

ALASKA STATE LEGISLATURE
SENATE COMMUNITY AND REGIONAL AFFAIRS STANDING COMMITTEE

April 25, 2019

3:31 p.m.

MEMBERS PRESENT

Senator Click Bishop, Chair
Senator Chris Birch, Vice Chair
Senator Mia Costello
Senator Lyman Hoffman
Senator Elvi Gray-Jackson

MEMBERS ABSENT

All members present

COMMITTEE CALENDAR

PRESENTATION: NUCLEAR MICROREACTORS

- HEARD

PREVIOUS COMMITTEE ACTION

No previous action to record

WITNESS REGISTER

JOHN WAGNER, Associate Director
Idaho National Laboratory
Idaho Falls, Idaho

POSITION STATEMENT: Delivered a presentation on nuclear energy and microreactors.

MARCUS NICHOL, Director
New Reactor Deployment
Nuclear Energy Institute
Washington, D.C.

POSITION STATEMENT: Delivered a presentation on the policy and regulatory opportunities of microreactors.

GWEN HOLDMANN, Director
Alaska Center for Energy and Power
University of Alaska Fairbanks

Fairbanks, Alaska

POSITION STATEMENT: Delivered a presentation titled "Nuclear Microreactors and Alaska."

GEORGE ROE, Manager
Arctic Remote Energy Networks Academy
Alaska Center for Energy and Power
University of Alaska Fairbanks
Fairbanks, Alaska

POSITION STATEMENT: Presented an overview of a microreactor workshop that was held in Anchorage on April 18, 2019.

MICHAEL PAWLOWSKI, Chief of Staff
United States Senator for Alaska Lisa Murkowski
Washington, D.C.

POSITION STATEMENT: Provided an update on Senator Murkowski's efforts to advance nuclear energy at the federal level.

ACTION NARRATIVE

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CHAIR CLICK BISHOP called the Senate Community and Regional Affairs Standing Committee meeting to order at 3:31 p.m. Present at the call to order were Senators Gray-Jackson, Costello, Birch, Hoffman, and Chair Bishop.

PRESENTATION: Nuclear Microreactors

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CHAIR BISHOP announced that the committee will hear a presentation on nuclear microreactors by John Wagner with the Idaho National Laboratory (INL) and Marcus Nichol with the Nuclear Energy Institute (NEI).

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JOHN WAGNER, Associate Laboratory Director, Idaho National Laboratory, Idaho Falls, Idaho, stated that he is a nuclear engineer and looks forward to answering questions and concerns about nuclear energy and its potential deployment in Alaska.

He commenced with his presentation, Microreactors: "not your grandparents' nuclear plants." He noted that the title of his presentation borrows a phrase from U.S. Senator Murkowski's recent op-ed, "Not your grandparents' nuclear plants." He said

it is a fitting remark when contrasting your grandparents' plants to a microreactor.

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MR. WAGNER reviewed slide 2, Why nuclear energy? as follows:

- Only carbon-free, scalable energy source that produces electricity 24 hours a day, 7 days a week, 365 days a year.
- Most reliable energy source in America:
 - Operating efficiency to 92 percent.
- Produces, by far, America's largest percentage of zero-carbon electricity, 56.1 percent.
- New reactors can be:
 - Right-sized to location.
 - Produce more than electricity.
 - Designed to sync with renewable resources.
- 19 percent of America's electricity is produced by carbon-free nuclear energy by:
- 98 nuclear power plants that operate in 30 states.

He explained that nuclear energy's baseload power is the most reliable energy source. Last year the collective operating fleet achieved a capacity factor of 92 percent. By comparison, solar typically achieves around 10 to 25 percent and the capacity of wind tends to be around 25 to 30 percent.

MR. WAGNER said nuclear energy produces, by far, the most carbon-free energy in the country of any source; 56.1 percent in 2018, which is more than all other carbon free emitting sources combined. One of the most relevant factors is energy density. For example, a uranium fuel pellet the size of a fingertip has the energy equivalent of three barrels of oil or a ton of coal. Because of nuclear energy's density, current reactors typically operate 18 months between refueling and some microreactors operate 10 or more years between fueling.

MR. WAGNER said the new reactors can be right-sized to the location, produce more than electricity, and can be designed to work in concert with renewable energy sources He reported that about 19 percent of the energy generated in 2018 was nuclear from 98 power plants that operate reactors in 30 states.

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SENATOR HOFFMAN asked what country produces the most nuclear power.

MR. WAGNER answered the United States of America.

SENATOR HOFFMAN asked if Japan at one time produced the most nuclear power.

MR. WAGNER answered no. He added that unless things change, China will surpass the U.S. because they are aggressively building new nuclear reactors.

SENATOR HOFFMAN asked where Russia ranks in nuclear power production.

MR. WAGNER answered that Russia is far behind.

SENATOR HOFFMAN asked if Russia was the country that designed the first nuclear submarine.

MR. WAGNER answer no. It was the U.S. and the nuclear reactor was tested at the Idaho National Laboratory (INL).

He explained that the origin of INL can be traced back to 1949 when it was established as the national reactor testing station. That is where the technology was developed for all nuclear reactors that have been deployed worldwide.

He said the current generation of light water reactors as well as advanced concepts like molten salt reactors, sodium cooled fast reactors, and high temperature gas reactors were built and operated at INL. There have been 52 different reactors over the years. The technology that is now deployed worldwide was all developed and demonstrated in concert with other organizations and other national laboratories.

He opined that INL now has an opportunity to develop and demonstrate what will be the nuclear technology for the next several decades throughout the world.

