

# Small Modular Reactor Hanford Site Analysis

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Final Report

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## Conclusions and Recommendations

On March 6, 2014, the state of Washington awarded a grant to the Tri-City Development Council (TRIDEC) to study the Hanford Site as a possible location to construct one of the nation's initial small modular reactor (SMR). This study explores the feasibility of redeploying existing assets at Hanford to realize potential cost savings from current Hanford operations, which can offset the high costs of licensing and constructing an initial SMR on the site.

### Conclusions

The study concluded that siting an SMR generating station at Hanford is technically feasible and many benefits come from using the existing infrastructure, local nuclear workforce, and other regional assets. Siting SMRs at Hanford will require a close partnership with the U.S. Department of Energy (DOE), state of Washington, and regional utilities and power planners. The study also reached the following conclusions regarding deployment of SMRs in the United States (US) and the viability of successfully siting an SMR at the Hanford Site:

### National Deployment of SMRs

1. Deploying SMRs in the US is a major objective for DOE due to the enhanced safety, carbon free base-load electricity, siting flexibility, and the smaller capital investment compared to large nuclear plants. The Secretary of Energy states that acceleration of timelines for SMRs through cost sharing with industry is one of his key goals.
2. The added cost to design, test, and achieve Nuclear Regulatory Commission design certification for the first SMRs licensed in the US could be about \$1 billion for each SMR vendor. Additionally, the cost to design and license a full SMR power station to be constructed at the owner's site could incur an additional \$1 billion in first-of-a-kind costs, borne by the purchasing utility. These large first unit costs require partnering between vendors, utilities, and the government to minimize impacts of the startup costs, which would mitigate the uncertainty of power prices eight to ten years from now.
3. Current DOE support for deployment of SMRs through its \$452 million Small Modular Reactor Licensing Technical Support Program is helpful, but insufficient. Additional funds are required to offset reactor design certification costs for multiple vendors and to assist utilities with costs to develop and license designs of the initial SMR generating stations.
4. If DOE is to achieve its stated intent of "shortening the timelines for SMRs through cost-sharing arrangements with industry partners," assistance of about 50 percent of the first-of-a-kind costs may be necessary for this technology to be deployed in the US.
5. DOE is positioned to help deploy SMRs by offering loan guarantees and mandating that DOE (and possibly other agencies, such as the Bonneville Power Administration) purchase the power generated by SMRs through long-term power purchase agreements and/or SMR energy credits similar to those in place for renewable energy.
6. Individual states could further reduce business risk for SMRs by including SMR generated power in mandated clean energy portfolios and/or by offering tax incentives. SMR power generation provides a stable carbon free base load to the power grid, enhancing effective use of less predictable clean energy sources such as wind and solar.

### Siting SMRs at Hanford

1. The Hanford Site and Pacific Northwest National Laboratory have a clear need for additional electric power as power consumption increases by 150% by 2022, thus benefitting from SMR power generated at Hanford.

2. Siting an SMR at the Washington Nuclear Power Plant Unit No. 1 site, leased from the DOE-Richland Operations Office by Energy Northwest and adjacent to the Columbia Generating Station, is technically feasible and would benefit from over \$300 million in existing assets, documentation, and cost avoidances. These assets could represent a substantial portion of a cost sharing arrangement with DOE.
3. Siting an SMR generating station near an operating commercial nuclear power plant offers attractive advantages such as shared services, infrastructure, and licensing agreements and permits. The Hanford Site is the only DOE site with an operating commercial and licensed nuclear power plant.
4. Hanford and the Tri-Cities region offer major resources such as a large, nuclear-trained workforce, nuclear qualified emergency services, and a local business base of nuclear engineering and manufacturing services that could enhance the attractiveness of siting an SMR at Hanford.
5. The state of Washington could further reduce business risk for an SMR sited at Hanford by including SMR-generated power in mandated clean energy portfolios or offering tax incentives for SMR generated power. SMR power would offer a carbon free baseload alternative that would help offset generation fluctuations associated with the large wind energy component in the state's energy portfolio.
6. Based on the Federal Energy Management Program-compliant preliminary assessment performed by Johnson Controls, Inc., savings over the first 23 years of conversion of the Waste Treatment and Immobilization Plant to natural gas could finance a new natural gas-fired steam plant and leave about \$70-165 million for other Hanford energy initiatives, such as a Hanford SMR.

### **Recommendations**

In addition, the study team makes the following recommendations. TRIDEC should:

1. Interface with Washington State congressional delegation to help members understand the Hanford Site savings that could stem from converting to natural gas to produce steam for treating Hanford's nuclear waste and offsetting the cost of an SMR cooperative agreement, over time. Draw other community leaders into these discussions.
2. Conduct meetings with DOE officials, the Washington State congressional delegation, and other energy communities interested in expanding DOE's current SMR Licensing Technical Assistance Program to include utilities that build the first three to five SMR generating stations in the US.
3. Encourage federal and/or DOE guidelines to be changed to require agencies to incorporate reduction of greenhouse gasses through all clean energy sources as an alternative to simply purchasing renewable energy. While the impact of the current requirements to purchase renewable energy or renewable energy credits is a minor consideration for Hanford planning, reconsideration of the federal energy goals to include reduction of greenhouse gasses through all available means would result in making SMR electricity more attractive and would further other national objectives.
4. Work with Tri-Cities community leaders to interact with the Northwest Power and Conservation Council, Bonneville Power Administration, and other northwest power planning organizations to exchange information related to new generation planning for the Northwest and to incorporate nuclear power into planning documents and ensure dependable approaches are proposed to meet northwest power needs. Consider

requesting nuclear power generation be added to the Northwest Power and Conservation Council Resource Strategies Advisory Committee.

5. Encourage similar changes to Washington State statutes to allow utilities to meet new energy goals with carbon free energy sources other than renewables. Develop legislation that would revise the priorities of the Pacific Northwest Electric Power Planning and Conservation Act of 1980 to include nuclear power as a means of reducing greenhouse emissions. Also promote tax incentives for SMR power generators and/or users.

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## Executive Summary and Background

### *National and Northwest Regional Concerns about Climate Change and the Nation's Energy Future*

President Barack Obama stated the importance of nuclear power in his March 2012 call for an “All of the Above” strategy to use carbonless power generation to solve growing climate change issues. However, even though nuclear power currently represents the nation’s largest carbon free energy source, the nuclear industry has remained flat since the 1970s while utilities move toward replacing coal power plants with natural gas plants to reduce carbon dioxide and other emissions. Natural gas represents only a 50% carbon reduction below that of coal and produces 1,220 lbs of carbon dioxide per megawatt-hour, perpetuating climate change concerns. The shift to natural gas reduces diversity in the nation’s energy portfolio, which could have adverse impacts not just for commercial use but, more importantly, in support of national security.

In view of nuclear energy’s importance to achieving carbon free energy objectives, Secretary of Energy Ernest Moniz recently called “...*acceleration of the timelines of small modular reactors through cost-sharing arrangements with industry partners...*” one of his key goals. Small modular reactors (SMR) have the advantage of enhanced safety, siting flexibility and lower capital cost than conventional large nuclear plants while producing zero carbon emissions.

On March 6, 2014, the state of Washington awarded a grant to the Tri-City Development Council (TRIDEC) to study the Hanford Site as a possible location to construct one of the nation’s initial SMRs. Hanford has a unique combination of siting advantages that could offset costs of building and operating an SMR. The grant allows TRIDEC to evaluate and quantify these advantages to test the feasibility of attracting financing, attaining owner sponsorship, and selling the power produced by an SMR located at Hanford. TRIDEC retained the URS Corporation, supported by Johnson Controls, Inc., and Independent Strategic Management Solutions, Inc., to analyze Hanford as a site for one of the nation’s first SMRs.

### ***SMR Deployment must be Initially Supported by the Federal Government.***

Deployment of SMRs in the United States (US) faces hurdles that are not uncommon for new capital-intensive technologies. While SMRs are an attractive carbon free energy source, they present difficulties for reactor vendors and utilities to license and build the first SMR generating stations. The study concluded that SMR deployment is unlikely unless sufficient federal assistance is made available. Three primary hurdles must be overcome.

1. **First-of-a-Kind Costs.** Capital and operating costs of SMR plants vary widely across the different reactor designs. Currently, the reactor industry is using capital cost figures of about \$2.5 billion for a 540 megawatt electric (MWe) multi-module SMR plant. This cost compares to \$7 billion for a conventional 1,100 MWe nuclear plant. Each SMR vendor will incur additional costs for deploying its first reactors. The added cost to design, test, and achieve Nuclear Regulatory Commission design certification could be about \$1 billion for each SMR vendor. Additionally designing and licensing the first full SMR power stations to be constructed at a given site could incur an additional \$1 billion in first-of-a-kind costs, borne by the purchasing utility. These large first unit costs present a difficult obstacle to for vendors and utilities to overcome alone.

- ✓ The initial SMRs will bear first-time design and licensing costs.
- ✓ Anticipated, mature cost of a 550 MWe SMR generating station is: ~\$2.5B.
- ✓ Added vendor costs for first SMRs is: ~\$1B.
- ✓ Added utility cost for first SMR generating stations is: ~\$1B.

2. **Business Risk/Financing.** With high first-of-a-kind costs and power market price uncertainties after the eight to ten years needed to license and construct SMR generating stations, utility boards and financiers are unlikely to accept the risk of being the first to build SMRs. As with other major technology deployments such as wind energy, the vendors and utilities cannot face the financial risks alone.
3. **Competition with Natural Gas.** Natural gas power generation is seen by utilities as less risky than new nuclear plants because natural gas plants are relatively easy and quick to construct and have lower capital costs. Utilities are attracted by natural gas prices, which have decreased due to the discovery and development of large gas reserves in the past decade. Consequently, when climate change is not taken into consideration, natural gas plants are often viewed as the best option for replacement and new generation in the US. Utilities are beginning to express concerns about the loss of fuel source diversification and potentially adverse impacts of higher natural gas prices in the future, as current low natural gas prices are threatened by carbon taxes, price escalation due to export, and environmental concerns with fracking and transportation. Federal leadership and policies can become a valuable tool to mitigate the risks of dependence on natural gas.

### **Government Industry Cost Sharing could Jump-Start SMR Deployment in the US.**

The U.S. Department of Energy (DOE) initiated its \$452 million Small Modular Reactor Licensing Technical Support Program to assist SMR reactor vendors in 2012. While this program is helpful, the study concluded that the funding is insufficient to overcome the financial risks that must be weighed by utilities, reactor vendors and the financing community. This national issue could cut short the Secretary of Energy's objective to deploy SMRs unless first-of-a-kind costs can be shared among DOE, SMR vendors, and purchasing utilities so financing risks are reduced.

A cost sharing program supported by DOE, SMR vendors, and utilities should be established to address initial plant capital costs, financing risk, and sale of the SMR power produced. The program should include:

- **Buy-Down of Capital Costs for the First SMRs.** First-of-a-kind costs for each SMR design total about \$2 billion for the first reactor modules and generating station. These costs are not likely to be shouldered by the vendors or utilities alone, given the uncertainty of power prices eight to ten years from now. If DOE assisted with half of these costs, it would total about a \$1 billion DOE commitment for each SMR design deployed or \$4 billion if all four of the most mature designs were supported. DOE's commitment would be smaller, about \$1-2 billion, if purchasing utilities used procurement processes to reduce the number of SMRs supported to the most viable one or two designs.
- **Share Financing Risk.** The mission of DOE's Loan Guarantee program is "to accelerate the domestic commercial deployment of innovative and advanced clean energy." The guarantees are available for a variety of clean renewable energy sources, but they do not

- ✓ Government and industry must work together to share the costs and risks of deploying the first SMRs.
  - Share initial reactor design certification costs.
  - Share first SMR plant design and licensing costs.
  - Reduce financing risk through DOE's loan guarantee program.
  - Use long term federal power purchase agreements at prices that offsets initial costs.
  - Require SMR power use by federal agencies (as for renewables).
- ✓ The current DOE cost share program helps but is insufficient in magnitude and does not cover utility costs.

specifically state eligibility of SMR generated power. Because SMRs emit zero pollutants or greenhouse gases and could provide peaking capacity and system flexibility that enhances less predictable renewable energy generation, they should be given the same consideration as these other carbon-free technologies. Loan guarantees would offset the financial risk of default for an SMR project.

