Preliminary Operational Requirements for ROK Military Microreactors

Lessons from U.S. Defense Microreactor Programs

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Outline

01	Energy resilience	→	Electrification, grid vulnerability and MCL	Prior study
02	Division -level MCL	→	Quantitative demand and power mix	Prior study
03	U.S. military microreactor programs	→	Operational lessons across reactor concepts	This study
04	ROK military microreactor requirements	→	Power availability and mission conditions	This study

01

PRIOR STUDY

Energy Resilience

Electrification, grid vulnerability and MCL

01 Energy resilience

02 Division - level MCL

03 U.S. military microreactor programs

04 ROK military microreactor requirements

Electrifying the ROK Armed Forces

Surveillance System — continuous



Coastal Surveillance Radar

Unmanned System — continuous



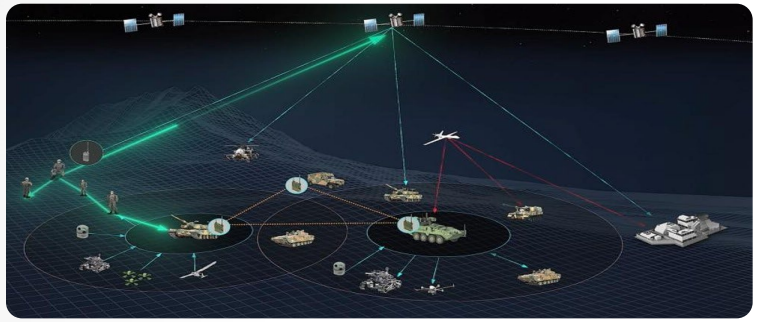
Multi-purpose unmanned vehicle

Warrior Platform — continuous



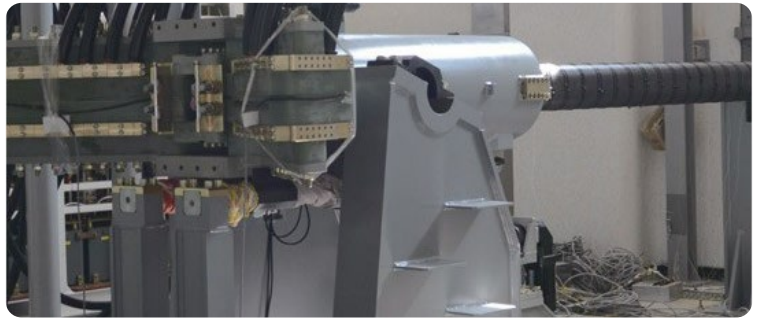
Electrically-powered soldier equipment

Hyper-connected network — continuous



Always-on command and communications

Railgun — peak



High energy weapon systems

Laser air defense — peak

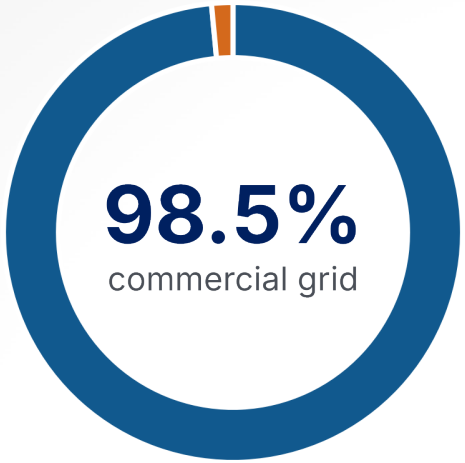


Cheon-gwang Block I system

Persistent electronics and networks raise continuous demand; high -power weapons add peak demand.

Images: ROK Army / Defense Daily; Hyundai Rotem; Hanwha Systems; ADD; DAPA

Grid Dependence of the ROK Army

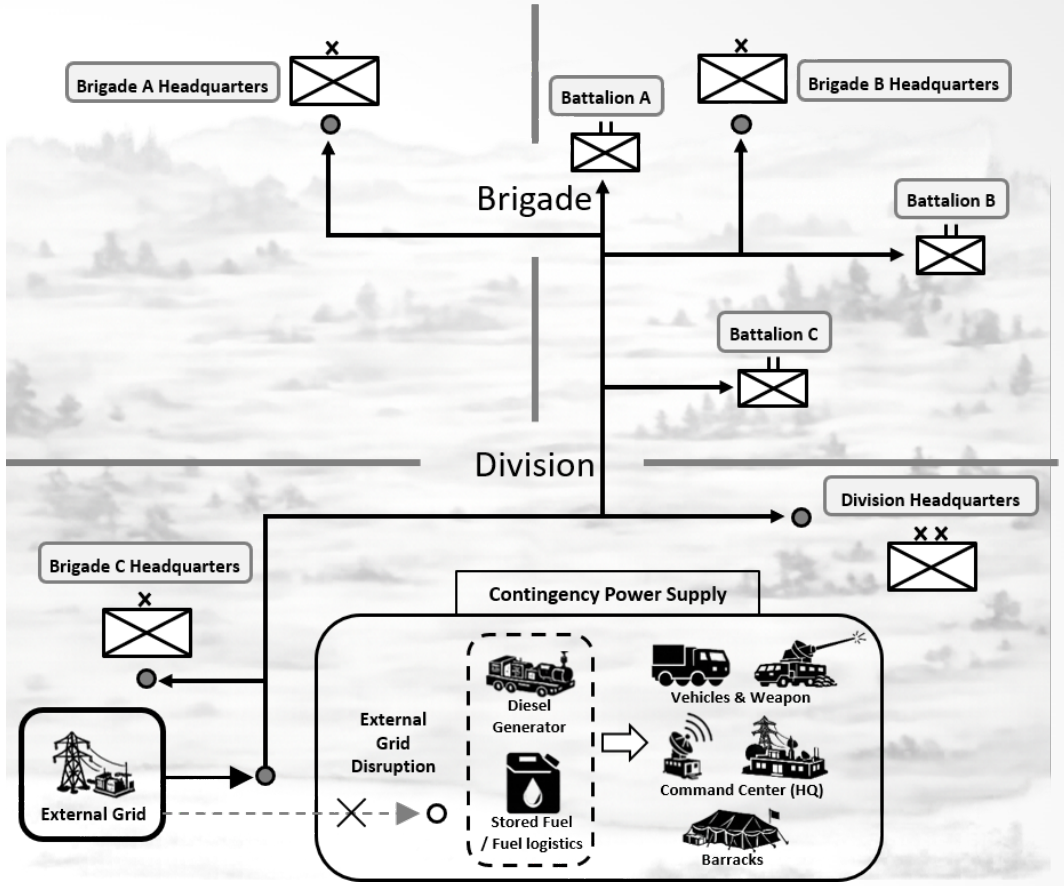


Self-generation: only 1.5%

ROK Army electricity supply, 2018 –2023

Energy facilities are priority targets in wartime — Ukraine, Middle East

Diesel backup depends on reliable wartime fuel resupply.



