

SMALL MODULAR REACTORS

Presented To: NMA Uranium Recovery
Workshop

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What is an SMR?

- Small Modular Reactors (SMRs) are a new class of nuclear reactors that are considerably smaller in size and power output than conventional nuclear power reactors, with enhanced safety features.
- SMRs are:
 - **Small:**
 - in both power output and physical size;
 - **Modular:**
 - meaning they are factory constructed, portable and scalable;
 - **Reactors:**
 - using nuclear fission to produce energy for electricity, hybrid energy systems, district heating, water desalination, and high-quality steam for heavy industry applications.

What are the Opportunities?

- *The International Energy Agency projects that **nuclear energy will need to double** within 20 years to meet a 2-degree Celsius climate target.*
- Nuclear energy is expected to play an important and growing role in a worldwide net-zero scenario with at least a doubling of installed capacity. Pathways to net zero will further benefit from the development and deployment of near-term innovative nuclear technologies. (NEA at COP 26)

International Energy Agency*

- Nuclear power and hydropower form the backbone of low-carbon electricity generation
 - Together, they provide three-quarters of global low-carbon generation. Over the past 50 years, the use of nuclear power has reduced carbon dioxide (CO₂) emissions by over 60 gigatonnes –nearly two years' worth of global energy-related emissions.
- Achieving the pace of CO₂ emissions reductions in line with the Paris Agreement is already a huge challenge
 - It requires large increases in efficiency and renewables investment, as well as an increase in nuclear power.

* IEA 2019, Nuclear Power in a Clean Energy System

EU Parliament backs “green” label for nuclear and gas

Nuclear News July 7, 2022



SMRs meet ESG

Nuclear News July 8, 2022



Large Range of SMRs

- SMRs can vary significantly in size, design features and cooling types.
- Examples of different SMR technologies include:
 - integral pressurized water reactors;
 - molten salt reactors;
 - high-temperature gas reactors;
 - liquid metal cooled reactors;
 - solid state or heat pipe reactors.



Advances in Small Modular Reactor Technology Developments

A Supplement to:
IAEA Advanced Reactors Information System (ARIS)
2020 Edition

>70 SMR and advanced reactors are under
consideration world-wide

Advances in Small Modular Reactors

(IAEA 2020)

The driving forces in the development of SMRs are their flexibility: characteristics:

- They can be *deployed incrementally* to closely match increasing energy demand resulting in a moderate financial commitment for countries or regions with smaller electricity grids.
- SMRs show the promise of *significant cost reduction through modularization and factory construction* which should further improve the construction schedule and reduce costs.
- SMR designs and sizes are *suited for partial or dedicated use in non-electrical applications* such as providing heat for industrial processes, hydrogen production or seawater desalination.
- Process heat or cogeneration results in significantly *improved thermal efficiencies* leading to a better return on investment.
- Some SMR designs may also serve *niche markets*, for example by deploying micro-reactors or mini-reactors to replace diesel generators in remote regions.

SMRs under Evaluation in Canada

Vendor design review service agreements in force between vendors and the CNSC

Vendor	Name of Design and Cooling Type	Approximate Electrical Capacity (MW Electrical)	Applied for	Review Start Date	Status
Terrestrial Energy Inc.	IMSR Integral Molten Salt Reactor	200	Phase 1	April 2016	Complete
			Phase 2	December 2018	Assessment in progress
Ultra Safe Nuclear Corporation	MMR-5 and MMR-10 High-temperature gas	5-10	Phase 1	December 2016	Complete
			Phase 2	June 2021	Assessment in progress
LeadCold Nuclear Inc.	SEALER Molten Lead	3	Phase 1	January 2017	On hold at vendor's request
ARC Nuclear Canada Inc.	ARC-100 Liquid Sodium	100	Phase 1	September 2017	Complete
			Phase 2	February 2022	Assessment in progress
Moltex Energy	Moltex Energy Stable Salt Reactor Molten Salt	300	Series Phase 1 and 2	December 2017	Phase 1 completed

SMRs Under Evaluation in Canada (Continued)

Vendor design review service agreements in force between vendors and the CNSC

Vendor	Name of Design and Cooling Type	Approximate Electrical Capacity (MW Electrical)	Applied for	Review Start Date	Status
SMR, LLC. (A Holtec International Company)	SMR-160 Pressurized Light Water	160	Phase 1	July 2018	Complete
NuScale Power, LLC	NuScale Integral pressurized water reactor	60	Phase 2*	January 2020	Assessment in progress
U-Battery Canada Ltd.	U-Battery High-temperature gas	4	Phase 1	Pending	Project start pending
GE-Hitachi Nuclear Energy	BWRX-300 boiling water reactor	300	Phase 2*	January 2020	March 2022 OPG awards contract for initial site preparation
X Energy, LLC	Xe-100 High-temperature gas	80	Phase 2*	July 2020	Assessment in Progress

GE Hitachi: BWRX-300

artists rendition looking south toward Lake Ontario

- ✓ **Dec 2021** OPG selects GE-H 300 for construction at Darlington
- ✓ **March 2022** OPG awards contract for initial site prep
- ✓ **Oct 2022** CNSC approves Darlington licence renewal March 2022