• **Power Price Support**

- *Power purchase agreements (PPA).* DOE sites across the US have large annual power needs to operate high use facilities such as Hanford’s Waste Treatment and Immobilization Plant and many of the large computing centers and particle accelerators located at DOE’s national laboratories. DOE is in a position to mandate that the power from initial SMRs be purchased for these needs using long-term PPAs at prices that justify financing. Executive Order 13513 issued October 2009 mandates that 20 percent of the total amount of electric energy consumed by each agency during any fiscal year shall be renewable energy by 2020, setting a precedent for assisting new energy technologies with guaranteed power pricing. Upfront PPAs would lower financial risks to utilities and financiers.
- *SMR energy credits.* If SMRs were added to the list of clean energy sources that qualify for energy credits, deployment of SMRs would have the same investment advantage as renewables such as wind and solar power.
- *SMR power in state-mandated energy portfolio policies.* Some states have enacted measures to move power consumption toward clean or renewable power sources. For instance, Washington State requires that the power portfolios of major utilities include no less than 15 percent renewable or clean energy by 2020. States should consider the same approach for clean energy produced by SMRs.

A cost sharing program of this nature could increase the overall chance to complete and certify one or more SMR designs, attain decisions by one or more utilities to construct SMR plants, and successfully finance the project. This study also recommends that several SMRs be based upon the designs supported by DOE to ensure diversification of the nation’s energy portfolio and jump-start the SMR industry in the US.

**Hanford and Northwest Utilities have Increasing Power Needs.**

The Bonneville Power Administration (BPA) forecasts a power deficit of over 500 MWe by 2021. While BPA plans to mitigate the shortfall through conservation measures, many northwest utilities are skeptical that conservation alone will be sufficient and are open to new power generation. The Hanford Site and Pacific Northwest National Laboratory have a clear need for additional electric power as power consumption will increase by 150% by 2022.

A Hanford SMR generating station could benefit the Northwest, satisfy the site’s power needs, and help forge the way for future SMR deployments elsewhere if the hurdles described above can be overcome. Local utilities interviewed expressed interest in purchasing power from an SMR constructed at Hanford, possibly at a small premium compared to other sources. This new power source could help mitigate future northwest power deficits forecasted by the BPA.

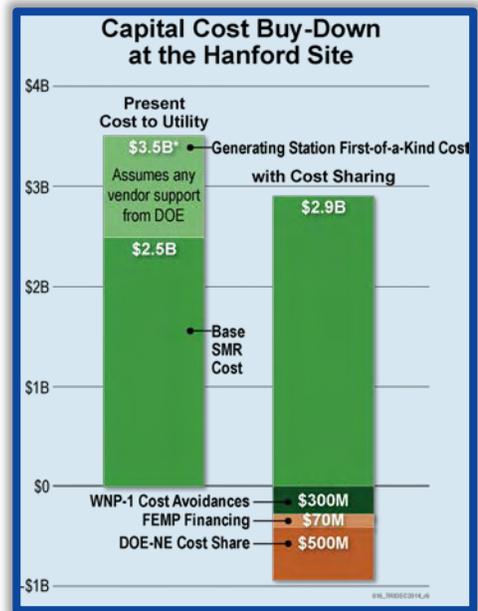
- ✓ The BPA forecasts a 507 MWe deficit by 2021.
  - It is relying on conservation to close this shortfall.
  - Northwest utilities expressed doubt that conservation will be adequate.
- ✓ Hanford power needs are expected to increase 150% by 2022.
- ✓ Local utilities interviewed expressed interest in buying Hanford SMR power.

**Siting an SMR at Hanford Could Work under a Cost-Sharing Arrangement.**

The study revealed that siting an SMR generating station at Hanford is technically feasible and many benefits come from using the existing infrastructure and local nuclear workforce and other regional assets. Siting SMRs at Hanford will require a close partnership with DOE, the state of Washington, and regional utilities and power planners.

The study recommends pursuing construction of an SMR generating station at the Washington Nuclear Power Plant Unit No. 1 (WNP-1) site, located on property leased from DOE by Energy Northwest and adjacent to the Columbia Generating Station, an NRC-licensed, 1,170 MWe nuclear plant. This site includes the unfinished WNP-1 power plant licensed for construction in 1973, but which was terminated in 1982 at 65 percent complete. Siting an SMR at the WNP-1 site could reduce capital costs by about \$300 million by using the constructed infrastructure and licensing documentation that has been maintained by Energy Northwest since project termination. Siting at this location also could allow sharing of nearby DOE and Energy Northwest services and use of the large nuclear workforce and business base offered by the Tri-Cities region. Energy Northwest has expressed its support to use the WNP-1 site and be the SMR plant operator.

A cost sharing arrangement for a Hanford SMR generating station is feasible if DOE and the state of Washington are willing to support the initiative in the ways discussed above. Additionally, a conceptual cost sharing arrangement is feasible wherein Energy Northwest would bring approximately \$300 million in WNP-1 infrastructure assets and documentation and DOE would participate by sharing the cost of siting one of the nation’s first SMRs at WNP-1 (\$500 million) and providing loan guarantees, a long-term PPA for the Hanford SMR-generated power, and other price support measures at a national level. The state of Washington should also participate by working with northwest power planners to include SMR generation and support the purchase of SMR power through its clean energy portfolio policies for utilities.



Energy cost savings for operation of the Hanford Site, such as a large energy savings investigated by the study team through the Federal Energy Management Program (\$70 million capital contribution) can also contribute to a Hanford SMR and could offset all or part of the DOE cost-sharing commitment.

**Recommendations from the Study**

Results of the study include recommendations that TRIDEC work with northwest utilities and power planners, federal and state legislators, DOE, and the Washington State Governor and Legislature to garner the support needed to bring this important power technology to fruition in the US and the state of Washington. In addition, the study recommended collaborating with other DOE communities such as Oak Ridge, Tennessee; Idaho Falls, Idaho; and Aiken, South Carolina to gain broad coordinated political support for SMRs. A combination of capital support, guarantees, and/or power price support could ensure that SMR technology can be deployed as an important element of the nation’s energy future.

## 1.0 Introduction

Across the United States (US), recent interest has grown in developing and employing small, inherently safe nuclear reactors known as small modular reactors (SMR). Advantages of SMRs over large, traditional nuclear power plants include lower initial capital investment, enhanced safety, scalability, and siting flexibility at locations unable to accommodate larger reactors.

The URS Corporation was retained by the Tri-City Development Council (TRIDEC) to analyze siting a commercially designed SMR at the Hanford Site. URS teamed with Johnson Controls, Inc., the current Hanford Site Energy Savings Performance Contractor and Independent Strategic Management Solutions, Inc., a local small business that has expert knowledge of the U.S. Department of Energy's (DOE) Hanford energy plans and policies. This report documents the findings and recommendations of their analysis.

### 1.1 Background

Nuclear power plants currently generate about 19 percent of the electricity produced in the US. All of the nation's operating nuclear plants are large, generating up to 1,400 megawatt electric (MWe) and were mainly built during the 1960s and 1970s. Since then, new nuclear generating capacity has been difficult to attain. Utilities and investors have been concerned about the large capital cost and long construction cycle for large nuclear plants versus the lower capital costs and shorter construction periods for alternative power plants such as those fueled by natural gas. Although natural gas is currently the least expensive method for new power production, it still emits about 50 percent of carbon dioxide such as coal. Uncertainties and future economic and environmental pressures are likely to drive up the cost of natural gas in the coming years. Natural gas relies heavily on low, stable gas prices which could be adversely affected by carbon taxes; price escalation due to export of natural gas and environmental concerns with extraction, production, and transportation. Due to these uncertainties in future gas prices versus relatively stable prices for uranium fuel, SMRs are being more seriously considered in the US as a reliable and potentially cost-effective means to generate electricity.

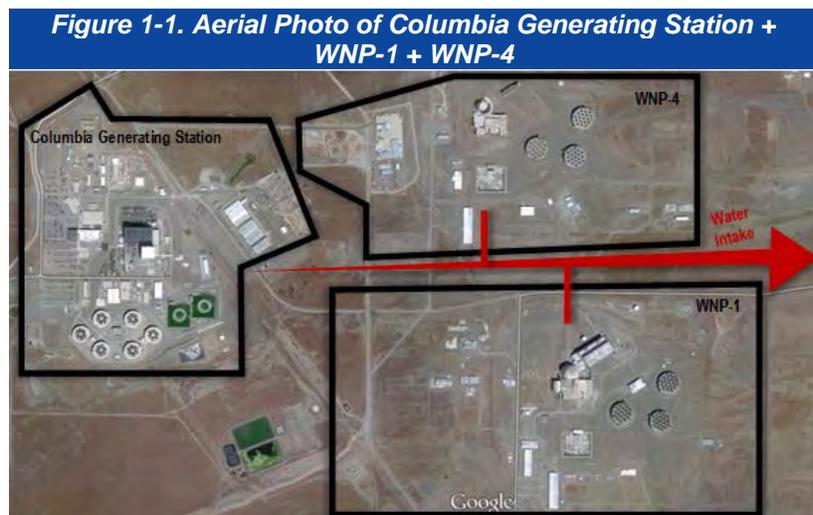
The first several SMR plants that undergo Nuclear Regulatory Commission (NRC) licensing, construction, and commissioning will bear the brunt of startup costs for this first-of-a-kind technology. In 2012, the DOE-Office of Nuclear Energy (DOE-NE) Small Modular Reactor Licensing Technical Support Program began a cost-sharing program to advance certifying and licensing domestic SMR designs that are relatively mature and can be deployed in the next decade. While this program offsets some of the technology startup costs for the reactor design and licensing, it is insufficient to cover more than a fraction of all first-of-a-kind costs that will be incurred. Consequently, the first SMRs will have higher break-even power prices than the market will be able to bear, creating high risk for owners and investors. However, careful examination of the market and world trends show that power production by fossil fuels and renewable fuel sources such as wind and solar carry risks of their own that could adversely affect their prices. Beyond pricing, considerations of national security, national energy independence, integrity and robustness of the US defense supply chain, and other factors affecting US global positioning argue persuasively for building a reliable and safe nuclear power infrastructure in this country. SMRs represent then, not just "electrons on the grid," but a crucial step in the inevitable transition of the US toward an all-electric economy that is competitive and sustainable in the world.

The Hanford Site offers an advantageous combination of siting advantages that could offset costs of building and operating one of the nation's initial SMRs. The Hanford Site itself and the surrounding Tri-Cities community possess the trained nuclear workforce; scientific expertise; supportive local community; engineering and manufacturing companies; emergency services; and physical assets presented by only a few places in the nation.

During the 1970s to mid-1990s, Hanford was a primary DOE site for the development of advanced nuclear reactors for commercial power generation, space exploration, and other beneficial nuclear technology applications. This mission helped grow the Pacific Northwest National Laboratory (PNNL), which is located at the southern edge of the Hanford Site in Richland, Washington. PNNL is now ~4,000-person, multi-program research facility, operated for the DOE-Office of Science (DOE-SC). In the early 1970s, DOE leased three square miles of land to the Washington Public Power Supply System (now Energy Northwest), a joint operating agency commissioned by the state of Washington and comprised of 27 northwest public utilities, to construct three large nuclear power plants. One of the plants, Columbia Generating Station, was completed in 1984 and currently produces about 1,170 MW of electricity. The other two plants, Washington Nuclear Power Plant Units 1 and 4 (WNP-1 and WNP-4), were partially constructed but not completed.

The WNP-1 site, about 65 percent complete, was maintained in its partially constructed state for many years and was partly funded by the Bonneville Power Administration (BPA). Much of the infrastructure supporting the planned WNP-1 plant remains intact, in good condition, and could support future nuclear power missions. The WNP-4 facilities were about 40 percent when the project was terminated in 1982. At that time, they were less complete than those of WNP-1 and have been less well maintained.

**Figure 1-1** and Figure 6-1 on Page 19 show the location and proximity of the Columbia Generating Station, WNP-1, and WNP-4.



**Figure 1-1. Aerial Photo of Columbia Generating Station + WNP-1 + WNP-4**

In addition to these capital, physical, and scientific assets, the Washington State Governor and legislature have shown increased willingness to consider the role of nuclear power in the Northwest, specifically at the Hanford Site. The state grant provides TRIDEC the opportunity to evaluate and quantify these advantages to test the feasibility to attract financing, attain owner sponsorship, and sell the power produced by an SMR located at Hanford.

## 1.2 Study Approach and Analysis

URS partnered with Johnson Controls and Independent Strategic Management Solutions, Inc., to assemble a multi-discipline team to analyze current data and evaluate the feasibility of siting an SMR on the Hanford Site. The study team included personnel with experience in the nuclear

power industry, the Federal Energy Management Program (FEMP) process, electrical and governmental agencies, and those familiar with nuclear history and regulations.