Upstream disruption can interrupt downstream missions.

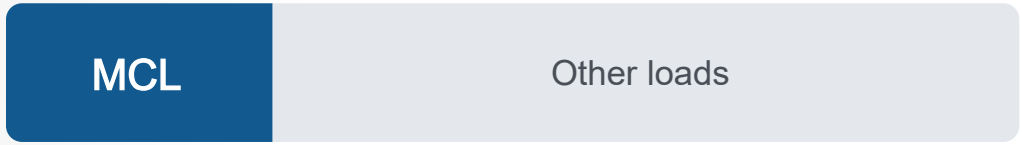
Source: Kim et al. (2026), prior study [1]; B. E. Humphreys, CRS R48067 (2024) [2]

Mission Critical Load (MCL)

DEFINITION

The minimum electrical load needed to sustain mission -essential functions during grid disruption

Total load



Total facility load includes other loads. In the three NREL cases, MCL accounts for 18.5 –37.5%.

> Not “how much electricity?” but “ which loads, for how long, from what source? ”

10 U.S.C. §2920 requires U.S. DoD to identify:

1. Critical missions
2. Mission critical energy requirements
3. How long they must be sustained
4. Current and alternative energy sources

U.S. Defense Energy Resilience Pipeline

Energy strategy → IEWP planning → ERCIP funding → Black-start tests

ROK GAP The reviewed public sources do not specify mission specific MCLs or sustainment durations.

Source: 10 U.S.C. §2920 [3]; Kim et al. (2026), prior study [1]; NREL [4]

MCL Benchmark: U.S. NREL 14 -Day Outage Scenarios

NREL **14-day outage case: PV + long duration storage without diesel**

Fort Bliss

37.81 MW avg total load

Avg MCL 6.99 MW (18.5%)

Total load peak/average: 1.79



1.43 km² of PV land

59 MWdc PV + 729.6 MWh LDES

Patuxent River NAS

21.44 MW avg total load

Avg MCL 5.04 MW (23.5%)

Total load peak/average: 1.58



1.68 km² of PV land

69 MWdc PV + 808.1 MWh LDES

Holloman AFB

9.01 MW avg total load

Avg MCL 3.38 MW (37.5%)

Total load peak/average: 1.77



0.63 km² of PV land

26 MWdc PV + 396.3 MWh LDES

Modeled PV + LDES achieves > 95% survival probability at day 14 with substantial land and storage needs.

Square areas are drawn to a common scale. 1 soccer field = 7,140 m².

Sources: NREL/TP-5C00-87646 [4], Tables 2, 8, A-2; FIFA field dimensions. MCL and areas calculated.

02

PRIOR STUDY

Division -Level MCL

Quantitative demand and power mix

01 Energy resilience

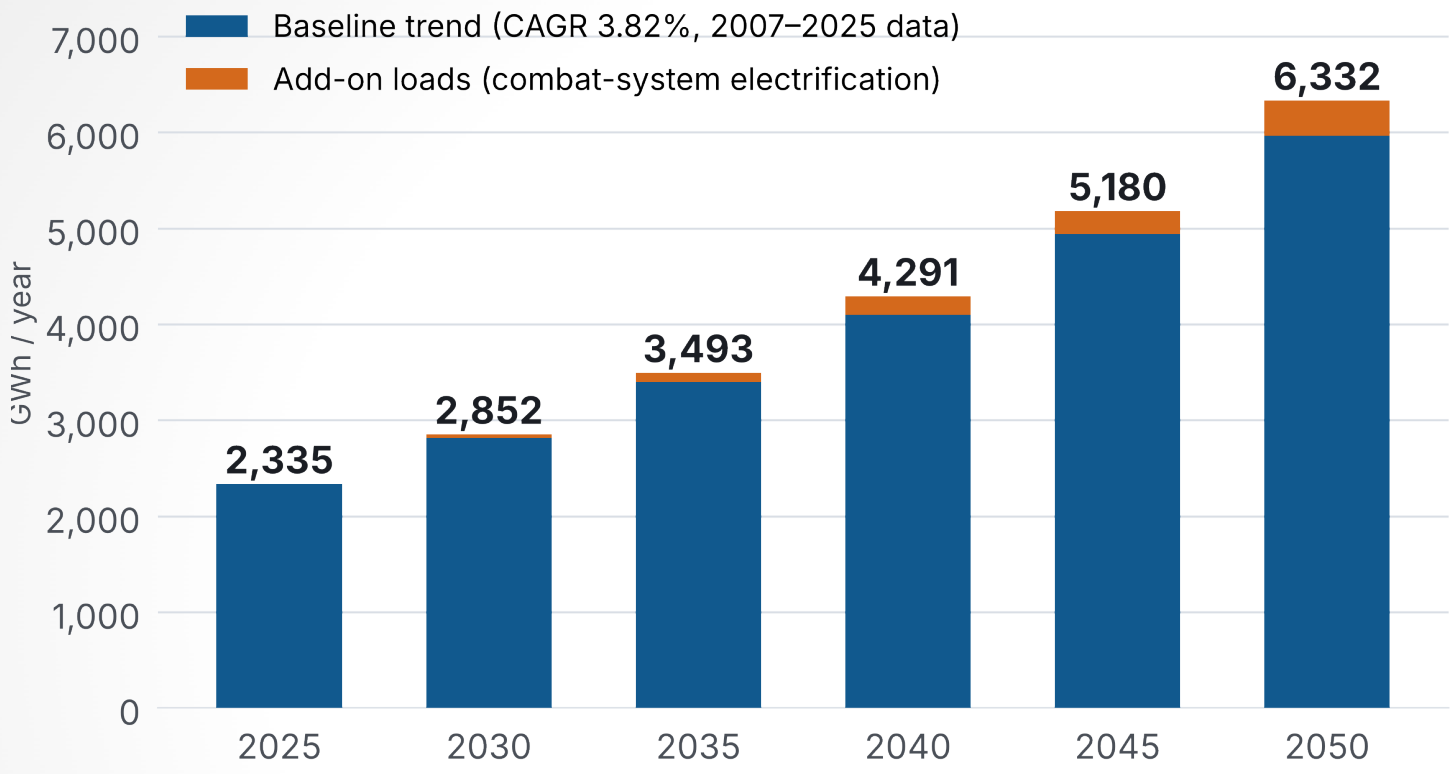
02 Division -level MCL

03 U.S. military microreactor programs

04 ROK military microreactor requirements

Electricity Demand to 2050

Estimated ROK military annual electricity demand (GWh)



