
# Global progress in the design and technological development of micro nuclear reactors: prospects and challenges

Joint IAEA-ICTP Workshop on Reactor Physics, Thermal Hydraulics and Plant Design Engineering of Small Modular Reactors (SMR4212)

Dandara Araujo da Silva
Nuclear Power Technology Development Section, IAEA
Division of Nuclear Power

14 April 2026

# Agenda

1. Microreactors: What and Why?
2. Technology Landscape
3. Conclusion and Outlook

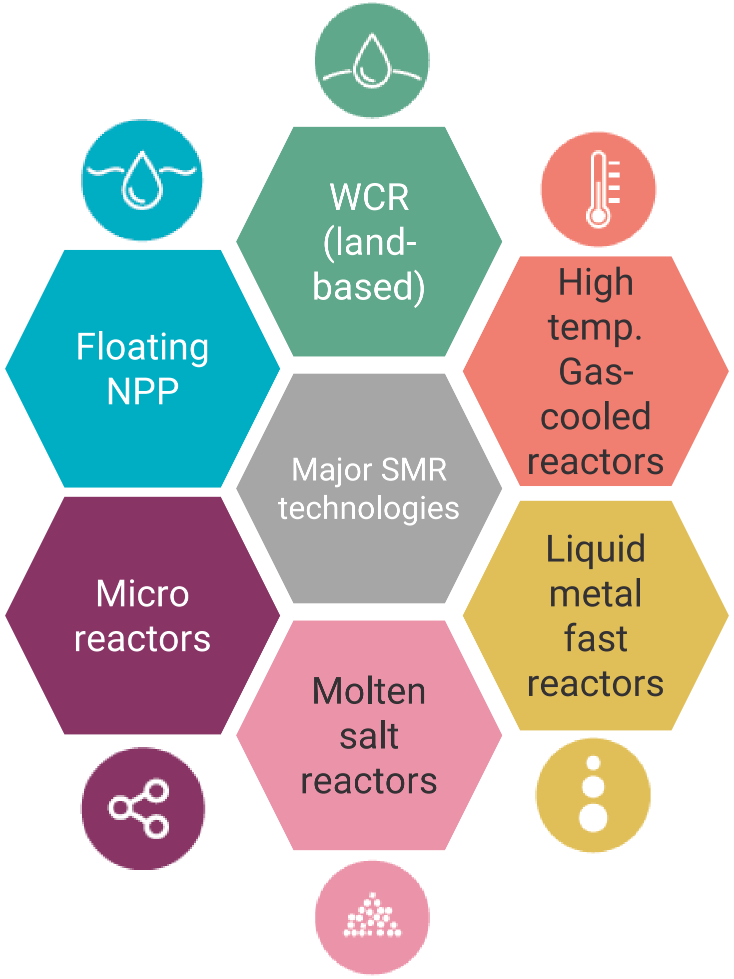
# Agenda

1. Microreactors: What and Why?
2. Technology Landscape
3. Conclusion and Outlook

# What is a Microreactor?

## A Small Modular Reactor

- US DOE: 1- 20 MWt
    - Market:  < 20 MWe or <50 MWt
- But has other characteristics, beyond power definition
    - Few or no on-site assembly
    - Small footprint
    - Semi-autonomous control system
    - Safety systems passively operated
    - Long refueling cycle
    - Do not require water source for cooling



# Why a Microreactor ?

## Specific Condition of Site and Electrical Grid

- Regions inaccessible to clean, reliable, resilient and affordable energy
    - Remote areas
    - Replacing diesel generators
    - Regions affected by external incidents (e.g. Natural disasters)
    - Mining Industries
    - Outer-space
- Fostering innovation in technology and advances in IT

Enabling Sustainable Energy Systems – minimizing the needs of fossil fuels



Designed by Freepik

# Microreactors Applications

Microreactors serve modern needs with compact, flexible energy solutions across diverse sectors.