Analysis of Hanford for siting an SMR focused on seven areas. First, the study team analyzed the current state of nuclear power in the US and the world and compared nuclear cost and security factors with those of natural gas (Section 2.0). Next, the team worked with the DOE-Richland Operations Office (DOE-RL) to gain understanding of future electric power needs and policies for the site (Section 3.0). Then the price of power and alternatives for selling power produced by a Hanford SMR site were analyzed (Section 4.0). Next, the team worked closely with Energy Northwest to determine the value of capital assets and existing site characterization studies that conservatively represent significant cost avoidances for siting an SMR at the WNP-1 site (Section 5.0). Other alternative Hanford siting locations were analyzed for compliance with current Hanford land use policies and their advantages were compared to those of WNP-1 (Section 6.0). Other siting advantages offered by local community assets were evaluated (Section 7.0). Finally, a cost sharing strategy that could attract construction of an SMR at Hanford was considered (Section 8.0). Results from these seven areas are summarized in this report.

## 2.0 Current State of New Nuclear Power Generation in the US and the World

As of 2014, 100 nuclear power reactors operate in the US, generating approximately 590 terawatt (590 trillion watt) hours of electricity. This amount represents about 19 percent of the nation's electrical generation and 69 percent of its carbon-free power. The US currently generates approximately one-third of the electricity generated in the world from nuclear power and operates more reactors than any other nation. However, the US share of nuclear power production is quickly declining as much of the rest of the world rapidly expands and increases its nuclear power capability, along with significantly reducing diversification of our energy portfolio. Worldwide, 72 reactors are currently under construction with only 5 in the US. Worldwide, 174 additional reactors are in the active planning stage, with only 5 in the US. In addition, US nuclear plants are aging, averaging 32-44 years old. Most US nuclear plants were licensed for 40 years with 73 of them having received 20-year license extensions. Fourteen more have filed for license extensions with 15 more expected to file by 2018.

Today, the US consumes nearly 4 trillion kilowatt hours (kWh) of electricity per year, 13 times more than in 1950. Most of this power (about 70 percent) is generated by fossil fuels. Demand for power is growing, and about one-third of this electricity, or about 1.4-trillion kWh, is used by the industrial sector, a category that includes government entities such as DOE and the Department of Defense. Much of the rest of the world, including China, Russia, and India, will be major US competitors in the coming years and are currently transitioning their economies toward greater use of electrical energy and, specifically, energy generated by nuclear power. This also weakens US influence on world nuclear non-proliferation policies.

### Current State of New Nuclear Power Generation

- ✓ The US is rapidly losing its world leadership in production of nuclear power and diversification of its energy portfolio.
- ✓ The nation has shifted toward natural gas power generation due to low construction cost, near-term risk, and current low gas prices.
- ✓ The future price of natural gas is uncertain as gas reserves are limited and pressures exist to increase prices.
- ✓ SMRs have gained national attention as a clean power source because of siting and load management flexibility and lower capital cost.
- ✓ First-of-a-kind costs for SMRs are large and create an imposing barrier to deployment.

Beginning in 1974, high inflation rates caused by the oil embargo levied against the US resulted in high financing and construction costs, causing orders for nuclear power plants to fall sharply. No reactors were ordered after 1977 and delays and cancellations began on reactors that were being constructed. Poor project performance and cost overruns at plants being constructed in the 1970s, and tighter and lengthier regulations after the NRC was created in 1974, further contributed to the unwillingness of utilities to build more nuclear plants. In March 1979, the nuclear industry received a serious setback when an accident occurred at the Three Mile Island Unit 2 plant. Although there was no human or environmental harm, fear and distrust of nuclear power gripped the public. Further industry setbacks occurred with nuclear events at Chernobyl in 1986 and Fukushima Dai-ichi in 2011. The US nuclear industry remained flat until four reactors (Vogtle Units 3 and 4 and V.C. Summer Units 2 and 3) were ordered in 2008.

Although a “nuclear renaissance” was predicted early in the 21st century, no such surge has occurred in the US. The main reason is that vast deposits of natural gas have recently been discovered, along with new extraction technologies such as fracking and horizontal drilling.

## **2.1 *Natural Gas versus Nuclear Power***

The Energy Information Administration (EIA) estimates that about 2,214 trillion cubic feet (tcf) of natural gas is technically recoverable in the US. Using the 2013 rate of US consumption of about 26 tcf per year, the recoverable natural gas supply is projected to last about 85 years. Currently, most new power generation uses natural gas because of low capital and fuel costs.

### **2.1.1 Capital Costs**

New natural gas plants are seen by utilities as less risky and more attractive than new nuclear plants because they are relatively easy and quick to construct and have lower capital costs. By contrast, nuclear plants are more capital-intensive and slow to construct.

In most cases, a natural gas combined cycle (NGCC) can be built in two years, while the large nuclear plants currently under construction in the US are projected to take seven to eight years after the license to construct has been granted by the NRC. The total time from reactor order to operations is approximately ten years. Many utilities prefer to manage the risks of constructing and financing for as short a time as possible, preferring short-term NGCCs to nuclear plants due to a better understanding of near-term costs and the average term of corporate board members.

The lower cost of natural gas plants is largely due to their simplicity and smaller size compared to traditional nuclear plants. The two Vogtle Units 3 and 4 now under construction are estimated to cost about \$7 billion each, while an average NGCC (400-600 MWe), which is smaller than traditional large nuclear plants such as those at Vogtle, may cost \$500 million to \$1.3 billion, depending on the size and presence or absence of a carbon capture system. The EIA places the overnight capital cost (cost to construct without financing) per megawatt for a conventional, NGCC plant at 16 percent of the cost of constructing a traditional nuclear plant. For an advanced NGCC with a carbon capture system, the construction cost is about 38 percent that of a traditional nuclear plant.

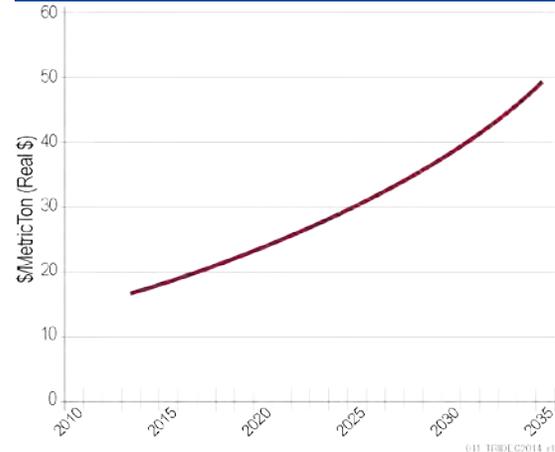
### **2.1.2 Fuel Costs**

Utilities are attracted by natural gas prices, which have decreased due to the discovery of large gas reserves in the past decade and new extraction methods. However, environmental concerns, pending or probable carbon taxes, and export pressures will likely cause prices to rise.

Natural gas is a fossil fuel that could potentially damage the climate. According to the Environmental Protection Agency (EPA), burning natural gas releases about half of the carbon dioxide (CO<sub>2</sub>) into the atmosphere as does burning coal, and about 70 percent that of burning oil. While replacing power plants burning coal with those burning natural gas, the nation will still be left with 70 percent of its power generation producing 1,220 lbs of CO<sub>2</sub> per MW-hour (MW-h). Carbon capture systems that capture CO<sub>2</sub> released from fossil fuel-burning plants and sequester it in deep underground storage sites are expensive, technically immature, and present environmental issues. If pursued and perfected, these capture systems would require retrofitting thousands of fossil fuel-burning installations in the US with carbon capture equipment, thus raising costs.

Congress and 19 states have been debating plans to levy carbon taxes or fees, impose environmental controls on new extraction techniques, and tighten regulation of all pipelines. California already imposes a carbon tax that amounts to about \$20 per ton of CO<sub>2</sub> emitted, and this rate is expected to rise to about \$50 per ton by 2040. In October 2013, the governors of Washington and Oregon signed an agreement with the governor of California and the Minister of the Environment of British Columbia, Canada, committing to add costs to greenhouse gas emissions. British Columbia and Alberta, Canada already have carbon taxes, as do Australia, India, Japan, New Zealand, many European nations, and some Central American nations. In the draft EPA carbon rule issued in June 2014, nuclear energy is named as a “best system of emissions control.” Under this rule, smaller nuclear plants such as SMRs will become useful to meet EPA’s requirements. **Figure 2-1** shows forecasted rises in CO<sub>2</sub> taxes for California.

**Figure 2-1. California’s CO<sub>2</sub> Tax Price Forecast**



Other pressures are likely to cause the costs of natural gas to rise. The EPA, which regulates the chemical components used in fracking, is considering regulating the entire fracking process. In addition, high demand for natural gas in Asia and other areas has produced prices that are 3 to 3.5 times higher than those in the US. This condition has increased plans to export natural gas. According to industry experts, exports will drive prices in the US market and Asia to converge in the next few years. Richard Guerrant, Exxon Mobil’s global vice president for liquid natural gas, stated that “*with the price of natural gas around \$3.5, we can land liquid natural gas in Asia for \$11-12 (per million British thermal units)...over time, you can expect a convergence of prices*” (somewhere in the middle).

By contrast, nuclear fuel has many advantages that bode well for the future. Once nuclear plants are constructed, their fuel costs are lower than gas and relatively stable. Presently, the EIA estimates that fuel costs for a nuclear plant total 24-25 percent of an NGCC and 21 percent of an NGCC equipped with a carbon capture and storage system. Nuclear power releases no gases into the atmosphere and provides steady baseload power. Utilities are becoming increasingly wary of losing fuel diversity in their generation portfolios, placing their industry at risk due to uncertain gas prices and availability.

Recognizing the price uncertainty and carbon emission issues of natural gas and knowing that wind and solar power do not provide stable baseloads, Secretary of Energy Ernest Moniz recently called “...*acceleration of the timelines of small modular reactors through cost-sharing arrangements with industry partners...*” one of his key goals. In August 2014, he told a gathering of energy leaders and political leaders in Idaho that the energy industry must adapt, modernize, and use nuclear power to minimize climate change.

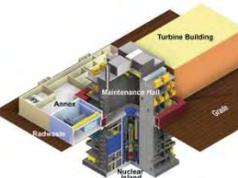
## 2.2 Types of Small Modular Reactors

SMRs may be either light water reactor (LWR) or non-light water reactor (non-LWR) designs, with a 300 MWe power capacity or less per module. A module is typically comprised of an integrated reactor and steam turbine generation system. The 300 MWe classification is consistent with the International Atomic Energy Agency (IAEA) definition used for small and medium-sized reactors. LWR SMR designs come closer to current conventional power reactor designs in that water is used to cool the reactor, using well-known, proven technology as the basis for the reactor’s design. Non-LWRs use different coolants such as molten metals or salts. For the purposes of this study, LWR SMR designs are the only ones technically mature enough to be considered in the near term.

The NRC considers an SMR to be an LWR design, with a 300 MWe generation capacity or less based on the “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition” (NUREG-0800). DOE extends the definition of SMRs to those whose major steam supply system components can be fabricated in a factory environment and shipped to the location where the reactor will operate.

SMR designs vary widely. Typical designs incorporate advanced features to enhance safety, capital cost, and operating efficiency. Examples include simplified component designs, advanced safety features that use natural phenomenon such as gravity or convection to control the reactor during off-normal events, existing commercial fuel designs, below-grade positioning, and extended periods between refueling and maintenance outages. These features reduce the need to construct safety class structures at the power plant site, lowering construction costs.

Examples of SMRs in various stages of development for the US market are shown in **Table 2-1** on the following page. Each of these SMRs is based on an LWR design, but they have major differences in technical readiness and other parameters. This study was not conducted using any single SMR design as a basis for cost estimates or other aspects. Instead, the study is based on a generic LWR SMR and uses general scaling of power plant systems, such as heat removal or power switch gear systems, for a plant station comprised of multiple modules totaling about 500 MWe generating capacity.

Table 2-1. Light Water Reactors		
SMR	Description	
NuScale Power™, LLC Module		The NuScale Power, LLC module is a new kind of nuclear power plant, a smaller, scalable version of pressurized water reactor technology with natural safety features which enable it to safely shut down and self-cool. Each NuScale power module has a power capacity of 45 MWe and has a fully integrated, factory-built containment and reactor pressure vessel. The NuScale SMR will be mass-produced in a factory and shipped by truck, rail, or barge for power stations generating between 45-540 MWe.
Babcock & Wilcox Co. (B&W) Generation mPower™ Reactor		The B&W mPower reactor design is a 180-MWe advanced LWR design that gravity, convection, and conduction to cool the reactor in an emergency with a belowground containment.
Holtec International SMR-160™		The Holtec SMR-160 is a 160-MWe reactor with an underground core. Holtec states that there is no need for a reactor coolant pump or offsite power ability to cool the reactor core.
Westinghouse SMR		The Westinghouse SMR is a 200-MWe integral pressurized water reactor with all primary components located inside the reactor vessel. It is based on the established Westinghouse AP1000® reactor design, which is being built in new nuclear plants around the world.

