Small Scale Nuclear Power: an option for Alaska?

Update January 2021

Prepared by the Alaska Center for Energy and Power University of Alaska Fairbanks acep.uaf.edu







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Table of Acronyms & De nitions

ACEP: C , , E, , aa aa A. . F.a.a ADEC: A. . D E. . . . C. AEA: A, E, A . . CHP: C₁ 4 4 , **a** a) DOD: . . D D . DOE: . D E. EBR-II:E + + + i B + · i ESP: E_{i} \bullet - \bullet $(C_{i}$ \bullet) 6 **6**1 GFR: . - GIF: G a com ao acom a Fa , (° oo :// · a = ~; · a / a/) IAEA: as a set of Asing E. A. INL: 9. · · · · · · · · · · · · ·

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Small Scale Modular Nuclear Power: An option for Alaska?

1. Executive Summary

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F: Sample non-hydroelectric communities in Alaska with su cient heating and electric loads to match Small Modular Reactor (SMR) or Micro Nuclear Reactor (MNR) capabilities currently under development. Note that loads included in this figure represent maximum electric loads only. Industrial and military sites are not included.











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2. Overview of Small Nuclear Technologies

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⁷ Permitting through the Nuclear Regulatory Commission (NRC) is a two-step process. Modular designs can help streamline permitting because the technology is permitted separately from the site.

⁸ From "DOD Awards Contracts for Development of a Mobile Microreactor," (March 9, 2020), Retrieved December 27, 2020, from <u>https://www.defense.gov/Newsroom/Releases/Release/Article/2105863/dod-awards-contracts-for-development-of-a-mobile-microreactor/</u>.



⁵ In comparison, the average size of conventional nuclear power plants is approximately 1000 MW, or 1 Gigawatt.

⁶ This is an arbitrary cuto , and there are some reactors that are slightly above this size that are still considered small reactors. For example, TerraPower is a company backed heavily by Bill Gates which uses liquid sodium as a coolant and is designed to generate 345 MW of electric power.





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F: . . Conceptual layout of a generic SMR or MNR plant. An SMR or MNR is designed to be delivered to the site with key components (or in some cases the entire system) packaged in self-contained housing that is designed to be placed below grade. Many of these reactors generate steam which is used to generate power. Heat can be delivered via a steam or hot water district heating system.

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¹⁶ For example, a Nuscale 12-module power plant would be capable of generating 720 MW. In comparison, the peak demand of the Golden Valley Electric Association grid is 220 MW, and the Railbelt in total is approximately 800 MW.





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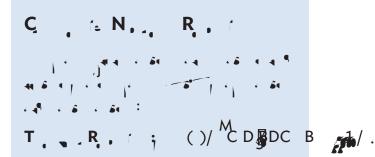
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²⁰ The IMSR design is currently undergoing licensing in Canada of a 400MW thermal (190MW electrical) reactor design, with the first phase of a prelicensing review completed by the Canadian Nuclear Safety Commission in 2017. This first phase provided a regulatory opinion that the design features are generally safe enough to eventually obtain a license to construct the reactor. (From "Pre-Project Design Review of Terrestrial Energy Inc. Integral Molten Salt Reactor," (November, 2017), Retrieved December 30, 2020, from http://nuclearsafety.gc.ca/eng/pdfs/Pre-Project_Design_Review/Terrestrial-Energy-Pre-Project-Design-Review-Exec-Summary-eng.pdf.)



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¹⁸ From "INL to provide Oklo access to recovered fuel for microreactor demonstration project," (February 20, 2020), Retrieved December 30, 2020, from http://www.bizmojoidaho.com/2020/02/inl-to-provide-oklo-access-to-recovered.html.

¹⁹ Information on TRISO fuel available from "TRISO particles: The most robust nuclear fuel on earth," (July 19, 2019), by Idaho National Lab, from https://art.inl.gov/News%20Highlight%20Attachments/TRISO-particles-most-robust.pdf.

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²³ NuScale was also used for the economic model developed for ACEP's 2011 report (Holdmann et al, 2011).

²⁴ This project is heavily subsidized by the U.S. Department of Energy.

²⁵ The family of nuclear reactors known as light-water reactors (LWIu (Looled and moderated using o(L) 8 tmsBT 50 (B) r) 2 eact) 2 or) 2 ked (L)

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³² Launch Alaska website: <u>http://www.launchalaska.com/</u>.

