

October 2023

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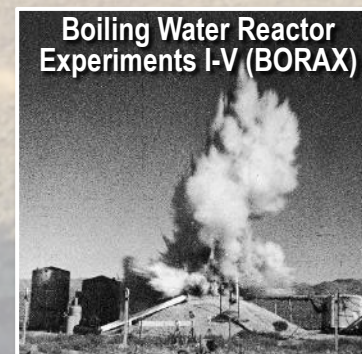
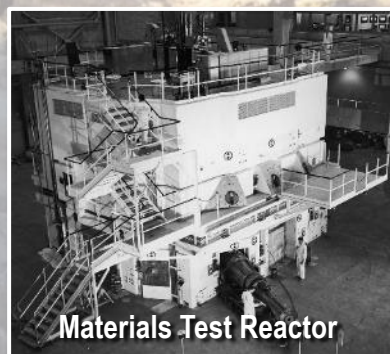
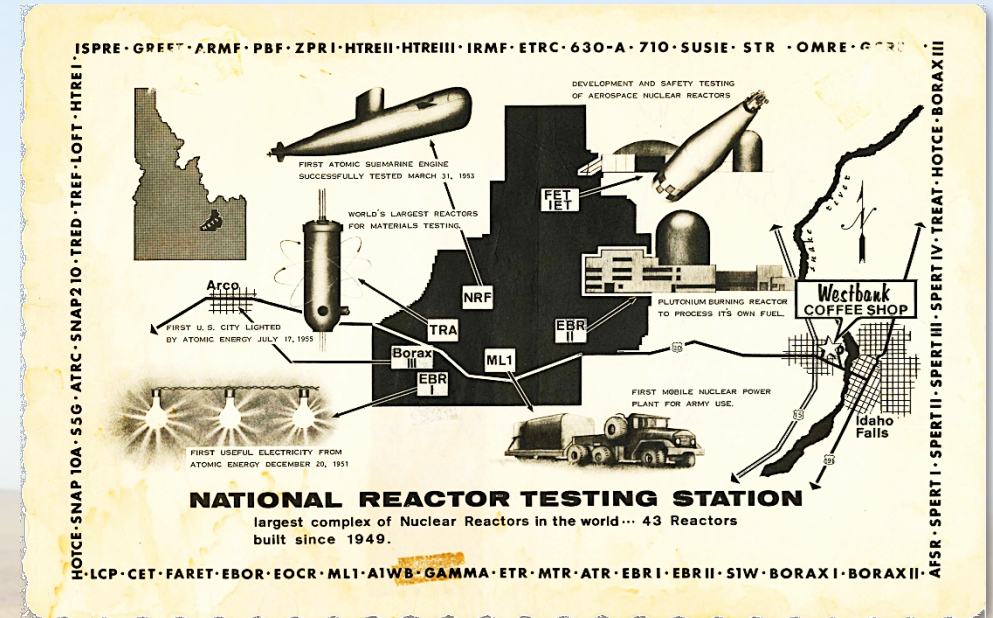
Perspectives on Partnerships to Facilitate Deployment of Advanced Nuclear Energy

Prepared for
NASEO Annual Meeting
October 2023

Idaho National Laboratory: The Nation's Nuclear Energy Laboratory

Over Seventy Years of Leading Into New Frontiers:

- First nuclear power plant
- First U.S. city to be powered by nuclear energy
- First submarine reactor tested; training of nearly 40,000 reactor operators until mid-90s
- First mobile nuclear power plant for the army
- Demonstration of self-sustaining fuel cycle
- Basis for LWR reactor safety
- Aircraft and aerospace reactor testing
- Materials testing reactors



A New Frontier of Economic Opportunity – and Competition

- A mature industry and simpler, appropriately sized reactors intersect emerging market demands for low emission, reliable energy
 - Heat and power – Beyond bulk grid applications
- **State energy, policy, and regulatory officials will need to know the landscape --**
Classes of Reactors, Size, Purpose, and Terminology
 - What's available and what's new
 - Why
 - Attributes and terms, what's hype, what's real, where are the risks
- Disruptive new business models and applications – an opportunity and imperative for U.S. leadership
- The way forward – leading into the new **global economic frontier** – will be led by state and community innovation

A Regional-to-Global Path

Why do we care?

