

SMR GLOBAL STATUS REPORT

March 2021



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Contents

Part I: Introduction 2

Part II: Light Water Reactors (Gen III/Gen III+)..... 3

Part III: Gen IV Reactors..... 5

Part IV: Government Initiatives to support SMR licensing and first deployment – Canada and USA..... 8

 Canada 8

 USA 10

Part V: DEFINITIONS 12



SMR Global Status Report March 2021

Part I: Introduction

- i. This report examines the global status of Small Modular Reactors (SMRs) and reviews their readiness for deployment.
- ii. This report separately categorises SMRs according to their design features as Light Water Reactors (Gen III/Gen III+) or Gen IV Reactors.
- iii. Small reactors have been in wide use for more than 50 years to reliably power submarines, aircraft carriers and ice-breakers and the early power reactors for electricity generation were “small”. A widely accepted definition of “small” is less than 300 MWe. Reports from 2019 Parliamentary inquiries at Federal and State levels in Australia identified SMRs as suitable for Australian conditions.
- iv. In August 2020 the US Nuclear Regulatory Commission (NRC) issued a final safety evaluation report (FSER) for NuScale’s SMR. This completed the safety review and allowed a Design Certification to be issued. This was the first SMR to pass NRC assessment and is a major milestone in the deployment of SMRs.
- v. Reviewing the latest generation of SMRs for electricity generation, this report identifies that the two reactors at Pevek in Russia are in commercial operation producing electricity and district heating, the HTR-PM in China is in final commissioning, and two other SMRs are under construction. Many more are at an advanced stage of licensing.
- vi. The South Australia State blackout in 2016 and the events in Texas in February 2021 showed how vulnerable the electricity supply system can be to extreme weather events. The frequency of these events is expected to increase and it will be important for the generation mix to include technologies which are independent of the weather. SMRs fulfil this role.
- vii. There is an increasing awareness that, in addition to electricity generation, other sectors of industry have to be decarbonized. Many countries are investigating the multipurpose use of SMRs, including process heat, hydrogen production and desalination as well as electricity generation.

Part II: Light Water Reactors (Gen III/Gen III+)

Country	Reactor/ Company	Module size	licences	Construction	Operation
Russia	KLT-40S PWR Floating Power Plant Rosatom	35 MWe (150 MWt)	June 2019 Operating licence	Vessel constructed at St Petersburg, 2 x 35 MWe reactors on a barge. Transferred to Murmansk, fuel loaded and reactors tested. 2019 deployed at Pevek, Chukotka region, grid connected December 2019.	In commercial operation May 2020 supplying electricity and district heating
Argentina	CAREM IPWR CNEA/INVAP	27 MWe	2009 EIS approved by local authority. Sept 2013 Construction Licence for Atucha site	Feb 2014 first concrete. Construction in progress	<i>Target 2023</i>
China	ACPR50S PWR Floating Power Plant CGN	60 MWe	2020 Preliminary design completed	Nov 2016 contract with Donfang Electric Corp for the pressure vessel. CGN teamed with China Shipbuilding Industrial Corp and China National Offshore Oil Co.	<i>Target ?</i>
China	ACP-100 IPWR CNNC/NPIC	100 MWe	April 2015 IAEA Generic Reactor Safety Review Agreement. PSAR approved June 2020 SAR approved by CNNSA	March 2019 EIA for site at Changjiang, Hainan. July 2019 Preliminary site work commenced. 385 MWt Industrial demonstration plant planned in Hainan Province	<i>Target 2025</i>
China	HAPPY200 PWR SPIC	200 MWt	Supply of district heating to towns in north China where 6 months of heating is required. Also desalination/hydrogen production.	<i>Construction start 2022?</i>	<i>Target 2024</i>
South Korea	SMART IPWR KAERI	100 MWe	Design approval 2012 (now updating for passive safety)	March 2015 MOU with Saudi Arabia	