³³ Information provided is derived from ACEP's nuclear educational series presentation by Wendy Simon-Pearson, General Counsel, Ultra Safe Nuclear Corporation presented December 17th, 2020.

³⁴ There are various reasons why a vendor would choose to license their technology in Canada rather than the U.S. Although initially having di erent approaches with the CNSC more flexible in addressing the unique needs of small reactor technology, today the CNSC and US-NRC are converging on harmonization of the licensing process, so the licensing work done for one country will be broadly applicable to the other.



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³⁷ From "Nuclear Power in Russia: Floating nuclear power plants," (Updated November 2020), by the World Nuclear



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3. Licensing SMR and MNR Technologies

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⁴⁴ NRC Early Site Permit Applications: <u>https://www.nrc.gov/reactors/new-reactors/esp.html</u>



⁴² Nuclear Regulatory Commission website: <u>https://www.nrc.gov/</u>

⁴³ NRC Design Certification Applications: <u>https://www.nrc.gov/reactors/new-reactors/design-cert.html</u>

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⁴⁵ Federal Register/Vol. 85, No. 32/Tuesday, February 18, 2020/Proposed Rules, available at



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⁵⁹ "Alaska State Senate Community and Regional A airs Committee Bill SB 194, 'An Act relating to advanced nuclear reactors'", Retrieved December 30, 2020, from <u>http://www.akleg.gov/basis/Bill/Detail/31?Root=SB%20194</u>



⁵⁶ "Alaska Nuclear Energy Statues 2019, Section 18, Chapter 45: Atomic Energy," Retrieved December 30, 2020, from <u>http://www.akleg.gov/basis/statutes.asp#18.45.020</u>.

⁵⁷ "Alaska Sustainable Energy Act (SB 220)", Retrieved December 30, 2020, from <u>http://www.akleg.gov/basis/get_documents.</u> <u>asp?session=26&docid=8040</u>.

⁵⁸ From "Research in Advanced Nuclear Development and Planning," by Kuca, M., (2014), Retrieved December 30, 2020, from <u>http://hdl.handle.net/11122/8842</u>.

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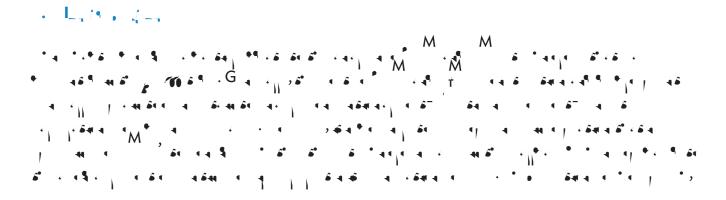
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⁶¹ A personal discussion with a legislator involved in the original development of these statutes acknowledges they were developed in response to concerns about nuclear proliferation and waste disposal and were not intended to hinder small-scale development that was not envisioned as a possibility at the time of authorship.



⁶⁰ "Decommissioning nuclear reactors is a long-term and costly process," (November 17, 2017), by Gospodarczyk, M.M., & Kincer, J., Retrieved December 30, 2020, from <u>https://www.eia.gov/todayinenergy/detail.php?id=33792</u>.

5. Economics of SMR and MNR Technology in the Alaska Context







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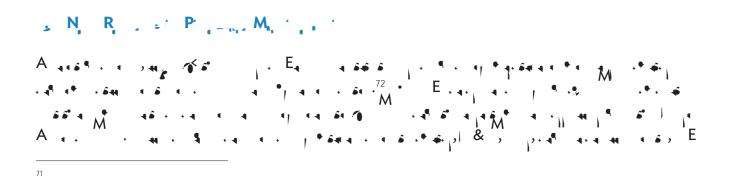
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⁶⁶ From "Cost Competitiveness of Micro-Reactors for Remote Markets," (April, 2019), by the Nuclear Energy Institute, Retrieved December 30, 20 2.u (4.s 3000 AEMC /P /L 6000) (5 meps) (5 sts-be





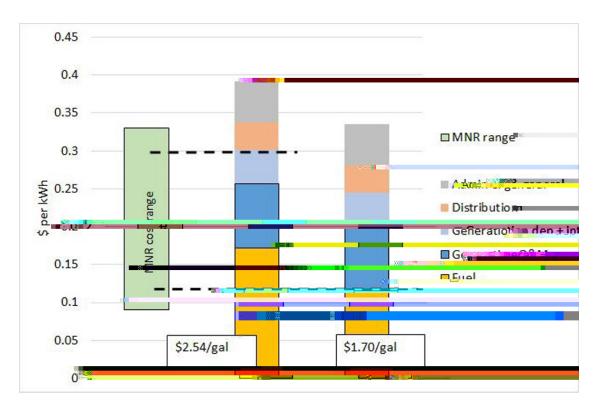
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F: Comparison of the cost components of electric service in a representative Alaska hub community, under two di erent fuel prices, to the potential range of production costs for electricity from an MNR.







