Micro Modular Reactor (MMR)

Energy Systems

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IFNEC Workshop - Warsaw, 24 September 2019
About USNC and the MMR® Energy System

• The USNC Company:
  o Founded 2011 - motivated by nuclear incidents at Fukushima
  o Fully privately funded - US owned and controlled company
  o Our head office is in Seattle WA, we have operations in 6 countries (US, CA, SA, UK, SK, EU)

• USNC develops and promotes its technology in two areas:
  o Fully Ceramic Micro-encapsulated (FCM®) fuel – origins from NGNP and Deep Burn Programs
  o Micro Modular Reactor (MMR®) - HTGR using FCM fuel for off-grid power applications

• The Micro Modular Reactor Energy System:
  o USNC is the leading company to provide energy as a service for remote mines and communities in Northern Canada
  o MMR Project at Chalk River; Submitted EA and LTPS application
  o Implementing with support from partner Ontario Power Generation (OPG)
American Company
Global Team

- **Seoul**, South Korea: Plant design
- **Manchester**, UK: ASMR program
- **Paris**, France: European market, Geminite+ program
- **Pretoria**, South Africa: MMR™ reactor plant engineering
- **Daejeon**, Korea: MMR™ technology development
- **Toronto**, Canada: Global First Power business and market development
- **Stony Brook Brookhaven**, New York: Next generation fuel and moderator types production of near-term FCM® for irradiation
- **Knoxville**, Tennessee: Maturation of mass production technology for the FCM® fuel
- **Los Alamos**, New Mexico: Business management, Federal projects
- **Seattle**, Washington: Global head office, MMR™ and Federal projects
Why is the MMR™ needed?

- Energy demand is increasing in remote mining communities and settlements
- Mining operations too remote to be supplied by electrical grid
- Electricity mostly supplied by diesel powered generators
  - Challenging logistics
  - High and increasing diesel prices
  - Concerns about pollution
- Carbon free power

Micro Modular Reactor (MMR™) Off Grid Systems
First Market – Northern Canada
## VENDOR DESIGN REVIEWS

<table>
<thead>
<tr>
<th>VDR No.</th>
<th>Country of origin</th>
<th>Company</th>
<th>Reactor type</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Canada/U.S.</td>
<td>Terrestrial Energy (IMSR-400)</td>
<td>Molten salt / 200 MWe</td>
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<tr>
<td>2</td>
<td>U.S.</td>
<td>Ultra Safe Nuclear/Global First Power</td>
<td>High-temperature gas prismatic block / 5 MWe</td>
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<tr>
<td>3</td>
<td>Sweden / Canada</td>
<td>LeadCold</td>
<td>Molten lead pool fast spectrum / 3-10 MWe</td>
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<tr>
<td>4</td>
<td>U.S.</td>
<td>Advanced Reactor Concepts</td>
<td>Sodium pool fast spectrum / 100 MWe</td>
</tr>
<tr>
<td>5</td>
<td>UK</td>
<td>U-Battery</td>
<td>High-temperature gas prismatic block / 4 MWe</td>
</tr>
<tr>
<td>6</td>
<td>UK</td>
<td>Moltex Energy</td>
<td>Molten salt fast spectrum / ~300 MWe</td>
</tr>
<tr>
<td>7</td>
<td>Canada/U.S.</td>
<td>StarCore Nuclear</td>
<td>High-temperature gas prismatic block / 10 MWe</td>
</tr>
<tr>
<td>8</td>
<td>U.S.</td>
<td>SMR, LLC. (a Holtec International Company)</td>
<td>Pressurized water / 160 Mwe</td>
</tr>
<tr>
<td>9</td>
<td>U.S.</td>
<td>NuScale Power</td>
<td>Integral pressurized water / 50 Mwe</td>
</tr>
<tr>
<td>10</td>
<td>U.S.</td>
<td>Westinghouse Electric Co.</td>
<td>eVinci micro reactor / &lt;25 MWe</td>
</tr>
<tr>
<td>11</td>
<td>U.S.</td>
<td>GE Hitachi Nuclear Energy (BWRX-300)</td>
<td>Boiling Water Reactor / 300 MWe</td>
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ENVIRONMENTAL ASSESSMENT PROCESS BEGINS IN CANADA FOR PROPOSED SMALL MODULAR REACTOR FEATURING USNC TECHNOLOGY

Micro Modular Reactor Project at Chalk River

Chalk River (Ontario)

Reference number: 80182
Federal Responsible Authority: Canadian Nuclear Safety Commission
Proponent: Global First Power
Environmental Assessment Commenced: 2019-07-15
Environmental Assessment Type: Environmental Assessment by Responsible Authority
Status: Environmental assessment in progress
https://ceaa-acee.gc.ca/050/evaluations/proj/80182

Latest Update
July 15, 2019 - An environmental assessment has commenced.
August 09, 2019 - A public participation period is underway.

