome. As such, they perceive it as a tremendous financial risk to the technology developer and project owner.

- The nuclear power plants currently operating in the US were licensed by the NRC under 10 CFR Part 50. Part 50 splits the process into a Construction Permit that grants approval to build the project, followed by an Operating License at project completion that grants approval to put it into operation. Numerous owners experienced years of delays in receiving operating licenses at the completion of construction, costing the owners millions of dollars a year to keep the plant staffed and maintained, and pay the interest on funds borrowed to build the highly capital intensive asset.
- While the Part 50 process is still available, most technology developers and owners have elected to follow the Part 52 process. The NRC developed the new regulatory process in the 1990s, with input from the nuclear industry, in an effort to provide greater certainty. The process, under 10 CFR Part 52 (referred to as “Part 52”) is built around the concept of standardization. Technology vendors develop and submit a standardized design and submit it to the NRC for Design Certification. Once received, the Design Certification is valid for 15 years. Owner-operators apply for a COL. Once a COL is granted, the owner has permission to operate the plant when it is completed, provided they demonstrate the plant was built in compliance with the license requirements. Owner-operators also have the option of first applying for an Early Site Permit (ESP), which allows them to adjudicate all site-related and environmental aspects of the proposed project. Once received, an ESP is “bankable” for up to 15 years. An ESP can later be incorporated into a COL application to expedite that process.
- An unintended consequence of the Part 52 process is that it dramatically changed the dynamic between the technology provider and the owner. Under Part 50, for example, the owner submitted a Preliminary Safety Analysis Report (PSAR) as part of the

construction license and a Final Safety Analysis Report (FSAR) with the operating license application. The owner paid for the PSAR and FSAR development as part of the project cost. Part 52 shifted this requirement, as well as the expense and business risk, to the technology developer as part of the Design Certification process. Further, to prepare the FSAR, the technology developer must complete a large portion of the design and engineering for the FOAK version of its standardized power plant. Given this, technology developers now bear hundreds of millions of dollars in costs and business risk associated with licensing, design, and engineering expenses previously borne by the project owner.

2.4.5. NRC Licensing Considerations. NRC requirements pose a number of potential impediments to Deployment Scenario 3, siting an SMR on an AFSPC or other DoD installation. Some pertain to control of and access to the site while others relate to DoD operations on the installation. In addition, NRC approval would be required for some of the operational modes under consideration in Scenarios 2 and 3 to provide mission critical needs following abnormal events. Based on NRC Regulatory Guide 4.7, March 2014, and other NRC regulations, the following present considerations the team will evaluate during the use case effort.

- Control of the Site
 - Lease Duration: San Onofre Nuclear Generating Station was built on Marine Corps Base Camp Pendleton, CA, and Columbia Generating Station was built on DOE property on the Hanford Nuclear Reservation, WA. Both are on leased land. Current DoD rules limit the length of a ground or enhanced use lease to 50 years, with the option for extension. The NRC could determine that this duration is insufficient.
 - Exclusion Area: The NRC will require that the SMR licensee designate an “exclusion area” with “authority to determine all activities within that area, including removal of personnel and property.” Depending on the location of the SMR within the installation, the NRC could determine that the licensee does not have sufficient control over the exclusion area.
 - Evacuation Time Estimate: Although the NRC does not specify a minimum required evacuation time, it could find that there is insufficient ability to evacuate personnel within the Emergency Planning Zone in a timely manner.
 - Unimpaired Access: NRC needs unimpaired access to the SMR site for inspections. Depending on the installation mission, location of the SMR, and operations contingencies, NRC may not have unimpaired access.
 - Audits: NRC audit requirements (e.g., training, records) could extend to DoD activities at the site, which the installation might find unacceptable for security and other reasons.
- Installation Operations
 - Hazards: Aircraft flight paths, munitions storage, ordnance and missile testing, and aspects of training could be seen by the NRC as posing an undue risk to the safe operation of an SMR. Although some of these factors do not apply to AFSPC installations, they must be considered for broader DoD application.
 - Visible plumes: NRC could determine that a visible plume from an SMR cooling tower presents a hazard to aviation operations.
- SMR Operations Following Abnormal Events.

- As stated previously, to fully meet the mission critical needs of an AFSPC or DoD installation, an SMR must have the capability to operate in a range of modes in a variety of abnormal situations. These situations might include a major outage on the electrical grid serving the facility, a seismic event that disrupted services, or flooding that isolated the installation from transportation routes. Based on the responses provided by the SMR vendors, their technologies can operate to meet mission critical needs following an abnormal event. These operational modes include:
 - Low power operations – producing as little as 5 MWe or less of power for sustained period. The technologies achieve low power operation by directing most of the steam from the reactor directly to the condenser, thereby limiting the amount of steam available to turn the turbine-generator.
 - Black start – restarting the plant after a complete shutdown and loss of all off-site power. The SMRs achieve black start by managing passive systems or the use of a limited amount of electrical power from batteries or on-site generators to operate certain components and instrumentation
 - Island mode – providing power to a specific micro-grid that has been isolated from the larger electric grid. The SMRs can first serve the installation’s mission critical needs and then increase power output to serve priority functions – water, hospitals, police and fire – in the surrounding community.

The NRC, however, could find that operating in these modes presents unacceptable risks or erodes safety. In addition, the SMR vendor/owner-operator may need design and engineering changes to facilitate these operations. License Change Amendments to the Design Certification and COL might also be required. The SMR vendor and project licensee could decide the time and expense are prohibitive.

- Low Population Zone: Although AFSPC installations were considered somewhat isolated when first constructed, in several instances community housing and neighborhoods have developed adjacent to the perimeters. Population growth could make it difficult to meet the Low Population Zone requirement that establishes a minimum distance from the SMR to the nearest population center with more than 25,000 residents.
- Support services: Discussions with SMR vendors and utilities about Scenario 3 often focus on the potential for the installation to provide services to help offset SMR operating costs. These services include physical security, emergency preparedness and response, fire and medical, and could also include environmental monitoring and testing. A key question to be answered during the next phase is whether the use of services outside of the licensee’s is control acceptable to the NRC. If so, the team will quantify the value of the services to determine possible benefits to lowering operating costs.
- Site characterization/monitoring: Similar to providing services, many installations have extensive information on site characterization that could support the licensing and permitting process (e.g., geology, seismology, meteorology, archaeology, hydrology, soils and flooding analysis). Available data pertinent to licensing could lower the costs and shorten the duration of the process. The team will identify and quantify the value of this information in the two use case studies.

2.5 Existing Studies

2.5.1. Scope. There have been multiple studies and reports on the utility of SMRs as an alternative for carbon-producing energy sources and renewable energy options, with national and international perspectives. There are also a number of studies that focus on the applicability of SMRs for DoD applications which serve as valuable examples for the AFSPC study. The DoD focus is due largely to Congressional interest highlighted in the 2010 National Defense Authorization Act (NDAA), which called for an active DoD role in SMR feasibility studies. Our team reviewed and catalogued the major studies in Appendix G, providing a synopsis of content, key points, issues, impediments, and other related observations. In this section we concentrate primarily on the studies with a DoD focus. We will reference various studies in other sections of the report where they have specific applicability (e.g., financial considerations and cost analysis).

2.5.2. Study Characteristics. In general, the studies emphasize the need for the DoD to pursue cost-saving efforts in energy consumption and a means to decrease dependence on the commercial grid. This is especially important given the ever-constrained DoD fiscal environment and significant share of the DoD budget dedicated to energy procurement. EOs and associated DoD goals for clean energy requirements have further influenced initiatives to seek more effective sources for energy to support military operations. The studies consistently cite the major advantages of SMRs and their possible benefits in a military setting:

- Energy reliability for critical, high-availability mission systems
- Cost reduction through factory fabrication of modular units and synergistic use of government land and support infrastructure
- Enhanced, passive safety
- Enhanced security
- Scalable design
- Decreased refueling cycles
- Reduced carbon footprint and reliance on fossil fuels

The following paragraphs address the principal DoD-focused studies.

2.5.3. Defense Science Board. In February, 2008 the Defense Science Board (DSB) released its *Report of the Defense Science Task Force on DoD Energy Strategy “More Fight—Less Fuel”* which, although it does not address SMRs specifically, noted major findings and recommendations relating to DoD energy consumption that could be effectively addressed by SMRs. The task force noted, “Critical national security... missions are at an unacceptably high risk of extended outage from failure of the grid and other critical national infrastructure”. Installations’ high reliability on the commercial grid, which is vulnerable to prolonged outages, put critical missions at risk. In its recommendations, the task force called for detailed risk assessments, a plan to “island” critical missions from the grid, DoD collaboration with DOE and other agencies, and investment in energy efficient and alternative energy technologies.

2.5.4. Science Advisory Board. In its *Alternative Sources of Energy for U.S. Air Force Bases* (2009), a study panel from the AF Scientific Advisory Board (SAB) analyzed installation energy needs and included in its recommendations a specific focus on the benefits of SMRs and addition

of nuclear energy in AF energy planning. This study was undertaken due to the reliance of AF installations on energy from local grids generated from fossil fuels. The panel encouraged increased DoD-DOE interaction for energy innovation. The panel further observed that nuclear energy complements renewable energy and noted that nuclear power is the only other major low-carbon option available. They recommended the AF consider taking a leadership role in use of SMRs, identify bases where an SMR would benefit the AF, and, augmented by DOE, determine an SMR candidate for siting on an AF base. They further urged consideration of partnerships within DoD, with DOE/other government agencies, with industry, and investors.

2.5.5. Center for Naval Analyses (CNA). *Feasibility of Nuclear Power on U.S. Military Installations* (2011) was a result of the NDAA 2010 direction for feasibility studies of nuclear reactors on military installations. This study addressed three questions:

- Could nuclear power plants contribute to DoD missions?
- What are the significant issues related to safety, certification, licensing, construction, and operations?
- Could a nuclear power plant on a military installation be constructed and operated in a cost effective manner?

The CNA study concluded use of SMR-generated electricity on military installations would contribute to energy assurance for critical facilities, providing reliable power at stable costs for extended periods. When combined with backup generators, SMRs substantially improve electrical power assurance and would also address requirements to reduce reliance on fossil fuels and GHG emissions. SMRs on military installations would also serve as a test bed for industry and advance US capabilities. However, the study underscored that SMRs are not economically feasible if the DoD must independently fund FOAK costs without partnerships or other means of cost sharing.

2.5.6. National Defense University. The article, *Small Nuclear Reactors for Military Installations: Capabilities, Costs, and Technological Implications* (2011) attributes the origin of DoD interest in SMRs to two vulnerabilities: dependence on the civilian electrical grid and the challenge of supplying safe and reliable energy to forward-based units. The key points are:

- The importance of DoD SMR involvement to prevent market domination by foreign countries
- The value of SMRs in islanding bases from the commercial grid
- The benefits of SMRs (passive safety, etc.)
- The leverage gained by DoD as a “first mover” in the market to ensure SMRs meet operational needs

2.5.7. American Society of Mechanical Engineers (ASME). In the proceedings of its 2011 Small Modular Reactors Symposium, ASME released *The Business Case for SMRs on DoD Installations*, a quantitative survey of the potential SMR market on 20 Army installations within the US. The authors concluded that the return on investment for SMRs was 10.2% and SMRs reduced GHG emissions for all installations by 76-96%, based on electricity or a combination of electricity and industrial (thermal) cogeneration. The authors noted that decisions on the benefits of reduced GHG emissions may be required in instances where SMR life cycle costs exceed the costs of the continued use of fossil fuels.

2.5.8. AF Chief Scientist. In *Energy Horizons, United States Air Force Energy S&T Vision, 2011-2026*, (2012), the AF Chief Scientist provides the AF outlook for energy science and technology for air, space, cyber, and infrastructure, including “small, auto-safing modular nuclear reactors.” The study notes the unique nature of space operating systems dictates that efforts to reduce space energy costs should focus primarily on ground facilities and systems--the ranges, control stations, and data processing facilities--the primary energy consumers for space missions (97.2%). The study also notes the “... most significant energy technology on the horizon...involves the use of nuclear energy to enable DoD installations”.

2.5.9. The Oak Ridge National Laboratory (ORNL). ORNL’s *Evaluation of Suitability of Selected Set of Department of Defense Military Bases and Department of Energy Facilities for Siting a Small Modular Reactor* (2013) provided invaluable information on Oak Ridge Siting Analysis for Power Generation Expansion tool (OR-SAGE) to assess AFSPC installations. The objective of this siting evaluation was to demonstrate the capability to characterize land occupied by a DoD site (e.g., military base) for possible deployment of an LWR SMR, using previously-developed Site Selection and Evaluation Criteria (SSEC).

This effort demonstrated the value of OR-SAGE in identifying options and challenges of SMR siting on military installations. They excluded sites labeled as “ranges” due to the potential for increased challenges associated with operations at these sites—which applies at the AFSPC bases with space lift missions (Patrick AFB/Cape Canaveral and Vandenberg AFB). In their summary, ORNL draws interesting conclusions regarding potential synergies to be realized by siting an SMR on a DoD installation: DoD sites support high technology and national security missions and are familiar with the similar technologies associated with operation of a nuclear power plant. They have staff considered capable and familiar with high technology activities similar to nuclear power plant operations, and necessary security capabilities.