## Power Security

- Secure microgrids for critical infrastructure
- Power for remote off-grid areas
- Disaster recovery and humanitarian assistance

## Non-Electric Applications

- Seawater desalination
- Hydrogen production
- Integration with renewables

## Integrated Industrial Solutions

- Naval propulsion
- Aerospace missions
- Remote mining operations
- Replacement for diesel gensets and repowering retired fossil plant sites

# Agenda

1. Microreactors: What and Why?
2. **Technology Landscape**
3. Conclusion and Outlook

# Microreactors Technology Landscape

## Economics and Financing

+ Lower upfront capital cost
+ Economy of serial production
- High cost for FOAK
- Certification fees

## Shorter Construction Span

+ Design simplification
+ Smaller footprint
- Availability of Nuclear Fuel
- Innovative material

## Energy Resilience

+ Flexibility
+ Ensured energy supply
+ Smaller grids/no grid
+ Remote regions
+ Transportability, mobility, portability

## Reduced $CO_2$ Production

+ Replacement of fossil fuel generators
+ Almost zero emissions

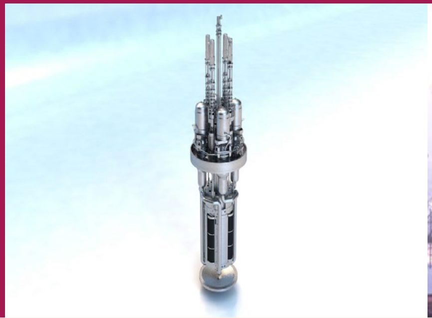
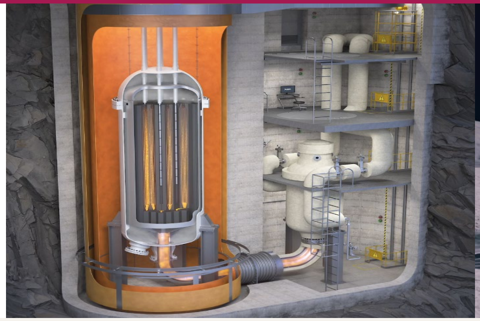
## Energy Sustainability

+ Cogeneration
+ Hydrogen production
+ Integration with Renewable to form Hybrid Energy Systems

## 3S

+ Inherent and passive design
+ EPZ reduced
+ Smaller radionuclide inventory
- Inspection and emergency preparedness
- Off-site staffing or even no-staff

# Microreactors Technology Landscape

| | **MARVEL**<br>Idaho National Laboratory (INL), USA | **eVinci**<br>Westinghouse Electric Company LLC, USA | **Holos-Quad Generators**<br>HolosGen, USA | **KRONOS MMR™**<br>NANO Nuclear Energy Inc's, USA | **LOKI MMR**<br>NANO Nuclear Energy Inc's, USA |
|---|---|---|---|---|---|
| |  |   |   |  |  |
| Development Status | Fabrication | Detailed design | Detailed design | Preliminary design | Conceptual design |
| Reactor type | LMTR | heat-pipe cooled and monolith-core | distributable modular nuclear power generator | HTGR | HTGR |
| Power output | 100-kWt /5-7 kWe | 15 MWt/5 MWe | 13 MWe | 10-45 MWt/3.5-15 MWe | 1.5 –5 MWe |
| Primary circulation | Natural Convection | Natural circulation | - | Forced circulation | Forced circulation |
| Primary pressure | 0.39 MPa | 0.12 MPa | - | 1.3 to 6 MPa | 2 MPa |
| Core outlet To | 520 °C | | - | 660 °C | 727 °C |
| Fuel type/enrichment | UZrH/19.75% | TRISO fuel/19.75% | - | FCM™ or TRISO/9.9 to 20% | TRISO/9.9% |
| Refueling Cycle | > 5 years | no on-site refuelling, 8 years | 12–20 EFPYs | 20 years | 5 years |
| Plant footprint | 8.9 $m^2$ | < 2 acres | - | - | - |
| Design life | 2-40 years (depending on transients) | 8 years | 60 years | 20 years | - |

# eVinci development timeline

**2015**
01
Westinghouse began internal development of heat-pipe microreactor concepts

**2021–2022**
02
Design refinement and technology development

**2023**
03
Westinghouse announces plans to deploy an eVinci microreactor in Saskatchewan, Canada
Manufacturing site announced in Etna, Pennsylvania; design near completion

**2024**
04
Completion of the Front-End Engineering and Experiment Design phase for testing at INL

**2025 (Current)**
05
U.S. NRC approved the Principal Design Criteria (PDC) Topical Report
Approval of the Preliminary Safety Design Report by the U.S. DOE
Preparing for prototype testing

**2026 (Planned)**
06
Prototype testing of the eVinci microreactor at INL's DOME facility
Start of site-specific licensing and construction for first test units.