**2.3 Base Cost of SMR Construction and Operation**

SMR vendors consider their cost estimates to construct and operate their respective SMR power plants to be proprietary. Capital and operating costs of an SMR will vary widely across the different designs and sizes of the SMR power plants (number of modules). Currently, the reactor industry is using capital cost figures of approximately \$2.5 billion for a 540 MWe multi-module SMR plant. This cost compares to \$7 billion for a large, conventional 1,100 MWe plant, such as the 1,117 MWe Westinghouse AP1000. A \$2.5 billion capital cost is consistent with the levelized cost of power for SMRs, considered to be in the range of \$85 MW-h. Levelized cost of energy is defined as the constant price per unit of energy that causes the investment to break-even.

**Base Cost of SMR Construction and Operation**

- ✓ Current US SMR designs are projected to cost about \$2.5B for 500-600 MWe multiple module plants.
- ✓ Costs will be higher for the first plants built due to design, licensing, supply chain, and construction development.

Each SMR vendor will incur additional costs for deploying its first-of-a-kind technology. The cost to design, test, and achieve NRC design certification could be about \$770 million to \$1 billion for each SMR design. Additionally, the cost to design and license a full SMR power station could create additional \$700 million to \$1 billion first-of-a-kind costs, borne by the purchasing utility. These large deployment costs present obstacles for vendors and utilities.

**2.4 Funding Support for Developing SMRs**

Until recently, planning and design work on SMR technologies was at a relatively early stage. In 2010, DOE-NE requested Argonne National Laboratory to examine the economics of SMRs. In

2012, the laboratory initiated the Small Modular Reactor Licensing Technical Support Program to advance certification and licensing of domestic SMR designs that are relatively mature and can be deployed in the next decade. DOE funds have been and continue to be used for design engineering and testing to receive design certification from the NRC.

In 2012, NuScale, along with B&W, Holtec, and Westinghouse applied for funding from the SMR development program. DOE selected B&W's mPower SMR design in that first solicitation. Under cooperative agreements with DOE, B&W will receive \$150-226 million of the \$452 million available through the program. In December 2013, DOE announced it would fund up to half the cost to develop, license, and commercialize NuScale's 45 MWe reactor's design.

While DOE's \$452 million program for SMR vendors is helpful, it is likely too small to overcome the huge first-of-a-kind costs incurred by each reactor vendor. Also, DOE's current program does not assist with the first-of-a-kind costs that will be incurred by utilities for the initial SMR generating plants constructed. A more aggressive cost-sharing program that spreads these costs among the vendors, utilities, DOE, and ratepayers will likely be needed before the first SMRs are built.

DOE is in a good position to further leverage SMR development by working with Congress to support national deployment of SMRs through price support measures, loan guarantees, and other tools, as has been done for other clean energy sources. In addition, DOE could enter into a PPA for the large amounts of electricity it uses in cleanup programs managed by the DOE-Office of Environmental Management and in the accelerators and laboratories managed by DOE-SC. PPAs could benefit DOE over time, as the costs of SMR-generated power come into parity or fall below those of other power sources.

## **2.5** *Licensing and Regulatory Requirements/Regulatory Guidance Applicable to SMRs*

While licensing issues have emerged due to the multiple-module nature of SMR power plants, the NRC has worked closely with license applicants to resolve these issues and encourage construction of SMR-based power plants.

The NRC has accomplished much to expedite review and licensing of SMRs. For instance, it has modified portions of NUREG-0800 for SMRs. This regulation prescribes standard review procedures for safety analysis reports submitted as part of license applications for nuclear power plants. The NRC also issued a final revision to the "Light-Water Small Modular Reactor Edition" section of NUREG-0800 in early 2014. A key issue for the NRC will be modifying rules that govern the number of modules that can be operated by one crew of workers. Present rules apply to large nuclear plants that are not composed of modules. Major licensing issues for SMRs and status or resolution are shown in **Table 2-2** on the following page.

**Table 2-2. Major Licensing Issues**

Licensing Issue	Status or Resolution
Review of new safety features	NRC reviews are underway for mPower; soon for NuScale
Lack of NUREG-0800 standard review plans for SMRs	In early 2014, the NRC issued a new section to the LWR Standard Review Plan for SMR review methodology
Multi-module power plants: Currently, the NRC requires each reactor to be licensed with stand-alone safety systems	The NRC has prepared draft proposal criteria assessing multi-module risk consistent with 10 CFR 50, Appendix A
Radiological source term characterization for multi-module reactor facilities	The Nuclear Energy Institute developed a white paper that NRC is using as an outline of options for analyzing design-specific source terms. The NRC is working with the Idaho National Laboratory, NuScale, and mPower to finalize methodology
SMR-specific design certification application requirements are needed	The Nuclear Energy Institute submitted a white paper to the NRC proposing phased design certification application submittals for SMRs to provide time to develop inspections, tests, and analyses acceptance criteria for SMRs

### 3.0 DOE’s Future Power Needs for the Hanford Site and Northwest Region

#### 3.1 Regional Power Needs

BPA conducts planning activities to ensure that an adequate supply of power is available for the Northwest. Every two years, BPA issues updates to the “Pacific Northwest Loads and Resources Study” (White Book) and the “Resource Program.” Together, these two documents estimate electric generation resources and load requirements on BPA’s system and for the Northwest. They also evaluate new resources to meet power demands to mitigate shortfalls in the system. In June 2013, BPA issued the “Case for Conservation,” which documented previous savings from conservation and detailed a market-based case for conservation as the most viable means to meet northwest power demands in the foreseeable future.

**DOE’s Future Power Needs for the Hanford and Northwest Region**

- ✓ BPA asserts that production shortfalls projected by 2021 can be mitigated by conservation.
- ✓ Northwest utilities doubt that conservation will be sufficient and believe new generation will be required.
- ✓ DOE’s Hanford average power needs will triple by 2022.
- ✓ Local utilities are interested in buying Hanford SMR power if competitively priced.

Plans for future capacity are strongly influenced by the Northwest Power and Conservation Council (Council). The most recent planning document prepared by the Council was the “Sixth Northwest Conservation and Electric Power Plan Mid-Term Assessment Report,” dated March 13, 2013. A key conclusion of this report states, “An updated analysis shows that with existing resources and projected energy efficiency, the region’s adequacy will fall short of the desired level by 2017. While new resources are expected to close this gap, the Council will continue to monitor regional resource adequacy.”

The most recent editions of the White Book (October 2013) and the Resource Program (February 2013) closely reflect analyses and conclusions in the Council’s Sixth Power Plan. The White Book projects a 507 MW avg deficit in the BPA system by 2021. The Resource Program proposes that deficits in 2021 will be mitigated by meeting conservation targets first and market purchases second. Both BPA and the Council are relying heavily on current trends to continue.

Analyses show that the current costs for conservation at \$20/MW-h could grow to as much as \$100/MW-h after the “low-hanging fruit” (consisting of measures that are easy to implement) is harvested. Market purchases may also become more expensive and difficult as Washington, Oregon, and California shut down coal-fired plants and other generation facilities to meet environmental goals. Electric utility officials interviewed all expressed doubt that the Council and BPA’s proposal to mitigate resource deficits through conservation will be successful and they are interested in new generation facilities.

Although the Council and BPA are key organizations involved in regional power planning, other northwest organizations conduct their own planning and/or have the ability to influence the Council and BPA. These organizations are:

- American Public Power Association
- Northwest Public Power Association
- Pacific Northwest Utilities Conference Comm.
- Public Power Council
- Washington Public Utility District Assoc.

### 3.2 Estimated Hanford Power Needs

#### 3.2.1 DOE-Richland Operations

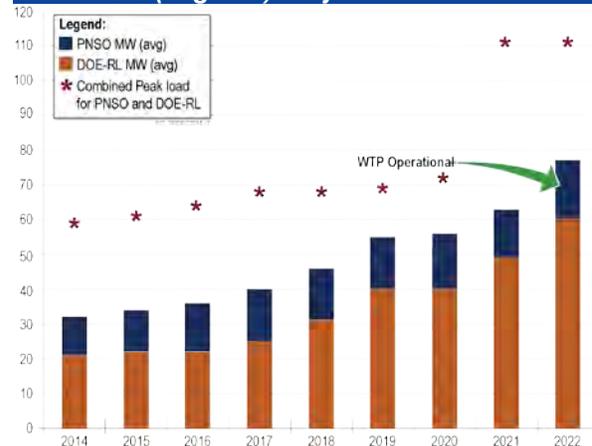
The Hanford Site power needs are expected to steadily increase, peaking when the Hanford Waste Treatment and Immobilization Plant (WTP) comes online, currently projected in 2022. At that time, the DOE-RL peak load is estimated to increase to 80 MW with an average load of 60 MW. DOE-RL receives more than 90 percent of its power directly from BPA and the remainder from the City of Richland (for its southern facilities), which is also a BPA customer. BPA’s average rate for power sold to Hanford was 3.10 cents per kWh in 2013. The Hanford Site electrical energy consumption from BPA was about 185,630,000 kWh in fiscal year (FY) 2013. Transmission costs are separate and are roughly 11 percent of the power costs.

In 1999, DOE-RL completed an electrical procurement options study, concluding that BPA’s power poses the lowest risk and the lowest price to DOE-RL. The current power and transmission agreements are effective from FY 2012-2028, and the agreement guarantees an additional 70 MW of power above the current load as needed at the Tier 1 (lowest) rate.

#### 3.2.2 Pacific Northwest Site Office

Power needs projected by the Pacific Northwest Site Office (PNSO) for PNNL and other Battelle facilities are expected to grow as the laboratory adds new high performance computing capabilities and facilities. PNSO receives all electrical power from the City of Richland under standard electrical utility billing practices (there is no formal PPA with the City of Richland). The current demand is approximately 12 MW avg at a cost of \$5.4 million per year. By 2030, PNNL and Battelle are projected to grow to about 23 MW avg. The combined DOE-RL and PNSO power projections are presented in **Figure 3-1**.

**Figure 3-1. Electrical Demand for DOE-RL and PNSO (avg MW) Projected to FY 2022**



### 3.2.3 City of Richland

As of May 2013, the City of Richland averaged 97 MW of electrical power usage with peaks of about 173 MW in summer and winter. The City of Richland currently purchases electrical power from BPA. In 2012, the average cost of power was 3.4 cents/kWh. Power purchased by PNSO is included in the total power used by the City of Richland.

The post-2011 rate period for BPA includes a two-tiered rate structure. The majority of Richland Energy Services power will be provided by BPA at the lower Tier 1 rate. Power requirements above that level will be available at higher rates. Richland power needs currently exceed the Contract High Water Mark. Consequently, Richland receives power from BPA through market purchases and a small amount from a contract established with a consortium of utilities called the Northwest Requirements Utilities.

## 3.3 Meeting DOE and Regional Power Needs with an SMR

### 3.3.1 DOE's Hanford Needs

As identified in Section 3.2, there is a need for additional electricity at the Hanford Site and city of Richland.

With current Tier 1 rates of \$30/MW-h available to DOE-RL, there is no immediate economic incentive for this agency to incorporate SMR power into future planning. However, the Tier 1 power is primarily hydropower and the amount of this cheaper Tier 1 power will be mostly fixed in the future. Competition for Tier 1 power between residential/humanitarian needs and federal government obligations could lead to a change in planning scenarios wherein DOE-RL use of SMR output would be beneficial. Lack of BPA action to acquire new resources may also incentivize DOE to consider supporting a Hanford SMR to ensure DOE programs will have adequate resources to meet legal obligations to operate WTP in the future. Supporting WTP operation with green and reliable power from an SMR can be expected to appeal to the public and to Washington State officials. On a national level, demonstrating new energy technology and supporting critical DOE programs at Hanford with SMR power provide further reasons for siting an SMR at Hanford. The same rationale also could apply to PNSO.

A DOE decision to use SMR power at Hanford would require modification of the bilateral interagency agreement between DOE and BPA. Such a modification could require a public participation process if it is considered a change to the Tiered Rate Methodology set in BPA's 2008 Regional Dialogue. The agreement applies to DOE-RL's current power usage and requires that DOE-RL make a future choice to receive additional BPA Tier 1 power. DOE-RL might benefit from avoiding changing agreements reached in the Tiered Rate Methodology and elect only to use SMR power for the 40 MW avg power above its current Tier 1 rate limit.

Direct purchases of power from a Hanford-based SMR by DOE-RL or PNSO would introduce complexities into their management of power due to the need to balance loads and resources at any given time. However, commercial entities in the Northwest offer services for resource shaping such that DOE-RL and PNSO could commit to direct purchases of SMR power. Also, PNSO would continue to purchase power through the City of Richland and Richland could purchase the SMR power.