2.71× vs. 2025

2,335 → 6,332 GWh/yr

2025 –2050 scenario
~91% of growth from the baseline trend

Source: Kim et al. (2026), prior study [1]; KEPCO Power Data Portal [5]

Mission Critical Load of the Reference Division

2025 reference: 50 GWh/yr (assumed)

Inje-gun military facilities: ~54 GWh/yr (from KEPCO)

136.0 GWh/yr
2050 reference case projection

⬇ × 1,000 ÷ 8,760 h

15.53 MW
Average total load

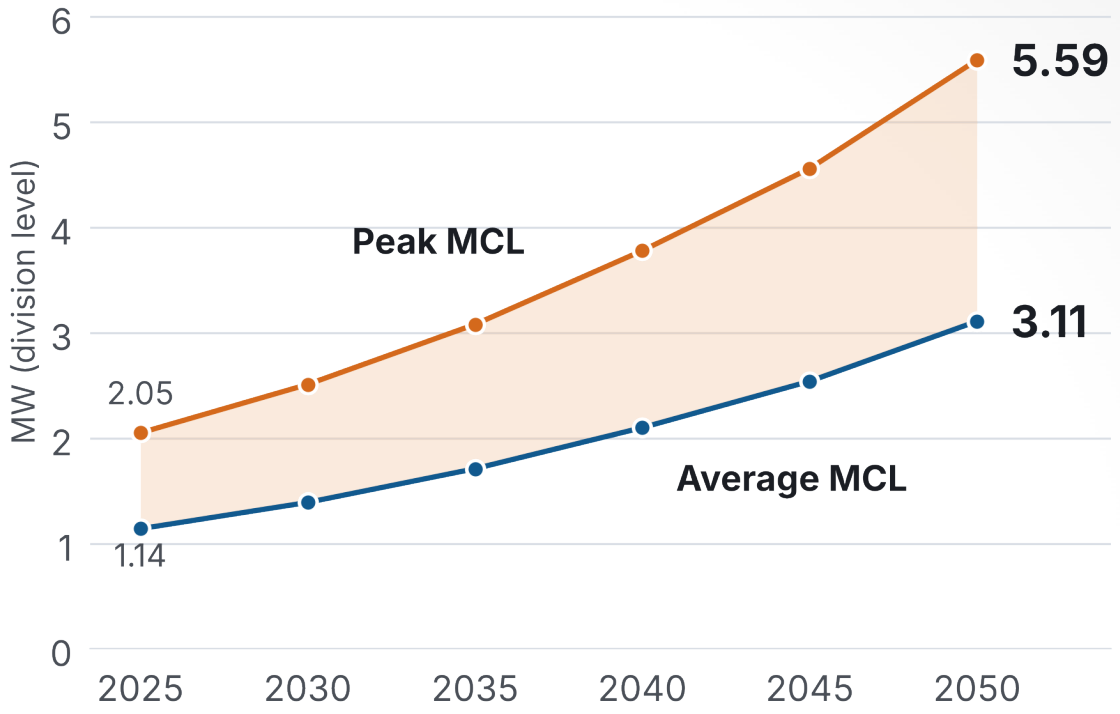
⬇ × 20% assumed MCL share

3.11 MW
Average MCL

⬇ × 1.8 peak factor (NREL informed)

5.59 MW
Peak MCL

Average and peak MCL (MW)

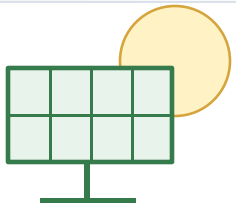


Assumed MCL share: 20%; peak/average: 1.8 (NREL informed).
MCL share 15 / 20 / 30%: average 2.33 / 3.11 / 4.66 MW.

Source: Kim et al. (2026), prior study [1]. U.S. installation data inform the planning assumptions.

Power Mix for Sustaining MCL

Sustaining MCL during a prolonged grid outage



Solar PV

Energy when available

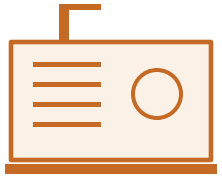
Terrain / shade / land limits
Time / weather / seasons