Emissions Content of Products Is Being Monetized ...

This Will Disrupt Global Competitiveness **And Security**



Projects to cut carbon emissions from steel manufacturing are being driven by consumer demand and government subsidies, according to BloombergNEF, a research firm.

-- NPR, June 27 2023



Russia- Year-round navigation of eastern part of Northern Sea Route planned for 2024 (Powered by nuclear)

Europe Reaches Historic Deal to Put Pollution Price on Imports

--- Bloomberg December 13, 2022



U.S. floats new steel, aluminum tariffs based on carbon emissions

--- Reuters December 7, 2022. 9:23 PM.



**The New Global Frontier
of Economic Competition
and Security**

Existing (large) nuclear reactors



Number in operation: **95 in U.S.**

Timeframe: **Built in the 1950s-1980s**

Products: **Electricity**

Megawatts: **1,000+ megawatts**

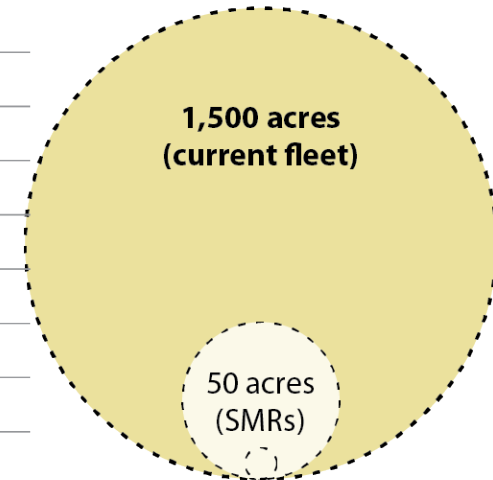
Customers: **Large utilities**

Emergency zone: **10 miles**

Construction: **Custom built on site**

Scalability: **Difficult due to size and cost**

Footprint



Less than an Acre
(Micro Reactors)

Applications:
Baseload electricity; 24/7

Coming soon: Hydrogen production

Did you know?

In November 2018, the Union of Concerned Scientist recommended that federal and state governments adopt policies to preserve the low-carbon electricity the current fleet of nuclear reactors provides.

Small modular reactors



Applications:
Baseload electricity, industrial heat, industrial processes such as hydrogen production

Number in operation: **None***

Timeframe: **First reactors expected by 2029**

Products: **Electricity, heat, and steam**

Megawatts: **60-300 megawatts per module**

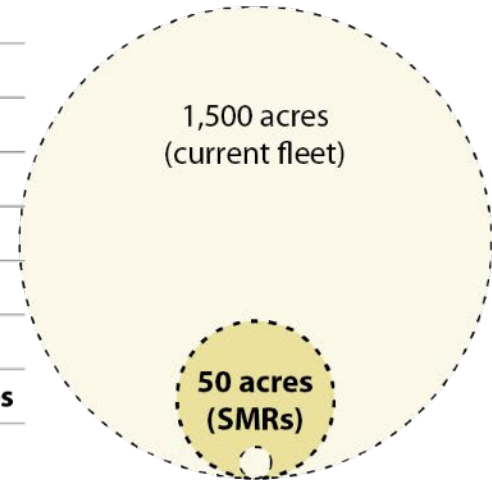
Customers: **Large utilities; municipalities; industry**

