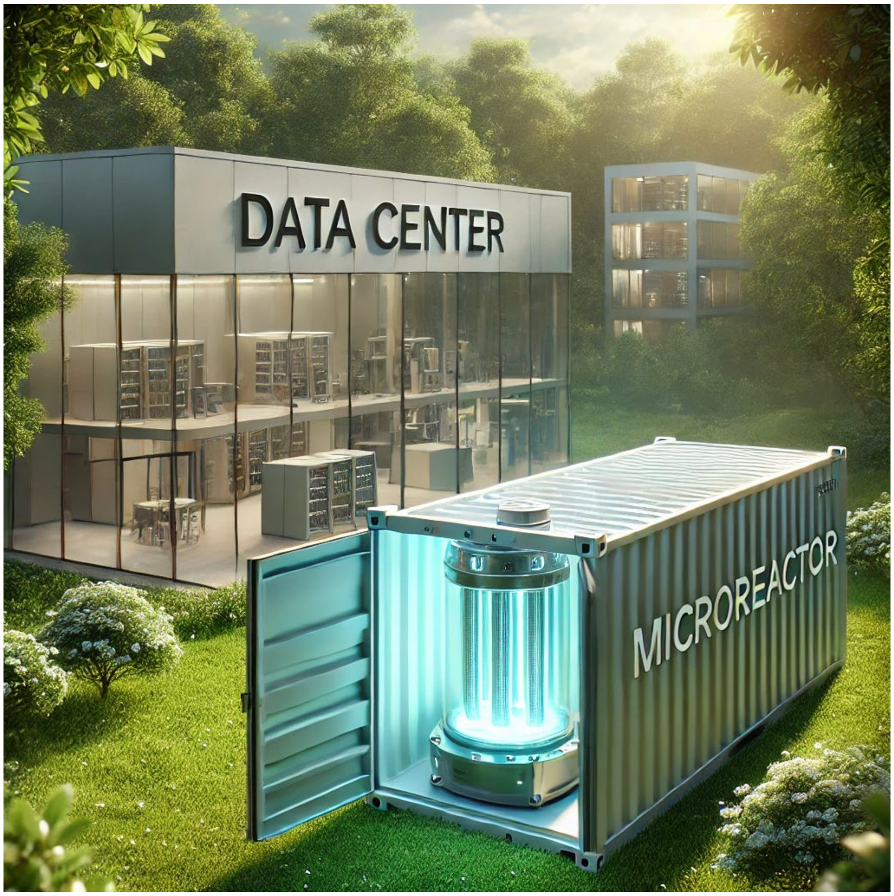
Microreactors for Data Centres: The Next Generation of Standby Power



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Contents

Abstract:

As global industries face escalating energy demands and increasingly stringent sustainability requirements, nuclear microreactors emerge as a groundbreaking solution for standby power. Designed for efficiency, safety, and adaptability, these compact reactors—also known as nuclear batteries—offer unmatched advantages in energy density, dispatchability, and emissions reduction. Microreactors produce 1–20 MW of power and eliminate the need for extensive storage or transmission infrastructure, making them ideal for data centers, industrial facilities, and remote operations.

Leveraging advanced safety mechanisms, passive cooling systems, and TRISO fuel technology, microreactors prioritize operational reliability and environmental sustainability. They require minimal land use, generate near-zero emissions, and are capable of mobile deployment, setting them apart from conventional power sources. This paper explores the technological innovations, market potential, and cost dynamics of microreactors, alongside real-world applications and their competitive edge in the drive for net-zero emissions.

By addressing challenges in decarbonization, grid reliability, and heat generation, microreactors position themselves as a transformative energy source, aligning with the future of resilient and sustainable power solutions.

Introduction:

Micro-reactors can provide electricity and heat to various applications, including factories, datacentres, seaports, and EV charging stations, without the need for extensive energy storage and transmission infrastructure typical of traditional energy systems.

The potential for cyber threats is minimized. The nuclear battery (NB) is a compact, transportable energy solution that combines a micro-reactor and turbine to generate heat and electricity with a power output of 1 to 20 MW. Designed for easy installation and operation, it can function for years without fuel resupply and is replaced when exhausted, eliminating the need for on-site high-level radioactive waste management. The concept builds on historical designs and leverages modern technologies, with aggressive timelines for testing and deployment, including projects for the Department of Defense and NASA. The NB features advanced safety mechanisms, ensuring rapid shutdown, adequate cooling, and containment of materials, significantly reducing accident risks. Security measures include robust design and remote monitoring, addressing both physical and cyber threats.