2.5.10. Key points from the studies.

- DoD installations’ high reliance on the commercial grid puts critical missions at risk
- SMR-generated electricity on DoD installations would contribute to energy assurance for critical facilities
- Reducing AFSPC energy costs should focus on ground facilities and systems
- SMRs are not economically feasible for the DoD if DoD must independently fund FOAK costs
- DoD should consider partnerships within DoD, with DOE/other government agencies, industry, and investors
- If it chooses to be a “first mover” in the market, DoD has the opportunity to ensure SMRs meet its specific operational needs and requirements
- The most significant near term energy technology is the use of nuclear energy to serve DoD installations
- Nuclear energy readily complements renewable energy sources
- SMRs address requirements to reduce reliance on fossil fuels and GHG emissions
- SMR siting on DoD installations provides opportunities for beneficial synergies
- Potential SMR disadvantages: loss in economies of scale, financial uncertainty, NRC fee structure, siting challenges, potential public resistance, and waste disposal

3.0 ECONOMIC MODELS

3.1. Evaluation of Extant Models for SMR Lifecycle Cost of Energy.

The team evaluated numerous studies to obtain details on and inputs into LCOE models. We also engaged with Prof. Tom Drennen of Hobart & William Smith Colleges to obtain the Power Life Cycle Analysis Tool (LCAT). LCAT was developed in collaboration with the National Energy Technology Laboratory with the support of DOE funding. In addition, the team has engaged the Nuclear Energy Institute (NEI) to help identify industry norms and best practices to further bind the inputs into the LCOE model. In the next study phase, we will use the LCAT model to test key variables in order to evaluate opportunities and options to lower the LCOE from an SMR. The key inputs to an LCOE model for an SMR nuclear plant include:

- Overnight capital cost
- Construction duration
- Debt / equity ratio
- Cost of debt
- Return on equity
- Amortization period
- Capacity factor – including time for refueling outages
- Fuel
- Fuel disposal fee
- Decommissioning reserve
- Operations and maintenance (O&M) - including personnel
- Capital improvements
- Insurance
- Property or in lieu of taxes
- Income taxes
- Owner's costs prior to commercial operation
- Owner's administrative overhead

3.2. SMR vendor inputs. Each of the SMR technology vendors was asked to provide its projected LCOE for a plant using its technology. Holtec provided a range of \$72-\$82/MWh. Westinghouse deemed the information proprietary. NuScale estimates a cost of \$72/MWh for a project owned by a municipally-owned utility and \$106/MWh for a plant owned by an investor-owned utility. Capital structure and taxes are the principal reasons that power from the same plant costs an investor-owned utility, and its customers, almost 50% more than a city-owned utility. NuScale further provided an overnight capital cost estimate of \$5,078/KW, in 2014 dollars. According to NuScale, the estimate is based on an extensive process by Fluor Corporation in 2014 that involved more than 10,000 hours and included 14,000 line items and budgetary quotes for some 85% of the materials and equipment. NuScale estimates that owner's costs for licensing, legal fees, owner's engineer and infrastructure, will add \$300M to the capital cost, which increases the LCOE by about \$6/MWh.

3.3. Studies/Analyses. The team reviewed a wide range of LCOE studies and analyses from academia, national laboratories, government agencies, international organizations and non-

governmental organizations. Although the assumptions and the paths taken to develop the inputs differed, most settle on an overnight capital cost for an SMR of approximately \$5,000 per kilowatt of capacity. Depending on the values applied to the other factors, the SMR LCOE estimates ranged from about \$65/MWh to about \$110/MWh. The average LCOE in the studies is approximately \$85/MWh.

3.4. LCOE drivers. It is important to note that none of the participants in an SMR project have control over all of the drivers for the LCOE outcomes.

3.4.1. The SMR technology vendor and the SMR owner-operator can affect some, but not all of the factors. The SMR technology developer can affect:

- The cost of the major components through the way they are designed and manufactured
- Construction costs through engineering and design that reduces the amount of materials and man-hours, and helps ensure the timely delivery of a project into commercial operation
- O&M costs, including staffing, by designing a plant that is efficient to operate and maintain

The owner-operator can affect:

- Project capital cost including licensing and pre-construction activities
- Construction duration
- O&M costs and staffing
- Capacity factor

Many of the key drivers, however, largely are outside of the control of either the SMR developer or project owner. These drivers include:

- The cost of debt – interest rates and leverage are determined by the capital structure of the project owner, and market perceptions of risk
- Return on equity – also a function of risk and often set through negotiations with a utility commission
- Taxes, including income and property taxes, which are set by Federal, state and local governments (under an EUL, a project might not be subject to local property taxes if the land is under Federal jurisdiction)
- Fuel disposal fee set by the Federal government
- Decommissioning trust fund payments determined by the NRC and approved by the utility commission

3.4.2. As NuScale pointed out in its survey response, the higher cost of capital and taxes paid by an investor-owned utility can increase the LCOE of an SMR by as much as 50% compared to the ability of a tax-exempt municipal utility to use 100% low-cost debt. Clearly, the effects of the cost of financing and taxes outweigh all other factors in the LCOE for a nuclear power plant or SMR.

3.4.3. Other elements that can positively affect the economics and LCOE of a new SMR are potential incentives such as PTC, ITC, grants, risk insurance and loan guarantees discussed previously.

3.5. Examples of SMR and New Nuclear Power Plant LCOE Analyses

3.5.1. Source: Energy Information Administration, *Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2014*

Advanced nuclear plant characteristics with an expected 2022 in service date (not eligible for PTC)

- Capacity factor – 90%
- Levelized capital cost – \$70.1/MWh
- Fixed O&M – \$11.8 / MWh
- Variable O&M, including fuel – \$12.2/MWh
- Transmission investment – \$1.1/MWh
- Weighted Average Cost of Capital (WACC) in 2022 – 6.2% before tax, 8.1% after tax

Total LCOE – \$95.2/MWh

3.5.2. Source: *Electricity Generating Portfolios with Small Modular Reactors*

Geoffrey Rothwell, Ph.D., Stanford University (retired) rothwell@stanford.edu and Francesco Ganda, Ph.D., Argonne National Laboratory, fganda@anl.gov, May 2014 (Table 4).

Table 4. LCOE Cost Parameters

Levelized Capital Cost Parameters	SMR Value
• Construction lead time in months	35 months
• Unit net capacity in MWe	180 MWe
• Number of units	2
• Plant net capacity in MWe	360 MWe
• Site improvements and structures	20%
• Reactor and steam generator	40%
• Turbine generator and condenser	25%
• Electrical equipment	10%
• Cooling system and misc. equipment	5%
• Indirect rate	10%
• Owners cost – licensing fee	\$200M
• Owners cost – administration	5%
• Contingency	15%
• Scale economies parameter	90%
• Simplified design parameter	85%
• Savings from serial economies	90%
• Average capacity factor	88.5%
• Depreciation life	40 years

At a WACC of 7.5% the LCOE mean is \$81.04/ MWh

4.0 SELECTION OF USE CASE INSTALLATIONS

4.1 Development of Selection Criteria

4.1.1. Approach. We used an iterative process to develop criteria to review the 12 AFSPC installations and determine the two use case installations that we will focus on in the next phase of the study. This process included information gleaned from previous studies, stakeholder/SME inputs, discussions, and findings from the OR-SAGE analysis of the installations. During the 2 April Kickoff meeting at the Colorado Springs Scitor facility, participants reviewed high-level “AFSPC priorities” and “installation considerations” relating to a potential SMR deployment and discussed various aspects of each. These factors, combined with the OR-SAGE criteria, evolved into the final criteria set listed below.

4.1.1.1. AFSPC-related criteria

- Mission priority
- Potential for installation-SMR support synergy
- Installation operations (e.g., aircraft operations, launch activities, other limiting factors)

4.1.1.2. Siting criteria. The team established values specific to the Site Selection Evaluation Criteria (SSEC) used in the OR-SAGE model, and obtained data for Clear AFS from separate sources.

- Power plant site ≥ 50 acres
- Population density < 500 people within 2 miles of site boundary (per DOE: 2 mile limit)
- Wetlands and open water are excluded
- Protected lands (e.g., national parks, historic areas, wildlife refuges) are excluded
- Land with moderate or high landslide hazard susceptibility is avoided
- Land within a 100 year floodplain is excluded
- Land with a slope $> 18\%$ ($\sim 10^\circ$) is avoided
- Land areas > 15 miles from sufficient cooling water makeup sources are excluded:
 - Upper threshold – stream flow of at least 84,000 GPM, makeup water of at least 8,400 GPM (12M GPD) based on a 600 MWe modular NuScale installation
 - Lower threshold – stream flow of at least 20,000 GPM, makeup water of at least 2,000 GPM (2.9M GPD) based on a 160 MWe modular Holtec 160 installation
 - An additional 64,000 GPM threshold for stream flow was included based on an assumption of lower water requirements for SMRs
- Land too close to fault lines is avoided (length of the fault line determines standoff distance)
- Land in proximity to hazardous facilities (within 5 miles of commercial airports and 1 mile of oil refineries) is avoided
- Land with safe-shutdown earthquake peak ground acceleration (2% chance in a 50 year return period) greater than 0.5 g is excluded. (included range from 0.25g to 0.5g)

4.1.2. OR-SAGE Values. Our Team worked with ORNL to identify the values to be used in the site SSEC to evaluate the AFSPC installations using the OR-SAGE tool. OR-SAGE uses NRC standards to develop appropriate criteria for screening sites. It employs Geographic Information Systems (GIS) data sources to identify candidate areas through development of exclusionary, avoidance, and suitability criteria derived from Electric Power Research Institute siting guidance. The SSEC results tend to recommend *against* sites, i.e., they identify challenges to using the site for the purpose of interest, in this case, SMR deployment. The OR-SAGE focus is on demonstrating how SMR candidate areas might be identified, but does not include detailed site evaluations or comparisons. This approach is designed to quickly identify favorable SMR candidate areas. Single OR-SAGE results should not be construed as an ultimate SMR deployment plan. The OR-SAGE results gave the team valuable insights into AFSPC installations which would have considerable challenges that may hinder SMR deployment. This allowed us to eliminate AFSPC installations with challenges that would preclude serious consideration for SMR siting. One exception is Clear AFS, Alaska, described below.

4.2 Identifying Use Case Installations

4.2.1. ORNL Siting Observations. Previous OR-SAGE studies highlighted that protected lands, seismic considerations, and slope are significant limiting factors in the West, and cooling water makeup is a significant restrictive factor in the West and Central US. However, combining stream flow and aquifer cooling SSEC layers makes much of the US west of the Rockies SMR-eligible. OR-SAGE results for the AFSPC installations noted that finding stream flows with at least 84,000 GPM is a siting challenge, except for New Boston AFS, NH and Patrick AFB, FL, but four additional installations are available at 65,000 GPM (Buckley AFB, Cheyenne Mountain AFS, Peterson AFB and Schriever AFB, all in Colorado). A stream flow of 65,000 GPM is sufficient to provide conventional cooling to the four light water SMR technologies. As described above, the team applied the OR-SAGE results to eliminate installations with clear challenges that make them poor candidates for further use case analysis. Based on the OR-SAGE data, ORNL concluded the best potential for SMR siting appears to exist at the following installations:

- Buckley AFB, CO
- Cape Canaveral AFS, FL
- New Boston AFS, NH
- Patrick AFB, FL
- Schriever AFB, CO

4.2.2. OR-SAGE and Scitor Team Observations. The ORNL summaries are provided in the paragraphs below, with our team's observations added as bullets. Our observations include other considerations not covered in OR-SAGE (e.g., military runways, space launch facilities, cultural artifacts). The complete OR-SAGE results are not included in this report due to their length, but can be provided separately. A color-coded summary is provided in Appendix H. Clear AFS was not included in the OR-SAGE review since data for Alaska are not currently loaded into the database. Our team used US Geological Survey data similar to the data in OR-SAGE to develop

conclusions for Clear AFS. ORNL is currently adding data on Alaska into OR-SAGE; which should be available for inclusion in Milestone Report 2.

4.2.2.1. Buckley AFB has solid potential for siting an SMR on the eastern portion of the base. Population density is the SSEC factor with the biggest impact on the base analysis. Stream flow at 20,000 GPM is not a factor anywhere on the base while stream flow of 84,000 GPM is not available within 15 miles of the base. At 65,000 GPM stream flow, the screening results match the results found at 20,000 GPM stream flow. Additional team considerations:

- The eastern portion of the installation identified by OR-SAGE has the potential for population density impacts as the City of Aurora continues to grow to the east of the E-470 toll road, which is .5 miles from Buckley AFB's eastern boundary.
- Buckley AFB has an active runway with routine F-16 and helicopter flight operations and the capability for larger, multi-engine aircraft (e.g., Air Force One and associated support aircraft have landed at Buckley AFB).

4.2.2.2. Cape Canaveral AFS has solid potential for siting an SMR on the southern portion of the installation. Wetlands and open waters are the SSEC factors with a large impact on the base analysis. Freshwater stream flow at any significant level is not available within 15 miles of the northern portion of the base, though ocean cooling is available. An additional team consideration:

- AFCEC notes this site has very limited buildable acres due to the hazard zones associated with missile and rocket launches (which are not illustrated on the OR-SAGE graphics).

4.2.2.3. Cape Cod AFS has low potential for siting an SMR. Freshwater stream flow at any significant level is not available within 15 miles of the base, though ocean cooling is available. Massachusetts has current legislation against building new reactors in the state.

- Available AFSPC land on Cape Cod AFS is very limited.

4.2.2.4. Cavalier AFS has low potential for siting an SMR. Freshwater stream flow at any significant level is not available within 15 miles of the base.

4.2.2.5. Cheyenne Mountain AFS has low potential for siting an SMR. Population density, slope, and fault lines are the SSEC factors with a large impact on the base analysis. Stream flow at 20,000 GPM is not a factor anywhere on the base, but stream flow of 65,000 GPM or 84,000 GPM is not available within 15 miles of the base.

- Available land on Cheyenne Mountain AFS is not suitable for SMR deployment and its proximity to other DoD installations argues against its candidacy for SMR deployment.

4.2.2.6. Los Angeles AFB has low potential for siting an SMR. Population density and nearby hazardous facilities have a large impact on the base analysis. Freshwater stream flow at any significant level is not available within 15 miles of the base, though ocean cooling is available. In addition, California has current legislation against building new reactors.

4.2.2.7. New Boston AFS has significant portions of the installation and the surrounding area with solid potential for siting an SMR. Only limited existence of wetlands and open waters influences the analysis results. Additional team consideration:

- Existence of unexploded ordinance from the installation's previous role as a bombing range and historical artifacts from the Underground Railroad and early colonial settlements restrict availability of land for SMR siting.

4.2.2.8. Patrick AFB has solid potential for siting an SMR on significant portions of the base. However, population density to the south of the base and dense infrastructure on the base may limit siting opportunities. Additional team considerations:

- The potential siting area overlaps Patrick AFB office buildings, the military airfield, and a base housing area. The only undeveloped land in this area is very small (a golf course), with wetlands in proximity to the active runway.

4.2.2.9. Peterson AFB has poor potential for siting an SMR. Population density impacts entire base. Stream flow at 20,000 GPM or 65,000 GPM is not a factor anywhere on the base but stream flow of 84,000 GPM is not available within 15 miles of the base. Additional team considerations:

- Peterson AFB has an active military runway and is co-located with Colorado Springs Municipal Airport. Three runways are involved.
- Per AFCEC, the City of Colorado Springs owns the majority of Peterson AFB land, which is leased by the AF.