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MR. WAGNER explained that One Size Does Not Fit All is the theme of the evolution and future of nuclear reactors. To that end, researchers at the Idaho National Laboratory are collaborating with industry and academia to develop nuclear reactor concepts of various sizes for various use cases.

He said the next few slides will outline grandparent reactors, existing reactors, what they look like, and the evolutions that

is generally towards smaller reactors culminating in microreactors.

MR. WAGNER reviewed Existing (Large) Nuclear Reactors as follows:

- 98 existing plants in the United States.
- New plants are on the order of a gigawatt of electricity per plant.
- Plant sites with multiple units can produce multiple gigawatts of electricity.
- Smaller plants, typically older ones in the United States, vary from 5 to 600 megawatts.
- Two nuclear plants are being built in the state of Georgia and both are a little over a gigawatt.
 - Two Westinghouse AP1000s.
- Economies of scale and getting as much electricity out of a given site as possible drove design principles for bigger and higher-powered plants.

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SENATOR GRAY-JACKSON asked how many reactors are located on the West Coast.

MR. WAGNER answered not very many; the density is in the Southeast, Northeast, and Midwest. He noted that Diablo Canyon Power Plant is located on the West Coast, one reactor is in Washington state, and three units are operating in Arizona.

SENATOR BIRCH asked how many employees work in a one gigawatt reactor.

MR. WAGNER answered approximately 500 to 700 employees.

He explained that as reactors were built from the 1950s to the 1980s, they grew in size and started to standardize. They were substantial and complex construction projects built on site. It took up to 10 years before power was generated, and cost billions of dollars. He referenced an illustration that shows the footprints of a tiny microreactor that is less than an acre, a 50-acre small module reactor site, and a 1,500-acre representation of a large existing reactor site.

MR. WAGNER described the illustration on slide 4 that shows a typical existing pressurized water reactor (PWR). In the U.S. there are two classes of light water reactors: PWR and the

boiling water reactor. Basically heat coming out of the nuclear fuel from the fission reaction heats up water in the reactor pressure vessel. Water flows through the vessel to a steam generator that drives a turbine to make electricity. Typical pressure vessels in a PWR system reach 2,500 pounds per square inch (PSI).

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MR. WAGNER described Small Modular Reactors on slide 5 as follows:

- The next generation of small-modular reactor designs started a decade ago.
- Small-modular reactors were driven by the following principles:
 - Not all areas need a gigawatt of power.
 - Smaller systems open opportunities for factory-built construction.
 - Potential for scalability.

He referenced an image of a new scale reactor with multiple 60 megawatt reactor modules.

SENATOR COSTELLO asked about the size the footprint for a small modular reactor.

MR. WAGNER explained that the site size is estimated to be around 50 acres. The actual footprint of the buildings is a few acres.

SENATOR HOFFMAN asked where the first microreactors are expected to be in 2026.

MR. WAGNER answered that they will be at Idaho National Laboratory. He said INL is working with Utah Associated Municipal Power Systems (UAMPS) that is a consortium of municipal utilities.

SENATOR HOFFMAN asked when and where the first reactors will be operative.

MR. WAGNER answered at the Idaho National Laboratory.

SENATOR HOFFMAN asked if he had heard of Evgeny Pavlovich Velikhov, the author of Strawberries from Chernobyl.

MR. WAGNER answered no.

SENATOR HOFFMAN explained that Mr. Velikhov oversaw the Chernobyl disaster and was also involved in Russia's nuclear submarine program. He said he had an opportunity to meet with Mr. Velikhov five or six years ago when he was working with top Russian military officials to design small nuclear reactors for northern Russian communities, similar to what Mr. Wagner was proposing. He recalled that Mr. Velikhov said Russia was going to have the small nuclear reactors ready by 2020. He asked Mr. Wagner if he had any information as to what Russia and other countries are doing with regard to developing small reactors.

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MR. WAGNER answered that he does not have special knowledge about Russia's activities other than that they recently deployed small reactors on ships for mobile power and are developing a variety of smaller scale reactors for both civilian and military applications.

SENATOR HOFFMAN noted that Mr. Velikhov convinced the Russian government to use a decommissioned nuclear submarine to provide electricity to a community. He added that he does not know where Russia stands on small nuclear reactors, but the concept for Alaska seems to be a solution.

MR. WAGNER agreed and noted that Russia continues to develop nuclear icebreakers.

He added that in addition to electricity, microreactors have applications for heat, industrial heat and steam for hydrogen generation, and desalination. Microreactors are also intended to be more integrable with intermittent and renewable sources.

He detailed that Utah Associated Municipal Power Systems plans to have a reactor operating on the Idaho National Laboratory's 890 square mile property. He noted that UAMPS will be demonstrating technology from the private company NuScale Power.

MR. WAGNER turned to slide 6 Microreactors, noting that as in Russia, this country has some experience with microreactors in military and civilian applications, but more demonstrated on the military side. Rather than an onsite construction project, microreactors are assembled in a factory and power is ready to go once they are plugged in onsite. He noted that the size of a microreactor is in significant contrast to the other two reactors he mentioned.

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SENATOR BIRCH recalled that a number of years ago consideration was given to the installation of a Toshiba 4S at Galena. He asked if different local, state and federal impediments stand in the way of any installation.

MR. WAGNER answered that the Nuclear Regulatory Commission (NRC) regulates siting, safety, and security of such systems so any design would need to go through the NRC licensing process. While the review process is largely federal, local communities and the state is engaged.