Emergency zone: **.19 miles**

Construction: **Factory built; assembled on site**

Scalability: **Reactor modules added as demand increases**

Footprint



**Less than an Acre
(Micro Reactors)**

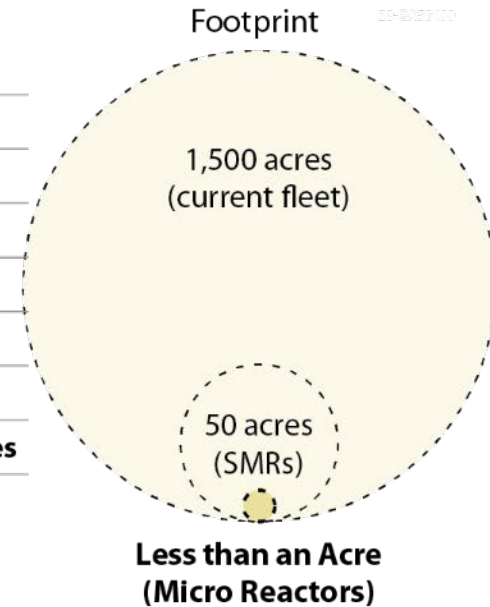
**NuScale SMR has completed NRC design approval with plan to start operation on INL site in 2029*

Microreactors



Applications:
Power for remote locations, maritime shipping, military installations, mining, space missions, desalination, disaster relief

Number in operation:	None
Timeframe:	First reactors expected by 2025
Products:	Electricity, heat, and steam
Megawatts:	20 megawatts or less
Customers:	Military; municipalities; industry
Emergency zone:	Less than 1 acre
Construction:	Factory built; assembled on site
Scalability:	Reactor modules added as demand increases

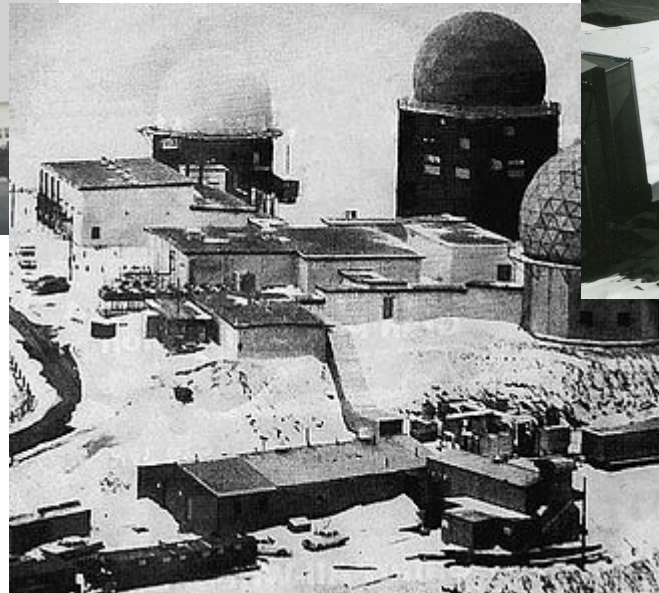


Sen. Lisa Murkowski, Improvements in nuclear technology “are enabling the emergence of so-called “microreactors” that could be a perfect fit throughout our state. As the name suggests, these smaller reactors can be right-sized for dozens of Alaska communities and will have off-grid capability that could solve the challenge of providing clean, affordable energy in our remote areas.”

R-Alaska, April 4, 2019
 Op-Ed in the Anchorage Daily News.

Microreactors, Transportable Reactors – Back to the Future !

- PM-1 – Sundance Wyoming
 - Transportable reactor powered military radars 1962-1967



Size of the Prize - Establishing U.S. Leadership on the Frontier

The Development of Microreactor Markets

Lead Market- Military
(First-Tier Pricing)



Military Operations

Second Tier Market- Remote



Microgrids (remote communities, islands)