4.2.2.10. Schriever AFB and the surrounding area have solid potential for siting an SMR. Stream flow at 20,000 GPM or 65,000 GPM is not a factor anywhere on the base but stream flow of 84,000 GPM is not available within 15 miles of the base.

- Given its location, Schriever AFB, while in proximity to an urban area (Colorado Springs), has no near term issues with population density and security is enhanced.

4.2.2.11. Vandenberg AFB has low potential for siting an SMR. Freshwater stream flow at any significant level is not available within 15 miles of the base, though ocean cooling is available. In addition, numerous partial issues overlap including values for population density, wetlands and open water, protected lands, landslide hazard, and safe-shutdown earthquake. In addition, California has current legislation against building new reactors in the state.

4.2.2.12. Clear AFS (based on our team's observations since OR-SAGE data does not include Alaska) and the surrounding area have solid potential for siting an SMR. The 100 year floodplain for the Nenana River impacts the western 10% of the installation but sufficient area is available outside the 100 year floodplain. While year round flow in the Nenana River is uncertain, the Tanana River is 14.5 miles away and has sufficient flow year round. Clear AFS appears to lie within an area of peak ground acceleration greater than 0.25 but less than 0.5 (2% chance in 50 years). This may be a concern and we have requested ORNL to run a seismicity analysis for Clear AFS. ORNL is adding the relevant data to OR-SAGE; the results should be available mid-summer.

4.2.3. Scitor Team and OR-SAGE Results. Based on the additional information obtained by our team and noted above (limited land availability due to launch hazard zones and an active runway) we eliminated Patrick AFB and Cape Canaveral AFS from the OR-SAGE use case candidate list and added Clear AFS. As a result, four use case potential installations remained:

- Buckley AFB, CO
- Schriever AFB, CO
- Clear AFS, AK
- New Boston AFS, NH

4.2.4. AFSPC-related Criteria: Mission Priorities. The next step was to apply the AFSPC-related criteria to the final four to determine the two use case installations, beginning with the mission priorities based on all missions performed on the installation. The key determinant of these priorities is the list of “Prioritized Space Superiority Activities” signed by the current AFSPC commander in his role as the AF Space Superiority Core Function Lead (Appendix I). With this list as the reference, the team gathered preliminary inputs from Scitor SMEs who have extensive knowledge of space missions and systems, then coordinated with HQ AFSPC experts from A2/3/6 and A5/8 to determine a prioritization based solely on installation mission(s). These mission considerations are unclassified. This assessment acknowledges that key space systems must operate continuously. The installations have backup power systems (generally diesel) to continue near term operations in the event of primary power failure. Responsibility for the each Space Superiority Activity is not unique to a specific installation but is based on the space systems operated from that installation. The installations are listed below in the order of their mission priority.

1. Schriever AFB operates multiple space systems. Its responsibilities include the number one Space Superiority Activity, three of the top four, and five other activities (Nuclear Survivable Communications; Space Situational Awareness & Battlespace Awareness; Protected, Tactical Communications; Unprotected Communications; Space to Surface Intelligence, Surveillance, and reconnaissance (ISR); Terrestrial Environmental Monitoring; and Nuclear Detonation Detection).
2. Buckley AFB also operates multiple space systems. Its responsibilities include the number two Space Superiority Activity as well as three additional activities (Launch Detection/Missile Warning, Satellite Operations, Space to Surface ISR, and Nuclear Detonation Detection).
3. Clear AFS operates a single space system. It also has responsibility for the number two Space Superiority Activity (Launch Detection/Missile Warning) as well as Space Situational Awareness & Battlespace Awareness. In addition, the Missile Defense Agency recently announced a new system, the Long Range Discrimination Radar (LRDR), will be deployed at Clear AFS, projected to become operational in 2020. LRDR would also support the Launch Detection/Missile Warning activity.
4. New Boston AFS operates a single space system. It has responsibility for the number five Space Superiority Activity (Satellite Operations).

4.2.5. AFSPC-related Criteria: Support Synergies. For this study, potential synergies are support services available on the installation through the host unit (e.g., the 50 SW is the Schriever AFB host unit). Services *could* be provided to the SMR owner/operator through formal

agreement. Schriever and Buckley AFBs are large installations with several missions and a mature wing level infrastructure (wings consist of two or more groups, groups have several squadrons). Clear and New Boston AFSs are smaller installations with a single squadron level organization. As expected, Schriever and Buckley AFBs can offer significantly more support services than Clear or New Boston AFSs. Support services available on an installation are listed in the Installation Support Agreement Catalog. Table 5 shows the types of support available (Y) at each installation that may benefit an SMR owner/operator. We will confirm availability of specific support services and related synergies during the use case studies. Another potentially synergistic aspect of DoD and AFSPC installations is the availability of data (hydrology, seismology, etc.) that may facilitate SMR permitting and licensing, saving time and funds.

Table 5. Host Unit Support Services

Type of support service available	SAFB	BAFB	CAFS	NBAFS
Antiterrorism program	Y	Y		
Hazardous Materials (HAZMAT) management	Y	Y		
Command Post (command and control service for on base responses)	Y	Y		
Communication services (e.g., telephone, information technology lines, radios)	Y	Y		
Emergency management	Y	Y		
Environmental monitoring/compliance	Y	Y		
Fire protection	Y	Y	Y	
Integrated defense (e.g., security, law enforcement)	Y	Y		Y
Safety	Y	Y		
Utilities (e.g., water, sewage, electricity)	Y	Y	Y	Y

4.2.6. AFSPC-related Criteria: Installation Operations. The team concluded additional aspects of operations on DoD and AFSPC installations, not addressed in OR-SAGE criteria, must be considered when evaluating the suitability of the installation for SMR deployment. Most obvious are aircraft operations and active runways, which exist at several AFSPC bases. Additionally, three AFSPC installations are directly involved in missile launch (space lift) operations: Patrick AFB, Vandenberg AFB, and Cape Canaveral AFS. These operations are major considerations for site suitability. Finally, other factors such as unexploded ordnance and historical artifacts present major limitations to SMR deployment. Where applicable, these criteria are addressed in the team’s comments in paragraph 4.2.2.

4.2.7. Use Case Installation Conclusions. Our assessment, based on the AFSPC-related and siting criteria combined with purely use case considerations, leads us to conclude that Schriever AFB and Clear AFS are the best options for detailed use-case studies. Our rationale is outlined below.

- Schriever AFB has the highest mission priority, opportunities for synergy, and positive Scitor Team/OR-SAGE results.
- Despite its high mission priority, Buckley AFB was eliminated due to siting challenges in the OR-SAGE/Scitor Team review (limited land availability, active runway, potential population growth, proximity to Denver International Airport).

- Clear AFS is a solid candidate for a use case study due to its high mission priority and favorable preliminary SSEC findings. OR-SAGE data on Clear AFS are in development. Additional considerations:
 - Clear AFS’s squadron-level operations, (current) single space system, and limited potential for synergies offers a valuable contrast to Schriever AFB’s multiple systems, squadrons, and mature infrastructure. This enables use case studies on two distinctly different AFSPC installation capabilities and characteristics--with implications for broader DoD SMR applications.
 - Clear AFS’s remote location offers a constructive contrast for use case assessment, compared to the urban proximity that benefits Schriever and Buckley AFBs.
 - In fall 2015, Clear AFS transitions its energy source from an installation-owned coal plant to the regional grid. It will begin steps to add the LRDR mission, projected to increase power requirements by approximately 30 MWe (22 MWe mission-related).
- New Boston AFS was eliminated due to the lowest mission priority and major siting challenges (unexploded ordinance and historical artifacts).

4.2.8. Aggregation. Since this study is focused on SMR feasibility for AFSPC installations, we did not specifically consider aggregation of energy demand as a criterion for use case installation selection, although this is a serious consideration and may be the key to successful SMR deployment. This was a point of discussion during the 2 April 2015 study kickoff meeting.

4.2.8.1. In its 2011 study, *Small Modular Reactors—Key to Future Nuclear Power Generation in the U.S.*, the University of Chicago Energy Policy Institute at Chicago notes that the federal government, although the largest US consumer of electricity, has procurement policies that do not encourage aggregation of demand. It further observed that the size of SMRs may limit the number of federal facilities that could take advantage of an SMR’s unique characteristics unless aggregation of several federal facilities’ demand is considered. We observed this when comparing the output of the candidate SMR technologies compared to the lower energy requirements of the majority of AFSPC installations. An aggregation approach could involve supplying several of the DoD’s Military Services or a combination of military and non-military federal facilities.

4.2.8.2. Aggregation is also an important consideration in relation to the AFSPC use case facilities. Schriever AFB is within proximity to two other AFSPC installations: Peterson AFB and Cheyenne Mountain AFS, as well as two additional DoD installations: Fort Carson and the US Air Force Academy. Additionally, the City of Colorado Springs is currently debating the future of its primary coal-fired power plant. Clear AFS is within proximity of Eielson AFB, Fort Wainwright, and Fort Greely, all near Fairbanks, AK, as well as Joint Base Elmendorf – Richardson near Anchorage, AK and numerous Alaskan municipalities, including the two largest—Fairbanks and Anchorage.

5.0 CONCLUSION

5.1. Summary. The combination of mission, synergy, operational characteristics, siting, and use case considerations makes Schriever AFB and Clear AFS logical choices to inform future studies and decisions relating to use of SMRs. Potential impediments, in some cases significant and requiring concerted congressional or federal action, can be effectively addressed through innovative solutions supported by informed government and private sector decision makers.

5.2. Next Steps. With Clear AFS and Schriever AFB as examples, the next phase of the study will focus on developing use case studies to evaluate the feasibility of siting SMRs immediately adjacent to, or on, the installations (Deployment Scenarios 2 and 3). The use case studies will:

- Evaluate the economics of SMR deployment
- Identify and quantify potential support synergies between installation services and SMR licensing and operations
- Use the LCAT LCOE model to examine different ownership structures and the effects of various incentives on costs
- Develop options for financial and business models to support deployment
- Identify in more detail the specific NRC regulatory requirements and potential impediments to siting the SMRs under Scenarios 2 and 3, and operating them to meet the installations' mission critical needs
- Assess potential impact of SMR deployment on installation missions
- Identify state and local regulations relating to the deployment scenarios
- Receive input from the local utilities and nuclear operating utilities on their interests and potential issues, e.g., loss of load
- Evaluate the potential use and cost of micro-grids to enhance energy surety
- Gather information on public perceptions regarding the use of SMRs on or near the installations within the adjacent communities

5.3. Additional considerations. In conjunction with a detailed assessment of SMR suitability for Schriever AFB and Clear AFS, the team will address opportunities for application of advanced technology to complement SMRs as an energy source, for example, smart grids, dry cooling, and the Brayton cycle.

APPENDIX B: SMR GUIDANCE AND POLICY SUMMARY

Publication Title, Date	OPR	Description	Issues, Impediments, etc.
AIR FORCE			
<i>AF Energy Strategic Plan</i> , March 2013	SECAF/C SAF	Incorporates energy security and operational energy into strategic energy priorities, goals, and objectives to help AF meet federal legislative provisions, EOs and DoD directives. “Operational Energy”, “net zero” energy by 2030. Alternative, renewable sources, but no mention of nuclear energy.	Need integrated DoD, local, regional, state, federal and international involvement with energy security.
HAF MD 1-18, <i>Assistant Secretary of the Air Force, (Installations, Environment, and Energy)</i> , 10 Jul 14	SAF/IE	Delineates SAF/IE responsibility for installations strategy and strategic basing processes; built and natural infrastructure; facility, process and operational energy ; environment, safety and occupational health; and to ensure the sustainability and operational readiness of the Department of the Air Force. Moves Logistics functions under SAF/AQ.	IEI - AFSBS and EIAP process IEE - real property and has specially arranged lines of authority to and oversight of the Installations Directorate within the AFCEC IEN - the AF Energy Office Stakeholders: SAF/IEI, IEIB, IEE & IEN
<i>The AF EUL Playbook</i> , 24 Feb 14	AFIMSC/ AFCEC	Provides process narratives for seven phases in a typical EUL project to develop project-specific plans and schedules. Internal and external stakeholder lists (unit level). Checklists for each phase. REPD decision tree matrix to determine EUL/PPA applicability. OSD certification of energy projects.	10 USC 2911 compliance requirements (+2667,2922 for PPA), approval process, state environ. policy acts (SEPA) Stakeholders: SAF/IEI & IEN, AFCEC/CI & CN
<i>AFCEC Guide for Submission of an Unsolicited EUL Proposal</i> , 24 Feb 15	AFIMSC/ AFCEC	Provides process narratives for unsolicited EUL proposals. Generally these are innovative and unique ideas or approaches and have been developed outside the AF.	Does not negate use of AF EUL Playbook. Stakeholders: SAF/IEI & IEN, AFCEC/CI & CN
AFPD 10-5, <i>Basing</i> , 14 Nov 13	AF/A8P	Review process for basing actions, four steps to AF Strat Basing, SAF/IE central role, EUL coordinated through Strat Basing Process, AFCS involvement	Decision/review authorities: SecDEF, AFSBS, AFCS
AFI 10-211, <i>CE Contingency Response Planning</i> , 16 Nov 11	AFCESA/ CEXX	Provides requirements for CE-unique contingency response planning--initial responses to enemy actions, major accidents, natural disasters, civil disorders and other contingencies. Requires revision for SMR content.	None
AFI 10-503, <i>Strategic Basing</i> , 20 Sep 10	AF/A8PB	Applies to basing actions involving non-AF entities requesting to move onto AF real property and special interest actions. Includes basing process (criteria, surveys, etc.)—similar to SMR candidate selection. EUL guidelines. Basing process would apply for an SMR decision. Currently in revision	Decision authorities and associated process. Stakeholders: SAF/IEI; AF/A4C, A8P; AFIMSC/AFCEC
AFI10-504 <i>Overseas Force Structure Changes and Host Nation Notification</i> , 21 Oct 2011	AF/ A8PB	Provides procedures for all basing actions affecting overseas installations and augments the Air Force Strategic Basing Process described in AFI 10-503	N/A for now
AFI 10-2501, <i>AF Emergency Mgt Prog Planning & Ops</i> , 21 Jan 07	AFCESA/ CEXR	Establishes responsibilities, procedures, and standards for AF mitigation and emergency response to physical threats from major accidents; natural disasters; conventional attacks (including high-yield explosives); and terrorist use of CBRN materials. Requires revision for	None