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MR. WAGNER said over the last few years there has been a lot more interest in microreactors for the purposes of:

- Applications that simply do not need that much energy.
- Power systems that may be able to operate for a decade or more without refueling.
- Applications for remote communities in Alaska.
- Mining areas in Alaska, Canada, and South Africa.
- The Department of Defense (DOD) has renewed interest in nuclear energy for some of their applications, including remote desalination.
- Beyond electricity, addressing the needs of remote installations for desalination and district heating.
- Power needs change and microreactors can be scaled by adding more systems, similar to large batteries or diesel generator replacement.

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MR. WAGNER directed attention to an image from the Los Alamos National Laboratory (LANL) that provides some size perspective. He explained that it is a solid block core system that relies on heat removal technologies called heat pipes instead of water or other coolants. The system is roughly 12 feet long and 6 feet in diameter with an additional diameter representing shielding from the system. He noted that Westinghouse has been working closely with LANL and INL via their eVinci design.

SENATOR COSTELLO asked if the federal guidelines prevent individuals from for accessing and possessing enriched uranium.

MR. WAGNER replied the federal government regulates and controls access to all enriched uranium so a person with a 3-D printer would not be able to access the basic materials to print nuclear

fuel. He added that microreactors rely on high-assay low-enriched uranium and INL was working on an important supply chain issue because there are no domestic sources. High-assay low-enriched uranium (LEU) contains up to 20 percent uranium.

CHAIR BISHOP asked him or the next presenter to get the bogeyman out of the closet and tell the committee how safe nuclear generation is or is not.

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MR. WAGNER explained that fission reaction creates fission products and transuranic elements, some of which have long decay times. He opined that any nuclear system ultimately requires geologic disposal of very long-life transuranic materials.

CHAIR BISHOP asked if the half-life is 500,000 years before the material goes back to lead.

MR. WAGNER answered not exactly, but it is thousands of years. He added that one of the interesting things about some microreactor systems is that fuel utilization is rather low. Some of the fuel INL is considering for the first reactor demonstrations will come from spent experimental breeder reactor fuel where the uranium is extracted for reuse.

MR. WAGNER directed attention to an image on slide 6 from the company HolosGen that depicts a microreactor in a cargo container that would support remote mining applications.

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He reviewed the following characteristics of microreactors listed on slide 7:

- Small, easily transported sources for electricity and heat
- Full factory built
- Easily and quickly installed and removed from site
- Self regulating, high degree of passive safety
- Reliable sources of demand-driven power
- Easier to operate and require minimal operation
- Capable of operating for several years without refueling
- Designed to serve a range of energy applications
- Distributed to serve a range of energy applications
- Non-emitting sources of power
- On track for demonstration within 3-5 years.

MR. WAGNER said unlike the trends for the existing large, high power density reactors, microreactors are designed to have smaller sizes and very low power density. That means there is a completely different way of removing heat from the reactors. In time, microreactors will be completely autonomous and monitored at an offsite location as opposed to current reactors that require dozens of onsite operators. Many of the designs have an intended operating life of a decade or more. With additional research, the operating life can be extended further. A key point is that some areas will rely on renewable wind or solar in concert with the non-carbon emitting microreactor system

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SENATOR BIRCH asked if the fuel for a microreactor has a density that might attract someone interested in aggregating the fuel to make an explosive device.

MR. WAGNER explained that microreactors all rely on low-enriched uranium, which is not a weapons-usable material. At maximum it contains up to 20 percent uranium. Regarding concerns about radiological dispersion devices, he said the NRC will be regulating the safety and security of any nuclear system deployed in this country. He noted that this oversight is the gold standard in terms of protecting health, safety, and security.

He highlighted that your grandparents' reactors have a significantly different physical security presence, but what the right physical security presence will be for microreactors to meet the NRC requirements for various threats will be determined in the licensing process.

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MR. WAGNER reported that there is a significant resurgence of interest in nuclear energy that is largely driven by interest in non-carbon emitting energy. He directed attention to slide 8 that highlighted the following points:

- Third Way identified less than 50 companies and developing advanced nuclear reactor designs
- Significant private sector investment combined with private-public partnerships
- DOE, ARPA-E and GAIN providing resources through funding opportunities and voucher program
- DOE Office of Nuclear Energy Programs performing research and development at National Labs to support reactor

development (Microreactor, Advanced Reactor Technology, and Cross Cutting programs)

- DOD interest in microreactors

He reviewed the following technology advances enabling microreactor development:

- Continued development of advanced reactor designs based on coolants other than water
- Advancements in heat removal technologies (heat pipes) and advanced, higher-efficiency power conversion systems (Brayton cycle, super-critical CO₂, Stirling engines)
- Materials with improved thermal and structural performance
- Development of advanced modeling and simulation capabilities
- Advanced manufacturing methods simplify fabrication
- Space reactor development and technology demonstration (KRUSTY reactor)
- Investment in infrastructure to support reactor development (fuel fabrication, irradiation testing)

MR. WAGNER reviewed the recent legislation that supports microreactor development listed on Slide 10:

- Nuclear Energy Innovation Capabilities Act (NEICA)
 - Signed into law September 2018
 - Calls for the creation of a National Reactor Innovation Center to support demonstration of cost-shared private reactors
- Nuclear Energy Leadership Act
 - Introduced in March by Senator Murkowski and others
 - Calls for demonstration of two advanced reactors by end of 2025, and 2-5 additional reactors by end of 2035
- 2019 National Defense Authorization Act
 - DOE to develop a report to Congress on requirements for a pilot program for microreactors

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MR. WAGONER reported that the Idaho National Laboratory is doing a lot to support microreactor demonstrations. He briefly touched on some of the following points on slide 11 that outline the support INL is able to provide:

- Proven record of nuclear facility operations

- Existing buildings and green-field sites for reactor demonstrations
- Engineering-scale fuel fabrication and advanced manufacturing capabilities
- Utility connections, integrated energy systems testing
- Adjacent world-class nuclear research and development experimental facilities and capabilities to support development
- Common site characterization, controlled emergency planning zone
- NRC-licensing and DOE-authorization for facilities as appropriate

CHAIR BISHOP asked when the committee could visit INL to see what is being done in the area of microreactors.

