



# ACEP

Alaska Center for Energy and Power

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Fostering development of innovative solutions to Alaska's energy challenges.

## Research Briefing

### Small-Scale Modular Nuclear Power: An Option for Alaska?

This study was conducted at the request of the Alaska Legislature, managed through the Alaska Energy Authority (AEA) and prepared by the Alaska Center for Energy and Power (University of Alaska Fairbanks) in partnership with the Institute of Social and Economic Research (University of Alaska Anchorage).

### Project Overview

The viability of a new generation of nuclear power plants, small modular reactors (SMR), has been studied as a possible way of meeting Alaska's energy needs in the near to intermediate future. However, in order to understand whether SMRs present a viable option for Alaska, a thorough understanding of the technical, permitting, environmental and economic constraints is required. The intent of this report is to provide the reader with a basic working knowledge of the technology and the conditions under which the technology could be applied in Alaska.

### Project Background

There are at least two reasons to discuss the nuclear power option. First, the supply of reliable, affordable energy to small, often-isolated communities remains a challenge. Most of these communities do not have access to developable local resources that can reduce their dependence on high-priced diesel fuel. Second, in other communities that are located near conventional energy sources — such as the gas fields of Cook Inlet or the coal fields of Healy — as much as 49 percent of the generation infrastructure will approach the end of its design life within the next 15 years. Decisions will have to be made regarding its replacement or refurbishment (*Alaska Railbelt Electrical Grid Authority (REGA) Study—Final Report, Sept. 12, 2008*).

As part of a new generation of nuclear power plants worldwide, SMRs are being developed that range in capacity from 10 MWe to 300 MWe. These SMRs are expected to be manufactured in

See the full report for the history of applications of nuclear technology in Alaska as well as updated information on technology readiness (excluding consideration of waste disposal), regulatory permitting, and comparative and economic analyses for select communities at [www.uaf.edu/files/acep/SmallScaleModularNuclear.pdf](http://www.uaf.edu/files/acep/SmallScaleModularNuclear.pdf).

factories, allowing standardized design and fabrication, high quality control, shorter power-facility construction times and lower financing costs during construction. For larger applications, multiple SMR modules could be combined to form a larger power plant complex, which would have several advantages over a single large reactor, including reduced downtime for maintenance and enhanced safety characteristics. Single SMRs could also be developed that are appropriately sized (smaller) for use in Alaska, making nuclear energy a better option for consideration. In addition to providing energy (heat and power) for rural communities and/or the Railbelt, other potential applications include providing energy for military bases and remote mining operations.

During the course of completing this report, a major earthquake and tsunami struck Japan, damaging a nuclear reactor complex near Fukushima. This damage resulted in a significant release of radioactive material into the environment. Although the most serious contamination appears to be limited to a relatively small geographic area surrounding the reactor site, the environmental cleanup after this accident will likely take years. The full extent of the long-term impact of this disaster on Japan and the global nuclear power industry is still unknown. However, the immediate impact to the nuclear power industry is likely to include re-examination of the safety of existing reactors worldwide and the development of the SMR industry specifically. For now, public support of nuclear power in general has been eroded by the Fukushima event, thus inhibiting new projects of any size despite the fact that the event happened at a power plant that was based on 1950s light water reactor technology very different from the SMRs considered here.

### Options for Deployment in Alaska

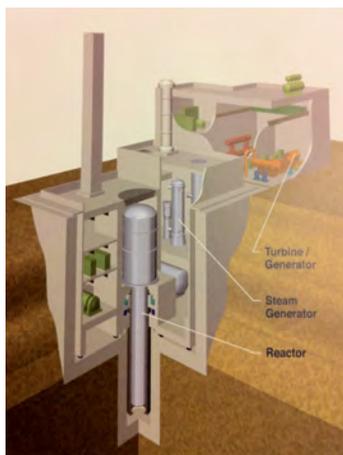
No small-scale nuclear reactor technology is approved for commercial use in the U.S., including Alaska. In fact, as of March



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Artist's rendition of the proposed Toshiba 4S 10 MW reactor proposed for Galena

2011, no SMR manufacturers had submitted a request for design review and certification to the Nuclear Regulatory Commission (NRC), a critical step toward development of a pilot project and a process that is expected to take several years to complete. Therefore, at least with regard to any SMR that could be installed in the U.S., this technology is still in a pre-commercial phase of development.