Country	Reactor/ Company	Module size	licences	Construction	Operation
Russia	RITM-200	53 MWe 175 MWt	RITM-200 already licensed and used to power latest icebreakers (first vessel launched 2019).	Plan to build first land-based plant at Ust-Kuyga, Yakutia, Far Eastern Russia. Site licence expected 2023	<i>Target 2027</i>
UK	PWR (close coupled) Rolls-Royce Consortium	440 MWe (1200 MWt)	Nov 2019 UK Research & Innovation provided initial match funding £18m to prepare for UK Generic Design Application. <i>Target application 2024</i>	2017 MOU with Jordan Atomic Energy Commission. 2020 MOU with Turkey's state-owned EUAS International ICC. 2020 MOU with Czech utility CEZ. 2020 MOU with Exelon to operate SMRs. 2021 MOU with Fermi Energia to study SMRs in Estonia.	<i>Target 2029</i>
USA	NuScale IPWR NuScale Power	77 MWe	US NRC 10 CFR Part 52 DCA Jan 2017 Final Safety Evaluation Report issued Aug 2020 CNSC phase1/2 vendor design review started Jan 2020	DOE providing site at INL for UAMPS. DOE awarded \$16.5m in matching funds to UAMPS to secure site and water and prepare COLA to NRC. Oct 2020 DOE awarded \$1.355b to UAMPS for Carbon Free Power Project	<i>UAMPS first module in operation Target 2029</i>
USA	SMR-160 IPWR SMR LLC (Holtec)	160 MWe (525 MWt)	July 2018 Phase 1 CNSC vendor design review started, completed Aug 2020. NRC pre-application activities – Dec 2020 Topical report to NRC. Dec 2020 \$116m DOE award for early stage design, engineering and licensing to accelerate development.	Oct 2020 Czech Republic evaluating. Holtec Advanced Manufacturing factory, Camden NJ ready to manufacture SMR modules	<i>Target 2026</i>
USA	BWRX-300 BWR GE-Hitachi	300 MWe	Phase 1/2 vendor design review by CNSC started Jan 2020 December 2019 started regulatory licensing process with NRC. First topical report lodged.	MOU's with Estonia, Poland and Czech Republic Oct 2020- MOUs with Canadian companies to establish supply chain Feb 2021 formation of Canadian SMR business announced	<i>Target 2027</i>

Part III: Gen IV Reactors

Country	Reactor / Company	Module size	Licence	Construction	Operation
China	HTR-PM High Temperature Gas-cooled Reactor (HTGR) China Huaneng + China Nuclear Engineering Corporation (CNEC) + Tsinghua University Institute of Nuclear and New Energy Technology (INET)	105 MWe	2008-9 PSAR review. Dec 2012 Construction permit issued	2014 construction commenced at Shidaowan, Shandong Province 2x105 MWe HTGRs drive one 210 MWe turbine. Oct 2020 completed cold test of first reactor. 2021 final commissioning in progress	<i>2021</i>
Canada	MMR Micro Modular Reactor High Temperature Gas-cooled Reactor (HTGR) Ultra Safe Nuclear Corporation (USNC) Joint venture - Global First Power (GFP) partnership formed between USNC-Power + Ontario Power Generation (OPG)	MMR 5 5MWe 15 MWt MMR 10 10 MWe 30 MWt	Feb 2019 CNSC phase 1 VDR completed. March 2019 site preparation licence application to CNSC. July 2019 Environmental Assessment commenced 2020 MOU with Hyundai Engineering and KAERI for heat/hydrogen development	In 3rd stage of process to site demonstration MMR at Chalk Rivers site - November 2020 host agreement signed. <i>Target construction 2023.</i> 2020 Deployments planned at Idaho National Laboratory and University of Illinois at Urbana-Champaign.	<i>Target 2025</i>
Canada	IMSR 400 Integrated Molten Salt Reactor Terrestrial Energy	195 MW	2017 CNSC Phase 1 vendor design review completed. Phase 2 review commenced Dec 2018 2020 detailed salt testing at Argonne National Laboratory. Graphite testing at HFR Petten. Oct 2020 Canada Strategic Investment Fund CAD 20m to accelerate development.	<i>Preferred site at Idaho National Labs</i> 2019 qualified to enter 2 nd stage for deployment at CNL Chalk River	<i>2020's</i>