Publication Title, Date	OPR	Description	Issues, Impediments, etc.
		SMR content.	
AFPD 32-90, <i>Real Property Asset Management</i> , 6 Aug 2007	SAF/IEI	Provides guidance relating to Air Force Real Property Asset Management. Specific Air Force Real Property responsibilities, procedures, and guidelines are published in AFI 32-9000 series publications.	N/A
AFPAM 32-1010, <i>Land Use Planning</i> , 1 Nov 98	HQ AFCEE/ECC	“How to” guide for base land use planning, includes factors to consider in determining location of facilities, etc.	N/A
AFI 32-1061, <i>Providing Utilities to USAF Installations</i> , 23 Feb 11	HQ AFCEA/CEN	Guidelines for utility service contracts and management. Establishes preferred order of options to acquire electric service (#1: supplier owned, para. 2.5). Computation of utility reimbursement rates. Metering policy. DUERS (reporting).	Reimbursement costs. Metering requirements. Stakeholders : SAF/IEN, AF/A4C, AFIMSC/AFCEC, installation CC, CE, CO
AFI 32-1062, <i>Electrical Systems, Power Plants and Generators</i> , 15 Jan 15	AF/ A4CX	Provides acquisition and O&M requirements for power systems, individual RPIE, and Equipment Authorized Inventory Data (EAID) generators. Focus is primarily generators.	N/A
AFI 32-7061, <i>Environmental Impact Analysis Process</i> , 28 Mar 2014	AF/A7CI	Directs the user to the regulatory source that describes the specific tasks and procedures for successfully conducting the Air Force EIAP	Follow the version of 32 CFR Part 989 that is current at the time the EIAP is begun for the proposed action
AFI32-9003, <i>Granting Temporary Use of Air Force Real Property</i> , 19 Aug 1997	AFREA/MI	Explains procedures and responsibility for temporary use of real property owned and controlled by the AF. Temporary use of AF real property if: No AF military purposes now, no mission interference, reasonable cost, compatible with AF needs, security, and safety. AF must charge fair market value. Use of real property for Government storage of haz waste.	No storage or disposal of non-DoD-owned hazardous or toxic materials Stakeholders: SAF/IEI & IEN, AFCEC/CI & CN
AFH32-9007, <i>Managing Air Force Real Property</i> , 1 May 99	AFREA/DR	Handbook supplements AFPD 32-90, Real Property Management, AFI 32-9003, Temporary Use of Air Force Real Property	AFI 32-9003 covers
AFPD 90-17, <i>Energy Management</i> , 29 Nov 2011	SAF/IEN	AFPC version of AFI 90-1017 below. Operational energy, governance structure, R&R, energy strategic plan requirement	N/A
AFI 90-1701, <i>Energy Management</i> , 8 May 2014	SAF/IEE	Establishes governance & mgt structure; lists nuclear in “energy” definition but nothing further; AF is DoD’s largest energy user; goal of public-private partnerships, R&R: SAF/US, SAF/IE, SAF/IEE*, AF/A47C, AF Real Property Agency (EUL); goals/ metrics	Renewable energy goals. Stakeholders: SAF/US (USecAF), IE, AQ; AF/A4C, AFIMSC/AFCEC
AFI 91-202, <i>The US Air Force Mishap Prevention Program</i> , 5 Aug 11 (certified current on 23 Mar 15)	HQ AFSC/SEG Certified by AF/SE	Establishes mishap prevention program requirements, assigns responsibilities, contains program management information. Cites AF/SE role in safety study groups for “terrestrial nuclear reactors”. Nuclear content is weapons safety and nuke surety. Would need to be expanded to address reactors.	Stakeholder: HAF/SE <i>Note: AFI 91-108 (radioactive materials safety) is focused on dismantled and decommissioned reactors. AFPD 40-2 & AFI 40-201 (radioactive materials mgt) are N/A for nuclear reactor programs.</i>
AF FY2012	SAF/US	Fiscal Year 2012 implementation plan describes	See DoD SSPP below

Publication Title, Date	OPR	Description	Issues, Impediments, etc.
<i>IPlan for DoD SSPP</i>		how the Air Force will achieve the goals and sub-goals of the Department of Defense's Strategic Sustainability Performance Plan (SSPP)	
AFPD 16-14, <i>Security Enterprise Governance</i> , 24 Jul 14	SAF/AAZ	Establishes Air Force policy and responsibilities for the oversight, management and execution of the Air Force Security Enterprise.	N/A
AFPD 91-2, <i>Safety Programs</i> , 24 Jul 12	SAF/SEA	Establishes policy for the Air Force's Safety Program.	N/A
DOE			
DOE & DoD MOU <i>Concerning Cooperation in a Strategic Partnership to Enhance Energy Security</i> , 22 July 2010	DOE & DoD	Identify framework for cooperation and partnership between DOE and DoD to strengthen coordination of efforts to enhance national energy security and demonstrate Federal Government leadership in transitioning America to a low carbon economy.	Provides the basis for cooperative SMR studies with DoD installations as test sites.
<i>Nuclear Reactor Safety Design Criteria</i> , 19 Jan 93, certified 18 Nov 10	DOE	Establishes nuclear safety design criteria applicable to design, fabrication, construction, testing, and performance requirements of nuclear reactor facilities and safety class structures, systems, and components within these facilities. Applies to new and existing reactor facilities.	Requirements for defense in depth, design features (e.g. coolant boundaries, electric power systems, reactor core, HVAC, waste storage).
<i>Nuclear Energy Research and Development Roadmap, Report to Congress</i> , April 2010	DOE Nuclear Energy (NE) office	Provides a roadmap for DOE NE research, development, and demonstration activities that will ensure nuclear energy remains viable energy option for the US. Objectives: improve affordability of new reactors to meet energy security & climate change goals	Key challenges: capital cost, continuing safety record, nuclear waste, proliferation. Impediments to new plant development: capital cost, uncertainties in time req'd for licensing and construction
<i>DOE Strategy for Mgt & Disposal of Used Nuc Fuel and High Lvl Radioactive Waste</i> , Jan 2013	DOE	Framework for a sustainable program to deploy an integrated system to transport, store, and dispose of used nuclear fuel and high-level radioactive waste from civilian nuclear power generation, defense, national security and other activities. Based on BRC recommendations. Three-phased approach.	Legislative action required. Calls for a new organization to manage the processes. Further analysis req'd for commingling of wastes.
<i>Choosing a Financing Vehicle for Energy-Efficiency Projects for Federal Sites</i> , 2009	DOE	Purpose: help acquisition teams assess benefits and constraints of private-sector alternatives and site-specific issues to choose the best financing strategy. DOE's Federal Energy Management Program (FEMP) is emphasizing use of private-sector technical expertise and investment resources via energy savings performance contracts (ESPCs) and utility energy service contracts (UESCs).	Intent of Congress is to have cost savings generated by a project cover the cost of its implementation.
NRC			
<i>Nuclear Power Plant Licensing Process</i> , 2004	NRC	Overview of NRC licensing process for commercial nuclear power plants: two-step process (10 CFR part 50) and Additional Licensing Processes (10 CFR Part 52)	Requirements for key licensing events to obtain NRC approval: early site permits, plant design, construction permit, operating license.

Publication Title, Date	OPR	Description	Issues, Impediments, etc.
NRC Regulatory Guide 4.7 <i>General Site suitability for Nuclear power Stations</i>	NRC	This guide discusses the major site characteristics related to public health and safety and environmental issues that the NRC staff considers in determining the suitability of sites for light water-cooled nuclear power stations.	The NRC issues regulatory guides to describe to the public methods that the staff considers acceptable for use in implementing specific parts of the agency's regulations, to explain techniques that the staff uses in evaluating specific problems or postulated accidents, and to provide guidance to applicants.
NRC, <i>Report to Congress: Advanced Reactor Licensing</i> , Aug 2012	NRC	Response to Congressional request, addresses NRC strategy for licensing advanced reactors; addresses licensing applications anticipated over 10-12 and 20+ years. Details on licensing of advanced reactors, including SMR. Major research req'd for advanced designs beyond LWR technology; NRC preparing reg. guidance for SMR designs—the current focus due to proximity of licensing requests. Much of SMR covered by current LWR requirements, but current guidelines apply. Addresses fuel transportation, storage, waste; safety; fuel; materials; structure; I&C (need research on SMR impacts); risk asmt; security; codes & standards.	No change to regulatory guidelines to take SMR technology into consideration. New NRC guidelines pending. Some research required to determine guidelines for SMR (e.g., I&C, risk).
DoD			
DoD Strategic Sustainability Performance Plan, FY2012	USD (AT&L)	As req'd by EO 13514. Vision, GHG, renewable goals. DoD installations as test beds. Private sector partnering, PPA.	Goal: 1 GW of renewable energy by FY2025, alternative funding, advanced micro-grid technology, GHG reduction goals: 34% (S1, 2), 13.5% (S3) by 2020. 18% of facility electricity from renewables.
DoD Sustainability Performance Report, FY2013	USD (AT&L)	Annual update to the DoD SSSP, sustainability performance expectations through FY2020. Performance-based contracting as payment for projects. Status of goal attainment.	See above
DODD 4140.25, <i>DoD Mgt Policy for Energy Commodities and Related Services</i> , 12 Apr 2004	USD (AT&L)	Policy and responsibilities for energy commodity management. Requires revision for SMR content.	None
DODD 4165.06, <i>Real Property</i> , 18 Nov 2008	USD (AT&L)	Delegates statutory and regulatory authorities and responsibilities relating to the acquisition, management, and disposal of real property	None
DODI 4165.57, <i>Air Installations Compatible Use Zones</i> , 2 May 2011	USD (AT&L)	Establishes policy, assign responsibilities, and prescribe procedures for the DoD AICUZ program for air installations	Facility/use restrictions within AICUZ
DODI 4165.70, <i>Real Property Management</i> , 6 Apr 2005	USD (AT&L)	Re-delegates various statutory and regulatory authorities and responsibilities relating to real property management	Addresses outgrants/leases, provides authority for AFI32-9003

Publication Title, Date	OPR	Description	Issues, Impediments, etc.
DoDI 4170.11, <i>Installation Energy Management</i> , 11 Dec 2009	USD (AT&L)	Tasks DoD components to establish & execute energy program mgt. structures. DoD vision: providing reliable and cost effective utility services to warfighter. Decentralized. Federal and private funding. Consider lifecycle costs. Aggregate energy efficiency and renewable energy projects. Private sector partnerships are crucial. Larger scale, off-grid electrical generation systems should be non-DoD.	“Utilities privatization is the preferred method for modernizing and recapitalizing DoD utility systems.”
DODI 4180.01, <i>DoD Energy Policy</i> , 16 Apr 2014	USD (AT&L)	Policy and responsibilities for DoD energy planning, use and management. Policy: Improve energy performance; diversify & expand energy supplies and sources; include energy in requirements, acquisition, and PPBE; consider energy risk; develop and acquire technologies. USD(AT&L) establishes DoD energy policy, ASD(OEPP) is principal advisor, ASD(R&E), with ASD(OEPP) and DUSD(I&E), oversees development of technologies to improve energy performance and diversify supply.	Stakeholders: USD(AT&L), ASD(OEPP), ASD(R&E), DUSD(I&E)
DODD 5134.15, <i>Asst. Sec of Defense for Operational Energy Plans and Programs ASD(OEPP)</i> , 17 May 2011	DA&M	Assigns responsibilities and functions, relationships, and authorities to the ASD(OEPP): principal advisor to SecDEF, DepSecDEF, USecDEF on ops energy plans & programs; establishes ops energy strategy; monitors initiatives; R&D investments; PPBE participation; funding recommendations; goals. Defines operational energy.	Stakeholder: ASD(OEPP)
USD (AT&L) <i>Financing of Renewable Energy Projects Policy</i> , 9 Nov 2012	USD (AT&L)	Provides guidance to the DoD Components on the authorities for mechanisms used to cover initial capital costs for energy projects utilizing private (‘third-party’) financing. Addresses certification of energy related EULs and the special agreement authority found in 10 U.S.C. § 2922a. Other power acquisition authorities: - Under 40 U.S.C. § 501, the DoD may contract for public utility services for a period of not more than 10 years. - Under 40 U.S.C. § 591, DoD may not purchase electricity in a manner inconsistent with state law governing the provision of electric utility service. - 10 U.S.C. § 2916, a Military Department may sell, contract to sell, or authorize the sale by a contractor to a utility company of all the electrical energy generated from an alternate energy or co-generation type production facility under the jurisdiction (or produced on land which is under the jurisdiction) of the Military Department	Under section 2922a, a Military Department may enter a contract for up to 30 years for energy production facilities on DoD real property or on private property and purchase the energy produced from such facilities. Allows Departments to contract for on-site energy generating projects without providing the capital costs at the time of construction. Developers may install an energy production facility on DoD or private property under an agreement pursuant to which the Military Department would purchase the energy generated by the facility. The Department would pay for some or all of the facility through these power payments over the life of the contract. After installation, the developer would own, operate, and maintain the facility for the life of the contract. An EUL can be used for renewable energy projects but must include payment (in cash or in-kind) by the lessee of consideration in an amount not less than the fair market value of the leasehold. An EUL shall be limited in term to the useful life of the energy production facility.
Executive Branch			
EO 13327, 6 Feb 2004 <i>Federal Real</i>	POTUS	Recognition of importance of real property resources through increased management attention, clear goals and objectives,	Performance measures: life-cycle cost estimations; operating, maintenance, and security costs;