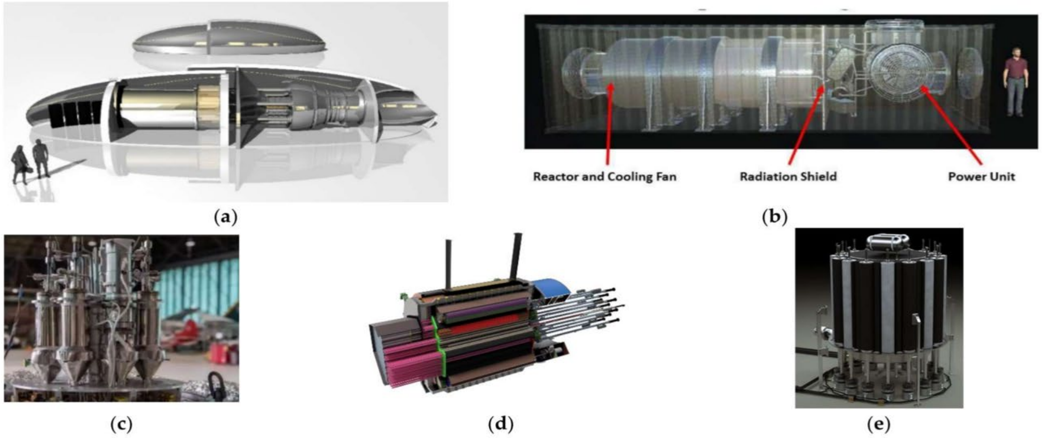


Figure 1 (a) MIT’s conceptualization of a nuclear battery (NB) with integrated gas turbine; (b) LANL’s Mega power; (c) NASA and LANL’s KRUSTY/Kilo power reactor using Stirling engine technology for space applications; (d) Westinghouse’s eVinci heat pipe micro-reactor;(e) Radiant Nuclear’ s high-temperature gas-cooled micro-reactor. [3]

Nuclear batteries (NBs) present a competitive energy source across various markets due to five key features: high energy density for heat and electricity, dispatchability (ability to supply energy on demand), zero emissions (including carbon and local pollutants), siting flexibility with minimal geographic constraints, and suitability for mobile deployment. These attributes position NBs as direct competitors to fossil fuel technologies, offering advantages in emissions and site requirements. In terms of material requirements, ten NBs generating 100 MW would need significantly less steel and concrete compared to wind and solar farms, while also having a higher capacity factor (0.9) compared to wind (0.35) and solar (0.2). NBs do not require additional energy storage systems, can be installed close to users, and thus avoid transmission costs, making them versatile for various applications.

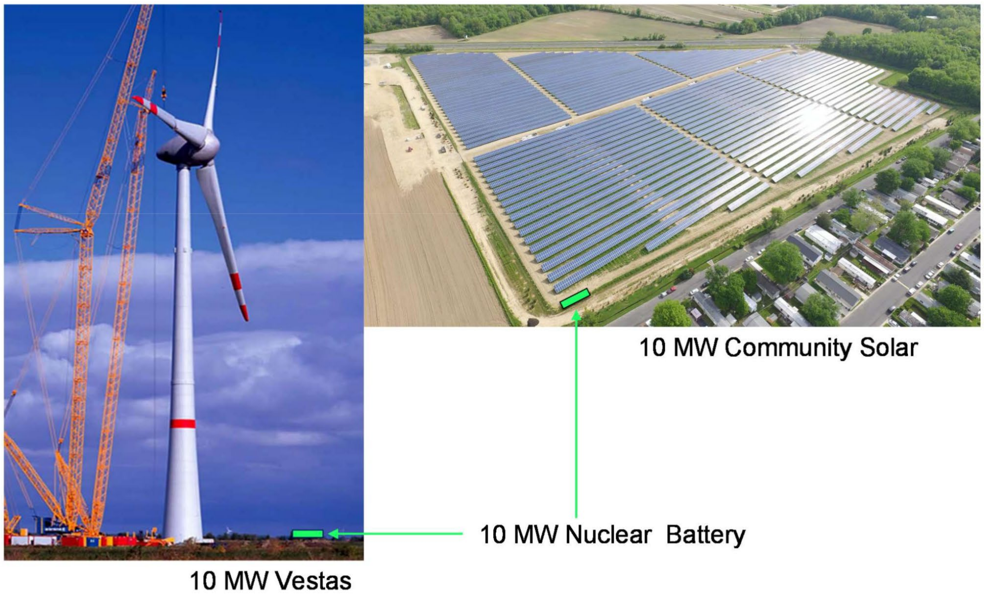


Figure 2: [3] size comparison of a 10MW NB (green rectangle) VS 10 MW of wind Vestas 164) and 10 MW of solar (NJ Altus solar farm)

Figure 3: [3] Examples of functional layout for (left) industrial and (right) urban NB installations.

A single 10 MW NB can power some 7,000–8,000 homes, a large shopping mall, a mid-size data center, or produce enough desalinated fresh water for over 150,000 people.

Prospective Markets for Nuclear Batteries:

Nuclear batteries may offer a competitive source of energy for a number of diverse markets. Before turning to those markets, it is useful to focus first on the distinctive features of NBs and how that positions them against alternatives.

Five distinct features determine where NBs are most likely to penetrate the market:

1-The first is energy density, for both heat and electricity.

2-The second is dispatchability, i.e., the ability to supply energy on demand.

3-The third is zero emissions, including both carbon and local air pollutants such as particulates, NO_x and SO_x.

4-The fourth is siting flexibility with minimal geographic constraints.

5- The fifth is suitability for mobile deployment, which might be important in certain applications, for example ship propulsion.

The first two features make NBs a direct competitor to fossil fuel-fired technologies, while the third and fourth give it a competitive advantage over them. Although NBs and fossil fuel-fired technologies are all dispatchable, the capital intensity of NBs means that their competitive advantage will be largest in serving baseloads, and smallest where the average capacity factor is low.

NBs will be competitive against renewables wherever the demand for heat, for energy density, for dispatchability and for siting without geographic constraints are significant. Table 1 summarizes the comparison of NBs with potential alternatives.