### 3.3.2 Selling Power to Bonneville Power Administration or Other Entities

The 2013 Resource Program evaluates alternatives for new generating capacity. Nuclear power currently is not included in the analysis. Unless BPA reconsiders its conclusions on acquisition of new resources, it does not appear that near-term planning should assume that an SMR would be incorporated into the BPA system and marketed through BPA.

### 3.3.3 Selling Power to Northwest Utilities

Other northwest utilities could consider adding an SMR to their systems by acquiring and operating the plant or through a PPA with another constructor/operations organization.

Energy Northwest would be a logical choice as an owner/operator of an SMR given the significant advantages of co-location with its Columbia Generating Station and the ability to serve a large customer base. As a Washington State not-for-profit, joint operating agency, Energy Northwest comprises 27 public power member utilities from across the state serving more than 1.5 million ratepayers. However, there may be some hesitation by the Energy Northwest board of directors to become an owner, based on financial risk.

The option of Energy Northwest operating a Hanford SMR for DOE or a private organization would be attractive due to the wealth of Energy Northwest experience in operating power-producing reactors and the economic benefits of co-location.

The utilities interviewed for this study indicated that they would be interested in SMR power at a competitive rate if an SMR generating plant is constructed at Hanford. They recognize that SMR nuclear power would offer advantages over renewable power such as wind because it can be used as baseload and, to some degree, could be load-following. The benefits would be even greater if SMR power could be used in lieu of renewable power to meet the requirements of the Washington State Energy Independence Act. They also understand that SMR fuel prices offer greater stability than those of natural gas and that SMR electrical power costs are more stable and reliable than market purchases.

DOE-RL, PNSO, and local utilities could significantly benefit from securing power from a Hanford-based SMR to meet emerging needs, especially those above the Tier 1 Contract High Water Mark for utilities. **Table 3-1**, on the following page, provides a summary of the feasibility to establish power purchase contracts to market Hanford-based SMR electrical power.

**Table 3-1. Summary of Options to Market Hanford SMR Power**

Organization	Potential Participation in SMR Project	Notes
BPA	Could “acquire” an SMR as part of federal system or offer SMR power to utilities via a Vintage Product Power Purchase Agreement	<ul style="list-style-type: none"> <li>• BPA does not plan to acquire new resources for the federal system</li> <li>• At the request of utilities in the BPA system for SMR power, BPA would establish an SMR Vintage Product*</li> <li>• This path forward is credible for marketing SMR power</li> </ul>
DOE-RL	Purchase power directly from SMR or through BPA	Most likely to retain current Tier 1 power purchase from BPA, but could meet expected 40 MW of growth with SMR power, benefitting DOE-RL, the Northwest, and national interests
Energy Northwest	Energy Northwest could become an owner-operator or serve as the operator for an SMR	<ul style="list-style-type: none"> <li>• The current structure of the executive board and board of directors might be an obstacle to Energy Northwest ownership of a Hanford SMR</li> <li>• It would be more likely that Energy Northwest serve as the operator</li> </ul>
Northwest Utility on BPA load-following contract (e.g. City of Richland)	Purchase power either directly from SMR or through BPA	The most likely scenario would be for utilities to request BPA to establish an SMR Vintage Product
Northwest utilities on BPA slice/block** contract (e.g., Franklin and Benton County Public Utility Districts)	Purchase power either directly from SMR or through BPA	A likely scenario could be that a number of slice/block utilities use power marketing to establish a PPA with the SMR owner
Northwest Requirements Utilities (or similar organization with member utilities)	Act as a representative for member utilities in establishing a PPA for SMR power to be shared by member utilities	Establish a PPA with SMR owner to provide power to member utilities
PNSO	Included with City of Richland, but could purchase power directly from SMR	Most likely scenario would be to continue purchasing power through City of Richland

\* Vintage products are PPAs that BPA establishes with one or more power producer and the power is provided to BPA customers needing power over the quantity of Tier 1 power guaranteed in their contract with BPA.

\*\* Slice/block is where BPA guarantees a block amount of flat-shaped power over the year and a slice amount that accounts for times of higher electrical usage.

### 3.3.4 Role of Washington State and Federal Officials

State and federal lawmakers can support multiple interests by amending federal and Washington State incentives to use renewable energy to include green, low-carbon footprint energy such as nuclear power. Examples of current incentives for renewable energy are:

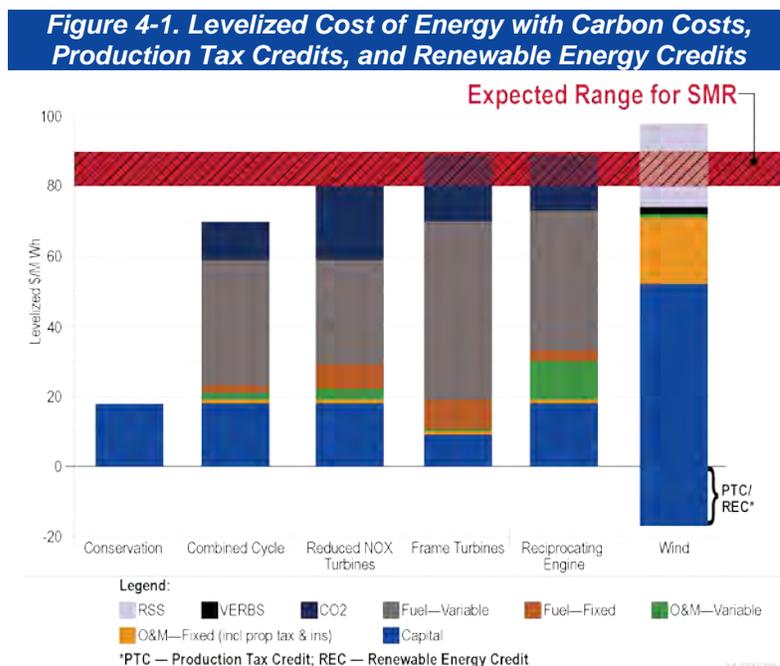
- A federal government requirement asserting that 20 percent of the total amount of electric energy consumed by each agency during any FY shall be renewable energy by 2020
- A Washington State statute mandating that utilities with at least 25,000 customers in the state use eligible renewable energy or purchase renewable energy certificates (REC) for up to 15 percent of their load by a specified date
- An REC can currently be sold for qualified renewable energy sources (wind and solar)

- Production tax credits for renewable energy sources were available up to 2013 and may be available in the future if Congress re-enacts the credit
- DOE Loan Guarantee program for renewable energy projects greater than \$25 million.

Including carbon free SMR power in the definition of renewable energy would benefit federal and state efforts to stem climate change and help utilities meet clean energy mandates. Local utilities subject to the mandate to use renewable energy currently purchase wind power directly and/or purchase RECs, which cost much less than wind power, but do not result in electricity being provided to the purchaser. Utilities that receive electricity from wind farms must also acquire balancing reserves to account for periods where wind is insufficient to drive their turbines. Consequently, federal agencies and utilities either pay for RECs that provide no benefit to their customers or pay for expensive wind power plus balancing reserves. If SMR generation is treated like renewables, utilities can gain credit for using carbon-free power while providing balancing reserves that enable use of renewable power.

#### 4.0 Future Cost of Power in the Northwest

Although not planning to add new capacity to its system, the BPA and the Council evaluate promising technologies for future capacity additions, including the potential cost of adding them to the system. **Figure 4-1** illustrates BPA’s projected electrical costs for conservation, natural gas and wind assuming expansion of a carbon tax to be imposed in California and continuation of current tax credits. In current dollars, conservation is by far the lowest cost option at a projected cost of \$20/MW-h or less followed by natural gas plants at \$70-90/MW-h when the carbon costs are included. Wind



generation is projected to cost approximately \$100/MW-h after tax credits are applied. However, BPA is reluctant to rely on wind power for future capacity because of the need to balance reserves.

An SMR that could sell electricity at a rate of \$85-100 per MW-h would be in the competitive range for BPA to consider as new resource capacity.

#### 5.0 WNP-1 Site Utilization and Estimated Cost Savings

The WNP-1 site is co-located with Energy Northwest’s Columbia Generating Station on a leased portion of the Hanford Site. Construction of the WNP-1 reactor began in 1973, but was stopped in May 1982 at 65 percent completion. For 12 years, the complex was maintained in ready

condition at an annual cost of \$5 million. The construction permit issued by the NRC was terminated in February 2007 and efforts to decommission the site and raze portions of it to final grade are underway.

A primary objective of this study is to evaluate the WNP-1 site for placement of an SMR and estimate the financial benefits. Ultimately, the size of the SMR-based plant at WNP-1 would be driven by economics and financing. This study focuses on a “generic” SMR comprised of multiple modules totaling about 550 MWe of generation capacity. The study team toured the WNP-1 site on May 12, 2014 to review current design documents and meet with Energy Northwest staff. The team concluded that, given the site’s overall condition, many of the existing facilities are adequate to support an SMR during its 60-year life span. The team judged the WNP-1 site to have the greatest potential for cost reductions for an SMR, and therefore, the team focused on this location for the site assessment.

Proximity to the Columbia Generating Station allows use of existing security and emergency response infrastructure. Approximately 40 to 100 acres, close to WNP-1, was the primary target area for siting an SMR. Groundwater, soil, and seismic characteristics for the site are documented and amenable to nuclear power plant construction and operation due to its co-location with the operating Columbia Generating Station.

**WNP-1 Site Utilization and Estimated Cost Savings**

- ✓ Use of the WNP-1 site for construction of an SMR is feasible and is beneficial because of existing infrastructure and licensing documentation.
- ✓ The WNP-1 site has been issued an NRC construction license.
- ✓ Seismic reports and other site characterization data and environmental studies have been performed for the WNP-1 site.
- ✓ Recently updated documentation for the Columbia Generating Station is beneficial to locate an SMR at the WNP-1 site.
- ✓ Conservative estimate of capital cost avoidances by using WNP-1 site: \$140-165M.
- ✓ Licensing documentation cost avoidances: \$30-50M.
- ✓ Schedule improvement cost savings (1 year): \$80-110M.
- ✓ **Total cost savings/avoidances: \$300M.**

## 5.1 SMR Costs Offset by WNP-1 Capital Assets

### 5.1.1 Description of the Energy Economic Database

The Energy Economic Database (EEDB) was developed to provide current, representative, and consistent power plant technical and cost information to DOE. The EEDB updates and incorporates costs for current regulatory requirements (not including potential Fukushima-related upgrades), design, construction and management practices, labor productivity, and labor/material. In the EEDB, base construction costs are in constant dollars and contain no arbitrary factors, such as contingency or escalation.

The database was first assembled in 1978 and was updated regularly for DOE from 1978 through 1990. Since 1991, when DOE discontinued funding, URS has maintained the database on a private basis. The purpose of the updates has been to reflect the impact of changing regulations and technology on the costs of electric power generating stations.

### 5.1.2 Items Identified for SMR Usage

Based on the results of the site visit, which included interviews with Energy Northwest personnel, and the detailed descriptions provided in the EEDB, the study team identified items that could be used for SMR application. About 51 percent of these savings reflect the excellent condition and availability of site infrastructure, structures, and facilities that could be used to

support construction activities. The projected cost savings for using the existing facilities range from approximately \$140-165 million (as of January 2014), as shown in **Table 5-1**.

**Table 5-1. Credits Identified by the Site Visit for an SMR Located at WNP-1**

Activity	Description	Cost Avoidance (Jan 2014 \$)
<b>Structures and Improvements</b>		
Yard work	Cut/fill, clearing/grubbing, grading, road/parking lot preparation, storm drains, outside lighting, and other improvements are completed.	\$17.5–20.3M
Administration and service buildings	Extensive building space is already installed and operational including administrative and service facilities.	\$3.2–5M
Fire pump house	The fire pump house, fire water main and loop, and yard fire protection components are installed and operational.	\$1–1.2M
Waste water treatment building	A waste water treatment facility is available to support SMR operations.	\$1.1–1.5M
Hazardous Materials Management and Emergency Response (HAMMER) facility	Use of HAMMER at the Hanford Site can be credited.	\$1.1–1.5M
Security building	Existing Energy Northwest and Hanford Site facilities can be used.	\$1–2M
Waste process building	A waste process building was constructed for WNP-1 and other facilities on the Hanford Site that could be used for SMR waste processing.	\$11.4–13.1M
<b>Electrical Plant Equipment</b>		
Station service equipment	Large portions of the station service system have been installed, including a major transformer, feeders, and a distribution network.	\$2.2–4M
Switchboards and protection equipment	Switchboards and protective equipment associated with service equipment have been installed.	\$1–1.5M
<b>Miscellaneous Plant Equipment</b>		
Air, water, and steam service systems	Air, water, and steam service systems associated with the fire pump house have been installed.	\$10.3–12.2M
Communication systems	Some communication systems, such as the plant address system and telephone service, are installed and available.	\$7–9.1M
Furnishings and fixtures	Fixtures associated with offsite radiological, meteorological, water quality, and seismic monitoring are installed and operational.	\$2–4M
Waste water treatment equipment	Equipment is located at the waste water treatment building.	\$5–7.1M
<b>Main Condenser Heat Rejection System</b>		
Heat rejection system structures	The make-up water intake structure is installed and in excellent condition.	\$1.5–3M
Heat rejection system structures	A portion of the heat rejection system equipment that is located at the intake structure and other locations, including piping that runs from the Columbia River is usable.	\$1.6–3M
<b>Construction Services</b>		
Temporary construction facilities	All of the construction infrastructure is in place and is mostly operational.	\$45.8–48.5M
Payroll, insurance, and taxes	Payroll, insurance, and taxes associated with the temporary construction facilities are also credited.	\$26–28M
<b>TOTAL</b>		<b>\$140–165M</b>

## **5.2 Relevancy of Prior Siting/Permitting Work: WNP-1 and WNP-4 Reactor Sites**

WNP-1, WNP-4, and the Columbia Generating Station underwent site characterization studies to support licensing in the 1970s. NRC construction licenses were issued for all three sites. The Columbia Generating Station has become licensed for full operation, requiring occasional updates to the studies because of changing criteria. The WNP-1 construction permit was terminated by the NRC, at Energy Northwest's request, in February 2007.