The Toshiba 4S nuclear power plant proposed for Galena in

2003 is familiar to many Alaskans. This project initiated a serious conversation about nuclear energy throughout the state when it was initially reported that Toshiba was willing to "give" a 10 MWe prototype reactor to the community of Galena. Though this project did not advance past the early conceptual phase, it influenced the national conversation about nuclear energy and brought the needs of small, remote communities to the attention of lawmakers and regulators in Washington, D.C. That conversation both identified market opportunities for SMR technology and highlighted regulatory barriers to such installations.

### SMR Technology Findings

- No SMR systems are expected to be in service before 2020. The first systems approved by the NRC will likely be smaller-scale versions of existing light water reactor technology, such as those proposed by NuScale and Babcock & Wilcox. Several of the newer designs for SMRs are based on fast reactor technology, as opposed to light water reactor technology. Finding a viable source for fuel is one of the critical steps in the development of this fast-reactor class of technology.
- Radioisotope thermal generators (RTGs), used for long-term space missions by NASA and for powering critical remote communications sites on Earth, are small enough for use in rural areas or other situations with relatively low power demand. Currently, however, there is little prospect that the special nuclear materials used as fuel for RTGs will be available. Even if the fuel were available, RTGs may still be unsuitable for village-scale power due to the high cost of the fuel.
- Mini nuclear reactor systems used in mobile applications, such as nuclear submarines or ships, might be suitable for small communities, but they have not been considered seriously for public use. Reactors on U.S. Navy vessels use weapons-grade enriched uranium, which is unavailable to the civilian market because of potential proliferation concerns.



An artist's rendition of the Russian floating-barge nuclear power station. The unit can carry two KLT-50S icebreaker-type reactors to a remote site.

- Some of the designs identified in this study are under construction in other parts of the world — for example, a Russian design for a barge-mounted power plant — but cannot be permitted in the U.S. unless NRC approval is sought and given. The Russian developer, Rosenergoatom, is not considering applying for NRC approval.

### Regulatory Findings

- The NRC has not yet reviewed any small reactor designs, although several companies have stated their intention to submit designs for review in the next year or two. Those designs are 10 MWe or larger, a size too large for most rural communities in Alaska. They may be more appropriate for a Railbelt installation or for powering a remote mine.
- In addition to the reactor design review, the NRC requires a thorough review of any proposed site for a nuclear power plant. Such a review considers emergency planning, emergency zones surrounding the plant and appropriate seismic qualification. Currently, there are no permitted, or even seriously contemplated, sites for commercial nuclear power plants in Alaska.
- The NRC evaluates the technical and financial capabilities of the plant owners, including the ability of the owners to finance construction of the plant; to attract, train, and retain a workforce with appropriate skills; and to construct and operate a plant that meets appropriate standards. For this reason, development of a nuclear power plant in Alaska may require partnership with a company from a location outside Alaska that has expertise in nuclear energy, especially when building and commissioning the first plant.

### Economics of SMRs in Alaska

An economic model was developed as an initial screening tool for determining if and where SMR technologies could be economically deployed in Alaska when the technology becomes available. The model was designed to be readily adaptable as new eco-



conomic information becomes available so that additional analyses can easily be conducted in the future. Since SMR technology is not commercially available anywhere in the U.S., this analysis is subject to significant cost uncertainties.

Small modular reactor technologies used for the economic analysis were those that are currently under development and that could potentially be used in Alaska based on the capacity of the units and the anticipated date of availability. Five manufacturers' designs were selected for economic viability screening: mPower, NuScale, Hyperion, Toshiba 4S large (50 MWe) and Toshiba 4S small (10 MWe).

Capital costs per installed kWe (kilowatts electric) are estimated to range from \$4,500 to \$8,000. The combined construction and operating license (site and technology) is estimated to cost an additional \$50 to \$70 million regardless of plant size, thus adding \$400 to \$7,000 per installed kWe.