Battery ESS

Fast response and peak support

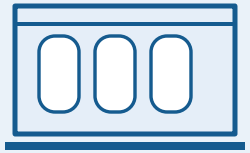
Finite stored energy
Recharge required



Diesel generator

Dispatchable backup

Extended operation depends on continued fuel resupply



Microreactor

Proposed firm supply

Long-duration operation
Less frequent fuel resupply

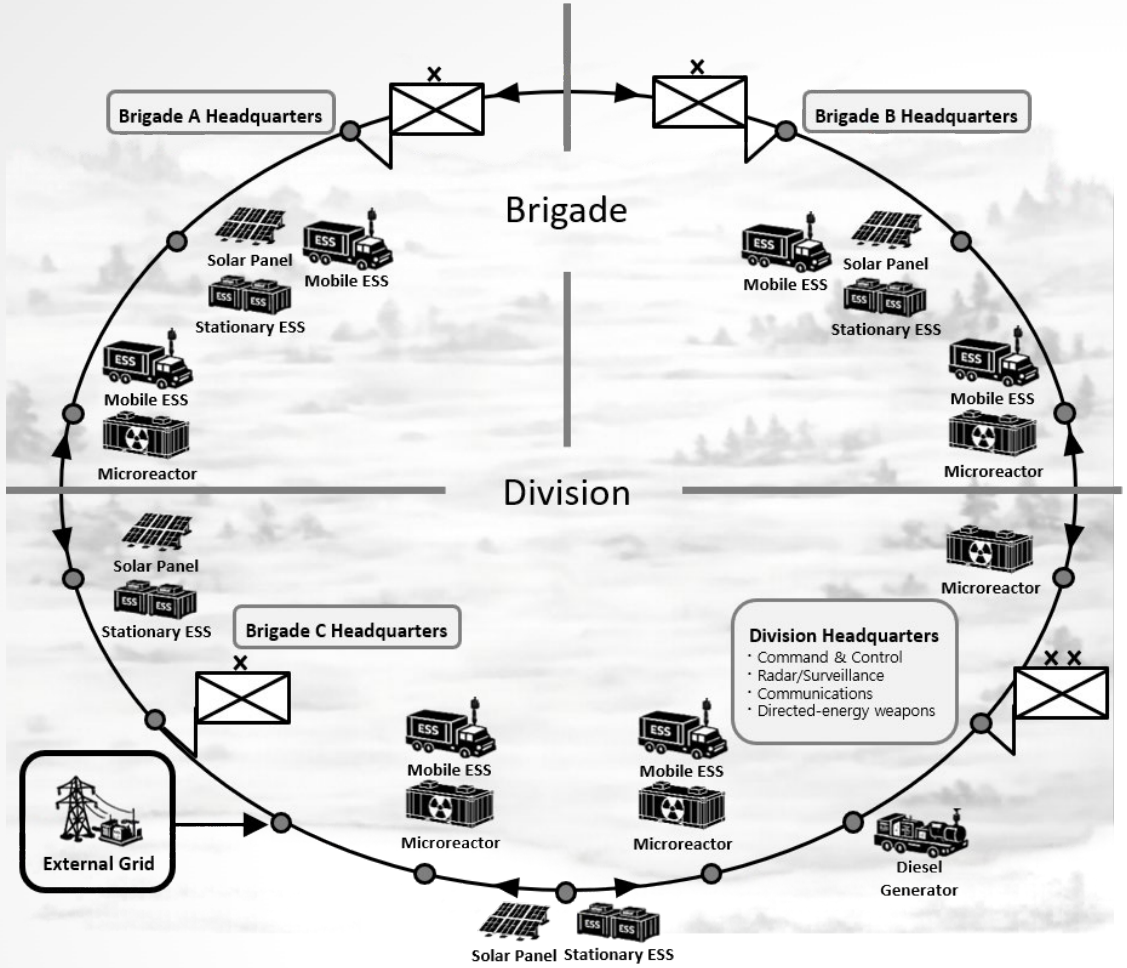
Mission-critical loads

3.11 MW average 5.59 MW peak

Proposed firm supply: microreactors (supported by ESS, PV and diesel)

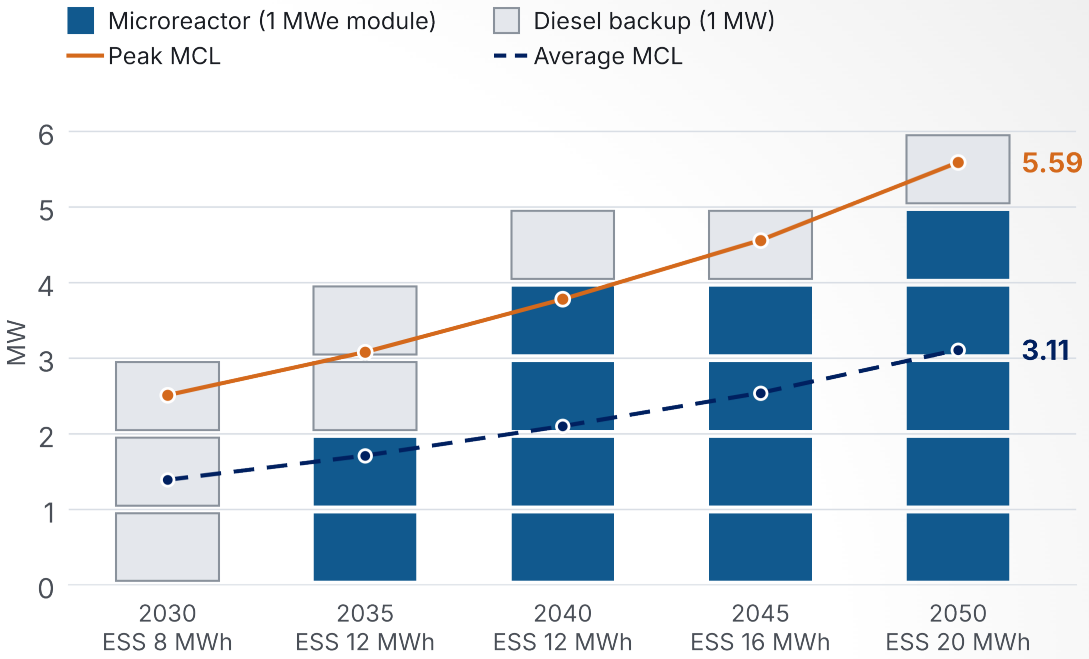
Sources: prior study [1]; NREL [4].

Ring-connected Microgrid and Roadmap



Alternate power paths and islanded operation

Installed firm capacity vs. MCL (MW)



2050: five 1 MWe modules

20 MWh ESS + 1 MW diesel backup

One module loss leaves 4 MWe of reactor capacity

Source: Kim et al. (2026), prior study [1], Fig. 4 and configuration roadmap

Operational Requirements for the Reactor

PRIOR STUDY

3.11 MWe

Average MCL, 2050 reference case

Policy prerequisites

- National policy and military ROC (required operational capability)
- Regulatory and operating roles
- Protection and emergency planning
- Training and support

THIS STUDY

ROK military microreactor requirements

- Power Availability, Modularity and Low Manning
- Fuel Endurance and Fuel Cycle Constraints
- Deployability, Heat Rejection, and Compactness
- Safety, Security, and Regulatory Framework

U.S. operational priorities and ROK MCL baseline

Source: Kim et al. (2026), prior study [1]; this study

03

PART 3 OF 4

THIS STUDY

U.S. Microreactor Programs

Operational lessons across reactor concepts

01 Energy resilience

02 Division - level MCL

03 U.S. military microreactor programs

04 ROK military microreactor requirements

Historical Precedent: Army ML -1



ML-1 full-scale transport mockup, ca. 1961 –1965

3.3 MWth
Design thermal power

N_2 cycle
Closed nitrogen gas turbine cycle

Mobile
Cargo aircraft or Army trailer

1965
Program ended: cost-effectiveness concerns and competing resource priorities

Transportability must be balanced with reliability and a manageable operating burden.