Publication Title, Date	OPR	Description	Issues, Impediments, etc.
<i>Property Asset Management</i>		improved policies and levels of accountability, etc. Establishes Agency Senior Real Prop Officer and Fed Real Prop Council (OMB) and responsibilities. Includes evaluating costs & benefits of ...maintaining, operating, managing... Federal real properties.	costs of utility services at unoccupied properties; environmental costs associated with ownership of property
EO 13423, 24 Jan 07, <i>Strengthening Federal Environmental, Energy, and Transportation Management</i>	POTUS	Agency GHG emission goals—3%/year through 2105 or 30% by EOY FY 2015 (baseline 2003). Half of renewable energy consumed from new sources. Implement sustainable practices. Definitions of key terms. DoD congressional reporting requirement per NDAA 2002 (PL 107-107)	Rescinded by EO 13693, 19 Mar 15
EO 13514, 5 Oct 09, <i>Federal Leadership in Environmental, Energy, and Economic Performance</i>	POTUS	Expands on the energy reduction and environmental performance requirements for Federal agencies identified in EO 13423. Requires agencies to establish goals using 2008 baseline.	Rescinded by EO 13693, 19 Mar 15
EO 13693, 19 Mar 15, <i>Planning for Federal Sustainability in the Next Decade</i>	POTUS	Reduce GHG by 40% over the next decade. Requires agency goals for 2025 based on 2008. Seek renewable or alternative energy solutions. Includes SMR as a potential alternative energy solution and adds SMR to “alternative energy” definition. Cites DoD goals in NDAA 2007 and 2010	Percentage goals, SMRs included as alternative energy sources
Executive Office of the President, “ <i>The President’s Climate Action Plan</i> ”, June 2013	Executive Office of the President	Broad-based plan to cut carbon pollution that causes climate change. Move US economy toward American-made clean energy sources, increase renewable electricity generation, issue permits for renewables on public lands (DoD--and military installations), investment in a range of energy tech—including SMR. Safe and secure use of nuclear power.	Commitment to fighting climate change via increased use of renewables. Highlights various climate change funding programs that might be used to contribute to SMR funding.
Law			
10 U.S. Code § 2688 - <i>Utility systems conveyance authority</i> , 28 Oct 2009	US Law	Authority to convey a utility system, or part of a utility system, under the jurisdiction of the Air Force to a municipal, private, regional, district, or cooperative utility company or other entity	May facilitate “tie in” to installation or local power grid
10 U.S. Code § 2692 - <i>Storage, treatment, and disposal of nondefense toxic and hazardous materials</i> , 7 Jan 2011	US Law	SECDEF may not permit the use of an installation of the Department of Defense for the storage, treatment, or disposal of any material that is a toxic or hazardous material and that is not owned by DOD	There is an exception for temporary storage of nuclear materials in accordance with an agreement with the Secretary of Energy
32 CFR § 989, <i>Environmental Impact Analysis Process</i> , Jul 1999	US Law	Provides procedures for environmental impact analysis both within the United States and abroad	Required for any bed down on AF facility

Publication Title, Date	OPR	Description	Issues, Impediments, etc.
40 U.S. Code § 591 - <i>Purchase of electricity</i> , 21 Aug 2002	US Law	Requires federal (i.e. AF) purchase of electricity consistent with state law governing the provision of electric utility service	Exception for unusual standards of service reliability necessary for purposes of national defense
10 U.S. Code § 2410q <i>Multiyear contracts: purchase of electricity from renewable energy sources</i>	US Law	SECDEF may enter multiyear contracts not >10 years from sources of renewable energy, per Energy Policy Act of 2005 (42 USC 1582) Contracts >5 years only if (1) the proposed purchase of electricity is cost effective for DoD, (2) not possible to purchase electricity from the source without a contract > 5 years.	Contract time restrictions
10 U.S. Code § 2662, <i>Real property transactions: reports to congressional committees</i>	US Law	Report by SECDEF to HASC/SASC required for purchase/lease of real property >\$750K, etc. See Section 2667 for in-kind considerations	\$750K threshold for various real property transactions, 30 and 14 day wait requirement for transactions, detailed report content, reporting timelines
10 U.S. Code § 2667, <i>Leases: non-excess property of military departments and Defense Agencies</i>	US Law	Provides the Secretary of a military department lease authority for real property that is: under the control of the Secretary concerned; not for the time needed for public use; and not excess property SECAF lease authority, includes conditions on leases, types of in-kind considerations, EUL evaluation, use of proceeds	7 lease conditions, 6 in-kind considerations (incl. provision or payment of utility services) Section 2662 does not apply to construction of new facilities for in-kind considerations
10 U.S. Code § 2922, <i>Contracts for energy or fuel for military installations</i>	US Law	Service secretaries may enter contracts for up to 30 years for provision and operation of energy production facilities on property under the Secretary's jurisdiction or on private property and the purchase of energy produced from such facilities. SECDEF approval required.	Contract time requirement.
10 U.S. Code § 2911, <i>Energy performance goals and master plan for the Department of Defense</i>	US Law	Establishes requirement for DoD energy performance goals and a master plan, submitted annually to HASC and SASC. Provides details on master plan content, including description of proposed investments for achievement of energy performance goals. Amendments require DoD guidance on financing renewable energy projects, use of business case analyses, energy security, DoD-DOE collaboration on military installations for pilot programs on micro grids	In goals and plan, include: - Opportunities to pursue alternative energy initiatives - Cost effectiveness, cost savings, net present value of alternatives - Value of diversification of types & sources of energy - Improving energy security for facility energy projects using renewable energy sources
10 U.S. Code §2916, <i>Sale of electricity from alternate energy and cogeneration production facilities</i>	US Law	Authorizes the sale of electrical energy generated from alternate energy or cogeneration type production facilities which are under the jurisdiction (or produced on land which is under the jurisdiction) of the Secretary concerned. Proceeds go to appropriation account currently available to the military department.	Possible impediment: If an SMR is built on an AF installation by a utility it appears that SECAF not the utility would have the authority to sell the power off base.
10 U.S. Code § 2809, <i>Long-term facilities contracts for certain activities and services</i>	US Law	Service secretaries may contract for services for construction, management, and operation of a facility on or near a military installation for utilities if the project is in the budget for the start date, the services provided can be more economically provided through a long-term contract	Contract awarded through competitive procedures, contract period not in excess of 32 years, required waiting period.

Publication Title, Date	OPR	Description	Issues, Impediments, etc.
10 U.S. Code § 100 <i>Reactor Site Criteria</i>	US Law	Requires the NRC to consider population density; use of the site environs, including proximity to manmade hazards; and the physical characteristics of the site, including seismology, meteorology, geology, and hydrology, in determining the acceptability of a site for a nuclear power reactor.	Part of Basis for NRC Regulatory Guide 4.7 General Site suitability for Nuclear power Stations
10 U.S. Code § 50 - <i>Domestic Licensing of Production and Utilization Facilities</i>	US Law	Governs the licensing of nuclear power plants. Applies to all plants built or were in construction or in licensing process before 10 U.S. Code § 52 took effect. (1989)	Original licensing process. Two steps; construction permit, operating license. Could not obtain operating license until after construction complete.
10 U.S. Code § 52 <i>Licenses, Certifications, and Approvals for Nuclear Power Plants</i>	US Law	Governs the issuance of early site permits, standard design certifications, combined licenses, standard design approvals, and manufacturing licenses for nuclear power facilities.	Some of the Part 52 criteria are directly related to site characteristics, as well as to events and conditions outside the nuclear power unit. Much of the required information for an application defines the basis of Site Selection and Evaluation Criteria as described in the EPRI Siting Guide.
Other			
Electric Power Research Institute (EPRI), <i>Siting Guide: Site Selection and Evaluation Criteria for an Early Site Permit Application</i> , March 2002	K. Turner, Principal investigator; E. Rodwell, Project Manager	Describes a four-step site selection process involving sequential application of exclusionary, avoidance, and suitability criteria, as well as incorporation of preferences (or weighting factors) that are applied to the suitability criteria. The exclusionary, avoidance, and suitability criteria address the full range of considerations important in nuclear power facility siting. These include health and safety aspects, environmental aspects, socioeconomic and land use aspects, and engineering and cost aspects. The criteria encompass construction, operations, transportation, and accident conditions.	KPs: Provides an up-to-date framework for the site selection process. Steps 1 and 2 of the siting process are areal in nature; screening of a relatively large region of interest is performed to identify a number of discrete "site-sized" parcels for evaluation as a potential nuclear power facility site. These steps are accomplished using capable information. Comparing individual sites based on their relative suitability is the focus of steps 3 and 4. This portion of the process begins with the use of mapped and other published information and concludes with detailed information collected through on-site investigations, as necessary. Step 4 culminates in selecting a preferred site for which an ESP application can be submitted.

APPENDIX C: AFSPC INSTALLATION SMR QUESTIONNAIRE

<p>OVERVIEW: This questionnaire is to gather data as part of a study on the feasibility of siting a Small Modular Reactor (SMR) power generation facility on an AFSPC installation. No siting decision will be forthcoming. Suggested offices of responsibility follow each question. Please provide the information below for the following <u>installations</u>:</p> <p>Buckley AFB Schriever AFB Clear AFS New Boston AFS</p>		
Your Name, phone, email address	Your Office symbol, organization	Response Date
Your Organizational responsibilities		
<i>What are the installation's energy priorities? (Wing or equivalent)</i>		
<p><i>What existing guidance, policy, directions, etc. (AFSPC, unit, state), impact your energy operations? (CE)</i></p> <ul style="list-style-type: none"> - Clean / alternative energy guidance? - Are there restriction / barriers? 		
<p><i>What are the installation's mission(s) and base operating characteristics? (OG) (please keep inputs unclassified)</i></p> <ul style="list-style-type: none"> - Primary mission (e.g., Missile Warning, Intel Support, Satellite Operations), tenants, housing, etc. - Characterize the mission criticality-24/7/365 ops, routine/non-critical - Projected mission changes - Impact of locating SMR on installation (e.g., emanations issues, line of site issues, etc.) 		
<p><i>Are there unique energy requirements for installation missions (AFSPC and tenants)/limiting factors? (CE) (please keep inputs unclassified)</i></p> <ul style="list-style-type: none"> - Steps taken to enhance or strengthen energy reliability - Back-up power requirement (type, endurance) - Systems availability requirements (e.g., 99.999) - Installation Energy Goals <ul style="list-style-type: none"> - Percent of current supply from clean / alternative energy and what type (Power Purchase Agreements [PPA] in place, terms price?) - Adequacy of water supply 		
<p><i>Synergies: If an SMR were sited on your installation, we're interested in available support capabilities. To facilitate this, please provide a copy of your Installation's Support Agreement Catalog (Agreements Manager)</i></p>		

From an energy perspective (CE):

- *How are the installation, its operations and personnel perceived by the local communities?*
- *What is the installation's perception of public reaction to nuclear power and/or an SMR on the installation?*

What are the current energy provider's capabilities? (CE)

- *Utility provider*
 - *Price per kWh*
 - *Projection for future years*
 - *Utility POC*
 - *Relationship with installation*
 - *Issues or concerns*
- *Location/number of tie-ins to local utility (voltage)*
- *Location of high voltage transmission lines (distance from Installation)*
- *Location of nearest local utility power distribution center (distance from Installation)*
- *Projected utility provider projects that will impact installation power*

Enhanced Use Lease (EUL) factors and lessons learned (CE)

- *Current EULs*
- *Availability of non-excess land*
- *Existing PPAs*

APPENDIX D: SMR TECHNOLOGY VENDORS QUESTIONNAIRE

The Use of Small Modular Reactors to Provide Clean, Secure Energy to AFSPC Installations

Project Introduction

The purpose of the study is to evaluate the feasibility of using commercially-owned and operated Small Modular Reactors (SMR) to meet the needs of certain Department of Defense (DoD) installations for clean, secure energy. The U.S Department of Energy (DOE) and Sandia National Laboratory (Sandia) are sponsoring the study and have selected Scitor Corporation, with support from Landrey & Company, to conduct the study. Air Force Space Command (AFSPC) is providing the DoD perspective on this option. The study will focus on SMR technologies that can reasonably be expected to be licensed and deployed by 2025. It is to be completed by December 31, 2015, and will rely on non-proprietary information.

Project Contacts

- Sandia National Laboratory – Dr. Bobby Middleton, (505) 284-8692, bmiddle@sandia.gov
- Scitor Corporation – Tom Boland, Scitor Corp., 719-380-4063, tboland@scitor.com
- Landrey & Company: Bruce Landrey, 503-715-7900, brucel@landreyco.com

Request for Information – SMR Technology Vendors

Technology Overview

Please provide an overview of a nuclear power plant that uses your technology.

- What is the thermal output of each reactor and electrical output of each NSSS?
- How many reactors are installed at each power plant?
- What is the total output of the power plant?
- How much land, in acres, is required for the power plant site?
- What types of systems are available to cool the power plant, e.g. is it designed to use dry cooling or other methodologies?
- Using conventional cooling, what are the requirements for cooling water in millions of gallons per day?
- What is the projected operating life?

Commercial Readiness

- In general, please describe the plans to bring your technology to market. Who do you have as strategic partners for EPC services, manufacturing, licensing support and other parts of the supply chain?
- What is the status of your USNRC licensing effort and preparation for a license submittal under 10 CFR Part 52 or Part 50?

- If AFSPC / DoD determined today that it wanted to use your SMR technology to meet its mission critical needs and clean energy targets, what do you see as the timeline for licensing, construction and commercial operation?

Deployment Scenarios

- There are three scenarios for deploying an SMR to serve an AFSPC installation. In all three the SMR is licensed to, and operated by, an experienced, highly qualified nuclear operator. How do you see each of the following as the best way to both serve an AFSPC installation and integrate a project using your technology into the commercial market?
 1. The SMR is built within the regional grid to serve both utility customers and the AFSPC installation through a PPA. The PPA helps the AFSPC installation meet its clean energy goals but does not help to ensure energy security.
 2. The SMR is built in proximity to an AFSPC installation. Using micro-grid capability it can potentially help meet critical mission needs and in the event of an emergency
 3. The SMR is located within the AFSPC installation site. It is specifically designed and configured to provide power in an emergency situation. This might include returning to operation in a “black start” or operating in “island” mode to isolate itself from the grid so that it only provides the AFSPC installation with its mission critical power needs. Further, the AFSPC installation is able to use its resource to lower operating costs by providing personnel and services that offset the SMRs needs

Economics

- What is the projected overnight capital cost for a nuclear power plant using your technology in what year dollars?
- If available, what is the projected Lifecycle Cost of Electricity (LCOE) from a nuclear power plant using your technology?

Capability to Serve AFSPC Mission Critical Needs

- Many AFSPC installations receive power from wind, solar and other renewable but intermittent resources. What capability does your system have to “load follow” to integrate intermittent resources to ensure an AFSPC installation receives a reliable supply of power? What is the minimum output from the power plant? How quickly can it both reduce and increase output to “load follow.”
- One concept is that SMRs might be able to provide secure power to an AFSPC installation in emergency situations or after abnormal events. What capability might your system have to serve an AFSPC installation in the following situations:
 - Loss of all off-site power to the installation. Can the SMR be isolated from the regional grid and deliver as little as 5-25 MWe to meet mission critical needs? What is the minimum output in MWe of the SMR that is sustainable for a 72 hour period?
 - An abnormal event results in a loss of off-site power to the installation and the SMR and shuts down the nuclear power plant. Can the SMR achieve a “black start” and operate without off-site power in order to serve the AFSPC installation?
- What are the vulnerabilities of the plant systems to an electro-magnetic pulse type of phenomena?