Capital Cost and Combined Operating License (COL) Costs							
Technology	Installed Capacity (MWe)	Capital Cost low (\$ Millions)	COL \$/inst kW Low	Capital Cost med (\$ Millions)	COL \$/inst kW med	Capital Cost High (\$ Millions)	COL \$/inst kW
mPower	125	\$560	\$400	\$750	\$480	\$1,000	\$560
Toshiba 4S Large	50	\$220	\$1,000	\$300	\$1,200	\$400	\$1,400
NuScale	45	\$200	\$1,110	\$270	\$1,330	\$360	\$1,560
Hyperion	25	\$110	\$2,000	\$150	\$2,400	\$200	\$2,800
Toshiba 4S Small	10	\$45	\$5,000	\$60	\$6,000	\$80	\$7,000

Capital costs include all costs for the SMR project "power island," which includes costs associated with buying, transporting and installing the reactor, as well as power-generation equipment, condensers and construction of the reactor facility. It excludes costs of transmission, distribution, roads and fuel. The combined construction and operating license includes both the NRC construction and operating license.

Communities that have at least an average annual power load close to, or larger than, 10 MWe were considered in this analysis. Eliminated from consideration were communities that meet the majority of their electrical power requirements with installed hydroelectric capacity. In addition, the analysis was limited to assessing community-based applications rather than large industrial loads, although the screening model could be applied to other possible users. Based on matching community electric loads with SMR unit capacity, potential economic viability was analyzed for rural hubs, including Bethel (4.5 MWe average annual load), Dillingham (2.3 MWe), Galena (1 MWe), Kotzebue (2.4 MWe), Naknek (2.2 MWe), Nome (3.3 MWe) and Unalaska (3.8 MWe). Galena was included in this group despite its smaller electric load for comparison with an analysis conducted in 2004.

The other areas with sufficient load to justify considering SMRs are the Railbelt, which includes Anchorage (652 MWe) and Fairbanks (223 MWe), and Tok (2 MWe), because of its relatively high load use of electrical power and its location on a major road system.

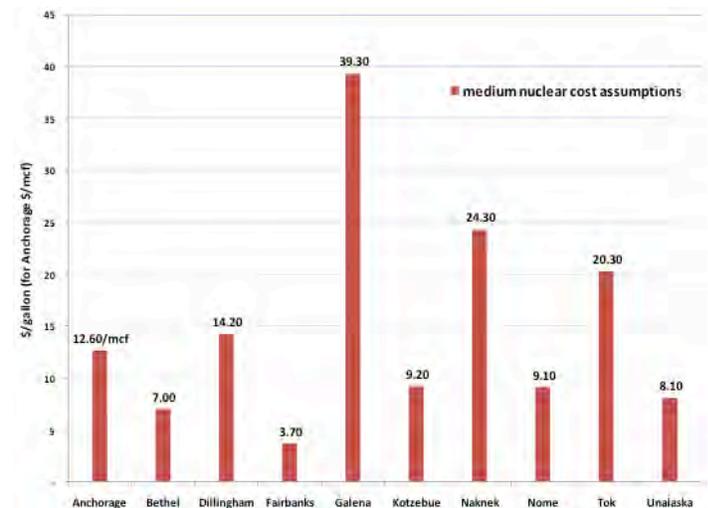
Economic scenarios for the development of SMRs involving assumptions of low- to high-price forecasts for crude oil, natural gas and carbon, coupled with low to high costs for SMR power

plant construction, fueling and licensing, comprise 36 unique variations. Five scenarios bracket economic viability of the alternatives based on the U.S. Energy Information Administration (EIA) crude oil and natural gas price forecasts and the Massachusetts Institute of Technology (MIT) carbon price forecasts. In addition to EIA forecast-based scenarios, a Railbelt scenario uses the natural gas price forecast of the Alaska Energy Authority Regional (AEA) Integrated Resources Plan (RIRP).

Under the medium and high EIA crude oil price forecast of between \$80 and \$100 per barrel over the next 20 years, SMRs become an economically viable alternative for the Railbelt, regardless of the assumed SMR cost range used in this analysis. Based on the analysis, small modular reactor technology is not economically feasible anywhere in Alaska under the current EIA low crude oil price forecast, even for the low-cost case of SMR construction and licensing.