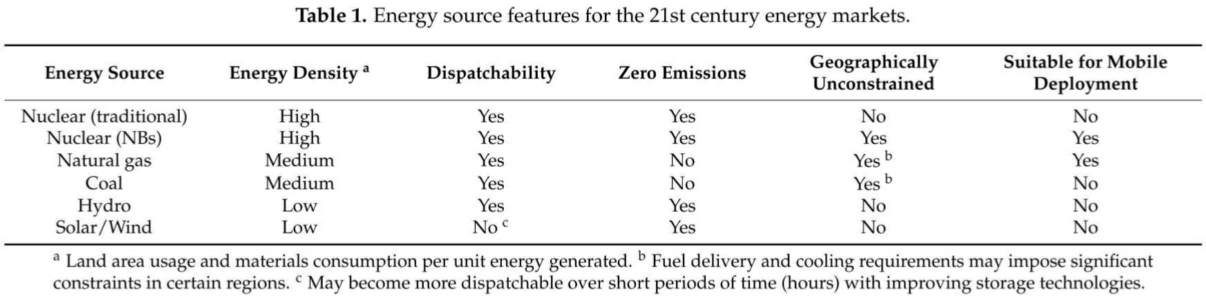


Table 1. Energy source features for the 21st century energy markets.

Energy Source	Energy Density [a]	Dispatchability	Zero Emissions	Geographically Unconstrained	Suitable for Mobile Deployment
Nuclear (traditional)	High	Yes	Yes	No	No
Nuclear (NBs)	High	Yes	Yes	Yes	Yes
Natural gas	Medium	Yes	No	Yes [b]	Yes
Coal	Medium	Yes	No	Yes [b]	No
Hydro	Low	Yes	Yes	No	No
Solar/Wind	Low	No [c]	Yes	No	No

[a] Land area usage and materials consumption per unit energy generated. [b] Fuel delivery and cooling requirements may impose significant constraints in certain regions. [c] May become more dispatchable over short periods of time (hours) with improving storage technologies.

In Off Grid Applications

Off-grid electricity markets present a significant opportunity for new battery (NB) customers, as these markets often rely on costly fossil fuels like diesel, which increases overall costs. To compete effectively, NBs must demonstrate reliability, especially in remote areas where servicing is challenging. Off-grid markets tend to Favor familiar technologies, such as diesel generators, and may invest in redundant systems. NBs also have potential in microgrids, which prioritize high reliability and resiliency. Currently, over 85% of microgrid capacity is fossil-based, but NBs offer a carbon-free, reliable alternative that can adapt to energy demand. As the electricity grid becomes more fragile and the need for decarbonization grows, the demand for NBs in microgrids is expected to increase.

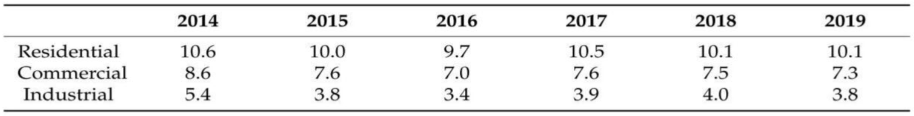
From Heat Generation Perspective:

Heat markets, traditionally reliant on fossil fuels for industrial and residential heating, are facing pressure to reduce carbon emissions, leading to a decline in new combined heat and power (CHP) capacity in the U.S. and Europe. Natural gas (NG) has dominated the market, but the need for zero-emissions solutions is prompting interest in alternatives like new technologies (NBs), NG with carbon capture and sequestration (CCS), and green hydrogen. NBs can meet essential requirements such as energy density, dispatchability, and proximity to users, making them a promising option for heat production. By co-locating energy generation with demand, NBs can enhance efficiency and reduce the need for extensive energy transmission infrastructure. The future envisions NBs being integrated into urban and industrial settings, forming a cleaner and more efficient backbone for producing goods, foods, and fuels.

Target price for NB based on different perspective:

1- The competitiveness of new technologies (NBs) varies significantly across different markets and customer segments, primarily influenced by their costs. As NB costs decrease, their market potential expands, especially if natural gas (NG) prices rise or carbon abatement regulations are implemented. The analysis focuses on three benchmarks, particularly the cost of NG for direct heat production, which is primarily provided by NG-fired boilers in the U.S. These boilers are often too small for carbon capture and sequestration (CCS), leading to substantial emissions and potential carbon taxes. CCS costs can reach up to 100 USD/tCO2, excluding transport and storage. The competitive cost target for heat from NBs is suggested to be in the range of 20–50

USD/MWh (6–15 USD/MMBTU), based on the relationship between NG prices and carbon tax values.



	2014	2015	2016	2017	2018	2019
Residential	10.6	10.0	9.7	10.5	10.1	10.1
Commercial	8.6	7.6	7.0	7.6	7.5	7.3
Industrial	5.4	3.8	3.4	3.9	4.0	3.8

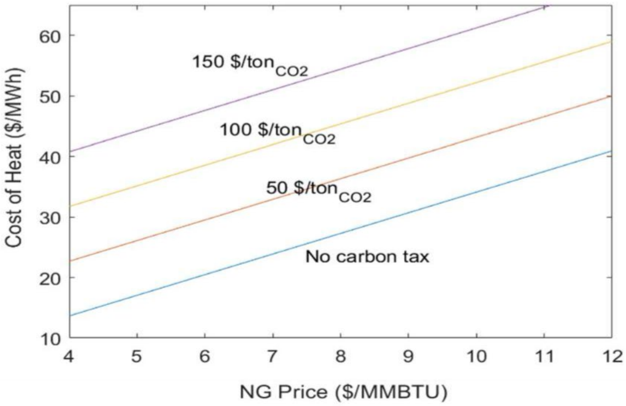


Figure 4. the cost of heat from NG as a function of NG price and carbon tax. The cost of the boiler is not included based on reference [3]