Mining



Shipping & Ports

Third Tier Market- Modular Industry



Data Centers



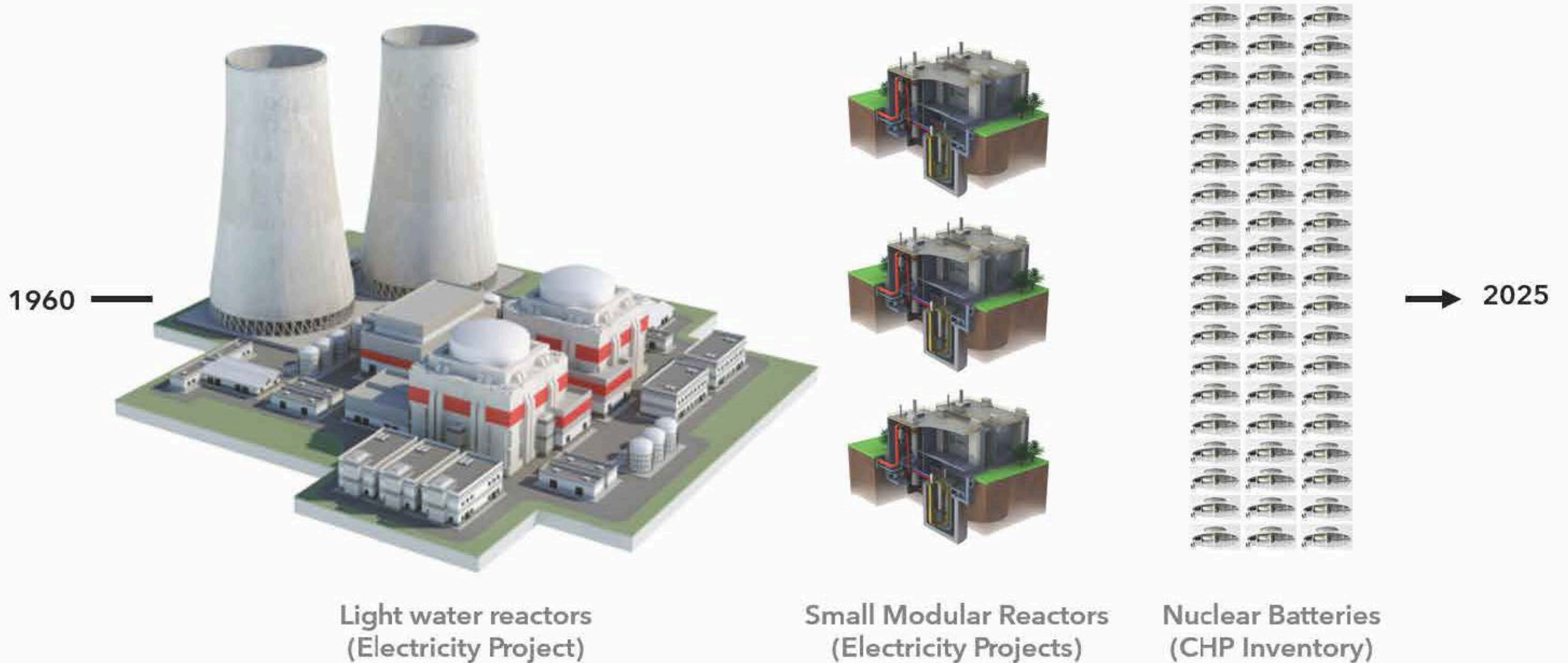
Desalination



Modular Industrial Plants



The March Toward "Embedded", Localized Energy As A Competitive Advantage



* All nuclear batteries are microreactors, but not all microreactors are nuclear batteries



Innovative Partnerships: The Frontiers Initiative

- Help first-mover states innovate, accelerate, lead
 - A *catalyst* for advancing US leadership
 - Focus on advanced nuclear energy as a *key* to enable competitive edge
 - Bring best information to key stakeholders, e.g. Nuclear 101, connect suppliers to load owners and innovators, envision “art of the possible”
- Key Partnerships: Government, Industry, Academia, NGO, Finance, etc
 - The Atlantic Council
 - Utah
 - Alaska
 - Wyoming
 - Idaho
- A Regional-to-Global Approach – States as the catalyst of deployment innovation

Initiative Elements

1. Frontiers Collaborations
2. Frontiers Project
3. Frontiers Global
4. Frontiers Global Security



Other Slides of Possible Interest

Licensing Commercial Power Reactors

- All commercial power reactors operate under NRC licenses
 - Originally issued for 40 years
 - Subsequent licenses extended to 60 and 80
- NRC has sole licensing authority; but states have permitting authorities necessary for plant operation
- 3 basic licensing paths
 - 10 CFR 50 – Construction licenses followed by Operating License (EACH ~ 36 months)
 - 10 CFR 52 – Combined Construction and Operating License **referencing a certified design** (~30 months)
 - 10 CFR 52 - Combined Construction and Operating License **NOT referencing a certified design** (~36 months)
- Design certification is NOT licensing – don't mix the two up