**Late 2020s (Target)**
07
Commercial deployment

Enclosure 2: WAAP-12580, Revision 0, "eVinci Microreactor Overview – Non-Proprietary Open Presentation“
https://info.westinghousenuclear.com/
Westinghouse Completes Study for First eVinci Microreactor Experiment | Department of Energy
Approval of Westinghouse test microreactor progresses - World Nuclear News

# MARVEL development timeline

**01** — **2017-2019**
Concept introduced and early design studies begin

**02** — **2021**
Detailed engineering begins. The core design finalizes as a liquid-metal-cooled (NaK), 85–100 kWth reactor with natural circulation.

**03** — **2022**
Idaho National Laboratory builds a full-scale electrically heated prototype (PCAT) to validate MARVEL design.

**04** — **2023**
Prototype testing begins at Creative Engineers Inc. in Pennsylvania; key thermal/hydraulic validation work completed
MARVEL reaches 90% design completion, enabling full-scale construction prep.

**05** — **2024**
Fuel fabrication begins by TRIGA International; UZrH fuel elements expected for delivery in early 2025.

**06** — **2025**
Fabrication of the primary coolant system initiated

**07** — **2025–2026 (planned)**
Final system integration and construction at INL's Transient Reactor Test Facility (TREAT) site

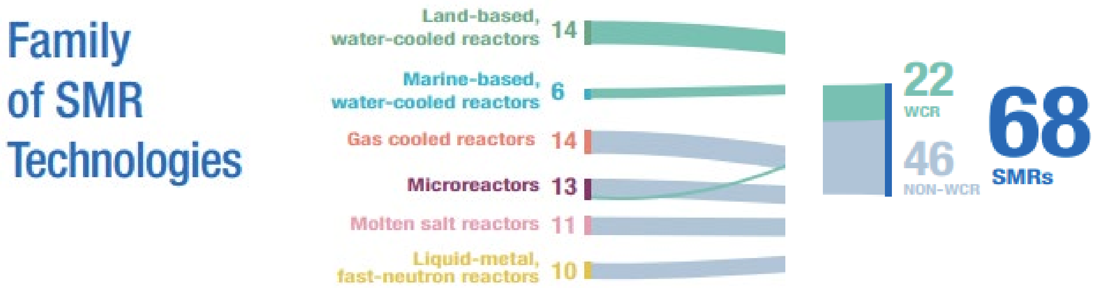
**06** — **2027–2028 (target)**
Startup and operation of MARVEL at INL


INL – MARVEL Project
DOE Microreactor Program
https://www.energy.gov/ne/articles/
INL – Coolant System
INL – MARVEL Overview
Power Magazine