Today's Antares R1 platform also uses a closed N_2 Brayton cycle.

Sources: INL reactor history; USACE photograph via Wikimedia Commons; CDC/NIOSH INL report [6]; Antares [7]

U.S. Military Microreactor Programs

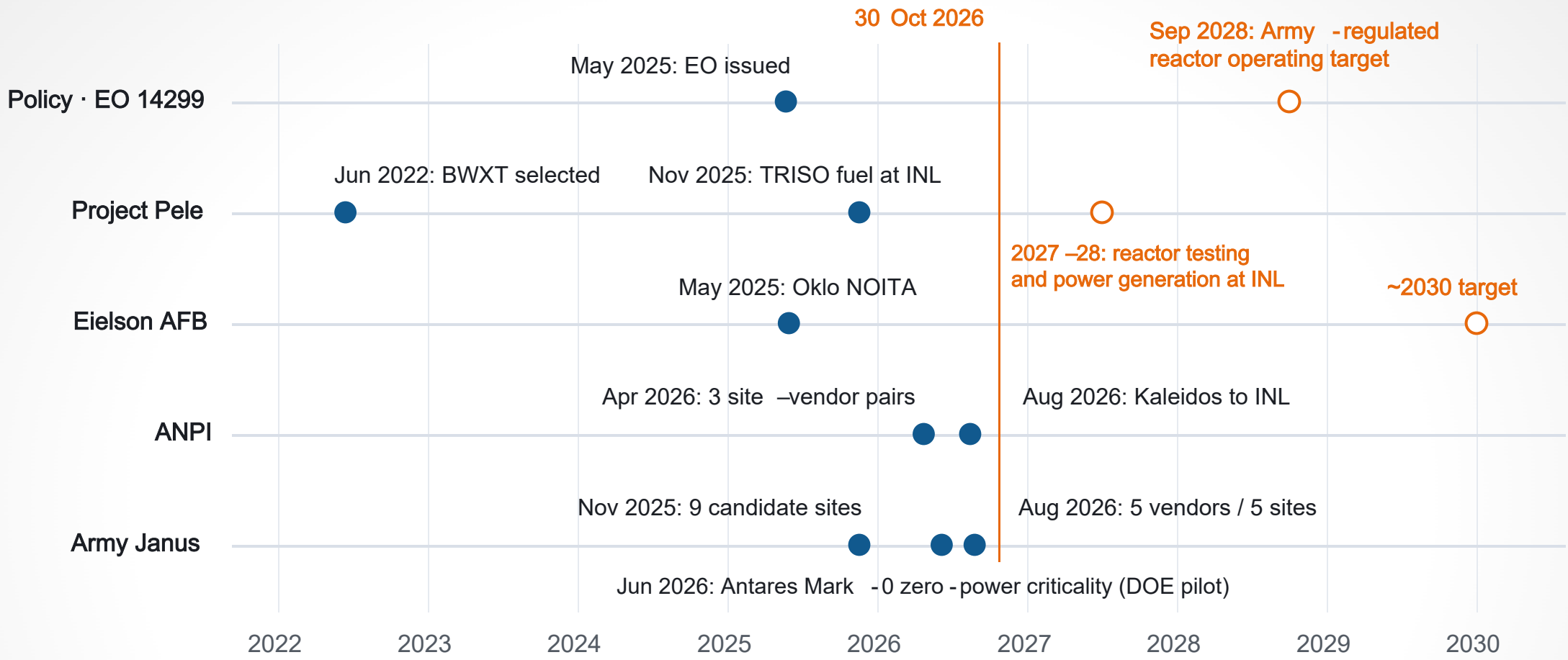
Project Pele	**Transportable reactor demonstration** SCO-led prototype for transport, operation and relocation testing at INL.
Eielson AFB pilot	**Power supply for a remote air base** Commercial microreactor pilot for critical infrastructure in Alaska.
ANPI	**Advanced Nuclear Power for Installations** DAF / DIU initiative to deploy commercial microreactors at multiple bases.
Army Janus	**Grid-independent power for Army installations** Army program to deploy commercial microreactors for critical missions.

Sources: Project Pele EIS [8]; Eielson AFB [9]; DAF / DIU [10]; U.S. Army [11].

U.S. Military Microreactor Milestones

● Announced / achieved ○ Planned target

From concept studies to fueled demonstration and site level acquisition

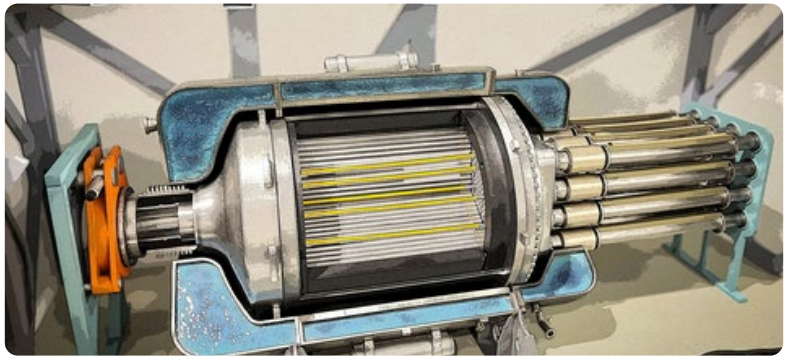


Sources: Army [12]; DAF [9, 10]; DOE/INL [13]; ANS [14]; EO 14299 [15]; WNN [16]. Targets are not completions.

Project Pele and Eielson AFB

Project Pele

BWXT prototype



1.5 MWe

Gas-cooled HTGR, HALEU TRISO
Open Brayton gas cycle (EIS design basis)
Up to 3 years without refueling
Atmospheric heat rejection
Semi-autonomous operation objective

Four standard 20-ft transport modules

Eielson AFB pilot

Oklo Aurora platform



Up to 5 MWe

Sodium-cooled fast reactor, metal fuel
Steam turbine (Aurora technology reference)
Proposed 30-year power purchase agreement
Commercial ownership and operation
Final Eielson configuration subject to licensing

Fixed power supply for a remote base under NRC licensing

Sources: [8, 9, 17 –20]; manuscript Table II. Eielson details use the Aurora technology reference.