Country	Reactor/Company	Module size	Licence	Construction	Operations
Canada	ARC 100 Sodium cooled Fast Reactor (SFR) ARC Nuclear Canada Inc	100 MWe	Sept 2017 CNSC Phase 1 vendor design review started, completed Oct 2019.	2018 First partner of New Brunswick nuclear research cluster at Point Lepreau site.	<i>Target 2028</i>
Canada	StarCore HTGR	10 MWe + 5MWt	CNSC service agreement under development	Completed first stage of CNL process for deployment at Chalk River	<i>Target 2026</i>
UK/Canada	Moltex Energy Stable Salt Reactor SSR-W300 Molten salt reactor (MSR) Moltex Energy UK and Canada	2 x 150 MWe	Dec 2017 CNSC Phase 1 vendor design review started.	2018 New Brunswick Power propose deployment at Point Lepreau site. Nov 2019 – final negotiations for project at Chalk River site. Jacobs assisting with development. Canadian Government investment CAD 50.5 million	<i>Target 2030</i>
UK/Canada	U-Battery URENCO consortium	4 MWe 10 MWt 750°C process heat	July 2020 UK BEIS awarded GBP 10million under Advanced Modular Reactor (AMR) program.	July 2019 completed first stage of CNL process for deployment at Chalk River.	<i>Target 2026</i>
Denmark	Seaborg Technologies Compact Molten Salt Reactor (CMSR) on a barge	100 MWe (250 MWt)	American Bureau of Shipping stage 1 feasibility statement.	Partnership with South Korean company to build the barge.	<i>Target 2025</i>
USA	Aurora Powerhouse Micro reactor Sodium cooled Fast Reactor (SFR) HALEU fuel Oklo Inc	1.5 MWe 4 MWt	2016 started pre-application activities with NRC. March 2020 submitted 10CFRPart52 COLA to NRC, accepted June 2020	Oklo has a permit for a site at Idaho National Labs.	
USA	BWXT Advanced Nuclear Reactor (BANR) HTGR		Project Pele for US Defence Department	Dec 2020 US DOE \$85.3m funding to develop transportable microreactor.	<i>Target 2024</i>

Country	Reactor/Company	Module size	Licence	Construction	Operations
USA	KP-FHR Hermes reduced scale test reactor TRISO fuel, fluoride salt cooled Kairos Power	140 MWe	2018 NRC pre-application review. June 2020 topical report for fuel qualification methodology submitted	CNL collaboration agreement funded under Canadian Nuclear Research Initiative (CNRI) Dec 2020 plan to deploy a test reactor at the East Tennessee Technology Park (ETTP) at Oak Ridge. Dec 2020 US DOE ARDP award \$303m.	<i>Target 2026</i>
USA	Molten Chloride Fast Reactor Terrapower	<i>Test reactor size?</i>		Jan 2016 US DOE \$40m award. Oct 2020 US DOE ARDP \$160m award to develop and construct.	<i>Target 2027</i>
USA	Sodium SFR with molten salt energy storage Terrapower + GE Hitachi	345 MWe		Oct 2020 US DOE ARDP \$80m award.	<i>Target late 2020's</i>
USA	Westinghouse eVinci Micro reactor	200 KWe to 25 MWe 600°C process heat	Feb 2018 application to CNSC for pre-licensing vendor design review	Dec 2020 US DOE ARDP award \$7.4m to support demonstration unit.	<i>Target 2024</i>
USA	Xe-100 High temperature gas-cooled reactor (HTGR) X-Energy LLC	80MWe (320 MWe four pack 4x80 MWe)	July 2020 CNSC phase 1/2 commenced	Oct 2020 DOE \$80m funding under Advanced Reactor Demonstration Program to demonstrate a four unit, 320 MWe plant at Energy Northwest's Columbia nuclear plant.	<i>Target 2027</i>

Part IV: Government Initiatives to support SMR licensing and first deployment – Canada & USA

Many countries are realising the potential benefits of SMR deployment. Canada and the USA in particular have launched major initiatives to speed up deployment.

Canada

The Canadian Government sees SMR technology as a great opportunity to establish a world class clean energy system that can be used towards Canada's goal of net-zero emissions by 2050, and also around the world, whilst providing economic opportunities and jobs. Canada, like Australia, has many remote areas where electricity provided by SMRs would be a major improvement over the existing systems.