The economic modeling suggests that four out of the five SMR power plants could lower the projected cost of electrical power in Fairbanks as soon as, or soon after, the nuclear technologies are expected to be deployed (2020 or 2025). Most promising was a hypothetical Fairbanks–Eielson Air Force Base scenario that utilizes excess heat from the power plant for the existing Eielson district heating system and delivers power to the Fairbanks market. It should be noted that this analysis was based on a comparison with current generation sources only and did not take into consideration possible changes from this baseline that would occur if a large hydroelectric or gas pipeline project were developed to serve the Fairbanks market. The analysis also did not compare the relative costs of SMR technology against a natural gas pipeline or new hydroelectric project.

Using EIA natural gas price forecasts, SMR technology did not lower the cost of energy in the Railbelt south of the Alaska Range. However, under the RIRP natural gas price forecast, the



Approximate local fuel price thresholds for SMR economic feasibility (2010)



larger light water reactor designs — NuScale and mPower — could potentially provide savings for Anchorage households shortly after deployment, assumed to be 2020 in the model.

Despite higher energy costs than in the Railbelt, the rural communities considered as part of our economic model were at a disadvantage because most SMRs are oversized for the community load, even when heating is included in the analysis. For this reason, the only rural community where SMRs would potentially lower projected future energy costs is Bethel. For Bethel, the local diesel-fuel price threshold for SMR economic feasibility is \$7 per gallon (2010 dollars). More communities might benefit from nuclear energy if smaller reactors more appropriately sized for typical village-scale loads were to become available, but such reactors are not currently being considered in the U.S.

## Conclusions

A number of advancements in the technology need to occur before SMRs can be seriously considered for Alaska. These include factors largely outside the control of the State of Alaska, including technology development, safety considerations, environmental considerations and economics (based largely on future world energy markets that are difficult to forecast). Along the way, there are many decision points related to adoption of the technology for Alaska applications.

Nevertheless, consideration could be given to steps designed to allow the State of Alaska to “keep the door open” on this technology. If appropriately sized SMRs were readily available today, they would be worth considering seriously for application both on the Railbelt and in rural communities. However, given the uncertainty of SMR commercialization, especially for the first few installations, combined with heightened negative public opinion of nuclear power in the wake of the Fukushima events, it is not prudent today to recommend investment in a SMR-based power plant for Alaska.

### Recommendations:

The State of Alaska could take the following actions to safeguard its interests as further advancements of this technology evolve:

1. Continue to explore options for smaller scale (<10 MWe) reactor technology. Since there is virtually no market niche

for mini nuclear power reactor technology in the contiguous U.S., little effort has been made to commercialize a product in this size range. However, research in this area has not been exhausted.



Core of a TRIGA research reactor, designed and constructed by General Atomics

There is no question that several small-power reactors have been developed in the U.S. and other countries. For example, General Atomics has a standard design for a research reactor installed in dozens of locations around the country; it is a nearly fail-safe design with minimal NRC permitting and licensing requirements. This TRIGA reactor could be converted to a power reactor, something that was explored by the manufacturer twenty years ago, but was discontinued due to lack of apparent market potential. Alaska could seek a partnership with other groups interested in pursuing mini nuclear power, such as the U.S. Department of Defense (DoD).

2. Identify a state technology lead. To stay abreast of developments in technology and permitting as well as economic efficacy, Alaska could identify a lead entity to follow developments by industry and federal agencies that are relevant for the state. Specifically, the AEA could designate a program manager for nuclear energy. Thus there would be a central point of contact and leadership for Alaska.
3. Consider SMR technology as one of several alternative scenarios. While SMR technology is not available commercially today, it may become available in the future and, as such, would be worth comparing with other alternatives now and in the future as a replacement for aging generation capability (such as coal plants) in the Railbelt. The RIRP process did consider a single Hyperion SMR module in the first stage of its screening analysis, but did not consider an array of SMRs added in increments over time to meet expected load growth. A scenario where individual modules were added over time could have the benefit of more closely matching loads and distributing costs over a longer time horizon.

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