About the Proposal

Global First Power is proposing the site preparation, construction, operation, and decommissioning of a single small modular reactor, using Micro Modular Reactor (MMR) technology. The proposed project is located at the Chalk River Laboratories site, in Renfrew County, Ontario, approximately 200 km northwest of Ottawa. The proposed project includes a nuclear plant, which would contain a MMR High Temperature Gas-cooled Reactor that would provide process heat to an adjacent plant, via molten salt. The MMR would produce approximately 15 Megawatt (thermal) of process heat to generate electrical power and/or heat, over an operating life-span of 20 years.
MMR Project Objectives

- The MMR Project at Chalk River will produce 15 MWt of process heat.
- The heat could satisfy the needs of the Chalk River Laboratories, and could replace the greenhouse gas emitting heat sources currently employed on the CRL site.
- Electrical power could also be supplied to the area grid, over 20 years.
- The Project will enhance the power and heat source reliability at the CRL site.
- The Project will support and have access to the CRL research community.

**Project Timeline**

<table>
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<tr>
<th>Phase</th>
<th>Bounding Start-End</th>
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<tr>
<td>Project Development</td>
<td>2016–2021</td>
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<tr>
<td>Site Preparation and Construction</td>
<td>2021–2027</td>
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<tr>
<td>Plant Operation</td>
<td>2023–2054</td>
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<tr>
<td>Decommissioning</td>
<td>2044–2058</td>
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<tr>
<td>Abandonment</td>
<td>2058-2060</td>
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The Project will consist of two major parts, the **Nuclear Plant** and the **Adjacent Plant**, and supporting infrastructure, collectively the “**MMR facility**.”

- The Nuclear Plant includes one (or two) MMR High Temperature Gas-cooled Reactor which provides process heat to the (non-nuclear) Adjacent Plant via molten salt.

- The Adjacent Plant consists of the equipment and systems that convert the process heat to electrical power or other forms of energy as per client requirements.

**MMR Project at CNL**
MMR Energy System Functional Blocks

• Heat is transferred from reactor core to molten salt heat storage through helium flow and compact heat exchanger.
• Power is extracted from molten salt heat storage through steam generator/turbine gensets.
MMR Nuclear Plant

Reactor Fuel and Reactor Core
MMR Nuclear Plant: Nuclear Heat Supply System

Reactor design Parameters:
15 MWth, 9-13% enriched UO₂
MMR Nuclear Plant

Citadel Building

The Nuclear Heat Supply System (includes the reactor core) is housed in a vertical cylindrical concrete structure

- Protects the reactor and the Intermediate Heat Exchanger from hazards
- Provides biological shielding that mitigates against possible radiation exposure from the reactor.
The MMR Facility: Adjacent Plant

- The Adjacent Plant is a power plant generating power from the heat supplied by the Nuclear Plant.

- The Adjacent Plant contains all the equipment to generate electrical power and/or process heat and supply it to the customer.
MMR Energy System
MMR-REM first use for remote areas

Thermal Power
30 MWth (15 x 2)

Electrical Power
10 MWe (5 x 2)

Lifetime
20 years

Refueling
Never

No infrastructure necessary
MMR Energy System deployable worldwide

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The MMR-REM Energy System

Highly Modularized Flexible Energy System, powered by two 15 MWt MMR micro reactors
Scalable up to 10 units with co-located thermal storage

- Currently in advanced licensing stage in Canada - for use in remote off-grid areas
- Environmental Assessment Started for First Site (CNL at Chalk River, Canada)
The MMR™ system is a small modular nuclear energy system that delivers safe, clean and cost-effective electricity and heat to remote mines, industry and communities.

**MICRO MODULAR REACTOR™**

The MMR™ system uses FCM™ fuel. Tiny grains of uranium are clad in several layers of silicon carbide that prevent any release of radioactive gases. The fuel is safe under all operating and accident conditions.

**The MMR™ Nuclear Reactor is only fuelled once in its lifetime.** There is no refuelling required or spare fuel on site.

**The MMR™ reactor is a walk-away, safe-power reactor.** In the case of an accident, the MMR™ reactor cannot melt down as any heat dissipates passively into the environment.

**The MMR™ plant is small and modular.** The modules, which are built on an assembly line, are easily installed at the user site. The MMR™ system is scalable from 5 to 50MW.

**The MMR™ plant is simple to operate, and flexible in its outputs.** The use of molten salt thermal storage allows for significant flexibility in the supply of both electricity and process heat.
The MMR Energy System: NOT just another reactor

- A safe, simple and scalable high-performance power plant
- Long-term energy storage with micro nuclear heat source
- Reliable, flexible power or heat, always available
- Replicable licensing path
- A versatile energy platform to build high-value power applications