SMR Roadmap

- In 2018 Natural Resources Canada (NRCAN) launched a process to prepare a roadmap to explore the potential for on-and off-grid SMR deployments
- Brings together industry, federal, provincial, and territorial governments, as well as utilities and other interested stakeholders that wanted a pan-Canadian conversation about new options for nuclear energy
- December 2019 - provinces of Ontario, New Brunswick and Saskatchewan signed an MOU to work together to support the development and deployment of SMRs
- December 2020 – NRCAN issues its SMR Action Plan laying out the steps for development, demonstration and deployment in Canada and abroad. First SMRs to be operating in late 2020's.

Canadian Nuclear Safety Commission (CNSC) Vendor Design Review

- Optional service provided by the CNSC when requested by a vendor. The vendor design review (VDR) provides feedback early in the design process based on a vendor's reactor technology. There are three VDR phases.
- The review identifies any fundamental barriers to licensing a new design in Canada
- Phase 1 completed: IMSR 400 (Terrestrial Energy); ACR-100 (ARC); SMR-160 (Holtec); MMR (USNC)
- Five more VDRs in progress

New Brunswick SMR vendor cluster

- New Brunswick sees the opportunity to become a world leader in SMR research, development and manufacturing
- June 2018 initial commitment of CAD10 million (USD7.5 million)
- New Brunswick Power's existing Point Lepreau site, home to a Candu 6 reactor, can accommodate several SMRs
- Nov 2020 - MOU signed by ARC, Moltex and New Brunswick Power
- March 2021 - Canadian Government announced CAD 56 million (USD 45million) to support this initiative, including CAD 50.5 million to Moltex

Canadian Nuclear Laboratories (CNL)

- In 2018, CNL issued an invitation to SMR developers for the construction and operation of an SMR demonstration reactor at a CNL site by 2026. Four phase process - Phase 1 = Pre-qualification, Phase 2 = Due diligence, Phase 3 = Negotiation of land arrangements and contractual agreements, Phase 4 = Project Execution
- Three proponents have completed phase 1 of the invitation process: Starcore Nuclear (14 MWe HTGR); Terrestrial Energy (190 MWe IMSR); and U-Battery Canada (4 MWe HTGR).
- Global First Power (USNC +OPG, 5 MWe HTGR) has advanced to phase 3. April 2019 GFP applied to the CNSC for a licence to prepare the site. The Environmental Assessment commenced in July 2019. In 2020 GFP completed the preliminary geotechnical studies. **The project host agreement was signed in November 2020.** Target construction start is 2023, with commissioning in 2025.

Canadian Nuclear Laboratories (CNL) Canadian Nuclear Research Initiative (CNRI)

- CNRI launched in July 2019 to provide reactor vendors access to CNL's research facilities and expertise.
- CNRI awards to Terrestrial Energy; USNC; Moltex and Kairos Power
- November 2020 – second round of CNRI program announced. Includes advanced reactor systems, fusion research and advanced reactor technologies

Ontario Power Generation (OPG)

- October 2020 OPG announced plans to advance engineering and design work with three developers of grid-scale SMRs: GE Hitachi; Terrestrial Energy and X-Energy
- OPG's Darlington site is licensed for new nuclear build
- Also OPG partnership with Global first Power (GFP) to support remote (off-grid) energy needs

Bruce Power

- October 2020 – Bruce Power agreement with Westinghouse to examine applications of eVinci micro reactor in Canada.
- EVinci designed for decentralised generation markets and microgrids such as remote communities, remote mines and critical infrastructure

USA

US Department of Energy (DOE) Funding

- Funding opportunities which are subject to congressional appropriations to assist the Office of Nuclear Energy to remove barriers through early-stage research development and demonstration of nuclear projects.
- Funding pathways include assistance with First-of-a-Kind (FOAK) nuclear demonstration readiness projects, advanced reactor development projects and regulatory assistance grants.
- \$452m for technical support of SMR licensing. First round of SMR funding awarded to B&W mPower in 2012
- 2013 second round of SMR funding - NuScale awarded \$217 million over 5 years

Advanced Reactor Demonstration Program (ARDP)

- The ARDP, launched in May 2020, aims to demonstrate a variety of US advanced reactor designs, through cost-shared partnerships with US industry to rapidly develop advanced reactors.
- \$160 million in initial funding with support provided for advanced reactor demonstrations, risk reduction for future demonstrations and advanced reactor concepts 2020

University of Illinois Urban-Champaign (UIUC)

- UIUC proposed the installation of a research-focused micro-reactor to support research, training, and technology demonstrations. The MMR would be built-in partnership with Ultra Safe Nuclear Corporation by 2026.