ANPI: Three Sites and Technology Options

Buckley SFB

Radiant Kaleidos



1 MWe

Up to 1.9 MW useful heat

Helium-cooled HTGR, TRISO

Closed sCO_2 Brayton

~5 years before refueling

150-hour unattended test planned

Factory return for refueling

Aug 2026: shipped to INL

Malmstrom AFB

Westinghouse eVinci



5 MWe

15 MWth core thermal power

Heat pipes, 19.75% enriched TRISO

Open-air Brayton

≥8 full power years

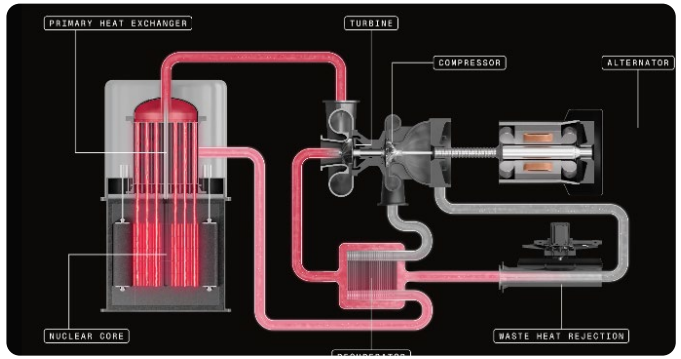
Passive decay heat removal

Factory assembly, rapid load response

No cooling water required

JB San Antonio

Antares R1 platform



0.1–1 MWe

Thermal rating: not specified[1]

TRISO + Na heat pipes

Recuperated closed N_2 Brayton, <300 psi

>6 years of operation

Integrated shielding, transport cradle

Direct microgrid interface

Mark-0: zero-power criticality

Sources: [7, 13, 16, 21–27]; manuscript Table II. [1]Not specified in the manuscript. R1 is a reference, not the final JBSA design.

Regulatory Pathways and Common Priorities

Two deployment pathways

Commercial NRC licensing

Eielson and ANPI: vendor ownership and operation

Army-regulated operation

EO 14299 target (domestic deployment): September 2028

5 **Janus, Aug 2026: 5 vendors paired with 5 Army installations**

Up to $2.2B, milestone based; contractor owned and operated

Site and mission needs shape deployment.

Common operational priorities

- Long fuel endurance
- Grid-independent operation
- Compact modular deployment
- Passive or inherent safety
- Limited operating burden

Sources: U.S. Army [12]; EO 14299 [15]; DAF ANPI [10]; this study (Table II)

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PART 4 OF 4

This study

THIS STUDY

ROK Requirements

Power availability and mission conditions

01 Energy resilience

02 Division MCL

03 U.S. military microreactor programs

04 ROK military microreactor requirements

Deriving Preliminary ROK Requirements

U.S. microreactor programs

Recurring operational priorities

ROK reference division MCL

3.11 avg / **5.59** peak

MWe, 2050 reference scenario

MICROGRID CAPACITY CRITERION

Retain average MCL after one module loss

OPERATIONAL REQUIREMENTS

- Power Availability, Modularity and Low Manning
- Fuel Endurance and Fuel Cycle Constraints
- Deployability, Heat Rejection, and Compactness
- Safety, Security, and Regulatory Framework

MCL based requirements are stated quantitatively.

Mission dependent requirements are stated functionally.

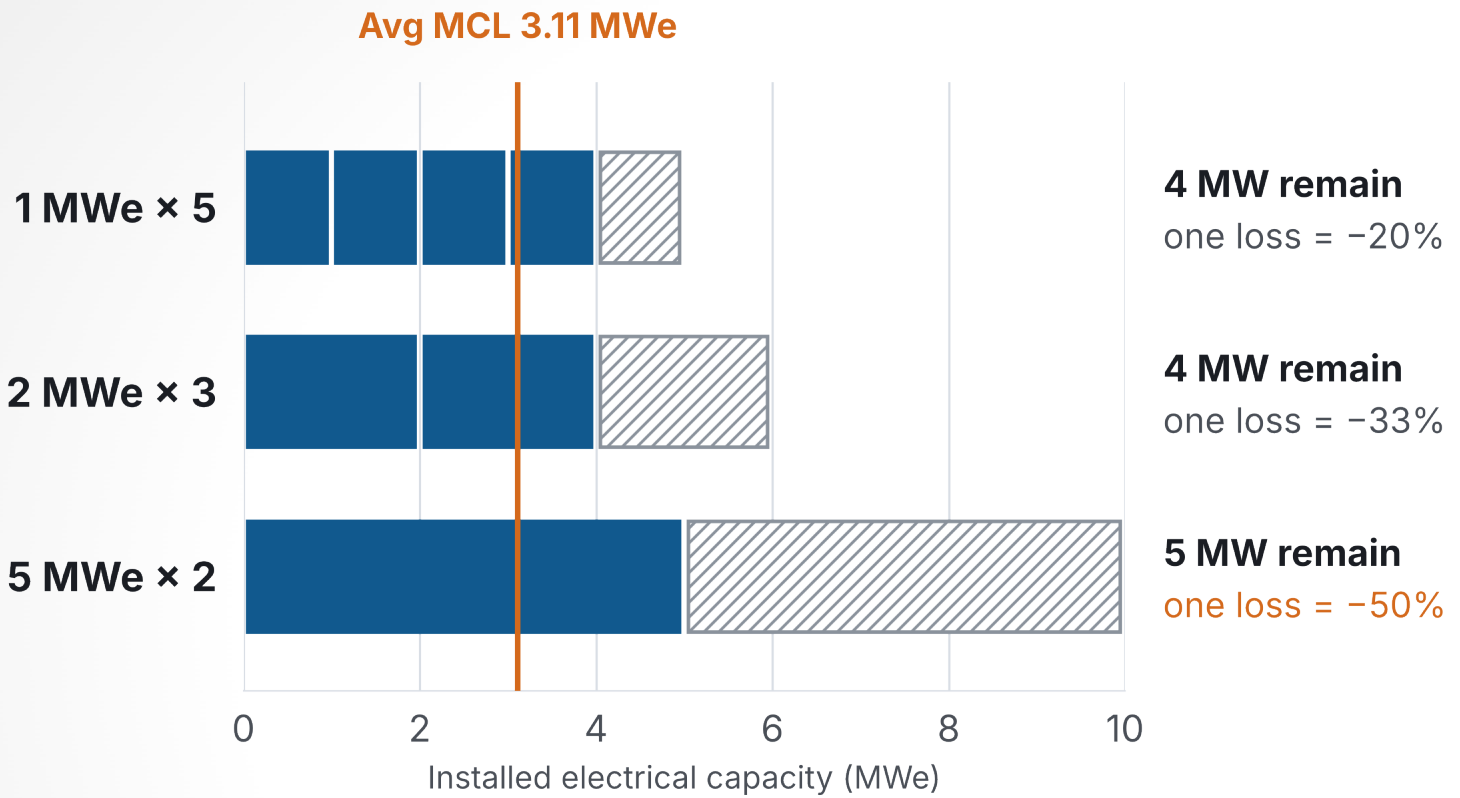
Source: Kim et al. (2026), prior study [1]; this study