# Agenda

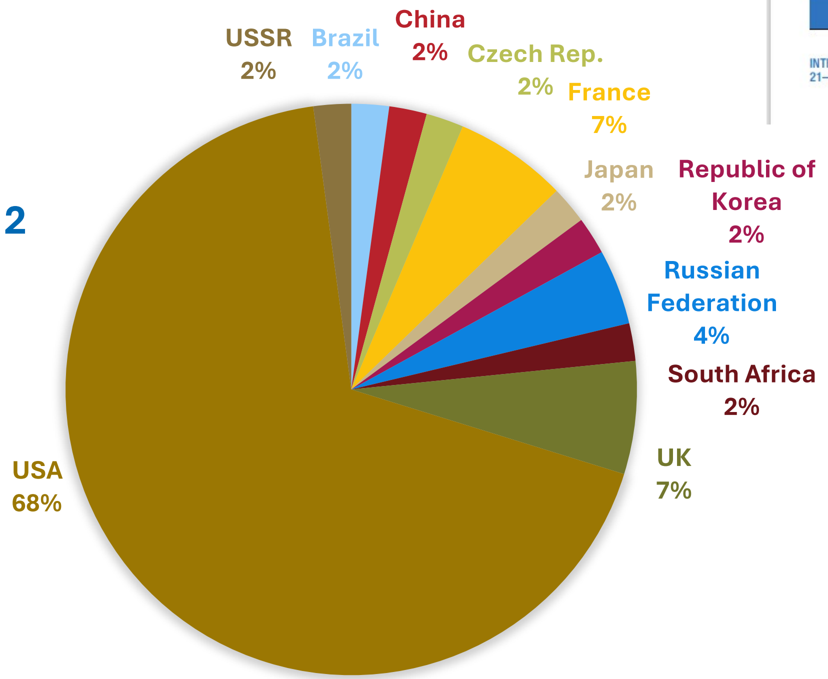
1. Microreactors: What and Why?
2. Technology Landscape
3. Conclusion and Outlook

# Global Perspectives and IAEA Work on Microreactors





- 13 listed on the Catalogue + 2 over 10MWe
- 42 designs detected on the market



# IAEA Activities on Microreactors and Space Applications

- Analysis of global microreactor market and technology trends, including space applications
- Organization of international Technical and Consultancy Meetings
- Participation in international conferences and expert panels
- Production of reference publications and technical reports

**Meetings**

- Consultancy Meeting on Advances in Design and Technology Developments for Microreactors, Vienna, Austria, 2 – 5 June 2025
- Technical Meeting on Advances in Design Development for Microreactors and their Applications, Vienna, Austria, 18 – 22 May 2026

**Trainings**

- Interregional Training Course on Advances in Microreactor Designs and Applications: Scalability and the potential for remote deployment, marine and space applications, St. Petersburg, Russian Federation, 21 – 25 Sept. 2026

**Documents**

- TECDOC Status of Microreactor Technology Development, expected for Q4 2026

# IAEA–UNOOSA Joint Workshop on Nuclear Power Sources in Space

### What It Is

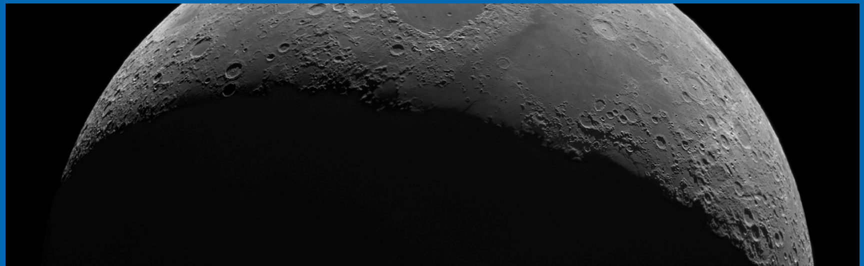
A joint initiative to host a **workshop in June 2026** on the use of **nuclear power systems** (NPS) in space missions.

### Why It Matters

Space missions increasingly rely on **advanced power systems**.

The workshop will address **technical, safety, and regulatory** aspects of deploying NPS in outer space.

It aims to foster **international dialogue**, share **best practices**, and guide **future developments**.



### Who's Involved

Collaboration between **IAEA**, **UNOOSA**, **Member States**, and **industry stakeholders** to support safe and effective use of nuclear power in space.

# Conclusion and Outlook

## Key Takeaways

Microreactors offer compact, flexible, and resilient energy solutions.

Ideal for remote, off-grid, and disaster-prone areas.

Long refuelling cycles and factory-built designs enhance deployment.

## Potential

Microreactors can significantly contribute to low-carbon energy strategies.

Integration with renewables and microgrids for enhanced energy security.

## Importance of Collaboration

International cooperation is crucial for addressing regulatory and safety challenges.

IAEA's role in supporting technology mapping, safety standards, and deployment efforts.

## Outlook

Continued innovation and research will drive microreactor technology forward.

Governments and industry must work together to realize the potential of microreactors.

IAEA

# THANK YOU