In a letter to the NRC in 2001, Energy Northwest stated that resumption of construction activities at WNP-1 would not be expected to cause adverse impacts to any listed aquatic or terrestrial species or their habitats, because in-river construction work and all significant earthmoving activities had already been completed. In addition, Energy Northwest noted that, because the Columbia Generating Station has the same intake and outfall design as that of the partially completed WNP-1 facility, experience gained at the Columbia Generating Station could be applied to the environmental impact evaluation process for construction/operation of a facility the WNP-1 site.

A permit was previously issued by the U.S. Army Corps of Engineers for a submerged river water intake structure for WNP-1. That intake structure has not been abandoned/removed and could be used for an SMR at the WNP-1 site.

### **5.2.1 Implications of Previous WNP-1 Licensing Activities for Licensing and Operating an SMR at WNP-1**

In its publication "Managing Siting Activities for Nuclear Power Plants," the IAEA ranks four options from "most favoured" to "least favoured" to determine where to site new nuclear plants. The "most favoured" ranking is given to sites where previous nuclear power plant studies have been conducted. The "least favoured" ranking is given to greenfield sites. Because the NRC has issued a construction permit for the WNP-1 site, licensing an SMR at that location would be considered "most favoured" and carries inherent advantages over new sites. Abundant useful licensing documentation is available for the WNP-1 site as a result of the previous WNP-1 permit application to the NRC and subsequent correspondence between Energy Northwest and the NRC. Site characteristics, terrestrial ecology, prior agreements regarding site restoration requirements, and existing Energy Northwest/DOE area lease agreement requirements all apply directly to licensing an SMR at the WNP-1 site.

The WNP-1 site is within the Columbia Generating Station exclusion area, which is defined as lands within a 1.2-mile radius of the Columbia Generating Station; it includes both leased and non-leased portions of DOE's lands. As a result, additional cost savings would be realized (e.g., facilities and services for emergency preparedness, nuclear security, operator training, and used nuclear fuel storage) by locating an SMR at this location.

## **5.3 Current Licensing Status at Columbia Generating Station**

Ongoing updates and revisions to site characterization documents for the Columbia Generating Station are useful for licensing an SMR at the WNP-1 site.

### ***Updated Site/Regional Seismic Hazard Evaluation***

Energy Northwest is preparing an updated seismic hazard evaluation and screening report for the Columbia Generating Station to comply with NRC's request for information dated March 12, 2012 (Fukushima 50.54(f) letter), per 10 CFR 50.54(f). Energy Northwest has completed analyses of the operating basis earthquake and safe shutdown earthquake for the Columbia

Generating Station. Volcanic hazards also are being reevaluated as part of the NRC's review of Energy Northwest's response to NRC Order EA-12-049, "Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond Design Basis External Events," dated March 12, 2012 (ADAMS Accession No. ML 12054A735).

Results of the above-mentioned studies and evaluations should reduce or eliminate the need to complete an updated seismic hazard evaluation for a nearby SMR at the WNP-1 site.

#### *Updated Site Subsurface Soil Investigation*

Costs for completing a supplemental site subsurface soil investigation at the selected SMR site may be reduced depending on additional site characterization data being acquired for the Columbia Generating Station to update the seismic hazard evaluation and screening report and the reevaluation of volcanic hazards. The data in these studies can be applied to the proposed SMR location at the WNP-1 site.

#### *Flood Hazard Evaluation/Dam Breach Analysis*

Energy Northwest is working with the U.S. Army Corps of Engineers and the NRC to prepare a dam breach analysis and complete an updated flood hazard reevaluation for the Columbia and Snake Rivers. This analysis also considers the effects of a potential dam breach on the Columbia Generating Station. Results of these analyses could eliminate the need to complete an updated flood hazard and dam breach analysis for a nearby SMR site.

#### *Updated Environmental Assessment/ Environmental Report/Environmental Impact Statement Documents*

An environmental assessment was also completed for WNP-1 in January 2002. Energy Northwest submitted an environmental report for the Columbia Generating Station license renewal application in January 2010. An environmental impact statement (EIS) was published by the NRC in April 2012 to satisfy NEPA requirements and to support the license renewal application review. These documents presented and evaluated information on major environmental resources in the area and potential impacts of operations on these resources (terrestrial and aquatic resources, threatened and endangered species, air quality and water resources, microbiological organisms, and historical and archeological resources). These studies should substantially reduce costs for completing an updated environmental assessment for a selected nearby SMR site.

### **5.4 Potential Licensing Cost Savings/Cost Avoidances for an SMR Located at the WNP-1 or WNP-4 Sites**

Due to licensing investigations performed for WNP-1 in the 1970s and continuously updated studies for the Columbia Generating Station, it is expected that a number of cost avoidances could be realized if an SMR were constructed and operated at the WNP-1 site. The study team agrees that the cost avoidances resulting from using already-available site characterization and licensing documentation from the Columbia Generating Station and previous WNP-1 studies conservatively total \$30-50 million, based on comparable projects at the Hanford Site. These savings are shown in **Table 5-2** (following page).

**Table 5-2. Cost Avoidances Realized by Using Existing Licensing Investigation Documents**

Investigation	Amount (\$M)
Environmental studies (NEPA)	\$10-20M
Geologic/geotechnical studies	\$10-15M
Cultural/historical investigations	\$3-5M
Water rights application and permitting	\$7-10M
<i>Subtotal</i>	\$30-50M
Addendum: Cost savings from schedule improvement of one year	\$80-110M
<i>Subtotal</i>	\$110-160M
With WNP-1 capital cost assets	\$140-165M
<b>Total Cost Savings</b>	<b>~\$300M</b>

Energy Northwest supports the URS estimate that the overall schedule to license and construct an SMR will be shortened by approximately one year if the WNP-1 site is selected. A 2011 study on nuclear permitting processes by the American Society of Mechanical Engineers also supports this estimation. This schedule improvement could generate \$80-110 million in financing and project management cost avoidances. Table 5-2 shows this amount and the capital assets from Table 5-1 for a total of about \$300 million savings gained by using that site.

### 6.0 Identification and Evaluation of Other Potential Hanford SMR Sites

Potential alternate sites for constructing an SMR at the Hanford Site have been evaluated for compliance with current land use policies, planning, and management decisions by DOE-RL. As a result, two viable alternate sites were identified that met land use planning criteria: the WNP-4 site and the Hanford 400 Area. Although these sites provide a viable backup to the WNP-1 site, their licensing and construction costs will be substantially greater than those at the WNP-1 site.

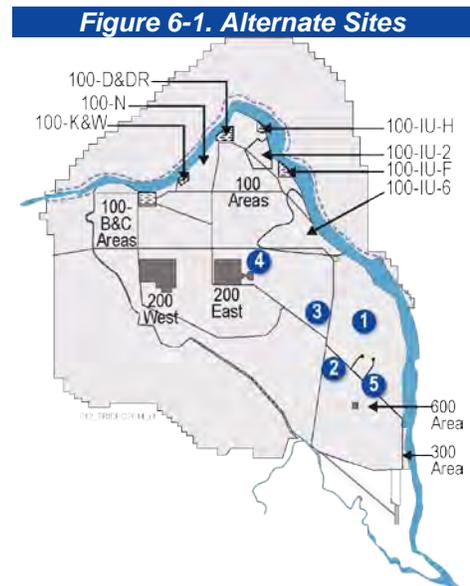
**Identification and Evaluation of Other Potential Hanford SMR Sites**

- ✓ Three potential Hanford locations meet land use planning criteria.
- ✓ The WNP-1 site offers the best features for reducing costs of construction and licensing.

#### 6.1 Alternate Sites Considered

This study evaluated Hanford Site locations that have existing and available infrastructure or have previously been considered for reactor missions. Using these criteria, the study team identified five alternate locations on the Hanford Site to construct an SMR, shown by blue circles with their corresponding numbers in **Figure 6-1**.

- 1 The WNP-4 site is managed by Energy Northwest and is near the Columbia Generating Station. The site has a partially constructed power reactor with some infrastructure. The project was terminated when the plant was about 40 percent constructed.
- 2 The Hanford 400 Area contains two major nuclear facilities: the Fast Flux Test Facility (FFTF) and the Fuels and Materials Examination Facility (FMEF). FFTF is a liquid metal cooled, 400-MW thermal test reactor that operated from 1980 to 1993. FMEF is a large hot cell facility that was built to support the examination of experiments irradiated in FFTF; it was never operated. Both facilities were supported by utilities offices and other buildings, some of which remain today.



- ③ The New Production Reactor site, a greenfield site, was considered for constructing a new tritium-producing reactor in the late 1980s and early 1990s.
- ④ A greenfield site located near the Hanford 200 East Area might be beneficial because of installed infrastructure and seismic and characterization studies that have been prepared.
- ⑤ A greenfield site located between FFTF and the Energy Northwest site might be beneficial due to licensing studies already performed for this area. This site is also close to existing infrastructure at the 400 Area and the Columbia Generating Station.

## 6.2 Evaluation of Potential Sites

The viability of the five sites was evaluated for compliance with DOE-RL policy and site land use planning. In November 1999, DOE issued a record of decision (ROD) for the Hanford Site's Comprehensive Land Use Plan, an EIS that defines future uses of the Hanford Site when its cleanup mission ends. Using the Comprehensive Land Use Plan, the study team determined that two of the alternative potential SMR sites were viable for consideration: the Hanford 400 Area and the WNP-4 site. These sites were further evaluated in comparison to the WNP-1 site.

### 6.2.1 Hanford 400 Area

An interim ROD for the 400 Area cleanup was issued in 2001, mandating cleanup actions in advance of a final ROD. As a result, 13 office, maintenance, and temporary buildings have been removed (**Figure 6-2**). Most of the original infrastructure remains, but some are inactive.

- Site assets and advantages
  - Most electrical utilities remain, including two 115-kV electrical substations, two switchgear stations, and the power distribution system
  - Water utilities supporting fire protection and potable water exist
  - Warehouses, security fencing, and guard facilities remain
  - Site characterization information such as geotechnical and seismic data exist from the site's construction in the 1970s.
- Site disadvantages
  - No outgoing power transmission facilities exist. Transmission lines would need to be extended to those supporting the Columbia Generating Station
  - Water supply is insufficient to support reactor cooling
  - Groundwater beneath the 400 Area contains tritium and nitrates that exceed EPA standards
  - Infrastructure would need to be rebuilt, including office, warehouse, maintenance buildings, and security systems.



**Figure 6-2. Hanford 400 Area with Removed Structures**

### 6.2.2 WNP-4 Site

Beginning in 1971, Washington Public Power Supply System designed, licensed, and constructed three nuclear power plants on land leased from DOE-RL. In 1982 and 1983, construction was terminated on WNP-1 and WNP-4 (**Figure 6-3**).



**Figure 6-3. WNP-4 Site**

Energy Northwest, with assistance from BPA, has maintained several structures and systems in a usable state. WNP-4 utilities, structures, and systems have not been maintained as well as the WNP-1 site.

- Site assets and advantages
  - Close to the operating plant at Columbia Generating Station
  - Main piping is constructed
  - Fire water with some hydrants and power distribution is available
  - Water intake facility is constructed and has been well maintained
  - Much of the site characterization studies to support licensing is complete and current.
- Site disadvantages
  - Site utilities are not as complete or well-maintained as the WNP-1 site
  - Many of the WNP-4 structures have been and are currently being demolished
  - Water intake pumps need to be procured and installed
  - Power vaults are in place, however a permanent plant power was note installed
  - The substation supporting the site is inactive and outgoing power transformers were not constructed.