MR. WAGNER answered that the committee has an open invitation and he would be happy to work with the chair offline on scheduling.

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MR. WAGNER offered the following summary of the presentation:

- Microreactors may offer significant advantages for some applications
- Microreactors have characteristics that enable rapid development and deployment
- Technology advancements and experience provide improved reactor designs
- A U.S. advanced reactor industry is developing several microreactor concepts
- Government is supporting development through funding and legislation
- INL is enabling developers by providing technical resources, capabilities and a demonstration site
- A demonstration is foreseen in the next 3-5 years, meaning it is time to consider applications of this emerging power source

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MARCUS NICHOL, Director, New Reactor Deployment, Nuclear Energy Institute, Washington, D.C., highlighted the following major benefits of microreactors:

- Can operate nonstop, 24 hours a day, 7 days a week, 365 days a year
- Maximum power output that achieves reliability factors higher than 95 percent, some at 99.999 percent reliability
- Do not emit carbon dioxide or other criteria pollutants into the air
- One of the lowest total carbon footprints for any of the power technologies, even lower than some of the renewables
- Can be paired with some other technologies in remote areas
- Can generate hydrogen for industrial processes or transportation
- Can produce heat for industrial processes or district heating of homes in addition to providing electricity
- A lot of interest for use in remote areas, typically to replace diesel generators
- Use in communities, industries including mines, or defense installations

He advised that his presentation will cover the typical questions he receives about microreactors such as when will they be available, how much will they cost, and what are the challenges to these reactors becoming a reality.

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MR. NICHOL displayed the Deployment Timeline from an October 2018 report that the Nuclear Energy Institute (NEI) developed. He made the following points:

- The timeline was developed specifically with defense installation in mind.
- The timeline is applicable to a remote community or mining operation.
- To deploy a commercial microreactor will take about seven years.
- A demonstration reactor will take three to five years.
- A commercial microreactor must go through a more involved check process because it will be producing power for commercial purposes.
- The first microreactor could be deployed before the end of 2027.
- The timeline could be earlier or longer depending on the challenges during deployment.
- The critical path that dictates the timeline schedule is driven largely by the NRC licensing and the construction and fabrication of the microreactor itself.

- Fuel development and the fuel cycle much be considered.
 - Many of the advanced microreactors will use fuel that is not typically used in today's light water reactors.
 - The NRC is very stringent on the fuel requirements because it is a key component to the safety basis of the reactor.
 - The NRC wants to see a lot of testing data to support the safety basis, but the data takes a lot of time to develop to prove to the NRC that it is safe.
 - While fuel development is not considered the critical path, the process is considered a secondary critical path that could extend the schedule if it isn't addressed in a timely manner.

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MR. NICHOL discussed the following estimated costs outlined on slide 4:

- Diesel generator costs
 - Primarily fuel costs
 - Fuel from \$2.86/gallon to \$4.89/gallon
- Microreactor costs
 - Include used fuel disposal and decommissioning
 - 10-year fuel life
 - 40-year plant life
 - 95 percent capacity factor

MR. NICHOL said the NEI finding that microreactors can be cost competitive with diesel generators is based on a 2019 NEI report. It looked at the cost of microreactors with sensitivity analysis to better understand the different cost components as well as competitiveness in different markets. The diesel generator costs are for not just remote Arctic communities in Alaska, they include remote areas and islands as well.

MR. NICHOL said NEI found that the first microreactor could cost somewhere between \$0.14 and \$0.41 per kilowatt hour (kWh), which would be competitive with diesel generators in the remote areas. NEI believes this is a positive finding because first-of-a-kind technology typically is more expensive and has a difficult time competing in the market. In this case, microreactors are expected to be cost competitive from the start. Ultimately, costs could come down to between \$0.09 and \$0.30 per kWh. The diesel generator costs were primarily estimated based on fuel cost in the range of \$2.86 and \$4.89 per gallon. Those are costs that have been seen in the remote markets over the past several years.

He pointed out that microreactor costs include the cost of disposing of the used fuel, decommissioning and removing the reactor, and returning the location to what is referred to as a green field. He said not many technologies include the end of life costs in their models, but NEI does. The law dictates that the industry pays for decommissioning costs up-front and as operations are performed.

MR. NICHOL concurred with Mr. Wagner that microreactors are expected to operate for 10 years without the need for refueling from offsite. He said this is a key attribute of microreactors that other technologies typically do not have.

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CHAIR BISHOP remarked that the diesel fuel price in rural Alaska are double those that were quoted so microreactors would be in the money very quickly in rural Alaska.

MR. NICHOL replied that a lot of benefits can be derived from the lower costs of microreactors. If the cost of energy is less, remote communities will be able to use their money for other needs. Having lower energy costs also makes industrial processes more competitive. Microreactors will make mines more profitable, operate longer, and make lower grade ores more profitable.

CHAIR BISHOP commented that he would think that environmental groups would embrace microreactors as a means of taking tons of carbon out of the atmosphere.