UAMPS Carbon Free Power Project (CFPP)

- Utah Associated Municipal Power Systems (UAMPS) is a not-for-profit organisation that provides energy services including wholesale electricity to 48 community owned power providers in six states in the US Intermountain West. The UAMPS CFPP was launched in 2015 to reduce emissions by deploying a 12 module NuScale SMR. In 2016 the DOE granted a permit to site the SMR on the Idaho National Laboratory (INL) site. On 16 October 2020 the US DOE approved a USD1.355 billion cost-share award allocated over 10 years, for development and construction of the 720 MWe NuScale plant.
- October 2020 – UAMPS completed CFPP phase 1 securing financial commitments from 27 of its 48 members. In phase 2 commencing 1 November 2020, UAMPS are preparing a COLA for the project, with a target submission date of April 2023.
- November 2020 NuScale announced a 25% increase in module output to 77MWe (gross) resulting in 924 MWe for the 12 module plant. They also offered options of four-module (308 MWe) and six-module (462 MWe) plants

Nuclear Production Tax Credit

- 2005 Energy Policy Act – production tax credit of 1.8 cents per kWh produced in the first 8 years of operation by advanced nuclear power facilities.

GAIN

- Gateway for Accelerated Innovation in Nuclear (GAIN), DOE-NE established initiative to provide the nuclear community with access to technical, regulatory, and financial support necessary to move new or advanced nuclear reactor designs toward commercialisation.

Consolidated Innovative Nuclear Research (CINR)

- CINR is a funding opportunity for the nuclear energy university program (NEUP), Nuclear Energy Enabling Technologies (NEET) crosscutting technology development (CTD), and nuclear science user facilities (NSUF)
- **NEUP** – funding to university-based research and development programs, requiring infrastructural support and R&D in key NE related areas.
- **NEET CTD** – Conducts research into crosscutting technologies directly supporting and enabling the development of new and advanced reactor designs and fuel cycle technologies.
- **NSUF** – researchers and collaborators are enabled to build on current knowledge to better understand complex behaviour of materials and fuels under irradiation by funding allowing access to the experimental irradiation and post-irradiation examination facilities.

US Department of Defense (DOD)

- The DOD needs a mobile, reliable, sustainable and resilient power source
- Advances in nuclear technology have made possible a largely autonomous, fully inherently safe mobile reactor
- *Project Pele* is on track for full power testing of a mobile reactor in 2023.
- Three companies selected in 2020 to develop preliminary designs- BWX Technologies, X-energy and Westinghouse
- 2021 BWXT Advanced Technologies and X-energy selected to develop final design

Part V: DEFINITIONS

- SMR** Small Modular Reactor, generally accepted as having an output of up to 300 MWe
- MMR** Micro Modular Reactor, generally accepted as having an output of up to 10 MWe, for off-grid applications
- PWR -** Pressurised Water Reactor (the most common type of reactor, used in submarines and nuclear power plants for more than 50 years).
- IPWR -** Integral Pressurised Water Reactor. Steam generators inside reactor pressure vessel.
- DCA –** US Nuclear Regulatory Commission (NRC) 10CFRPart 52 Design Certification Application. Allows a design to be licensed without a site being identified.
- COLA –** US NRC 10CFRPart52 combined construction and operating licence application. Brings more certainty to the licencing process by combining the construction and operating licences so that once construction starts the project can continue to completion. The design certification can be referenced in the COLA.

SMR Nuclear Technology Pty Ltd (SMR-NT) is an independent Australian-owned specialist consulting company established in 2012.

SMR-NT was established to advise on and facilitate the siting, development and operation of safe nuclear power generation technologies, principally by Small Modular Reactors (SMRs).

Questions about this report may be directed to:

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