2-The analysis focuses [3] on the levelized costs of electricity (LCOE) for natural gas combined-cycle generators (NGCC) and NG-fired distributed generation, incorporating a carbon cost. Using the EIA's 2021 Annual Energy Outlook assumptions, the LCOE is calculated based on natural gas prices and carbon taxes. The modelling indicates significant installation of dispatchable generators, which help avoid transmission investments. At a natural gas price of 4 USD/MMBTU and a carbon price of 100 USD/tonCO2, the LCOE for NGCC is approximately 70 USD/MWh, while for NG-fired distributed generation, it is about 115 USD/MWh. Thus, a reasonable cost target range for electricity generation by new builds (NBs) is identified as 70–115 USD/MWh.

3-The cost of generating hydrogen is evaluated through two low-carbon production methods: steam methane reforming with carbon capture and storage (CCS) and renewable power with electrolysis. Methane reforming with CCS, assuming over

95% capture efficiency and a carbon tax of 100 USD/tCO2, can produce hydrogen at about 1 USD/kg, potentially rising to 3 USD/kg if capture efficiency needs to exceed 98%. The renewable electrolysis method is less certain due to challenges in scaling and the costs associated with energy storage, with current estimates placing hydrogen production costs at 4–5 USD/kg, assuming a levelized electricity cost of 50 USD/MWh. For high-temperature electrolysis powered by nuclear batteries to be competitive, costs would need to fall within the 3–4 USD/kg range.

Evaluate Of Cost Of Electricity And Heat Generate From Nb:

The analysis evaluates the costs associated with nuclear batteries (NB) that are shipped with a fuelled core and operated continuously for several years before returning to a central facility for refuelling and servicing. The model assumes no on-site refuelling, but allows for short maintenance outages, which impact the capacity factor. The levelized costs of electricity (LCOE) and heat (LCOH) are calculated by summing the annualized capital, fuel, and operational and maintenance (O&M) costs, then dividing by the total electricity or heat generated in a year.[3]

$$\mathrm{LCOE} = \frac{\text{Annualized Fuel} + \text{O\&M} + \text{Capital Costs}}{\text{Electric power} \times \text{capacity factor} \times 8760} \quad [\mathrm{USD/MWh}]$$

$$\mathrm{LCOH} = \frac{\text{Annualized Fuel} + \text{O\&M} + \text{Capital Costs}}{\text{Thermal power} \times \text{capacity factor} \times 8760} \quad [\mathrm{USD/MWh_t}]$$

Breaks down the fuel costs associated with operating a nuclear reactor by examining several critical factors:

1. Fixed Reactor Parameters:
    - Core Power: The reactor's total output capacity
    - Discharge Burnup: A measure of how much energy is extracted from the nuclear fuel before it's replaced.
    - Refuelling Interval: The time between each refuelling operation.
    - Capacity Factor: A ratio reflecting how consistently the reactor operates at full capacity over a given period.
2. Fuel Mass and Uranium Requirements:
    - Based on the reactor's energy needs, the analysis calculates the mass of fuel required to sustain operations until the next refuelling.
    - It determines how much natural uranium is necessary to produce this fuel, considering enrichment (the process of increasing the proportion of fissile uranium-235). Here, the fuel is enriched to 5% uranium-235, with a tailing assay (residual uranium-235 in waste) of 0.22%.
3. Enrichment Process and SWU:
    - Enrichment demands separative work units (SWU), a measure of the effort needed to increase uranium-235 concentration. The SWU cost is a significant part of the fuel cycle cost.
4. Fuel Type and Fabrication Costs: The analysis assumes the reactor uses uranium dioxide (UO_2) fuel, which is more expensive to fabricate than fuel for

a light water reactor (LWR). This higher cost reflects differences in design and handling for the specific reactor type, called a nuclear boiler (NB).

5. Total Fuel Cycle Costs:

    - The total costs include natural uranium acquisition, conversion (to prepare for enrichment), enrichment itself, and fuel fabrication.

    - These costs are then levelized (spread evenly) over the refuelling period using a capital recovery factor. This factor ensures the inclusion of carrying charges, which are interest costs or financial charges associated with the investment in fuel.

6. Spent Fuel Disposal: The cost of disposing of spent (used) fuel is estimated at 1 USD per MWh of generated electricity, aligning with U.S. industry practices for nuclear waste management.