USDOE

- *The U.S. Department of Energy (DOE) approved a multi-year cost share award to a new special purpose entity named Carbon Free Power Project, LLC, an entity wholly owned by Utah Associated Municipal Power Systems (UAMPS), that could provide up to \$1.4 billion to help demonstrate and deploy a 12-module NuScale power plant located at Idaho National Laboratory.*
- [Advanced Small Modular Reactors \(SMRs\) | Department of Energy](#)

USNRC

Small Modular Reactors (LWR designs)

- [NuScale](#)
- [BWXT](#)
- [GEHC](#)
- [Etc.,](#)

[See link below for details](#)

[Small Modular Reactors \(LWR Designs\) | NRC.gov](#)

Siting

SMRs can be used on and off the grid:

- co-located on the site of an existing NPP;
- on sites that differ from those of traditional nuclear power plants:
 - Former coal plant sites;
 - Large industrial sites;
 - Greenfields;
 - Remote communities;
 - Etc.

Small Modular Reactor Siting Projects in the U.S.

The U.S. Department of Energy (DOE) vigorously supports the deployment of advanced small modular reactors (SMRs) through public-private partnerships to advance and develop these innovative designs, certify their safety, and assist site permitting and licensing. SMRs are a clean, safe and economical option to re-energize retired fossil energy power plants or fill the need where smaller capacities are needed.

With DOE support, NuScale Power has significantly accelerated the engineering and licensing of its unique design. NuScale's SMR is an advanced light-water reactor technology in which each self-contained reactor module operates independently. The design eliminates many costly, complex systems, and the compact design allows for the efficiency of factory manufacturing.

The result will be a safe, reliable, carbon-free, economical, and scalable power source. NuScale submitted its design certification application to the U.S. Nuclear Regulatory Commission

(NRC) in January 2017, with design approval expected around 2020.

DOE is currently in a partnership with Utah Associated Municipal Power Systems (UAMPS) and NuScale to deploy a commercial NuScale SMR power plant at the Department's Idaho National Laboratory (INL) site in 2026. DOE is providing cost-shared financial assistance for the analysis supporting the development of a Combined Operating License (COL) application. DOE has issued a Site Use Permit outlining terms and conditions for use of land on the INL

site. UAMPS is currently conducting internal analyses to inform a Decision to Proceed to the development of a license application.

DOE also provides cost-shared financial assistance to the Tennessee Valley Authority (TVA) in its efforts to permit and license an SMR at its Clinch River site near Oak Ridge, Tennessee. The NRC accepted TVA's Early Site Permit (ESP) application for review in December 2016; once granted, an ESP will certify the Clinch River

site meets safety and environmental standards for the construction and operation of an SMR. TVA plans to begin development of a COL application for submission to the NRC for review around 2020.

One of the goals of DOE's work with SMR developers and first-mover utilities is to potentially access the capabilities of the reactor as a research and development test bed.

INL, NuScale, and UAMPS are exploring a Joint Use Modular Plant (JUMP) proposal, making two NuScale reactor modules available to DOE to enable industrial-scale research applications in areas like grid security and hybrid energy.

DOE will partner with nuclear technology developers in 2018 through cost-shared awards to overcome many barriers to deployment. The pending solicitation will be focused on, but not limited to: finalizing the most mature designs; improvements in manufacturing; fabrication and construction techniques; sensors; digital instrumentation and control systems; plant auxiliary and support systems; operational inspection and monitoring capabilities; modeling and simulation of various elements of plant life cycle; and resolution of regulatory risk.

For more information, visit us at energy.gov/oe



18-50022-2

The USA

[Energy 101: Small Modular Reactors | Department of Energy](#)



The USA

[Analysis: THE BIG potential of nuclear micro-reactors - YouTube](#)

The
Potential for...



Micro-reactors

Together

CNSC President Rumina Velshi and U.S. NRC Chairman Kristine Svinicki sign the Memorandum of Cooperation during an official signing ceremony in Ottawa, Ontario.



Greenpeace co-founder, ex-director calls nuclear safest energy

- <https://www.newsnationnow.com/business/tech/greenpeace-co-founder-ex-director-calls-nuclear-safest-energy/>

There is Global Interest

- <https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/small-nuclear-power-reactors.aspx>
- <https://www.gov.uk/government/news/uk-backs-new-small-nuclear-technology-with-210-million#:~:text=Next%20steps%20in%20developing%20the,Plan%20and%20creating%20good%20high%2D>
- <https://www.world-nuclear-news.org/Articles/TVA-announces-new-nuclear-programme?feed=feed>
- <https://www.world-nuclear-news.org/Articles/Macron-announces-French-nuclear-renaissance?feed=feed>
- <https://www.world-nuclear-news.org/Articles/Nuclear-makes-a-comeback-in-the-Netherlands>
- <https://www.ans.org/news/article-3180/nine-mile-point-picked-for-hydrogen-demonstration-project/>

There are Opportunities!



The need for large and small nuclear, today and tomorrow