- What other capabilities does your technology have that might help AFSPC meet mission critical energy needs in an emergency situation?
- Are there any NRC regulations that would prohibit the operation or configuration of your SMR technology in the events described above?

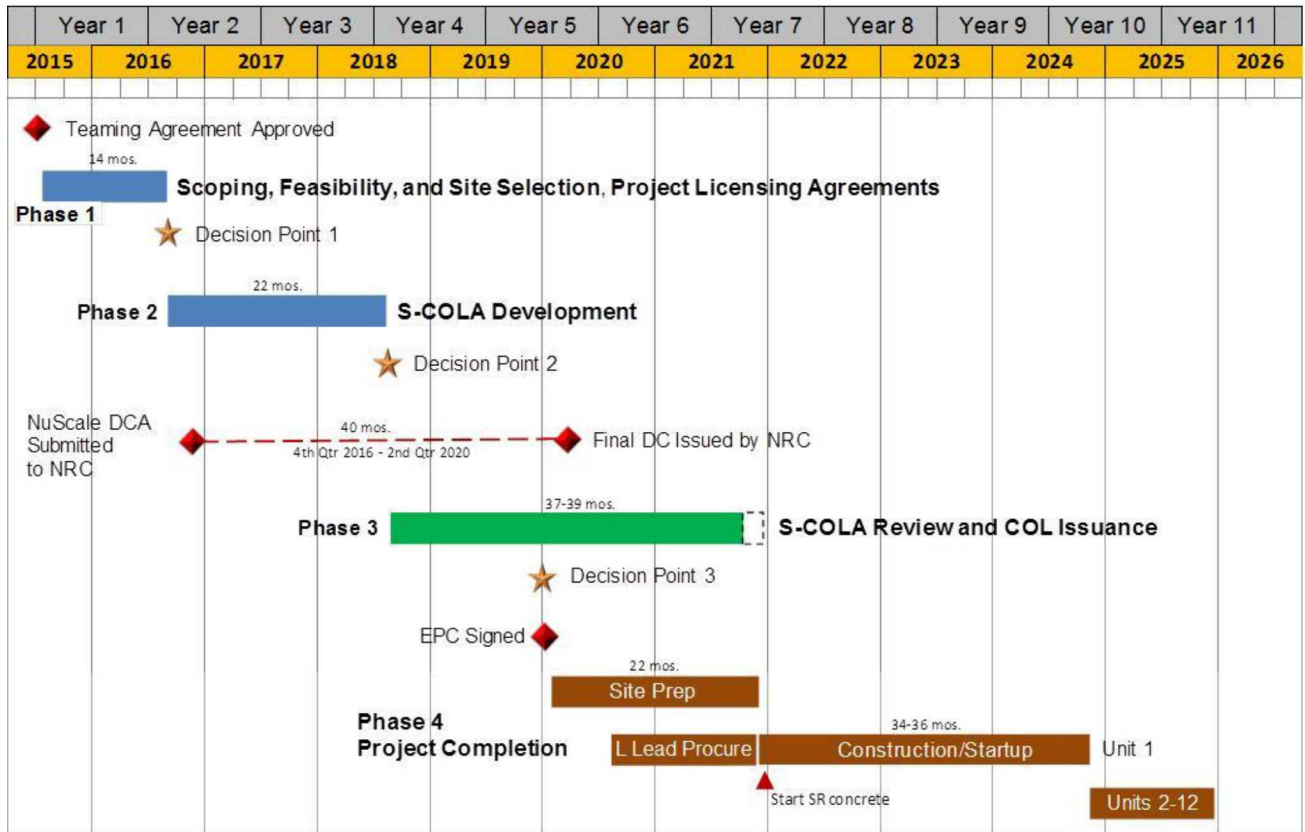
Fuel Cycle

- What type of fuel will your technology use?
- How often is each reactor refueled, how much of the core is replaced at that time, and what is the expected duration of the refueling outage?
- What are the plans for storing used fuel? What is the storage capacity, in refueling, of the used fuel pool?
- How many years after commercial operation will the first fuel be stored in an on-site, interim storage facility?
- Are plans for an on-site ISFSI included in the design and layout for the power plant site?

APPENDIX E: REPRESENTATIVE SMR DEPLOYMENT TIMELINE

Source: NuScale Power response to the SMR Technology Vendors Questionnaire, May 20, 2015
APPENDIX E: REPRESENTATIVE SMR DEPLOYMENT TIMELINE

Source: NuScale Power response to the SMR Technology Vendors Questionnaire, May 20, 2015



APPENDIX F: UTILITIES QUESTIONNAIRE

The Use of Small Modular Reactors to Provide Clean, Secure Energy to AFSPC Installations

Project Introduction

The purpose of the study is to evaluate the feasibility of using commercially-owned and operated Small Modular Reactors (SMR) to meet the needs of certain Department of Defense (DoD) installations for clean, secure energy. The U.S Department of Energy (DOE) and Sandia National Laboratory (Sandia) are sponsoring the study and have selected Scitor Corporation, with support from Landrey & Company, to conduct the study. Air Force Space Command (AFSPC) is providing the DoD perspective on this option. The study will focus on SMR technologies that can reasonably be expected to be licensed and deployed by 2025. It is to be completed by December 31, 2015, and will rely on non-proprietary information.

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- Landrey & Company: Bruce Landrey, 503-715-7900, brucel@landreyco.com

Request for Information – Utilities with Nuclear Operations

Power Supply to AFSPC / Other Federal Installations

- Do you provide power to AFSPC or other DoD installations? If the information is not classified, how much power, in terms of average and peak MWe and total annual MWh, do you provide to each?
- Do you provide power to any large DOE or other large Federal installations? (excludes office buildings, hospitals and other smaller facilities). If the information is not classified, how much power, in terms of average and peak MWe and total annual MWh, do you provide to each?
- Does any of the power specifically supplied to the AFSPC /DOC / DOE / Federal installations come from renewable resources? If so, how much?
- Are any of those renewable resources located within the AFSPC / DoD / DOE / Federal installation? Please describe.
- If so, what arrangements did your utility need to establish in order to develop, license, permit and operate the renewable resource on Federal land?
- If the land for the resource was obtained using an Enhanced Use Lease agreement, please describe your utility's experience with this process?
- What benefits do you see in an EUL agreement? What challenges?

Nuclear Power

- Is new nuclear power a consideration in your long term integrated resource plan?
- Is your utility interested in, or following the development of SMR technology?
- From a regulatory or policy standpoint, is there anything that would prohibit your utility from purchasing power from an SMR nuclear power plant? An ownership share?
- If an SMR nuclear power plant was sited on, or in proximity to, any of the AFSPC or other Federal installations under discussion, what would be the reaction of the local community and elected officials?

Serving an AFSPC Installation with an SMR Nuclear Power Plant

- There are three scenarios for deploying an SMR to serve an AFSPC installation. In all three the SMR is licensed to, and operated by an experienced, highly-qualified nuclear operator such as yourselves. What is your company's perspective on each of the following as the best way to both serve an AFSPC installation and integrate a project using SMR technology into your system and the regional market?
 1. The SMR is built within the regional grid to serve both utility customers and the AFSPC installation through a PPA. The PPA helps the AFSPC installation meet its clean energy goals but does not help to ensure energy security.
 2. The SMR is built in proximity to an AFSPC installation. Using micro-grid capability it can potentially help meet critical mission needs and in the event of an emergency
 3. The SMR is located within the AFSPC installation site. It is specifically designed and configured to provide power in an emergency situation. This might include returning to operation in a "black start" or operating in "island" mode to isolate itself from the grid so that it only provides the AFSPC installation with its mission critical power needs. Further, the AFSPC installation is able to use its resource to lower operating costs by providing personnel and services that offset the SMR's needs

Capability to Serve AFSPC Mission Critical Needs

- Many AFSPC installations receive power from wind, solar and other renewable but intermittent resources. What is your company's perspective on whether an SMR has the capability to "load follow" to integrate intermittent resources to ensure an AFSPC installation receives a reliable supply of power?
- Ideally what types of performance range would you want from an SMR to "load follow"? What is the minimum output from the SMR? How quickly should it be able to both reduce and increase output to "load follow." What other capabilities are important?
- One concept is that SMRs might be able to provide secure power to an AFSPC installation in emergency situations or after abnormal events. What is your company's perspective on whether an SMR might be capable of serving an AFSPC installation in the following situations:

- Loss of all off-site power to the installation. Can the SMR be isolated from the regional grid and deliver as little as 5-25 MWe to meet mission critical needs? What is the likely minimum output in MWe of the SMR that is sustainable for a 72 hour period?
- An abnormal event results in a loss of off-site power to the installation and the SMR, and shuts down the nuclear power plant. Can the SMR achieve a “black start” and operate without a connection to off-site power in order to serve the AFSPC installation?
- What other capabilities might an SMR have that might help AFSPC meet mission critical energy needs in an emergency situation?
- From your knowledge, are there any NRC regulations that would prohibit the operation or configuration of SMR technology in the events described above?
- In the last two deployment scenarios described above – the SMR is sited within the AFSPC installation or in proximity to it. From your company’s perspective, is it possible to configure the grid, or build a micro-grid, so that the SMR can be “islanded” to only supply mission critical power to the installation? What is the feasibility?

Synergies

In discussions about siting an SMR on a AFSPC / DoD installation, there is an expectation that there are potential synergies between the installation’s capabilities and the needs of the SMR operator. Based on your experience with nuclear operations, what is your company’s perspective on the feasibility of the following:

- The military installation provides some or all of the SMRs needs for physical security.
- Siting the SMR on the military installation reduces the SMRs requirements for physical security.
- Installation personnel can offset some or all of the SMR operator’s needs for emergency planning and response.
- Are there other potential synergies that might be explored and evaluated, e.g., training, environmental monitoring.....?

APPENDIX G: SMR STUDIES AND REPORTS SUMMARY

Publication Title, Date	Author(s)	Description	Issues (Iss), Impediments (Im)s, key points (KPs), etc.
Testimony To Congress, <i>Paper Reactors and Real Reactors</i> , June 1953	Adm H. G. Rickover	In a statement to the U.S. Congress in 1953, early on in the development of nuclear reactors, Rickover addressed the confusion amongst the nation's decision-makers and notably pointed out the chasm between the world of academia and the world of practical engineering.	KPs: Academic (paper) reactors: simple, small, cheap, light, built quick, flexible in purpose, minimal development and use off the shelf parts. Reactor is in the study phase not being built now. Practical (real) reactor: being built now, behind schedule, immense development of trivial items, expensive, long build time, large, heavy and complicated.
International Atomic Energy Agency (IAEA)-TECDOC-1587, <i>Spent Fuel Reprocessing Options</i> , August 2008	Multiple, to include individual country reports	Provide an updated (2008) evaluation on spent nuclear fuel reprocessing options with emphasis on reprocessing technologies to improve sustainability of nuclear energy.	KPs: Nuclear electric generating capacity will continue to grow. Reprocessing is key to reducing HLW and maintaining levels of nuclear resource materials. Multi-national fuel cycle centers can ensure a sustained supply of nuclear fuel while reducing the risk of proliferation. Next generation reprocessing could further reduce HLW.
<i>Alternative Sources of Energy for U.S. Air Force Bases</i> , 1 August 2009	AF Scientific Advisory Board	Six month study to analyze AF installation energy needs and recommend solutions, including alternative energy technologies. Four top-level recommendations: 1. Use a systems approach to pursue alternative energy sources; partner with DOE 2. Strengthen security of energy sources and distribution. 3. Concurrently pursue energy storage solutions and renewable energy sources 4. Evaluate SMRs, identify bases that would benefit from SMRs, make nuclear energy part of AF energy Planning Review of key factors associated with SMRs, benefits of on-base siting (p. 51)	KP: AF's primary emergency response is backup diesel generators connected to mission-essential buildings and run with limited supplies of on-site stored fuels; can reduce vulnerabilities with alternative energy projects. - AF strategy should promote partnerships with power providers (utilities, grid operators) - Include mixes of fossil, nuclear and various forms of renewables - AF should take a leadership role in the use of SMRs
International Energy Agency (IEA) & Nuclear Energy Agency (NEA), <i>Projected Costs of Generating Electricity</i> , 2010	Lead authors: María Sicilia Salvadorés (IEA) and Jan Horst Keppler (NEA)	The study focuses on the expected plant-level costs of baseload electricity generation by power plants that could be commissioned by 2015. It also includes the generating costs of a wide range of renewable energy sources, some of which have variable output. The calculations are based on the simple levelised average (unit) lifetime cost approach using the discounted cash flow (DCF) method.	KPs: In the low discount rate case, more capital-intensive, low-carbon technologies such as nuclear energy are the most competitive solution compared with coal-fired plants without carbon capture and natural gas-fired combined cycle plants for baseload generation. In the high discount rate case, coal without carbon capture equipment, followed by coal with carbon capture equipment, and gas-fired combined cycle turbines (CCGTs), are the cheapest sources of electricity. Is: Did not look at SMRs.
<i>Report of the Defense Science Task Force on DoD Energy Strategy "More Fight—Less Fuel"</i> , February 2008	USD (AT&L)	Task Force tasked to... identify opportunities to deploy renewable and alternative energy sources for facilities... identify potential national benefits from DoD deployment of new energy technologies. Focus is primarily tactical, and on	Finding #2: Critical national security...missions are at an unacceptably high risk of extended outage from failure of the grid and other critical national infrastructure. Recommendation #4: Invest in energy efficient and alternative energy technologies commensurate with their operational and