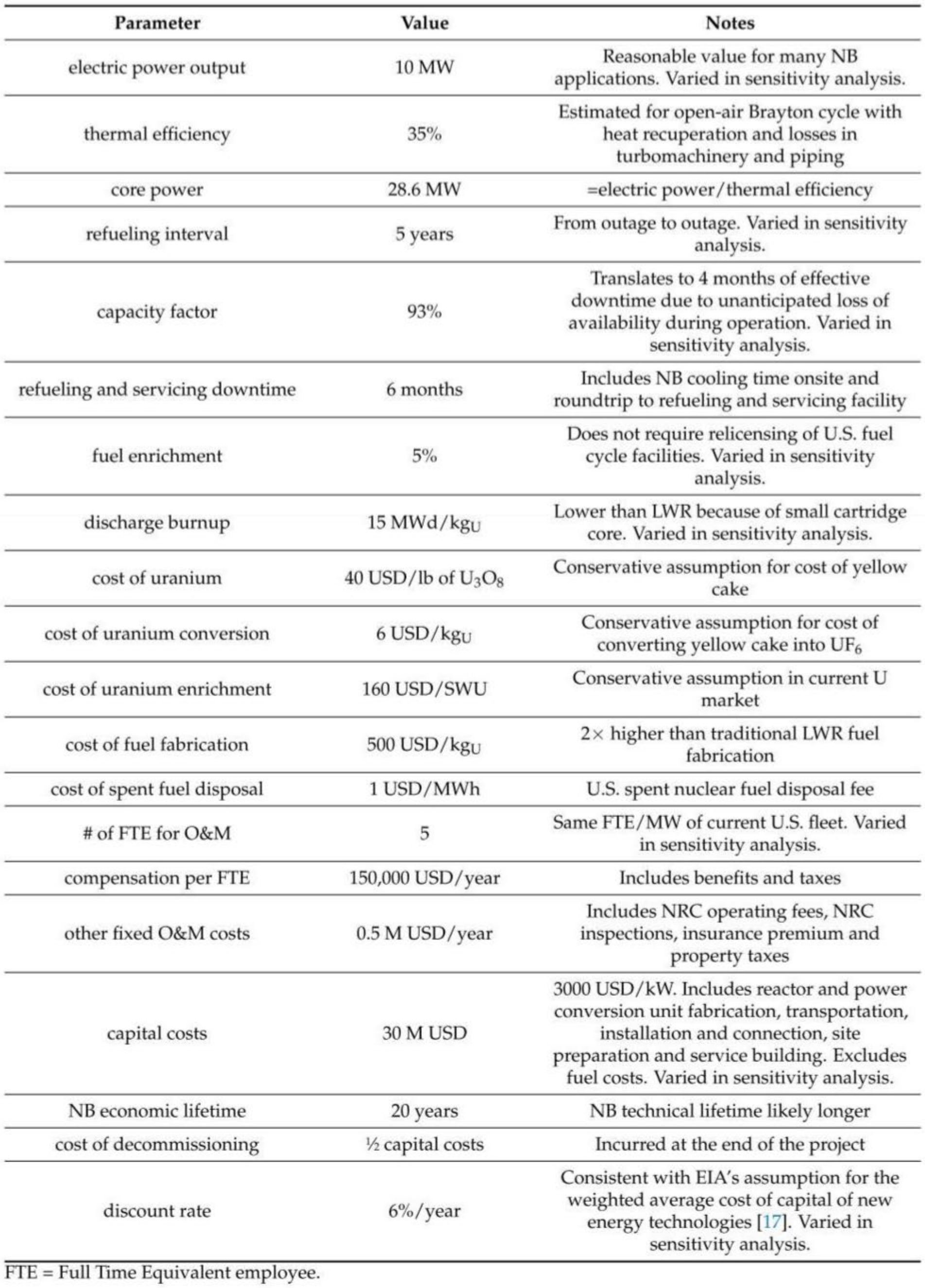
The O&M costs for the NB design, which utilizes dry cooling, are expected to be low due to its simplicity, primarily involving labor charges for staff to operate, inspect, service, and secure the site. The necessity of onsite operators is uncertain, with the possibility of remote-control operations being feasible. Security requirements are also unclear, whether relying on physical protection and remote surveillance or needing onsite armed guards.

The base case assumes a staff of 5 FTEs, costing 150 kUSD/year each, equating to one person on site 24/7. Additional fixed costs include NRC fees, inspections, insurance premiums, and property taxes, estimated conservatively at about 0.5 M USD/year, drawing parallels to the MIT research reactor.

Installation on the site: The NB site will require minimal preparation due to its design features, such as dry cooling and seismic robustness, allowing it to fit various locations without modification. The construction involves excavating a rectangular hole for a prefabricated steel/concrete vault to house the nuclear reactor. Above ground, there will be a small flat area for the power conversion unit, permanent equipment, and a prefabricated service building for security, staffing, and maintenance storage. A dedicated fence may be necessary depending on the site's characteristics.

To able to get idea about the price based on the research [3]:

There was some assumption had been taken in the report it is good to mention it:



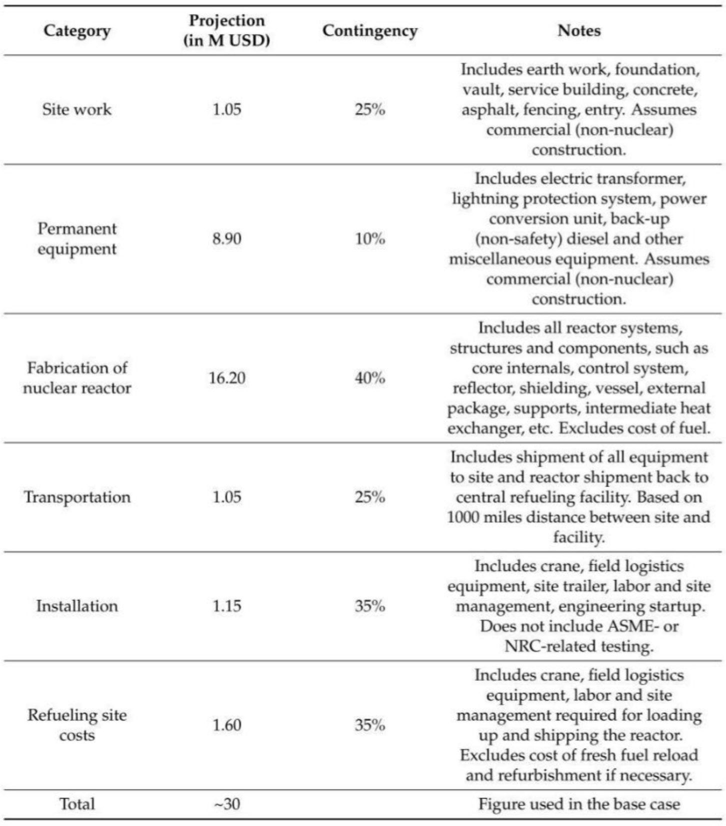
Parameter	Value	Notes
electric power output	10 MW	Reasonable value for many NB applications. Varied in sensitivity analysis.
thermal efficiency	35%	Estimated for open-air Brayton cycle with heat recuperation and losses in turbomachinery and piping
core power	28.6 MW	=electric power/thermal efficiency
refueling interval	5 years	From outage to outage. Varied in sensitivity analysis.
capacity factor	93%	Translates to 4 months of effective downtime due to unanticipated loss of availability during operation. Varied in sensitivity analysis.
refueling and servicing downtime	6 months	Includes NB cooling time onsite and roundtrip to refueling and servicing facility
fuel enrichment	5%	Does not require relicensing of U.S. fuel cycle facilities. Varied in sensitivity analysis.
discharge burnup	15 MWd/kg_U	Lower than LWR because of small cartridge core. Varied in sensitivity analysis.
cost of uranium	40 USD/lb of U_3O_8	Conservative assumption for cost of yellow cake
cost of uranium conversion	6 USD/kg_U	Conservative assumption for cost of converting yellow cake into UF_6
cost of uranium enrichment	160 USD/SWU	Conservative assumption in current U market
cost of fuel fabrication	500 USD/kg_U	2× higher than traditional LWR fuel fabrication
cost of spent fuel disposal	1 USD/MWh	U.S. spent nuclear fuel disposal fee
# of FTE for O&M	5	Same FTE/MW of current U.S. fleet. Varied in sensitivity analysis.
compensation per FTE	150,000 USD/year	Includes benefits and taxes
other fixed O&M costs	0.5 M USD/year	Includes NRC operating fees, NRC inspections, insurance premium and property taxes
capital costs	30 M USD	3000 USD/kW. Includes reactor and power conversion unit fabrication, transportation, installation and connection, site preparation and service building. Excludes fuel costs. Varied in sensitivity analysis.
NB economic lifetime	20 years	NB technical lifetime likely longer
cost of decommissioning	½ capital costs	Incurred at the end of the project
discount rate	6%/year	Consistent with EIA's assumption for the weighted average cost of capital of new energy technologies [17]. Varied in sensitivity analysis.

FTE = Full Time Equivalent employee.

Based on the research assumption: Capital costs for a nuclear reactor include both one-time expenses (e.g., fabrication, site preparation) and recurring costs (e.g., transportation). For simplicity, these costs are consolidated into a single initial cost of 30 million USD per nuclear block (NB), which is then amortized over a 20-year lifespan using a capital recovery factor.

The levelized cost of electricity (LCOE) and levelized cost of heat (LCOH) for the baseline assumptions are calculated at 85 USD/MWh and 30 USD/MWh (or 8.7 USD/MMBTU), respectively.

These figures are promising as they fall within acceptable cost ranges, but significant uncertainties in the assumptions necessitate a sensitivity analysis. Decommissioning costs are estimated to be half of the initial capital cost and are accounted for at the end of the NB's life using a sinking fund factor.



Category	Projection (in M USD)	Contingency	Notes
Site work	1.05	25%	Includes earth work, foundation, vault, service building, concrete, asphalt, fencing, entry. Assumes commercial (non-nuclear) construction.
Permanent equipment	8.90	10%	Includes electric transformer, lightning protection system, power conversion unit, back-up (non-safety) diesel and other miscellaneous equipment. Assumes commercial (non-nuclear) construction.
Fabrication of nuclear reactor	16.20	40%	Includes all reactor systems, structures and components, such as core internals, control system, reflector, shielding, vessel, external package, supports, intermediate heat exchanger, etc. Excludes cost of fuel.
Transportation	1.05	25%	Includes shipment of all equipment to site and reactor shipment back to central refueling facility. Based on 1000 miles distance between site and facility.
Installation	1.15	35%	Includes crane, field logistics equipment, site trailer, labor and site management, engineering startup. Does not include ASME- or NRC-related testing.
Refueling site costs	1.60	35%	Includes crane, field logistics equipment, labor and site management required for loading up and shipping the reactor. Excludes cost of fresh fuel reload and refurbishment if necessary.
Total	~30		Figure used in the base case

Microreactors vendors:

Nuclear Microreactor vendors (Westinghouse, X-Energy, UltraSafe Nuclear Company, Radiant)

Characterization of Nuclear Microreactor Technology:

Most Nuclear Microreactors being designed today fall under HTGRs, SFRs, LFRs (lead-cooled fast reactor), MSRs (molten salt reactor), microreactors.