Capacity after One Module Loss

QUANTITATIVE

$$(N - 1)\,P_{unit} \geq 3.11\ \text{MWe}$$

N: number of installed modules
Punit: electrical output per module



4 MW remain
one loss = −20%

4 MW remain
one loss = −33%

5 MW remain
one loss = −50%

4–5 MWe

exceeds the 3.11 MWe average MCL in this reference case

Continuous average MCL
should remain available after the loss of one generating module.

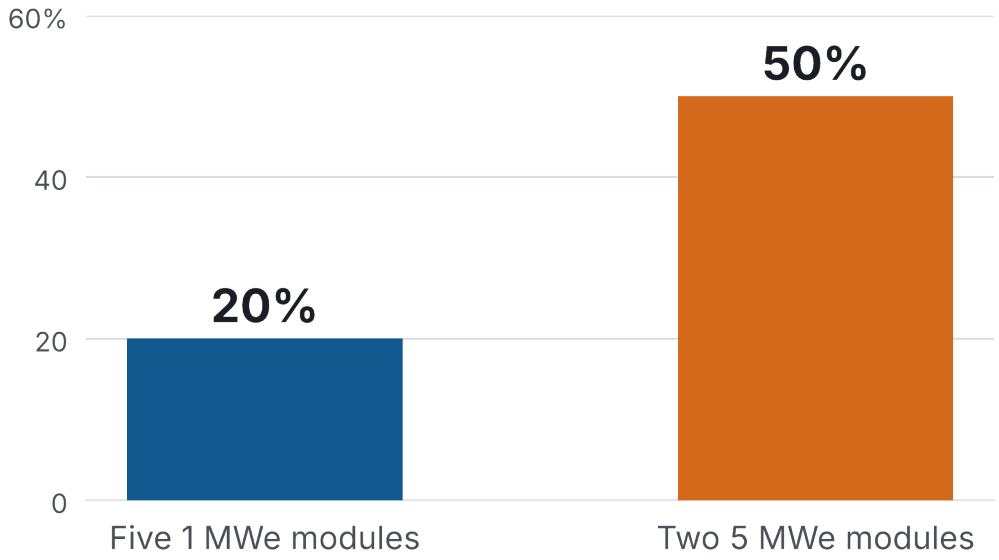
Grid compatibility for stable islanded operation and power sharing.

Average capacity check assumes independent modules and support systems.

Source: this study (Table III); Kim et al. (2026), prior study [1]

Module Size and Operating Burden

Share of installed output lost



4 MW remaining
5 MW installed

5 MW remaining
10 MW installed

More modules increase BOP interfaces, maintenance, and safeguards requirements.

Low manning operation

- Automated monitoring and diagnostics
- Centralized supervision, independent protection
- Physically separated essential support systems

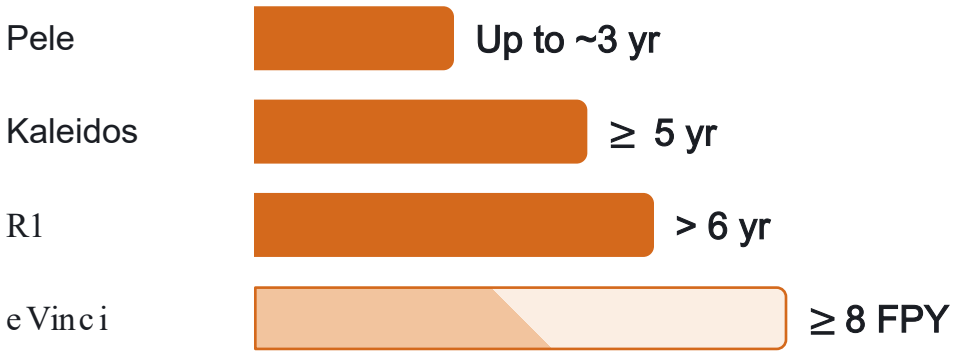
Low MWe modularization is advantageous only when multiple modules can be operated and maintained efficiently.

NuScale's 2023 certified design:
6 licensed control - room operators for up to 12 modules.

Source: this study; Kim et al. (2026), prior study [1]; U.S. NRC, NuScale design certification [28]

Fuel Endurance and Fuel Cycle Constraints

Reported time before refueling



Reported design targets, not equivalent operating results (eVinci in full power years).

Core lifetime depends on enrichment, fuel availability, neutronic design, and safeguards constraints.

FUEL AVAILABILITY AND FUEL CYCLE CONSTRAINTS

Available enrichment and assured fuel supply

Safeguards and physical protection

↓

CORE DESIGN

Fuel form and allowable burnup

Power density, reactivity, materials

↓

Multi year fuel endurance is required

Core lifetime under realistic fuel cycle constraints

Sources: [7, 17, 22, 26]; reported design targets, not equivalent operating results

Deployability, Heat Rejection, and Compactness

Transportable or relocatable

e.g., Pele, Kaleidos

- Minimum site infrastructure
- Compact transport packaging
- Ambient air heat rejection where suitable