Licensing – Past and Future

- Recent Experience
 - NuScale SMR – 42 months for design certification (completed !)
 - Oklo Aurora Microreactor – 10 CFR 52 - 36 month planned review period; recently NRC denies license application w/out prejudice (i.e. they are welcome to start again)
 - Vogtle – Combined license with certified design
- NRC is Considering "Risk-Informed, Technology Inclusive Regulatory Framework for Advanced Reactors" – i.e. a new "Part 53"
 - This is a long, in-depth rule making process
- NRC is Analyzing Microreactor Licensing Strategies *Using Existing Authorities*
 - Key elements of consideration
 - Standardized design, standard site conditions
 - Factory manufactured – license the manufacturing process
 - Operations standardized
 - No spent fuel storage at operations location
 - Generic EIS

Microreactor concepts and developers (2023)

Developer	Name	Type	Power Output (MWe)	Fuel	Coolant
Alpha Tech Research Corp.	ARC Nuclear Generator	MSR	12 MWe	LEU	Fluoride Salt
BWXT	BANR	HTGR	17 MWe	TRISO	Helium
General Atomics	GA Micro	HTGR	1-10 MWe	—	gas
HolosGen	HolosQuad	HTGR	13 MWe	TRISO	Helium/CO2
Micro Nuclear, LLC	Micro Scale Nuclear Battery	MSR/heat pipe	10 MWe	UF4	FLiBe
Nano Nuclear	ZEUS	FR/HTGR	1 MWe	UO2	Helium
NuGen, LLC	NuGen Engine	HTGR	2-4 MWe	TRISO	Helium
NuScale Power	NuScale Microreactor	LM/heat pipe	< 10 MWe	Metallic	Liquid Metal
Oklo	Aurora	SFR/heat pipe	1.5 MWe	Metallic	Sodium
Radiant Nuclear	Kaleidos Battery	HTGR	1.2 MWe	TRISO	Helium
Ultra Safe Nuclear	MicroModular Reactor	HTGR	5 MWe	TRISO	Helium
Westinghouse	eVinci	Heat pipe	5 MWe	TRISO	Sodium
X-energy	Xe-Mobile	HTGR	7.4 MWe	TRISO	Helium

Microreactor Cost Assessments and Licensing

Preliminary estimates for cost of electricity -
Not Including credits

Timeframe	1 st Units	Profile Markets	Cost Targets at Cumulative Number of Builds				
			1-9	10	100	1,000	10,000
2020-2030	FOAK units/ DoD Units		<\$0.60/kWh				
2030-2035	Remote Operations			<\$0.50/kWh	<\$0.35/kWh	<\$0.20/kWh	<\$0.15/kWh
2035-2040	Distributed Energy				<\$0.35/kWh	<\$0.20/kWh	<\$0.15/kWh
2040-2050	Resilient Cities					<\$0.20/kWh	<\$0.15/kWh

Credit: DOE Microreactor Program, Shropshire, Black, and Araujo; 2021, Global Market Analysis of Microreactors, INL/EXT-21-63214.

- **AK Remote Applications Present Cost: \$0.54 / kWh (average)**
- Capital cost estimates for MRs range from about \$6K/kWe - \$30K/kWe.
- Costs are uncertain, and achievement of cost targets critical for competitiveness in markets.
- Key is VALUE – incremental provisioning, reliability, zero carbon, security, etc

- MIT Study Findings:
 - Adding CHP (Combined heat and power) is key for MRs competing against diesel and natural gas.
 - Modest carbon emissions caps raise the capital cost ceiling and make MRs viable beyond isolated markets.
 - Additional tax treatment, investment and credits (e.g. IRA, BIL, DPA) being determined
- NRC Assessing Licensing Strategies
 - High degree of design and ops standardization
 - Generic EIS streamlines site env. review
 - Factory manufactured
 - No spent fuel storage