## 7.0 Other Regional Assets

### 7.1 *Excellent Existing Tri-Cities Area Nuclear Workforce, Economy, and Business Climate*

The Hanford Site, the major employer and economic driver in the Tri-Cities, has performed pioneering nuclear work since its founding in World War II. It produced two-thirds of the defense plutonium ever manufactured by the US and for the past 25 years, has performed the largest environmental cleanup project in world history.

The Tri-Cities, home communities to the Hanford Site, constitute the fourth largest metropolitan statistical area in Washington State. Approximately half of the population of 250,000 is employed, with about 20,000 in nuclear work as direct government or government contractor employees. In mid-2014, the Tri-Cities’ unemployment rate was 5.7 percent, which is below the Washington State average. The Tri-Cities workforce is highly educated, with among the highest number of scientists and engineers per capita than anywhere else in the nation.

The Tri-Cities has strong trade, transport, and utilities sectors (17,500 jobs), much of which support nuclear work. The community also has a vibrant and growing manufacturing sector (8,000 jobs) that includes technical engineering companies specializing in nuclear work.

Approximately \$3 billion in federal money comes into the Tri-Cities every year, providing a solid economic base. The ongoing cost of nuclear remediation work is estimated by the government to be more than \$113 billion over the next 56 years.

**Other Regional Assets**

- ✓ Approximately \$3B in federal money comes into the Tri-Cities every year.
- ✓ Large engineering and construction companies anchor the nuclear construction, treatment, and remediation contracts at the Hanford Site, performing nearly \$2B per year.
- ✓ Robust local base of small engineering, fabrication, and testing consulting firms that support nuclear work.
- ✓ PNNL is a national laboratory that provides a scientific and analytical foundation to the community.
- ✓ Columbia Basin College and Washington State University Tri-Cities provide educational opportunities and growth.
- ✓ Documented political support from the Washington State Governor and Legislature facilitate the development of SMRs at the Hanford Site to advance carbon-free energy.

The Tri-Cities has recently been rated one of the top 10 likeliest places to see increases in housing values due to its stable economy. In 2011, it was the fastest-growing metropolitan area in the nation. The average household income for the Tri-Cities region has increased 21.5 percent since 2000 and now stands at more than 30 percent above the national average. The Tri-Cities has the lowest cost of living index in Washington State, at 20 percent below the national average. A favorable business climate is enhanced by the fact that Washington State is one of only seven states that does not levy corporate, unitary, or personal income taxes. Washington State also does not tax inventory, interest, dividends, or capital gains.

Major large, international engineering and construction companies anchor the nuclear construction, treatment, and remediation contracts at the Hanford Site and, together, perform nearly \$2 billion of work per year. These companies and their employees have expertise in nuclear construction, facility management and operations, nuclear safety, and environmental remediation of hazardous and radioactive wastes. Each company has corporate reachback capability to deploy additional expertise as needed. The Tri-Cities is home to dozens of engineering, design, fabrication, testing, and manufacturing businesses that serve as subcontractors to these major Hanford contractors. These smaller companies specialize in nuclear work and some possess Nuclear Quality Assurance-1 certifications in welding and other disciplines of nuclear work. The Tri-Cities is also home to nuclear service industries that perform work nationally and internationally. Among them is the Richland AREVA nuclear fuel services facility (**Figure 7-1**), which produces 25 percent of the nation's nuclear fuel (5 percent of the nation's electric power). Siting one of the first SMRs at Hanford will place the Tri-Cities manufacturing community in an excellent position to produce SMR components as they are installed across the nation and exported around the world.

**Figure 7-1. AREVA Nuclear Fuel Services Plant in Richland, Washington**



PNNL, based in Richland, Washington, is one of ten national laboratories managed by DOE-SC. Recognized as a technology-driven research laboratory, PNNL has vast experience in applied materials science and process engineering, applied nuclear science and technology, licensing, environmental capabilities, and has ongoing relationships with the National Nuclear Security Administration, DOE-NE, and the NRC. PNNL has ~4,000 employees, performs approximately \$1 billion of business annually, and is the largest employer in the Tri-Cities.

The Hanford Atomic Metal Trades Council is a labor organization headquartered in the Tri-Cities, composed of 15 different craft unions working at the Hanford Site. The Hanford Atomic Metal Trades Council represents approximately 3,000 employees, forming one of the largest collections of experienced nuclear workers in the nation.

Recognizing the need for robust and targeted nuclear programs to address current and future workforce needs, companies from the Tri-Cities have teamed with Columbia Basin College and Washington State University Tri-Cities to develop special courses and programs, such as Columbia Basin College's Nuclear Technology Program, to ensure that the labor force of tomorrow is trained to operate and manage nuclear work.

A nearly unprecedented and unlimited array of hazardous materials training, can be leveraged through the HAMMER facility, located on the Hanford Site (**Figure 7-2**). HAMMER occupies a 120-acre campus and possesses an immense selection of training and education props and facilities to aid simulating real-life hazardous environments. It is one of the few centers in the world and the only center west of the Mississippi River that has such an extensive selection of different and complex training material in one setting.



The Industrial Development Complex (IDC) is located east of Columbia Generating Station on land leased from the Hanford Site and is comprised of warehouse, office space, fabrication facilities, roads constructed for heavy-duty use, fencing, security lighting, a storage lay-down yard, and other associated property in excess of Energy Northwest's current operating needs. The site is 57 percent occupied, with more available after 2015. The IDC can also supply backup water and power to the Columbia Generating Station. A new Emergency Preparedness Center is being built near the IDC and Energy Northwest is considering building an additional fire station.

Transportation infrastructure such as road, barge, and rail are in place and available for use in and around the Tri-Cities. A maintained road system leading to the proposed SMR site is safe, compliant, reliable, and includes roads specifically designed and constructed to accommodate very heavy loads of materials. The Tri-Cities offers mainline rail freight services and short-line rail service to the IDC. Barges currently travel the Snake River and the Columbia River, transporting sealed reactor sections from U.S. Navy nuclear submarines for burial on the Hanford Site. Barge slip access is within 10 miles of the Energy Northwest site.

Lampson International, LLC, located in the Tri-Cities, is capable of supporting construction of nuclear facilities anywhere in the world. Lampson offers equipment rental, full service heavy lift and transportation, heavy rigging operations, specialized equipment design/build, lift and transport engineering, and project management with vast experience in both general and nuclear construction environments. Lampson is also familiar with water transportation offload, rail offload, and over-the-road transport of extremely heavy and oversized cargo loads at the Hanford Site. Lampson's headquarters, maintenance facility, and fabrication shops are located less than 30 miles from the Energy Northwest complex.

## **7.2 The Tri-Cities can Support an SMR**

It is estimated that about 380 staff members (security, operations, health physics technicians, maintenance, and administrative support) are needed to operate an SMR. Economies of scale can be realized by locating an SMR on the Hanford Site near Energy Northwest, as these skill sets are currently in place at Energy Northwest and can be augmented within the local community to accommodate a new SMR. In addition, other resources are available through contractors at the Hanford Site as well as from local, specialized engineering companies.

Strong, documented political support from the highest elected officials in Washington State back DOE's initiative to facilitate development of SMRs in the US. This strong backing will promote a domestic SMR industry to advance carbon-free energy and avoid the financial burden imposed by large nuclear reactor plant construction.

All of the key elements – technical expertise, workforce, education and training, infrastructure, and political support – make siting an SMR on the Hanford Site a cost-effective decision.

## 8.0 A Plan to Jump-Start SMRs

As discussed in Section 2.3, designing, licensing, and constructing the nation’s first SMR plants will be more costly than for plants that follow. While DOE-NE has taken steps to assist the US-based reactor industry with initial costs by providing funding to accelerate design certification and licensing of SMRs, the funding provided is insufficient and does not address first-of-a-kind costs incurred by utilities that construct the first SMR-based generating stations at their sites. Since these costs are large and will ultimately affect the cost of power produced by the initial SMRs, it will be difficult for the reactor industry and utilities to bear these costs and enable wide-scale deployment of SMR technology in the US.

This section presents an approach to reduce the extraordinary first-of-a-kind costs to design, license, and construct the first SMRs built in the US. If the nation is to succeed in deploying SMR technology, it is important to assist the emerging SMR industry to overcome first-unit costs by sharing these costs between the parties that will benefit from the clean alternative to natural gas to provide reliable base power for the country. This cost-sharing approach could be used for the first several SMRs successfully licensed and designed in the US and could be used as a model for future government platforms. Since this siting study specifically focuses on the Hanford Site, the recommended WNP-1 site is used to illustrate the workability of this approach at Hanford through cost sharing with others.

### Plan to Jump-Start

- ✓ Capital risks are high for the first SMRs constructed in the US.
- ✓ Federal and state support will likely be needed to enable financing of the nation’s first SMRs.
- ✓ Cost sharing between DOE, reactor vendors, and utilities will be necessary.
- ✓ DOE should use its Loan Guarantee program, PPAs, and/or SMR energy credits to further support SMR deployment.
- ✓ Conversion of WTP to natural gas steam production could, over time, produce savings that more than offset DOE support for an SMR at Hanford.
- ✓ States should impose power portfolio mandates and/or tax incentives.

## 8.1 Cost Sharing

Section 2.3 estimates that the first-of-a-kind costs for SMRs and SMR-based generating stations to be about an additional \$2 billion dollars for each SMR design deployed, a cost that may be unsurmountable for the reactor and utility industries. An approach that could overcome this obstacle is to engage in cost sharing among the parties that benefit. Those parties include the federal government (especially DOE), reactor vendors, utilities, and rate payers. Sections 8.1.1 through 8.4.3 describe ways that each of these parties might participate in sharing the first-of-a-kind costs and the ultimate benefits to each party.

### 8.1.1 Buy Down Capital Costs

Reducing the capital financing needed to build the first SMRs to levels that attract conventional financing would have a major effect on overcoming the hurdle of first-of-a-kind costs. DOE, the SMR vendors, and owner/operator utilities should all share in reducing capital financing needed for the first units.

Per DOE Secretary Moniz, DOE’s policy clearly includes accelerating the timeline for deployment of SMRs and diversification of the US’s energy portfolio. While much of the cost of design certification and licensing should be borne by the reactor vendors and utilities, DOE

should support them by contributing to these costs and encouraging deployment. If DOE assisted with half of these costs, it would total about a \$1 billion DOE commitment for each SMR design deployed, \$4 billion if all four of the most mature designs were supported. This cost to DOE would be smaller, about \$1-2 billion, if purchasing utilities used procurement processes to reduce the number of SMRs supported to the most viable one or two designs. DOE is currently using cooperative agreements to support the reactor vendors through the Small Modular Reactor Licensing Technical Support Program. This program should also be extended to the owner utilities at the funding levels discussed above. Cooperative agreements have the advantage of allowing the ownership of the designs, licenses, and SMR generating stations to remain with the vendors and utilities, thus complying with DOE's policy not to own power generating facilities.

### 8.1.2 Financing Risk Reduction

To build an SMR, utilities will need to obtain market financing for the remaining capital after buy-down, but risks and uncertainties exist with project costs and market price for power when the SMR begins generation. DOE is in a good position to assist via its Loan Guarantee program whose mission is “to accelerate the domestic commercial deployment of innovative and advanced clean energy technologies at a scale sufficient to contribute meaningfully to the achievement of our national clean energy objectives—including job creation; reducing dependency on foreign oil; improving our environmental legacy; and enhancing American competitiveness in the global economy of the 21st century.” The available guarantees are for a variety of clean renewable energy sources, hydrogen, conservation, pollution control, and carbon sequestration technologies, but they do not specifically include SMRs. Because SMRs emit zero pollutants and greenhouse gases and could provide peaking capacity and system flexibility to enable less predictable renewable energy generation, they should be given the same consideration as these other clean technologies. Loan guarantees would offset the financial risk of default for an SMR project.

### 8.1.3 Power Price Support and Guarantees

A provision to guarantee or subsidize the future power price for the first SMRs could offer substantial risk reduction for financiers and owner utilities. In 2011, renewable energy subsidies reached \$8 billion with fossil fuel subsidies reaching \$90 billion. Figure 4-1 shows the positive pricing effect of wind power subsidy compared to other energy sources.