set by the mission

Fixed installation

e.g., Eielson AFB

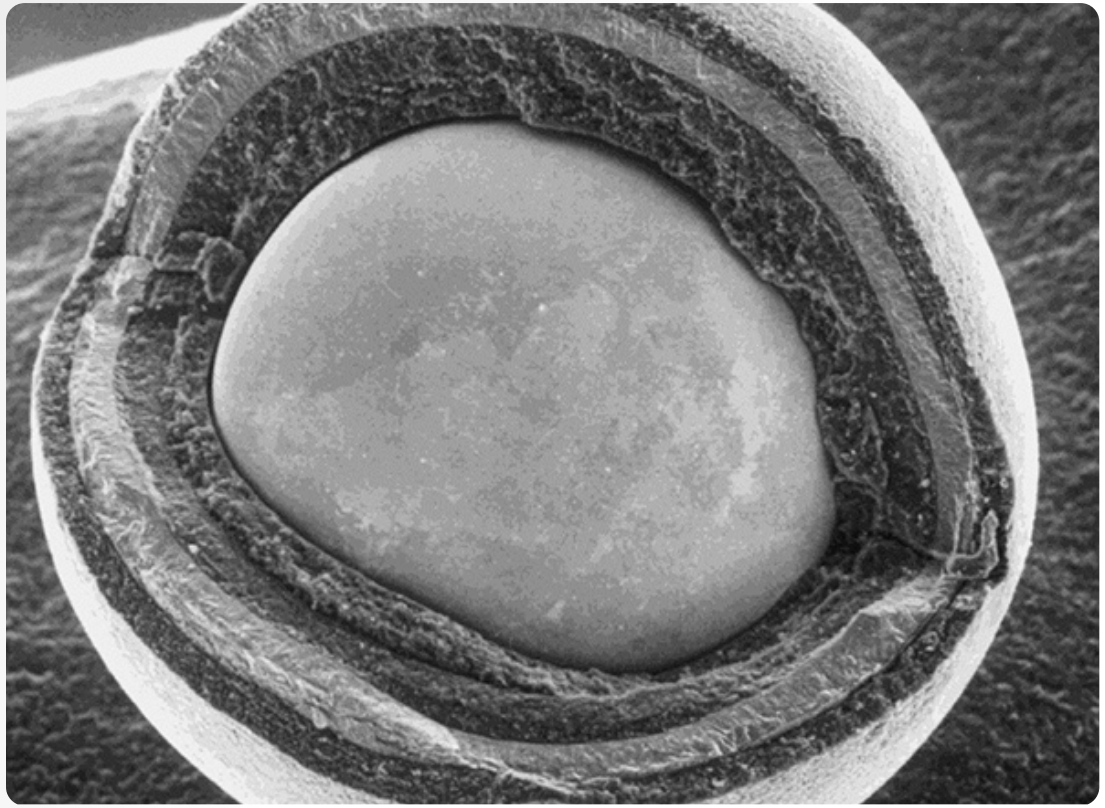
- Long term reliability and maintainability
- Air or water heat rejection
- Site conditions govern final configuration

Compactness should be evaluated for the complete power system.

Core + Shielding + Power conversion + Heat rejection + Auxiliaries

Source: this study; [7 –9, 16, 17, 23]

Safety, Security and Regulatory Roles



TRISO fuel: fission product retention

Barriers to unauthorized material access and fuel processing.

Safety under degraded external support

Maintain safety when external power, infrastructure, communications, or operator availability are degraded.

Safety, security, and safeguards

Low potential source term near command facilities.
Consider safety, security, and safeguards together.

Regulatory and operating roles

Military operator, reactor vendor, and civilian regulator

Sources: this study; INL / U.S. DOE TRISO micrograph; DOE QTR 2015 [29]; IAEA SMR Regulators' Forum [30]

Conclusions

- A previous study estimated a 2050 average MCL of **3.11 MWe** for a reference ROK Army division, assuming a **20% MCL share** .
- U.S. military microreactor programs pursue resilient power across diverse technologies, with **common operational priorities** .
- The ROK military needs **firm, long duration power** during grid outages, making microreactors a promising option.
- This study derives **four preliminary operational requirements** from U.S. priorities and the ROK MCL baseline, subject to **ROK operating and fuel constraints** .

Power Availability, Modularity and Low Manning

Maintain average MCL after one module loss with low manning operation.

Fuel Endurance and Fuel Cycle Constraints

Multi year operation under realistic fuel supply and fuel cycle constraints.

Deployability, Heat Rejection, and Compactness

Mission based deployment and heat rejection; whole system compactness.

Safety, Security, and Regulatory Framework

Safety under degraded external support, with safeguards and clear roles.

FUTURE WORK **Detailed military mission conditions should be defined before suitable reactor technologies are selected and evaluated.**

References

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Images: ROK Army / Defense Daily; Hyundai Rotem; Hanwha Systems; ADD; DAPA; BWXT; Oklo; Radiant; Westinghouse; Antares; INL / U.S. DOE.

Thank you

Q&A

Appendix

Demand Model and Planning Assumptions

$$E_{total}(y) = E_{base}(y) + E_{add}(y)$$

Baseline

$$E_{base}(y) = E_{2025} \times (1 + g)^{y - 2025}$$

E_{2025} = 2,335.07 GWh/yr; g = 3.82%/yr

Historical growth includes existing modernization.

Add-on load

$$E_{add}(y) = 10^{-6} \Sigma_i N_i(y)\, e_i(y)$$

$$e_i = \Sigma_s P_{i,s}\, h_{i,s} + \varepsilon_i\, n_i$$

N: units; P: kW; h: hours/year; ε: kWh/event; n: events/year

Input	Value / operational assumption	Evidence / assumption
Baseline	2,335.07 GWh (2025); annual growth 3.82%	KEPCO trend, 2007–2025
Surveillance / DEW	50% deployment by 2035; 100% by 2040	Deployment and duty-cycle assumptions
MUM-T / Warrior	40% by 2045; 100% by 2050 Standby load: 15% of active load	ReARMM-based operating scenario
Network + AI	8 / 20 / 60 / 250 kW per node; 24 h/day	TITAN / modular data-center proxies
Reference division	50 GWh/yr; Inje military facilities: ~54 GWh/yr	Adjusted planning proxy for 2025
MCL conversion	MCL share: 20%; peak/average multiplier: 1.8	Planning assumptions informed by NREL

Annual energy model (GWh/yr). Add-ons represent incremental future systems beyond the baseline.

Sources: Kim et al. (2026) [1], Tables 3 –7; KEPCO [5]; NREL [4], Table 2.

ESS Support During a Module Outage

Five 1 MWe modules, one module unavailable

Available reactor output	Peak mission-critical load	Required ESS discharge power
4.00 MW	**5.59 MW**	**1.59 MW**

Illustrative support duration with 20 MWh of usable ESS energy

20 MWh ÷ 1.59 MW ≈ 12.6 h

Ideal upper bound for a constant power deficit

Full initial charge and 20 MWh fully usable. Diesel and PV contributions excluded.

Losses, reserve SOC, and aging excluded. Verify against time-series mission loads.

Check ESS discharge power, usable energy, and state of charge before sizing the system.

Sources: prior study [1]; this study, Table III. Illustrative ESS calculation.