Publication Title, Date	Author(s)	Description	Issues (Iss), Impediments (Im)s, key points (KPs), etc.
		petroleum-based fuels.	financial value.
Center for Advanced Energy Studies, Energy Policy Institute (EPI), <i>Economic and Employment Impacts of Small Modular Reactors</i> , June 2010	David Solan et al	<p>Review of types, advantages, and potential uses of SMRs. Estimated market potential and market share of SMRs based on four scenarios: high, moderate, low, and disruptive nuclear adoption to determine SMR economic impacts. Domestic and international.</p> <p>While fossil fuels will continue to play an important role in supplying future energy requirements, the role of nuclear power may increase significantly as rising energy demand is balanced with the need to effectively address issues such as climate change, domestic energy security, and electricity access and utilization by developing economies.</p>	<p>KP: based on projections and estimates of SMR manufacturing, construction and operation. Cost estimates may be off, e.g., \$500M to manufacture and install a 100 MWe SMR.</p> <p>KP: A robust SMR market, both globally and nationally, will add to the U.S. manufacturing base and provide a significant number of high-paying jobs in manufacture and operations. This conclusion is based on a number of dependencies that temper the relative certainty of the results; successful/timely navigation the NRC licensing process, anticipated carbon regulation, and assumes SMRs easier to site than traditional nuclear plant.</p> <p>Is: Study did not address domestic investment climate for SMRs.</p>
Center for Naval Analyses, <i>Feasibility of Nuclear Power on U.S. Military Installations</i> , March 2011	Marcus King, LaVar Huntzinger and Thoi Nguyen	Congress directed the DoD, in section 2845 of the NDAA 2010, to “conduct a study to assess the feasibility of developing nuclear power plants on military installations”. DUSD(I&E), asked CNA to conduct this feasibility study.	KPs: SMRs can contribute to DoD missions by increasing energy assurance while reducing carbon emissions and reliance on fossil fuels for electricity. Identified key issues in SMR safety, certification and licensing including siting and community considerations (resolving these issues will take time and resources). Cost analyses found an SMR a viable electricity option for a DoD installation as long as DoD does not assume FOAK expenses. If DoD is required to assume FOAK expenses, an SMR is not a viable option.
National Defense University, <i>Small Nuclear Reactors for Military Installations: Capabilities, Costs, and Technological Implications</i> , February 2011	Richard B. Andres and Hanna L. Breetz	The purpose of this paper is to explore the prospects for addressing critical DoD vulnerabilities (dependence of U.S. military bases on the fragile civilian electrical grid, and the challenge of safely and reliably supplying energy to troops in forward operating locations) through small-scale nuclear plants.	<p>KPs: SMRs could address dependence on civilian grid. Using SMRs at forward locations (for power or possibly hydrogen production) would lessen dependence on supply convoys and has the potential to save hundreds or thousands of U.S. lives</p> <p>Iss: Due to cost issues SMRs may fail to be commercialized without DoD/Federal assistance. If DoD is not involved in the early stages of SMR development the designs locked in for private market may not be optimal for DoD’s needs.</p>
American Society of Mechanical Engineers (ASME) Small Modular Reactors Symposium, <i>The Business Case for SMRs on DOD Installations</i> , September 2011	Dr. William J. Barattino, Dr. Benjamin J. Cross, D. Jeffrey Smith, Wendi Goldsmith, Scott Foster, Michael Holt, and Col. Paul E. Roege	A systems perspective is critical toward understanding the potential for SMRs to enable pursuing the parallel objectives of reducing fossil fuel usage, making installations energy self-sufficient, and reducing greenhouse gas emissions with long term operations at lower costs. This paper explores the business case conditions for how SMRs located on U.S. Army installations by a servicing utility could provide a viable energy alternative to the DOD for meeting these objectives.	KPs: Case Study Data (R&D and Certification costs not included); SMR does not produce power until 11 years after program start (yrs. 1-3 R&D; 2-6 Cert; 5-10 site prep, manufacture and construction; 10-11 start up) income begins at this point. SMR operates for 30 years (yrs. 10-40). Recurring costs are O&M (yrs. 10-40), on site waste storage (yrs. 14-40) and refueling (yrs. 14-36). One final cost is decommissioning (yrs. 40-50). Breakeven point occurs in year 33 after program start (year 22 after power available to grid). Return on investment was 10.2%. Installation GHG reductions averaged 75.9% for electric only and 96.1% with industrial energy added in.

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University of Chicago, Energy Policy Institute at Chicago (EPIC), <i>Small Modular Reactors – Key to Future Nuclear Power Generation in the U.S.</i> , November 2011 (white paper)	Robert Rosner, Stephen Goldberg and Joseph S. Hezir	Analysis of economics of SMRs. Topics include the safety case; economics; the business case and a business plan; government incentives; licensing, design, and engineering; and future research. Capital cost estimates cover a range of categories, including the plant capital costs for the nuclear steam supply system, turbine building, and balance of plant; costs for engineering and construction services; owner’s costs and contingencies; and escalation and financing costs.	KP: Extensive conclusions on licensing, economics and business case: licensing framework, vendor cost estimates based on assumptions on NRC regulation and therefore uncertain, regulatory uncertainty may cause delays, cost model based on “economies of mass manufacturing”, activity increases SMR vendors may not get private investment for 2020 target, economic returns on investment probably 20 years away, electric power companies have limited incentive to invest, policy on carbon reduction is uncertain, “late adopters” may have advantages over “early movers”, need level playing field for federal incentives v/v other clean energy technologies, SMR acceleration requires govt incentives, “market pull” can enhance “tech push”— incentives, coal plant replacement, aggregation of demand would help
Blue Ribbon Commission on America’s Nuclear Future, January 2012	Co-chairs: Rep. Lee H. Hamilton, Gen Brent Scowcroft	Recommends a new strategy for managing the back end of the nuclear fuel cycle. Eight key recommendations, highlights proposed legislative changes. Detailed background information.	KP: Waste management recommendations can be implemented using revenue streams <i>already dedicated for this purpose</i> (e.g., Nuclear Waste Fund and fee). Timing and implementation: recommendations are interconnected and will take time to implement, many require legislative action, but near term actions can begin in selected areas.
<i>Energy Horizons, United States Air Force Energy S&T Vision, 2011-2026</i> , 31 Jan 2012	Dr. Mark T. Maybury (and staff) (AF/ST (AF Chief Scientist)	The AF vision for energy Science and Technology (S&T) spanning air, space, cyber, and infrastructure. Focused on S&T in the near-, mid- and far-term for survivability, efficiency, affordability, and effectiveness of AF operations. Includes sections on “Space Energy”, “Cyber Energy”, and “Infrastructure Energy”. SMRs cited as part of a “culture change”. Addresses SPIDERS, smartgrids, energy storage Delineates S&T areas where AF should Lead, Follow, or Watch in order to advance operational readiness, resiliency, and robustness while at the same time supporting national objectives of economic development, environmental stewardship, and supply independence.	KP: Near term goal: lower ground facility and systems energy consumption, mid/long term— expand use of renewables. - Overwhelming share of energy use for space ops is in terrestrial facilities and systems. AFSPC mission energy consumption: 97.2% for terrestrial +facilities. - Many investments into SMRs can be leveraged for space based systems. - AF should consider piloting SMRs-- recommended by the AF Scientific Advisory Board (see above). - Ensure energy savings don’t come at mission expense. - Greatest energy savings in space likely to be in infrastructure efficiencies: ranges, ground stations, data processing facilities. - IT energy consumption growing. Data centers 2% US total in 2010. - AF should employ early adopter/fast follower role; deploy the most advantageous solutions - Most significant technology on horizon is use of nuclear energy to enable DoD installations. Congress: 2010 NDAA, PL 111-08428 October 2009 Sec 2845. - SMRs can potentially fuel local facilities (mid, FY16-20, to far term, FY21-25) - The business case for autosafing and waste reusing SMRs should be developed to provide enhanced grid security.
US Army War	George E.	The purpose of this paper is to evaluate	Iss: 99% of DoD electrical requirements from

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College Strategic Research Paper, <i>Small Modular Reactors: The Army's Secure Source of Energy?</i> , March 2012	Robitaille	the current state of the electric energy grid, the factors that influence its reliability, and identify the Department of Defense (DoD) requirements for secure energy sources at critical military facilities. This paper outlines the history of small modular reactors (SMR) relative to the DoD, the current state of SMR design, development, safety, and describes the need for DoD to pursue this technology as a viable source of secure energy in the future.	civilian grid. Due to aging infrastructure, susceptibility to severe weather events, and potential for cyber-attacks the grid may not be reliable enough for critical military facilities. KPs: SMRs could help DoD to meet sustainable energy initiatives, significantly reduce the generation of GHGs, reduce dependence on fossil fuels, and provide a secure source of independently generated electricity. SMRs may be cheaper and should be safe and secure.
IAEA Nuclear Energy Series, NG-T-3.7, <i>Managing Siting Activities for Nuclear Power Plants</i> , 2012	IAEA POC: V. Nkong-Njock	Guidance on organizational, engineering, socio-economic, and environmental issues of siting—management of siting activities, methodology, stakeholder involvement	KP: international focus, but guidelines are good reference points for siting and stakeholder activities
<i>New Mission Beddown and Construction, Clear AFS, AK</i> , August 2012	Missile Defense Agency (MDA)	Evaluates potential for environmental impacts of proposal to beddown new mission requirements and upgrade the Early Warning Radar (EWR) and associated facilities at the Solid State Phased-Array Radar System (SSPARS) at Clear AFS, AK	Summary information on biological, cultural, geology and soils, seismicity, and surface water at Clear AFS.
<i>Energy 20/20: A Vision for America's Energy Future</i> , February 2013	Senator Lisa Murkowski	Meant to begin a conversation about where energy and natural resource policies should go over the next few years. Intended as a blueprint for discussion, not an “energy plan” in and of itself.	KPs: Nation is too often hamstrung by regulatory overreach, permitting delays, and litigation seeking to apply environmental laws well beyond their original intent. Too often, necessary and worthwhile energy and resource projects are rendered uneconomic by attrition, and endless rounds of administrative disputes and lawsuits. These never-ending cycles stand in the way of timely, efficient, and urgently-needed investments in energy supply and conservation. KP: Advocates expanding nuclear power and support for new technologies, including SMRs, and resolving the pressing back-end issues of the fuel cycle.
<i>Evaluation of the Applicability of Existing Nuclear Power Plant Regulatory Requirements in the U.S. to Advanced Small Modular Reactors</i> , May 2013	Jeffrey LaChance, et al	Identifies the regulatory requirements and associated guidance utilized in the licensing of existing reactors and the potential applicability of these regulations to advanced SMR designs, taking into account the unique features of these types of reactors. Includes valuable references to key guidance publications, e.g., NUREG 0654, NUREG 1791.	KP: SMRs have several technological advantages that can affect the operation, safety, and security of the plant, e.g., passive safety features, reduced emergency planning zones. One area where SMRs may provide significant cost savings without compromising safety and security is plant staffing.
UK National Nuclear Laboratory, <i>Small Modular Reactors (SMR) Feasibility</i>	Gordon Waddington	UK Government asked Industry to determine a) whether SMRs are viable; b) the potential UK industry role; and c) the possible role that UK Government might play in that process. This request	KPs: Significant market for SMRs. Four reactor designs technologies (3 US) were identified as potentially meeting both the technical and financial requirements, potentially viable within 10 years and with the

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<i>Study</i> , December 2014		was driven both by recognition from Government of a need for further industrial development, and for low carbon, secure and affordable energy supply.	possibility of UK involvement. A number of technical areas (21) have been identified that provide innovation opportunities. Financial analysis shows SMRs to be comparable with large scale nuclear on a FOAK basis and through the use of modular construction and factory production techniques, conceivably more competitive on NOAK basis. Without UK government support it is unlikely that SMRs will be developed there. Im s: As with the US NRC the UK ONR would likely follow the current large reactor regulatory process for SMR.
URS, <i>Small Modular Reactor Hanford Site Analysis</i> , Sept 2014	URS Corporation	Study of the Hanford Site (Washington) as a possible SMR location and estimate financial benefits. Good breakout of study methodology, details on types of SMR, coverage of related regional assets for SMR deployment	KP: SMR deployment unlikely without Federal assistance. SMR Licensing Tech Supt Program helpful, but insufficient. Natural gas is best option--less risky, quick to construct, lower capital costs-- <i>when climate change is not taken into consideration</i> . Govt-industry cost sharing could jump-start SMR deployment (also: vendor-utilities-DOE-ratepayer cost sharing). Collaboration among DOE communities may gain SMR support.
EIA, <i>Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2014</i> , April 2014	Not listed	This paper presents average values of levelized costs for generating technologies that are brought online in 2019 as represented in the National Energy Modeling System (NEMS) for the Annual Energy Outlook 2014 (AEO2014) Reference case. ² Both national values and the minimum and maximum values across the 22 U.S. regions of the NEMS electricity market module are presented.	KP : Good discussion of LCOE and LACE. Is : Did address SMRs only “Advanced Nuclear” with no clear definition.
Electric Power Research Institute (EPRI), <i>Siting Guide: Site Selection and Evaluation Criteria for an Early Site Permit Application</i> , March 2002	K. Turner, Principal investigator; E. Rodwell, Project Manager	Describes a four-step site selection process involving sequential application of exclusionary, avoidance, and suitability criteria, as well as incorporation of preferences (or weighting factors) that are applied to the suitability criteria. The exclusionary, avoidance, and suitability criteria address the full range of considerations important in nuclear power facility siting. These include health and safety aspects, environmental aspects, socioeconomic and land use aspects, and engineering and cost aspects. The criteria encompass construction, operations, transportation, and accident conditions.	KPs : Provides an up-to-date framework for the site selection process. Steps 1 and 2 of the siting process are areal in nature; screening of a relatively large region of interest is performed to identify a number of discrete "site-sized" parcels for evaluation as a potential nuclear power facility site. These steps are accomplished using map able information. Comparing individual sites based on their relative suitability is the focus of steps 3 and 4. This portion of the process begins with the use of mapped and other published information and concludes with detailed information collected through on-site investigations, as necessary. Step 4 culminates in selecting a preferred site for which an ESP application can be submitted.
Oak Ridge National Laboratory (ORNL), <i>Application of Spatial Data Modeling and</i>	G. T. Mays (Project Manager), R. J. Belles, B. R. Blevins, S. W. Hadley,	Development of OR-SAGE. The objective in developing OR-SAGE was to use industry-accepted approaches and/or develop appropriate criteria for screening sites and employ an array of Geographic Information Systems (GIS) data sources at ORNL to identify	KP : In depth discussion on the methodologies used to develop site selection and evaluation criteria (SSEC) used in OR-SAGE. As a guiding document, ORNL staff employed the general concepts presented in the 2002 EPRI Siting Guide. KP : The objective in conducting this type of