- **Power Purchase Agreements.** DOE sites across the US have large annual power needs to operate high-use facilities such as WTP and the many large computer systems and particle accelerators located at DOE's national laboratories. DOE is in a position to mandate that the power from initial SMRs be purchased for their needs using long-term PPAs at prices that justify financing. This policy could also be extended to the Department of Defense and other federal agencies with a target of purchasing 50-70 percent of the power produced by the first three to four SMRs. In addition to PPAs with DOE, northwest utilities could directly enter into PPAs with an SMR owner, participate in a consolidated PPA with several utilities, or request that BPA offer a PPA exclusively for SMR power under BPA's Vintage Power program.
- **Energy Credits for SMRs.** Currently, 33 states use energy credits to guarantee that certain percentages of electric power consumed in each state is generated by a qualified renewable energy source. In addition, Executive Order 13513 issued in October 2009,

mandates that 20 percent of the total amount of electric energy consumed by each federal agency during any fiscal year shall be renewable energy by 2020. If SMRs were included on the list of clean energy sources that qualify for energy credits, deployment of SMRs would have the same investment advantage as other clean energy sources such as wind and solar power.

- **Include SMR Power in State-Mandated Energy Portfolio Policies.** Several states have enacted measures to move power consumption toward clean or renewable power sources. For instance, the state of Washington will require that the power portfolios of major utilities include no less than 15 percent renewable energy by 2020. Tax incentives for generation and/or use of SMR power is another example. All states should consider these approaches for the clean energy produced by SMRs. While this action alone is unlikely to lower business risk sufficiently to allow construction of an SMR, it would lessen the burden on the other measures listed above. Local utilities near the Hanford Site have indicated they would welcome SMR power in lieu of some or all of the mandated renewable energy.

## **8.2 Cost Sharing to Build an SMR Generating Station at Hanford**

Using the approach summarized in Section 8.1, the study team believes it is feasible to locate one of the nation's first SMRs at the Hanford Site.

An SMR sited at Hanford, such as at Energy Northwest's WNP-1 site, requires an ownership structure that promotes financing and facilitates selling electric power produced. Although DOE could participate by providing grants and cooperative agreements to the industry, operation of a reactor solely for production of commercial power is inconsistent with current DOE policies.

Likely ownership choices are Energy Northwest or a new business entity that includes Energy Northwest. Energy Northwest operates the adjacent Columbia Generating Station and maintains the WNP-1 site. Energy Northwest delivers nearly 1,300 MW of electricity to the northwest power grid using nuclear, hydroelectric, natural gas, solar, and wind power generation facilities. Energy Northwest has a history of collaboration with DOE as a current tenant on the Hanford Site and a previous operator of the steam turbine facility at Hanford's N Reactor.

If a new business entity was formed to become the owner of the Hanford SMR, it should be structured to facilitate:

- Attracting commercial financing
- Attracting DOE funding such as grants or a cooperative agreement
- Managing the construction and operating phases
- Marketing the power produced.

## **8.3 Funding Construction of an SMR at Hanford**

A decision to seek financing to construct an SMR would be based on northwest electric power need projections, as discussed in Section 3.0. Those projections show needs for new power by the early 2020s and local public utilities queried have shown interest in purchasing power from a Hanford SMR, even at a modest premium, if constructed. Currently, with higher capital costs for the first SMRs and natural gas prices low, the risk is perceived by the utilities as too high unless a robust cost-sharing partnership is undertaken. The study team believes that mitigating the high cost risk of constructing one of the nation's first SMRs at Hanford could be accomplished if cost sharing, as described in Section 8.2, comes to fruition.

### 8.3.1 Buy Down of Capital Costs for a Hanford SMR Generating Station

A program to offset extraordinary site licensing and construction costs at Hanford, similar to DOE-NE's Small Modular Reactor Licensing Technical Support Program, could reduce financing needs by using DOE funds to buy down a portion of the first-of-a-kind costs, while preserving non-DOE ownership of the power plant. A cooperative agreement requires that both the grantor (DOE) and the recipient (such as Energy Northwest) bring substantial resources to the project. For instance, a cooperative agreement could be structured such that DOE contributes funding to offset first-SMR costs. DOE capital support of about \$500 million would be useful when added to the approximately \$300 million in existing infrastructure assets and cost avoidances held by Energy Northwest (Section 6.0). Under this arrangement, Energy Northwest would remain the owner.

Furthermore, a DOE loan guarantee would greatly reduce the risk to an owner utility such as Energy Northwest and could make the difference, when combined with other capital offsets described in this report, in obtaining approval from the board of directors to seek financing for the remaining capital cost. Some combination of PPAs, price guarantees, energy credits, and Washington State-mandated energy portfolio policies would further lower business risk.

### 8.4 Hanford Site Cost Savings That Could Offset DOE's SMR Support at Hanford

The study team investigated savings within Hanford's current programs that could offset, over time, a DOE investment in a Hanford SMR. The team focused on an initiative to construct a natural gas-fired steam plant in the 200 Area of the Hanford Site to service the 242-A Evaporator and WTP. Current plans call for shipment of diesel fuel by truck to these facilities to generate steam needed to treat Hanford's 53 million gallons of high level nuclear waste. At full operation, 40,000 gallons of diesel would be needed each day through the 2050s. Conversely, natural gas would be delivered to the Hanford Site by Cascade Natural Gas through a new pipeline. The cost of diesel fuel far exceeds the cost of natural gas to meet steam needs for the two facilities. The study team took two approaches to estimate the cost for operating the two facilities:

1. Using the FEMP to generate financing of capital costs for the change to natural gas based on a 25-year payback period mandated by the FEMP
2. Taking a broader look at cost savings over 40-years plus crediting carbon tax savings.

#### 8.4.1 Federal Energy Management Program Savings

A preliminary assessment as prescribed by FEMP was developed by Johnson Controls, the current Energy Savings Performance Contracting for the Hanford Site and a member of the study team. To meet FEMP requirements, Johnson Controls was restricted to considering a payback period of 25 years of operation of the 242-A Evaporator and WTP and could not take into account parameters that might be, but currently are not, implemented such as a carbon tax imposed on the natural gas or diesel used. The preliminary assessment found the following:

- Over **\$530 million** in savings would accrue over the 25-year payback period by converting from diesel to natural gas.
- At a 4.6 percent interest rate, this savings would avail about **\$189 million** capital financing in 2019 to construct the gas-fired steam plant and for other Hanford energy initiatives. This funding would be obtained through FEMP and would not impact the DOE budget for WTP construction or the Hanford Site cleanup.

- Of this available capital, about **\$121 million** is needed to build the gas-fired steam plant. About **\$70 million** would be available for other Hanford energy initiatives like an SMR.
- In addition, if DOE chooses to convert the existing diesel steam generators to natural gas, conversion costs would be about **\$15 million**, leaving **\$165 million** available for other energy initiatives.

#### 8.4.2 Further Savings to Offset DOE Support for an SMR at Hanford

The study team analyzed savings outside of the constraints of FEMP during a 40-year period of supplying natural gas-produced steam to WTP and the 242-A Evaporator (or its replacement).

The team concluded:

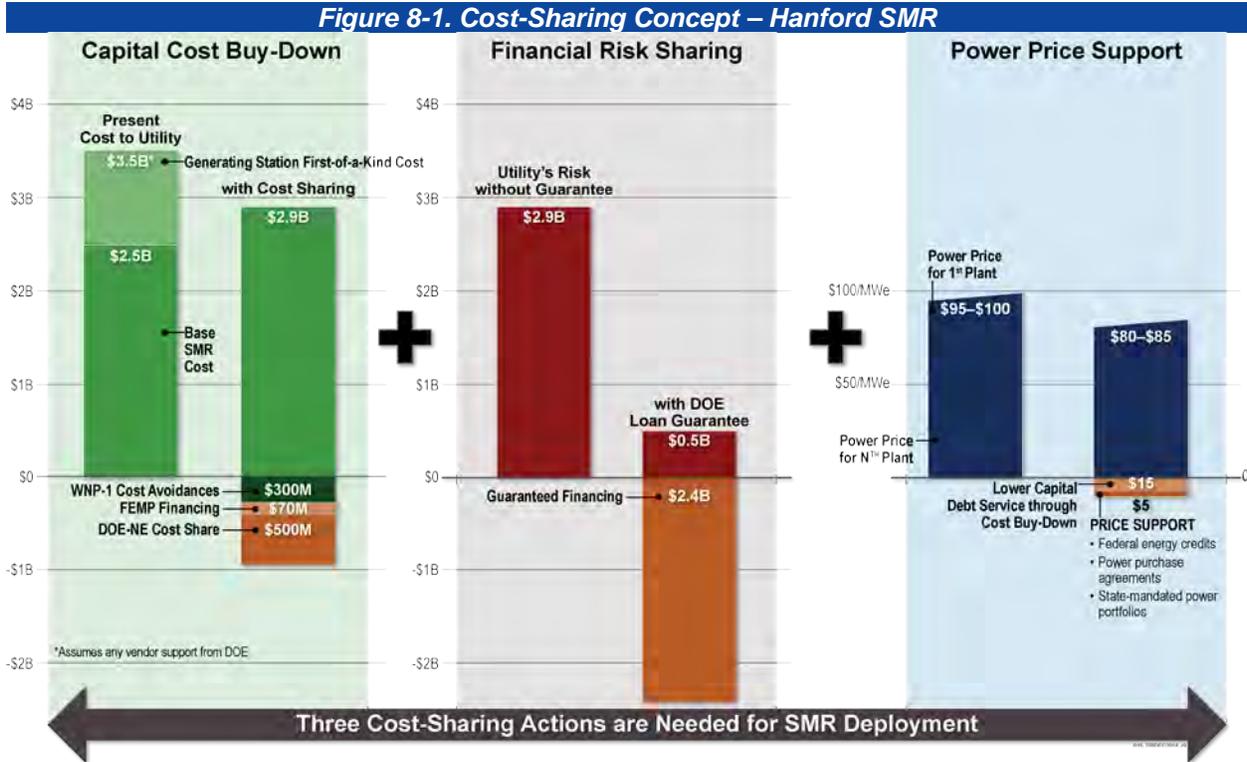
- Estimated gross savings through FY 2050 (operating 40 years) are about **\$1.059 billion**
- Natural gas emits 40 percent less carbon dioxide and reduces other greenhouse gases. If natural gas is used, **656 million lbs** of carbon dioxide emissions would be avoided.

#### 8.4.3 Cost Sharing Summary

A cost sharing arrangement between DOE, a local utility such as Energy Northwest, and the state of Washington could make construction of an SMR generating station at Hanford feasible. A summary of contributions by the parties include:

- **DOE**
  - About \$500 million to support first-of-a-kind costs to build an SMR plant at WNP-1
  - Loan guarantee for Energy Northwest acquired financing for the remaining capital
  - Work with the Administration to make SMRs eligible for federal energy credits, DOE PPAs, and power price support for SMR-generated electricity
  - Approve an initiative at Hanford to convert diesel steam plants to natural gas, thus generating FEMP financing that would cover the cost of the conversion and could apply \$70-165 million toward an SMR's capital costs.
- **Utility (such as Energy Northwest)**
  - Ownership of the SMR plant
  - About \$300 million in infrastructure assets/cost avoidances by using the WNP-1 site
  - Energy Northwest acquired financing for the remaining capital cost.
- **State of Washington**
  - Support SMR power for inclusion in northwest power planning entities
  - Including SMR-generated power in the state's clean power portfolio policies.

These measures would generate up to \$800 million to buy down capital costs, reduce risks to the owner utilities and financiers, and ensure that the power produced would be sold at or above break-even prices (Figure 8-1).



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**ACRONYMS**

B&W	Babcock & Wilcox Co.
BPA	Bonneville Power Administration
CO <sub>2</sub>	carbon dioxide
Council	Northwest Power and Conservation Council
DOE	U.S. Department of Energy
DOE-NE	U.S. Department of Energy-Nuclear Energy
DOE-RL	U.S. Department of Energy-Richland Operations Office
DOE-SC	U.S. Department of Energy-Office of Science
EEDB	Energy Economic Database
EIA	Energy Information Administration
EIS	environmental impact statement
EPA	Environmental Protection Agency
FEMP	Federal Energy Management Program
FFTF	Fast Flux Testing Facility
FMEF	Fuels and Materials Examination Facility
FY	fiscal year
IAEA	International Atomic Energy Agency
IDC	Industrial Development Center
HAMMER	Hazardous Materials Management and Emergency Response Federal Training Center
kWh	kilowatt-hour
LWR	light water reactor
MW	megawatt
MWe	megawatt electric
MW-h	megawatt-hour
NGCC	natural gas combined cycle
non-LWR	non-light water reactor
NRC	Nuclear Regulatory Commission
PNNL	Pacific Northwest National Laboratory
PNSO	Pacific Northwest Site Office
PPA	purchase power agreement
REC	renewable energy certificates
ROD	Record of Decision
SMR	small modular reactor
tcf	trillion cubic feet
TRIDEC	Tri-City Development Council
US	United States
White Book	Pacific Northwest Loads and Resources Study
WNP-1	Washington Nuclear Power Plant Unit No. 1
WNP-4	Washington Nuclear Power Plant Unit No. 4
WTP	Waste Treatment and Immobilization Plant