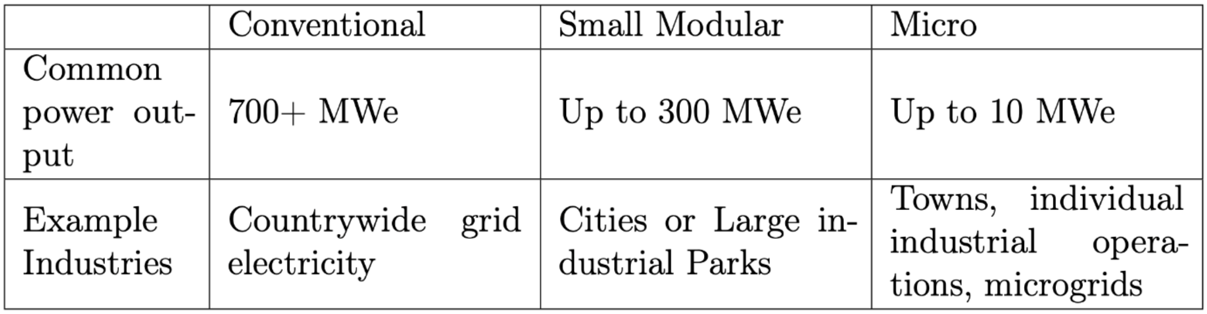
It is important to note that this type of microreactor has important characteristic is that of "passive safety systems." These mechanisms work in such a way that if the reactor is subject to an incident, the systems will not depend on external operator intervention or energized systems to be able to maintain the reactor under control or shut it down.

Are Nuclear Microreactors Safe? (Internal Safety Features)

- **Advanced Passive Safety Systems**: The reactors are designed with passive safety systems and contain fewer pressurized components and moving parts, enhancing reliability compared to earlier generations.
- **Enhanced Fuel Safety**: The use of TRISO (tri-structural isotropic) particle fuel pellets prevents fission product diffusion up to extremely high temperatures (1600-1800°C), significantly reducing potential radiological releases even in hypothetical accident scenarios.
- **Radiation Shielding and Lower Radiation Levels**: These reactors are encased in radiation-shielding materials, and the core contains a minimal amount of fissile material. This design results in low external radiation, allowing personnel to safely work near the reactor's exterior.

- **Inherent Safety Features**: Features like a non-boiling coolant, high thermal capacity to prevent rapid temperature increases, and passive cooling systems further reinforce the safety of nuclear microreactor technology.

The second category discussed was that of size. Small modular reactors (SMRs) and Nuclear Microreactors are often lumped together because of common factors such as modularity, reactor generation, and fuel. However, the distinction of size is relevant because it directly translates into industrial applicability. Small modular reactors can serve larger loads than Microreactors but also need more space and often a complete facility given that they will generally be fueled on-site.



	Conventional	Small Modular	Micro
Common power output	700+ MWe	Up to 300 MWe	Up to 10 MWe
Example Industries	Countrywide grid electricity	Cities or Large industrial Parks	Towns, individual industrial operations, microgrids

What are the key distinctions among different microreactor suppliers in terms of technology, efficiency, and applications?

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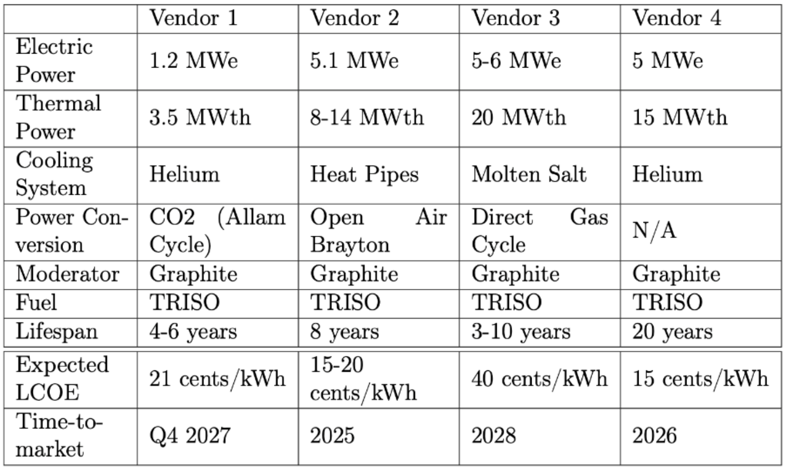

	Vendor 1	Vendor 2	Vendor 3	Vendor 4
Electric Power	1.2 MWe	5.1 MWe	5-6 MWe	5 MWe
Thermal Power	3.5 MWth	8-14 MWth	20 MWth	15 MWth
Cooling System	Helium	Heat Pipes	Molten Salt	Helium
Power Conversion	CO2 (Allam Cycle)	Open Air Brayton	Direct Gas Cycle	N/A
Moderator	Graphite	Graphite	Graphite	Graphite
Fuel	TRISO	TRISO	TRISO	TRISO
Lifespan	4-6 years	8 years	3-10 years	20 years
Expected LCOE	21 cents/kWh	15-20 cents/kWh	40 cents/kWh	15 cents/kWh
Time-to-market	Q4 2027	2025	2028	2026

Are Nuclear Microreactors Sustainable? (Environmental Impact)