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<i>Geographical Information Systems (GIS) for Identification of Potential Siting Options for Various Electrical Generation Sources</i> , May 2012	T. J. Harrison, W. C. Jochem, B. S. Neish, O. A. Omitaomu, A. N. Rose	candidate areas for a power generation technology application. The OR-SAGE tool is essentially a dynamic visualization database. The strength of the OR-SAGE tool is that numerous alternative scenarios can be quickly generated to provide additional insight into electrical generation or other GIS-based applications.	siting evaluation is to perform early site characterization of the candidate areas to identify any particular issues for power plant siting; it is not intended to be a definitive assessment per se as to the overall suitability of any particular site.
ORNL, <i>Updated Application of Spatial Data Modeling and Geographical Information Systems (GIS) for Identification of Potential Siting Options for Small Modular Reactors</i> , September 2012	R. J. Belles, G. T. Mays, O. A. Omitaomu, W. P. Poore	Stream flow is the primary cooling water makeup source evaluated in this study. Plants are limited to 10% of available stream flow for makeup water. Stream flow is based on a composite of calculated 7-day, 10-year low-flow data from the U.S. Geological Survey and existing lake and reservoir data. Also limited evaluation of aquifers, municipal waste water, shoreline cooling, and dry cooling alternatives. There are 22 datasets supporting the SMR evaluations. Processes and assumptions for OR SAGE computations. Overview of the 4 primary vendors. Nominal site selection criteria. Individual composite US maps for each SSEC layer. Maps for rail transport and transmission lines. Review of advantages in SMR siting due to technology differences—siting requirement changes.	KP: The most significant contributor to the single-issue area on the nominal SMR composite map is cooling water makeup from existing stream flow. Over half the areas that fail due to a single-issue are due to <u>inadequate makeup water</u> for closed-cycle cooling. 65K gpm cooling water requirement (reduction to 30K due to SMR design). “At 250 MW(e), only 30,000 gpm stream flow is required for cooling water makeup in a closed-cycle cooling system” - Protected lands, seismic considerations, and slope are significant limiting factors in the <u>west</u> . - Cooling water makeup is a significant restrictive factor in the <u>west</u> and central US. - American Electric Power: 345 kV single circuit line costs \$1.1-2. M/ mile (2008 \$) -- proximity to available lines carries significant weight in site selection. - Combining stream flow and aquifer cooling SSEC layers makes much of US east of the Rockies SMR eligible. - Except for the west coast, population densities in western half of US don’t support use of gray water as a makeup water alternative. - Significant improvement in SMR candidate area availability in western US using dry-cooling technology
ORNL, <i>Identification of Selected Areas to Support Federal Clean Energy Goals Using Small Modular Reactors</i> , December 2013	R. J. Belles, G. T. Mays, O. A. Omitaomu, W. P. Poore	Identifies several locations with a high concentration of federal government agency electricity usage—federal energy clusters. Includes summaries of clusters in Denver-Colo. Spgs. and southern California (Vandenberg and LA).	KP: Significant areas in Denver-Colo. Spgs have one SSEC issue based on a lack of sufficient makeup cooling water, high slope, or because they are protected land. - There is possible federal energy cluster from Denver to Fort Carson; very limited area where SMR siting would be favorable. - Much of southern California has one SSEC issue due to exceeding the safe shutdown earthquake threshold, fault lines, inadequate stream flow for cooling water makeup, excessive slope, or protected land.
ORNL, <i>Evaluation of Suitability of Selected Set of Department of Defense Military Bases and</i>	W. P. Poore, R. J. Belles, G. T. Mays, O. A. Omitaomu	Summarizes the second phase of the ORNL approach for screening a sample set of DoD military base sites and DOE sites for possible powering with an SMR; the methodology employed, including spatial modeling; and initial results for several sample sites. A top-	KP: 1000 acre installations, 50 acre SMR site, within 5 miles of land with no siting issues. SMR composite US map. A 540 MWe SMR installation requires approx. 65K gpm stream flow assuming no more than 10% of available stream flow is used for power production. Cooling water already used by a

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<i>Department of Energy Facilities for Siting a Small Modular Reactor</i> , March 2013		down look at SMR siting at a national and regional scale. Focused on installations >1000 acres with land that had no siting issues, a single siting issues or within 5 miles of land with no siting issues. 50 acre SMR site area (5% of 1K acres)—“engineering judgment”—higher % would impact mission. Used previously established SSEC. Exclusionary, avoidance and suitability criteria. Did not consider national interests (critical loads) relating to missions, mission support. Eglin AFB, Beale AFB, Ft. Carson.	given coal station may be sufficient for a replacement SMR. “The DOD sites also support high technology and national security-related missions and are familiar with the similar technologies associated with operation of a nuclear power plant. They have adequate land areas available, staff considered capable and familiar with high technology activities similar to nuclear power plant operations, and necessary security capabilities.”
<i>ORNL, Evaluation of Potential Locations for Siting Small Modular Reactors near Federal Energy Clusters to Support Federal Clean Energy Goals</i> , 2014	R. J. Belles, O. A. Omitaomu	Task 4 report. Provides an analysis of three additional diverse federal energy clusters using previously developed SSEC, application of spatial modeling and GIS. Used same eval. criteria as Task 2. Shows clusters by ZIP codes (FY 09-12). Used SMR plant parameter envelope for two-unit installation of Babcock and Wilcox (B&W) SMR. Independent of population density. Includes Denver-Colo. Spgs. Lists criteria used for OR-SAGE screening. Used a 10 mile buffer for initial SMR siting--corresponds to the EPZ. Focus: Ft Carson, Nixon power plant, Arapahoe Station—none identified as unlikely SMR candidates. Includes population density maps for >500 people, 1-10 miles.	Site binning: 1) no current or near-term site selection/SSEC issues, 2) near term OK but may have longer term issues, 3) not a likely candidate—numerous SSEC not met. Shows Schriever, Peterson, Buckley, USAFA, Ft Carson on regional population density map.
<i>Department of Defense Annual Energy Management Report Fiscal Year 2013</i> , June 2014	Deputy Under Secretary of Defense (Installations and Environmt) DUSD (I&E)	Details DoD’s FY 2013 performance toward objectives of energy efficiency and demand reduction, expansion of energy production (renewable and on-site generation), and leveraging advanced technologies on fixed installations. Also activities addressing climate change impacts, including enhancing energy security and resilience. Overview of AF energy governance structure, microgrids, Installation Energy Test Bed funding for demonstrations, SPIDERS	KP: DoD fixed installations are 30% of total energy use. <u>Facility energy</u> powers fixed installations; <u>operational energy</u> required for training, moving, and sustaining forces and weapons platforms for operations, including energy used by tactical power systems, generators, and weapons platforms. - The West had the second highest average time per utility outage: 1.6 days (FY12 & 13); Pacific (incl. AK): 0.7 days. - In FY13, Congressional appropriations just over \$755M funded 1,259 energy efficiency, renewable energy, and water conservation projects; AF spent \$112M for 250 projects - In FY 2013, DoD awarded ~ \$256 million in non-governmental third-party financed ESPCs and UESCs.
<i>Department of Defense Annual Energy Management Report Fiscal Year 2014</i> , May 2015	Assistant Secretary of Defense (Energy, Installations, and Environmt)	Details DoD’s FY 2014 performance toward objectives of energy supply expansion, energy efficiency and demand reduction, and the adaptation of future forces and advanced technologies on fixed installations. It also details its activities addressing climate change impacts to its energy portfolio,	KP: DoD fixed installations are 30% of total energy use. <u>Facility energy</u> includes energy needed to power fixed installations and enduring locations as well as NTVs. <u>Operational energy</u> is the energy required for training, moving, and sustaining military forces and weapons platforms for military operations, including energy used by tactical power

Publication Title, Date	Author(s)	Description	Issues (Iss), Impediments (Im), key points (KPs), etc.
		including enhancing energy resilience.	systems and generators at contingency locations.
<p>Nuclear Energy Insider, <i>Small Modular Reactors: An industry in terminal decline or on the brink of a comeback?</i>, 2015</p> <p>Note: No part of this document may be copied, performed in public, broadcast or adapted without DecomWorld's prior written permission. Contact Kerr Jeferies kjeferies@nuclearenergyinsider.com.</p>	Kerr Jeferies	Interviewed more than fifty of the SMR industry's leading specialists and decision makers in order to provide exclusive insight into the crucial challenges that have been faced in the past 6-8 months, and a clear view of the opportunities available to drive modular reactor technology into a successful future.	<p>KPs: Four critical challenges, solutions required.</p> <p>- <i>Licensing and Design Certification: Im</i> – Light Water SMR's are not simply shrunken PWR's (enhanced safety) and should have different (i.e. smaller, less restrictive) siting requirements. NRC currently not prepared to do this. + Positive signals that NRC will establish policy on broad siting and ops safety expectations by end of 2015</p> <p>- <i>Funding & Financing of SMR's: Im</i> – FOAK costs high with great risk (i.e.: certification, construction time, material selection, logistical challenges in assembly).</p> <p>+ Possible fixes: Build a showroom model with Fed \$ support. Fed \$ to cover excess FOAK costs of manufacture (could be Fed tax incentives or actual \$).</p> <p>- <i>Understanding SMR's in the Nuclear Energy Market: Im</i> – Smaller reactors produce less thermal energy which reduces energy efficiency. + More modules increases energy efficiency, increases energy stability (take one mod off line for maint/refuel vice all), marketing process heat will increase efficiency.</p> <p>- <i>Creating a Brand New Supply Chain: Im</i> – An effective SMR supply chain will need to be localized - despite the reactors being built off site, a great amount of the on-site infrastructure and materials will still require precision assembly. SMR material selection will be challenging (i.e.: to increase the efficiency of a unit)</p>
<p><i>The Advanced Microgrid, Integration and Interoperability</i>, March 2015</p>	Ward Bower, et al	A synopsis of many microgrid technologies and system configurations to be used for an "advanced microgrid" development activity. A compilation of microgrid status, advanced microgrid goals, requirements, new challenge, opportunities, tools for designs, and tools to strengthen infrastructure and standards activities.	<p>Critical need: improved resiliency of our electric grid. Goal: integrate advanced microgrids to operate in parallel with the utility distribution system and transition seamlessly to an autonomous power system.</p> <p>Benefits of advanced microgrids:</p> <ol style="list-style-type: none"> 1. Add resilience to grid infrastructure, compensate for variable supply of renewable energy 2. Ensure UPS for critical loads, control power quality and reliability at the local level, promote customer participation through demand-side management and community involvement in electricity supply 3. Enable grid modernization and interoperability of multiple smart-grid interconnections and technologies 4. Enhance integration of distributed and renewable energy resources to help to reduce carbon emissions, peak load congestion, and line losses
<i>Electricity</i>	Geoffrey	This paper provides a method for	KPs: SMRs, show promise in replacing coal

Publication Title, Date	Author(s)	Description	Issues (Iss), Impediments (Ims), key points (KPs), etc.
<i>Generating Portfolios with Small Modular Reactors</i> , May 2014	Rothwell, Ph.D. and Francesco Ganda, Ph.D	estimating the probability distributions of the levelized costs of electricity. These probability distributions can be used to find cost-risk minimizing portfolios of electricity generating assets including Combined-Cycle Gas Turbines (burning natural gas), coal-fired power plants with sulfur scrubbers, and Small Modular Reactors, SMRs.	units while natural gas prices are low and could be built to replace natural gas units as the price of natural gas rises. To reduce the unknowns associated with carbon emissions and to reduce the volatility of electricity prices, electric utilities, and their investors and financiers, should consider adding new nuclear power to their unnaturally gas-heavy (CH4 and CO2) generating assets.

APPENDIX H: SUMMARY OF OR-SAGE RESULTS FOR AFSPC INSTALLATIONS

Installations	50 Acres	Pop Den	Wetlands	Protected	Landslide	Flood	Slp >18%	Fault Ln	Haz Fac	.25 g	.5 g	84k gpm	65k gpm	20k gpm
Buckley AFB CO														
Cape Canaveral AFS FL													Ocean cooling available	
Cape Cod AFS MA	Massachusetts has current legislation against building new reactors in the state.											Ocean cooling may be available		
Cavalier AFS ND														
Cheyenne Mtn AFS CO								Except road						
Los Angeles AFB CA	California has current legislation against building new reactors in the state.											Ocean cooling available		
New Boston AFS NH	Previous bombing range still being cleared. Significant historical/cultural artifacts from fence to fence.													
Patrick AFB FL													Ocean cooling available	
Peterson AFB CO	Colorado Springs owns 90% of the land Peterson sits on													
Schriever AFB CO														
Vandenberg AFB CA	California has current legislation against building new reactors in the state.											Ocean cooling available		
Plant footprint of at least 50 acres (20 hectares)													No issues	
Population density less than 500 people per square mile within two miles of the site boundary													Partial Issues	
Wetlands and open water are excluded													Full Issue	
Protected lands (e.g., national parks, historic areas, wildlife refuges) are excluded														
Land with moderate or high landslide hazard susceptibility is avoided														
Land that lies within a 100 year floodplain is excluded														
Land with a slope of greater than 18% (~10°) is avoided														
Land too close to identified fault lines is avoided (the length of the fault line determines the standoff distance)														
Land located in proximity to hazardous facilities (commercial airports with a 5-mile buffer and oil refineries with a 1-mile buffer) is avoided														
Land with safe-shutdown earthquake peak ground acceleration (2% chance in a 50 year return period) greater than														
a. 0.25 g is excluded														
b. 0.50 g is excluded														
Land areas that are more than 15 miles from sufficient cooling water makeup sources (based on taking no more than 10% of available stream flow calculated using 7-day, 10-year low flow data) of at least														
a. 84,000 gpm are excluded														
b. 65,000 gmp are excluded														
c. 20,000 gpm are excluded														

APPENDIX I: PRIORITIZED SPACE SUPERIORITY ACTIVITIES

Prioritized Space Superiority Activities	Schriever	Buckley	Clear	New Boston
1. Nuclear Survivable Communications				
2. Launch Detection / Missile Warning				
3. Position, Navigation and Timing (PNT)				
4. Space Situational Awareness & Battlespace Awareness				
5. Assured Space Access / Spacelift				
6. Space Command and Control				
7. Defensive Space Control				
8. Satellite Operations				
9. Protected, Tactical Communications				
10. Offensive Space Control				
11. Unprotected Communications				
12. Space to Surface ISR				
13. Terrestrial Environmental Monitoring				
14. Nuclear Detonation Detection				
Mission priority by installation	1	2	3	4

6. REFERENCES

See Appendix B for References to SMR Guidance and Policy G for References to SMR Studies and Reports.

DISTRIBUTION

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