MR. NICHOL answered that many, but not all, environmental groups embrace nuclear energy. The Union of Concerned Scientists has expressed support for the existing fleet of nuclear reactors, but they have not expressed support for the advanced reactors. The Nature Conservancy has expressed support for nuclear to address climate change. They have suggested that to meet climate change goals, nuclear power generation in the U.S. needs to increase from 20 to 30 percent. It is broadly recognized that nuclear energy needs to be part of the solution if climate change is going to be addressed.

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MR. NICHOL explained that the Nuclear Regulatory Commission (NRC) sets very high safety and security standards for these reactors as part of its regulation of the nuclear industry. The safety requirements are set based on protecting the public from the hazards of radiation. What that typically means is the core

needs to be kept cool. Step one in helping to protect the public is that microreactors have less radioactive material than larger reactors. Second, many microreactor designs incorporate advanced techniques and features that will allow heat to be removed from the core and remain cool indefinitely, even if there is no power or additional cooling water. He noted that the inability to keep the core cool was a cause for the Fukushima Daiichi accident in 2011. By comparison, microreactors are being designed with inherent natural physics that will keep the core cool.

MR. NICHOL said the NRC sets very high standards for nuclear plant security based on the design-basis threat for the facility. The federal government in consultation with the Department of Homeland Security and others define the adversarial characteristics these nuclear power plants must be protected against. He said the current reactors are protected with a large number of security guards to prevent the bad guys from doing any harm. He noted that some of the more advanced reactors will have security built into the design itself.

MR. NICHOL stated that the NRC could safely license a microreactor today but the current regulations are designed for the very different technology of large, light water reactors. The current regulations could require some things that are not necessary for microreactors. He said NEI believes that there are a number of areas where the NRC requirements could be right-sized to better fit the microreactor technology.

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He continued to discuss the following regulatory opportunities listed on slide 5:

- Right-size requirements
 - Emergency preparedness
 - Large reactors today have 10-mile emergency planning zones. These are area where emergency procedures need to be preplanned.
 - Because of the size and safety of microreactors, there is almost no risk to the general public for offsite release of radiation.
 - It could be that it would not be necessary to preplan the emergency preparedness. There would still be the capability of having emergency response, but without an advance preplan.
 - Security

- This is being built into the plant itself in order to reduce the number of required security guards.
- The different posture on security would be able to rely on the local law enforcement to help with a threat.
- o Siting
 - The current siting regulations are very specific regarding how close reactors can be located to population centers.
 - The enhanced safety of microreactors will make it possible to locate closer to towns, especially if the heat is used for heating homes.
- o Staffing
 - Staffing needs for microreactors are not the same as large, light water reactors.
 - Make sure staffing is appropriate, especially for microreactors that have the capability of automatic operations.

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CHAIR BISHOP asked if he was talking about cogeneration, so a village could get electricity and have a distribution for hot water as well.

MR. NICHOL answered yes. He added that pairing transportation to either hydrogen or electric generation could eliminate the use of fossil fuels as well.

MR. NICHOL returned to the discussion of regulatory opportunities. He highlighted the following about streamlining reviews:

- Streamline reviews
 - o It may take the NRC three years to review the application and safety basis for the reactor, but that may possibly be reduced to two years.
 - o One of the challenges is the environmental timeline.
 - o Environmental
 - There are opportunities to streamline the environmental review as well for microreactors to reduce the timelines.
 - o Safety

SENATOR BIRCH asked if the size and power output of a microreactor is equivalent to the reactor used on a nuclear submarine.

MR. NICHOL replied the physical size is roughly the same, but he didn't know about the power output equivalency.

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MR. NICHOL reviewed the federal policy opportunities outlined on slide 6:

- Support clarification of the technical basis
 - Cross-cutting R&D
 - Demonstrations.
- Support deployment
 - Power purchase agreements
 - Loan guarantees
 - Fuel
 - Supply chain.
- Fulfill used fuel responsibilities.

He explained that the federal government is looking at modifying its power purchase agreements to make it easier to procure power from microreactors. He described this as an important change for DOD installations.

MR. NICHOL explained that there is no commercial domestic supply for low-enriched uranium because there hasn't been any demand. That won't change until microreactors or advanced reactors demand that fuel, but there won't be those reactors without the fuel. It's a chicken and egg situation. He highlighted that DOE appears to be willing to step in and provide a bridge supply until the commercial supply develops.

He said it is the federal government's responsibility to dispose of used fuel. A final disposal place for nuclear waste is located at Yucca Mountain in Nevada. A lot of work has gone into proving the site's technical and safety basis for nuclear waste. It is funded by the industry. He noted that the Nuclear Waste Fund has over \$30 billion, but appropriations for nuclear waste activities continues to be a political issue.

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MR. NICHOL reviewed the following state policy opportunities listed on slide 7:

- Equal treatment with other generation sources
 - Clean energy policies
 - Reducing barriers to entry

- Support the formation of an industrial base:
 - Lower financing barriers,
 - Incentives for supply chain.
- Provide infrastructure support:
 - Training,
 - Transportation improvements.
- Foster stakeholder engagement.

He said there are opportunities at the state level as well. The first is equal treatment with other energy generation sources, especially in the area of clean energy policies that address climate change. Clean energy should include nuclear power. A lot of places are focused strictly on renewable energy to address climate change, but nuclear power is important in the climate change arena and should not be excluded.

He opined that another state-level opportunity is reducing barriers to entry. He noted that in 2010, the Alaska State Legislature passed Senate Bill 220 (SB 220) that removed a moratorium on nuclear power in the state and allowed nuclear projects to gain access to funding.