6. Next Steps and Recommendations for Action





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7. Appendices



A h d A: **TABLE OF REACTOR TECHNOLOGIES** (LESS THAN, MW)



erated by Argonne National Laboratory in	y's nuclear-powered submarines and aircraft	pment project pathway, <u>cbcglic.com</u>	umindustries.com	ary coolant: also has been pursuing a MNR	p a 50 MWe fast modular reactor. <u>framatome.</u>	(DOE) Savannah River site. <u>nuclear.gepower.</u>	he U.S. (TRIGA).		ad following ability.		Wer.com		multiples of 60 MWe systems (up to 12 units)	scalepower.com		clear (CAle				(tealenay :	elerence
Based on the EBR-II, a sodium-cooled fast-reactor power plant operated by Argonne National Laboratory in Idaho for 30 years. <u>arcnuclear.com</u>	BWX is the prime contractor building the reactors on the U.S. Navy's nuclear-powered submarines and aircraft carriets. <u>bwxt.com</u>	Received \$400k in 2018 under the DOE advanced reactor development project pathway. cbcglic.com	Currently seeking approval/funding for a 10MWe pilot plant. <u>elysiumindustries.com</u>	Proposes lithium f uoride/beryllium f uoride (FLIBe) salt as its primary coolant. also has been pursuing a MNR design. <u>fibe energy.com</u>	Recently announced a partnership with General Atomics to develop a 50 MWe fast modular reactor. <u>framatome.</u>	Planning a demonstration deployment at Department of Energy's (DOE) Savannah River site. <u>nuclear gepower.</u> com	Has historically developed many of the research reactors used in the U.S. (TRIGA) www.ga.com	Completed the Vendor Design Review Phase 1 process in Canada holtecinternational.com	Designed to be packaged in a standard shipping container with load following ability. holosgen.com	hydromineinc.com	Recently funded under DOE ARPA-E (GEMINA) program. kairospower.com	www.nucdev.com	Leading US manufacturer of SMRs. Current plans are to deploy in multiples of 60 MWe systems (up to 12 units) some discussion of smaller units in future. <u>Duscalepower.com</u>	Still "paper reactor" but NuScale leading SMR company in US. <u>nuscalepower.com</u>	Signif cant engagement in Alaska: has participated in Launch Alaska. <u>oklo.com</u>	radiantnuclear.com	Canadian based company: planning demonstration at Chalk River by 2026: planning to seek design approval through NRC in future. <u>terrestrialenergy.com</u>	Plan to deploy demonstration reactor at Chalk River Laboratories (Canada) site in next few years. <u>usne com</u>	Los Alamos National Lab; funded through Project Pele. <u>westinghousenuclear.com</u>	Designed to be scaled as a four-pack to 320 Mwe. <u>x-energy.com</u>	<u>x-energy.com</u>
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MNR	MNPP	SMR	SMR	SMR	SMR	SMR	MNR	SMR	MNPP/ Modular	MNR	SMR	MNR	SMR	MNR	MNR	MNPP	SMR	MNR	MNPP	SMR	MNPP
Advanced Reactor Concepts	BWX Technologies	Columbia Basin Consulting Group	Elysium Industries	Flibe Energy	Framatome	G E -Hitachi (Prism)	General Atomics	Holtec	HolosGen (Quad)	Hydromine	Kairos Power	NuGen	NuScale	NuScale (micro)	Oklo (Aurora)	Radiant Industries	Terrestrial Energy (IMSR)	Ultra Safe Nuclear (MMR-5) Corporation	Westinghouse (eVinci)	X-energy (Xe-10)	X-energy (Xe-Mobile)

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A d C: SUMMARY OF ACEP EDUCATIONAL SERIES ON SMALL SCALE NUCLEAR POWER



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