- **Low Greenhouse Gas Emissions**: Nuclear fission generates no direct carbon emissions during operation, contributing to a low overall carbon footprint. Emissions are limited to indirect sources (Scopes 2 and 3), such as embedded carbon in the supply chain and grid electricity, which are minimal as the industry continues reducing its carbon footprint.
- **High Energy Density and Small Footprint**: Nuclear fission's high energy density requires minimal land use, leading to reduced deforestation, lower material needs, and minimized environmental impact compared to many renewable energy sources.
- **High Capacity Factor**: Nuclear reactors operate at high capacity factors, often over 90%, ensuring continuous energy production and maximizing the return on investment with minimal downtime—unlike some variable renewable sources.
- **Reduced Infrastructure Needs**: When co-located with energy demand centers, nuclear microreactors require minimal additional infrastructure, reducing the embedded carbon and transportation emissions associated with construction. As a comparison, nuclear energy's median land footprint is just 0.3 m^2/MWh, whereas natural gas is 1 m^2/MWh and solar PV fields require around 22 m^2/MWh.
- **Manageable Waste Generation**: Nuclear waste from microreactors is minimal, with only about 0.002 kg/kWh produced. When managed properly, this waste occupies little space relative to the energy generated, although waste management remains a topic of political and public scrutiny.

The Evolving Landscape of Nuclear Microreactors

- The nuclear microreactor market is an emerging and competitive landscape, with various vendors developing distinct designs suited to different applications. Predicting which design will ultimately dominate is challenging, as each configuration may be better suited to particular use cases, and this industry is still in the early stages of R&D and design. Early adopters of successful microreactor technologies will likely gain competitive advantages, benefiting from increased access to grants, subsidies, and investments as both public and private sectors focus on nuclear energy as a pathway to reduce global emissions.

- A critical factor in advancing microreactor deployment is the TRISO fuel supply chain. TRISO fuel, though highly efficient and safe, is not yet produced on a large scale, and few licensing patents exist. This limited availability poses a potential bottleneck, particularly as demand for nuclear microreactors grows. To secure the needed fuel supply, industry stakeholders must carefully manage TRISO production and accessibility, similar to the challenges associated with graphite.

Current Orders in The Market:

The U.S. Department of Defense's Strategic Capabilities Office (SCO) has initiated Project Pele to develop a transportable nuclear microreactor delivering 1–5 megawatts of electrical power for at least three years. In June 2022, BWXT Advanced Technologies was awarded the contract to build this Generation IV reactor, with initial plans for delivery to Idaho National Laboratory (INL) in 2024. However, as of September 2024, the timeline has been adjusted: assembly is set to begin in February 2025, with transport to INL scheduled for 2026.

This reactor, utilizing High-Assay Low Enriched Uranium (HALEU) TRISO fuel, aims to enhance energy resilience for defines operations and serve as a model for future commercial applications.

BWX Technologies (BWXT) is actively engaged in developing microreactors to enhance energy resilience and support grid stability in the United States. Notably, BWXT has entered into a two-phase contract with the Wyoming Energy Authority to assess the feasibility of deploying small-scale nuclear reactors within the state. The first phase involved defining requirements for nuclear applications and evaluating Wyoming's supply chain capabilities for reactor component manufacturing. In June 2024, BWXT commenced the second phase, focusing on completing a conceptual design of a lead microreactor unit and demonstrating the state's ability to manufacture nuclear components.

Additionally, BWXT has signed an agreement with Burns & McDonnell to further the design and development of microreactors capable of providing thermal and electric power. This collaboration aims to advance the BWXT Advanced Nuclear Reactor (BANR), a passively safe design intended to supply economical, secure, carbon-free heat and electricity. The BANR microreactor is envisioned to support industrial users, including mining operations, and contribute to Wyoming's energy portfolio.

These initiatives underscore BWXT's commitment to advancing microreactor technology and exploring its integration into the U.S. energy grid, particularly in Wyoming.

Conclusion:

In the rapidly evolving landscape of energy systems, nuclear microreactors (NMs) represent a pivotal innovation, especially for applications requiring reliable, sustainable, and efficient power solutions. With their unmatched energy density, minimal emissions, and flexibility in deployment, NMs are poised to revolutionize the way power is delivered to critical sectors such as data centers, industrial facilities, and remote operations. By addressing the challenges of decarbonization, energy security, and infrastructure limitations, nuclear microreactors stand out as a viable alternative to traditional fossil fuel-based and renewable energy systems.

While the technology's cost dynamics, regulatory hurdles, and TRISO fuel production limitations remain areas of concern, the ongoing advancements in safety mechanisms and modular designs highlight the potential for widespread adoption. The competitive advantages offered by NMs, such as high capacity factors, reduced land requirements, and dispatchability, position them as a transformative force in achieving global sustainability goals.

As stakeholders—from governments to private enterprises—invest in the development and integration of microreactor technologies, the opportunity to redefine standby power and support net-zero emission targets becomes increasingly tangible. Nuclear microreactors, thus, serve not only as an innovative energy solution but also as a cornerstone for resilient, sustainable, and forward-thinking energy systems.

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Mahmud Elashaal serves as the Global Upstream Marketing Strategy Manager for Data Centres at Cummins Inc., bringing over 20 years of expertise in renewable energy solutions. A dedicated researcher in data centre sustainability and demand challenges, Mahmud combines a strong academic foundation with extensive professional experience.

He holds a Master of Applied Business Research from the Swiss Business School, an MBA in Technology Management from Torrens University Australia, and a master's in electrical engineering from AASTMT. Additionally, Mahmud is a certified Lean Six Sigma Green Belt and an Accredited Tier Designer from the Uptime Institute, reflecting his commitment to driving efficiency and innovation in the data centre industry.