MR. NICHOL said supporting the formation of an industrial base is a state-level opportunity. If Alaska is looking at having microreactors deployed in remote areas, attracting a supply chain makes sense. The state could help by incentivizing the supply chain and lowering financial barriers as well.

He opined that supporting infrastructure is another state-level opportunity. Supporting infrastructure includes training people who might work at a microreactor and others who may work within the microreactor industry. Perhaps even more important for remote applications is transportation improvements for roads and bridges. Many of the microreactors will be small enough to transport by truck, rail, or C-17 aircraft.

MR. NICHOL said the final state-level opportunity is to foster stakeholder engagement, especially in remote areas. There may be a lack of nuclear understanding, so fostering engagement is important to address concerns and perspectives.

MR. NICHOL concluded saying that Alaska is not alone in its interest in microreactors. There are international opportunities as well. Canada issued a roadmap in 2018 to address its interest in microreactors for Arctic communities and mining operations.

CHAIR BISHOP thanked Mr. Nichol and announced that the committee will next hear from Gwen Holdmann and George Roe.

GEORGE ROE, Manager, Arctic Remote Energy Networks Academy Manager, Alaska Center for Energy and Power (ACEP), University of Alaska-Fairbanks, Fairbanks, Alaska introduced himself and said he and Ms. Holdmann would provide some background and recent information on nuclear microreactors and Alaska.

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GWEN HOLDMANN, Director, Alaska Center for Energy and Power, University of Alaska Fairbanks, Fairbanks, Alaska, said she would provide the background on what the Alaska Center for Energy and Power (ACEP) has done and Mr. Mr. Roe would talk about the workshop they attended last week.

She explained that ACEP was formed 11 years ago with the mission to perform research on energy systems that are relevant to Alaska, both now and in the future. ACEP is a mission-driven organization that works closely with communities and industries that have technologies that could potentially be relevant to Alaska.

MS. HOLDMANN stated that ACEP is constantly assessing opportunities for new technologies from other markets, providing information to policy and decision makers and industry representatives about the Alaska market, and ensuring that the organization's use-cases are considered. For example, ACEP has been advising microreactor companies on a technical level about Alaska use-cases.

She reviewed the following discussion topics on slide 3:

- Highlights from prior (2010-2011) study of small modular reactors.
- Observations from April 18, 2019 workshop.
- Proposed next steps.

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MS. HOLDMANN reviewed the following points on slide 4, Context for 2010 Study on SMR's, Small Modular Nuclear Power: an option for Alaska?

- Requested by Alaska State Legislature in 2009.

- Response to 2008 Global oil price spike that exposed vulnerabilities of Alaska to annual (and intra-annual) fluctuations in oil prices.
- Interest in solutions that can provide baseload power (many remote locations only have access to intermittent renewables).
- Interest in options that can offset heating loads as well as electric power.
- Fukushima disaster occurred the same month the study was finalized.

She explained that the 2010 study was an opportunity to take a comprehensive look at small modular reactors which at the time was what was being considered for potential use in Alaska.

MS. HOLDMANN said the 2010 report was a collaboration between the University of Alaska Fairbanks and the University of Alaska Anchorage. She detailed that she was the lead author of the report. Contributors to the report included Dr. Dennis Witmer, materials engineer; Dr. Frank Williams, chemical engineer; University of Alaska students; and economists from the Institute for Social and Economic Research (ISER).

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MS. HOLDMANN detailed that the 2010 study started out by reviewing the history of nuclear technology utilization in Alaska. The most well-known is the 2 megawatt reactor installed at Fort Greely as part of the Army Nuclear Power Program. It operated for about a decade. Several similar modular reactors were installed in various places including the McMurdo Station in Antarctica. It was decommissioned at the same time as the unit at Fort Greely. Other examples of nuclear technology in Alaska include the seismic monitoring station at Burnt Mountain north of Fort Yukon. It used small radioisotopes thermoelectric generators that allowed the station to monitor Russian underground nuclear testing.

She said there are examples of actual nuclear activity in Alaska related to the weapons. Amchitka was the site in the Aleutians where three underground nuclear tests were performed. One was the largest in the United States. Project Chariot was considered between 1958-1962 to demonstrate the peaceful use of nuclear explosives for major construction projects. However, it was proposed before there was an understanding of the environmental impact and potential impact to the food chain from radioactive fallout.

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MS. HOLDMANN turned to slide 7, Representative Small Reactor Sizes and Operating Temperatures. She noted that when the study came out, reactor technology at the time was very large by Alaska standards. The Toshiba 4S Project that was proposed for Galena was of real interest because the 10 megawatt reactor was a smaller scale that was potentially relevant to Alaska. She said she believes that is why it generated so much interest and discussion at the time.

She said slide 8 shows a slice of the microreactor technology that is being considered today. This is smaller, lower outlet temperature technology that was not on the drawing board at the time of the 2010 study. She noted that the number one recommendation from the 2010 study was to continue to explore options for smaller than 10 megawatt reactor technology. She quoted from the 2010 report:

There virtually is no market niche for mini nuclear power reactor technology in the contiguous U.S. and therefore little effort has been made to commercialize a product in this size range. None the less, there is a real potential here and this is what we should be tracking.

She said that is why ACEP is excited to address the committee on current smaller scale reactor technology.

MS. HOLDMANN explained that the Alaska map on slide 9 shows the hub communities in Alaska based on the economics of potentially deploying a reactor. She said a real challenge that makes the 2010 study obsolete is that it looked at reactors in the 45 megawatt range. That is uneconomic even in Alaska's rural communities where energy costs are high because it's not possible to use all the electrical and thermal energy that is produced. That's still an issue today for the small module reactors even if the prices are in the \$0.14 to \$0.17 range that Mr. Nichol mentioned and the heat and power output is maximized. However, possibilities are greater with these microreactors.

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MS. HOLDMANN displayed the bar graph on slide 10 that shows the local price thresholds for small module reactor economic feasibility. She explained that most of this work was done by ISER but the numbers aren't accurate today because the additional cost for the combined construction and operating license would more than double the installed cost estimate in

2010. However, the relative size of the bars for the different communities is relevant. For example, the smallest bar is Fairbanks, which means that community is the best economic opportunity for displacing existing sources of fuel. She reminded the committee that the work in 2010 was based on a 45 megawatt reactor and since the current talk is about a much smaller reactor, the communities such as Bethel that have smaller loads would probably look much better if the analysis was redone. She suggested that updating the analysis would be worth doing in the near future.

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MS. HOLDMANN reviewed the report findings listed on slide 11. She said one finding was that most of the proposed designs were quite large by Alaska standards. Another finding was that the technology is not mature. Both of the previous speakers alluded to the fact that microreactor technology is moving along and there is likely to be a demonstration at the Idaho National Laboratory in the next several years. However, it is not something that can be purchased off the shelf and installed in Alaska in the next five years. At best it will be a decade before microreactor technology is available so investment decisions can't be made today. She suggested taking a wait and see approach. She also pointed out that there are limitations as to which sites would be available for deploying small microreactors in Alaska. A low price point will require maximizing the base load system for the electric power output and the heat output and those are more difficult to modulate for nuclear systems than for diesel generators.

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MS. HOLDMANN displayed the decision making chart that ACEP developed in 2010 for a pilot project in Alaska for a small scale modular nuclear system. She said she believes that the chart is still relevant. She explained that ACEP established a set of stage gates with yes and no decision points that ask whether the technology exists, is safe, has potential significant environmental concerns, and is economic.

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She directed attention to slide 12 and explained that ACEP has tried to follow through on the action items that came out of the 2010 report. ACEP continues to maintain active monitoring efforts of nuclear technology and the industry by sending interns to work in the INL. ACEP has also advised manufacturers or potential developers of the Alaska market. The following action items came out of the study:

1. Maintain active monitoring effort to stay abreast of developments in the nuclear power industry.
2. Provide input to NRC on unique needs, circumstances in Alaska.
3. Identify mechanism to address ownership/insurance issue.
4. Remove technical and siting barriers in state statutes.
5. Explore options for small scale (10 megawatts or less) reactor technology.

SENATOR HOFFMAN asked what the initial cost of the study was and whether she thought it needed to be updated.

MS. HOLDMANN answered that \$200,000 was directed to the Alaska Energy Authority (AEA) for the study and ACEP did most of the work. She opined that updating the study would be pretty fantastic. ACEP has the framework in place for the economic analysis which could be used to provide an updated look through the lens of the smaller technologies. That shouldn't take much time and probably wouldn't be too expensive.

SENATOR HOFFMAN thanked her for all the work she has done on the study.

CHAIR BISHOP invited Mr. Roe to continue the presentation.

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MR. ROE said he would provide a brief update on the workshop that he and Ms. Holdmann attended in Anchorage on April 18, 2019. The goal was for a cross section of Alaskan perspectives and interests to gather and learn from the experts and then play that against what Alaska needs for a cogeneration system for both thermal and electrical energy to meet the needs of industry, perhaps small communities, and certainly larger hub communities. The participants then explored the kind of engagement, if any, Alaska should have with these pilot studies. The intention was to provide a record for industry to understand what Alaska cares about in terms of microreactor technology and its integration.

MR. ROE directed attention to the slide that illustrates and lists the multiple and diverse stakeholders that ACEP gathered from across the state. They represented the different regions, economic drivers, and people who care for the state from the perspective of the people and place. He said the response to the invitations was so overwhelming that a virtual meeting was added to accommodate the interest.

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MR. ROE explained that the stakeholders tried to discern the logical place to start if microreactors were to come to Alaska. The consensus was that a stationary reactor would be the right approach. He explained that stationary does not mean that the installation would be there forever, just that it is not on wheels. The focus was on something that would provide a continuous level of baseload power. He noted that microreactors have more inertia than a diesel generator so they will likely need to be paired with thermal or electrical storage to allow the system to run without cycling beyond their initial capabilities.

He said the exact mix of thermal and electric power will depend on whether the intent is to generate hydrogen or power electric vehicles in addition to more conventional loads. He noted that ACEP received U.S. Economic Development Administration (EDA) funds to do a study for a small reactor company. They have been looking at the generator sizes in many small communities to see what the logical pairing might be. He said ACEP has been paying attention to the communities that have existing heat recovery systems because in addition to electrical, they are familiar with how to run thermal energy in their community environment. This is very important, especially in areas that have permafrost.

MR. ROE said the logical progression seems to be to start in a fairly controlled setting such as a military base. The next step would be to move to a larger industrial or institutional site that also needs large amounts of heat and power. One of these systems can be integrated into a larger system so that there is no single thread dependence on a particular system. He said ACEP has looked at the assets at various military bases that might accommodate integration and several locations in Alaska have expressed interest publicly in this technology.

He said mining is an interesting application in Alaska. These are very controlled, small, isolated sites with fairly low risks and they need large amounts of power and heat. Several people at the workshop stated on the record that the cost of energy was limiting the development of the resource. He said that is an interesting statement that should be considered looking forward.

MR. ROE highlighted that ACEP facilitated discussion at the workshop by asking different groups what they would be interested in doing if they had a source of heat and power that

was small, compact, and could be installed without much effort. He said he boiled the three pages of suggestions down to the following points:

- Stakeholder consultation
- Assess reliability, safety, environmental risks
- Determine siting requirements
- Characterize regulatory and policy environment
- Incorporate cradle-to-cradle thinking
- Develop integrated commercialization roadmap
- Monitor industry / regulatory developments
- Incorporate Alaska interests and use cases in any microreactor pilot program(s)

The most important point that came back from the various groups was that people wanted to make sure stakeholders were consulted.

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SENATOR GRAY-JACKSON asked if the stakeholders included representatives from Chugiak Electric and Municipal Light & Power (ML&P).

MR. ROE answered yes; he named the individuals from those utilities as well as from Matanuska Electric Association (MEA).

He said the other thing that was important to the various groups was to have the risks of a nuclear accident well characterized. That is part of the siting requirements that is based on the size of the reactor and geo-technology, among other considerations.

MR. ROE noted that one of the voices from Nome encouraged cradle-to-cradle thinking so consideration is given to what happens when the reactor is shut down. He said the intent is to keep from creating a problem for communities by understanding the technology and staying informed using the roadmap that Ms. Holdmann shared. He said NEI has released two documents and Canada has developed roadmaps for microreactors that are very useful.

MR. ROE said the bottom line is that wherever a pilot study is done, for example the demonstration reactor at INL in 2026, it is important to ensure that Alaska-use cases are incorporated so ACEP can help with the design to get as much value as possible out of the pilot. Wherever the pilots may be, Alaska needs to be at the table.

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CHAIR BISHOP opined that Alaska would be the premier spot for a test drive because the Arctic nations are a target-rich environment for microreactors.

MR. ROE concurred. He said it's important to proceed carefully, but the benefits of affordable heat and power changes the game for so many different perspectives.

He suggested the committee visit the Idaho National Laboratory on June 18, 2019 when there is a by-invitation workshop in Idaho Falls. He disclosed that the INL is in the process of reviewing a proposal from the University of Alaska Anchorage to look at the Alaska microreactor study. It focuses on public perception, the use cases, and deeper-dive case studies so it should be a very useful update to the 2010-2011 study.

CHAIR BISHOP thanked the presenters and recognized Mr. Michael Pawlowski, Chief of Staff for U.S. Senator Lisa Murkowski.

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MICHAEL PAWLOWSKI, Chief of Staff, United States Senator Lisa Murkowski of Alaska, Washington, D.C., said the senator thanks the committee for looking at the potential for nuclear energy for Alaska, the U.S., and ultimately the world. He related that Senator Murkowski has been the leader on the federal level of advancing nuclear power for the past several years. In 2016 she held a hearing to understand what was happening in the advanced nuclear realm. Stakeholders at that time agreed that the Department of Energy (DOE) needed some policy changes to get the federal government to work better with the private sector.

MR. PAWLOWSKI said Senator Murkowski included the Nuclear Energy Innovation and Capabilities Act (NEICA) in the broad bipartisan energy bill that she sponsored with U.S. Senator Cantwell in 2016. She continued to work the legislation until it was signed into law in 2018. Once the law is implemented, it will accelerate the development path for deploying the technology.

He said Senator Murkowski's colleagues also completed work on the regulatory side. The regulatory oversight that the U.S. Nuclear Regulatory Commission (NRC) provides is very beneficial for reactor safety, but it can be a burden to innovators in the industry. The nuclear regulatory framework that has been developed over the decades is specifically tailored to the large, light water reactor technology, which is a regulatory

mold that microreactors do not fit. He said microreactors are inherently safe if there is a shutdown and inherently secure so they may not need the massive and expensive security force that the current reactors require. To deal with this challenge Congress adopted the Nuclear Energy Innovation Modernization Act (NEIMA). It requires the NRC to create a sensible regulatory pathway specifically for advanced reactors. He stated that this should speed the process for approval and decrease the regulatory cost of advanced reactors all while ensuring world-class levels of reactor safety.

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MR. PAWLOWSKI also mentioned the Nuclear Energy Leadership Act (NELA) that is a bipartisan effort to allow nuclear developers to successfully move their concepts through the challenging developmental phases to full commercial deployment. He said the Senate Energy Committee has scheduled an oversight hearing on the bill next week so the Alaska Community and Regional Affairs Committee efforts are timely.

MR. PAWLOWSKI said the ultimate point he would like to make is the importance of fostering stakeholder engagement. While Senator Murkowski is working on the different issues at the federal level, she deeply appreciates the committee diving in and looking at what might need to be done at the state level.

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SENATOR HOFFMAN said he believes it would be beneficial to include a section in the NELA legislation about how microreactors can reduce energy costs in rural Alaska, potentially as a demonstration project. He agreed with the chair that Alaska would be ideal to implement a microreactor project. It would be a game changer for rural Alaska. He asked Mr. Pawlowski to convey his comments to Senator Murkowski.

CHAIR BISHOP asked Mr. Pawlowski to reach out if there was anything the committee could do to help Senator Murkowski move NELA forward.

MR. PAWLOWSKI said he would convey Senator Hoffman's very important points and work to see if language could be added to the legislation for the types of demonstration projects and partnerships that Senator Hoffman mentioned.

CHAIR BISHOP thanked the presenters.

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There being no further business to come before the committee, Chair Bishop adjourned the Senate Community and Regional Affairs Standing Committee meeting at 5:07 p.m.