Microreactor Economic Performance & Market Analysis

Microreactor Program Stakeholders Workshop

May 12-13, 2021

David Shropshire | INL

Idaho National Laboratory | Oak Ridge National Laboratory | MRP Microreactor Program | Los Alamos National Laboratory | Argonne National Laboratory

Microreactor Market Opportunities

- Scope Overview:
  - This work supports understanding the market and economic potential for microreactors in the U.S. and internationally.
  - Provides a techno-economic basis for support to industrial microreactor deployment and operation.
  - Uncover emerging market opportunities.
  - Helps to inform R&D opportunities.
  - Integrates research performed by the INL [Boise State/Energy Policy Institute], and the U Alaska Anchorage, U Wisconsin-Madison, and Nuclear Alternatives Project in Puerto Rico.

MRP Microreactor Program

What we're doing | Studies Completed

- Puerto Rico
  - Preliminary Feasibility Study for Small Modular Reactors and Microreactors (Nuclear Alternatives Project).
- Microreactors in Alaska
  - Use Case Analysis and Customer Discovery and Perception for hypothetical small rural communities, rural hubs, railbelt producers, remote mines, and defense installations. (University of Alaska Anchorage)
- Federal Facilities
  - Analysis of the Case for Federal Support of Micro-Scale Nuclear Reactors to Provide Secure Power at U.S. Government Installations (University of Wisconsin-Madison)
- Journal Paper – (draft)
  - "Prospects for Nuclear Microreactors: A Review of the Technology, Decision Analysis and Regulatory Considerations" (BSU/EPI, INL)
- Handbook of Small Modular Nuclear Reactors
  - Small modular reactor (SMR) adoption: Opportunities and challenges for emerging markets in the 2nd Edition, 2021 (INL, BSU/EPI)

MRP Microreactor Program

What we're doing | Studies Under Development

- Studies under development:
  - Global Market Analysis of Microreactors (INL, BSU/EPI)
    - Understanding of the market and economic potential for microreactors in the U.S. and internationally.

SMR/Microreactor Deployment Indicator Categories					
National Energy Demand	***Microreactor Energy Demand***	***Financial/ Economic Sufficiency***	***Physical Infrastructure Sufficiency***	***Climate Change Motivation***	***Energy Supply Surety Motivation***
Growth of Economic Activity	Dispersed Energy/ Remote/Land/ Locked	Ability to Support New Investments	Electric Grid Capacity	Reduce CO_2 Emissions per Capita	Reduce Energy Imports/Diversify Energy Sources
Growth Rate of Primary Energy Consumption	Local Co-Generation	Openness to International Trade	Limited Access to Energy	Reduce Fossil Fuel Energy Consumption	Use Domestic Uranium Resources
Per Capita Energy Consumption	Local Energy Intensive Industries	Fitness for Investment	Land Availability	Achieve Carbon Reduction Goals	Balance Intermittent Renewables/ Scalability
Local Economic Growth Potential	Local Energy Price Premiums/Seasonal	Limited Access to Local Capital	Limited Access to Trades/ QA	Local Climate Change/ Disaster Vulnerability	Local Critical Loads/Facilities

Microreactor Specific Indicator	Microreactor Benchmarking Indicator	Not Applicable to Microreactors

MRP Microreactor Program

What we're doing | Studies Under Development

- Global Market Analysis of Microreactors (INL, BSU/EPI)
  - Evaluates 8 use cases developed by UAA, U Wisc, and NAP
  - Identifies new profile markets, including:
    - Emerging Regional Economies (Electric – Developing Economies)
    - Remote Operations (Electric/Heat - Developed Economies)
    - Vulnerable Megacities (Electric/Heat – Developing Economies)
    - Disaster Relief (Electric – Developed/Developing Economies)
    - Marine Propulsion (Electric/heat – Global Shipping Fleets)
  - Uses Top-down and bottoms-up techniques to assess global market demands for microreactors.
  - Provides qualitative insights and additional factors for consideration (regulatory, risks, investment environment, etc.).

MRP Microreactor Program

Why it matters | Part 1 – Key Microreactor Roles

- Replacing fossil fuels particularly in remote applications and locations lacking centralized energy sources and transmission. (UAA)
- On Islands to improve energy security (supply chain independence) and reliability. (NAP)
- Federal Facilities to improve resilience and reduce dependence on backup diesel generators. (U Wisc)
- Integrated in microgrids to increase resilience to mitigate extreme natural events (earthquakes, hurricanes, etc.). (INL/EPI)
- In distributed energy systems (in developing economies) with renewable sources and energy storage, and heating needs. (INL/BSU)

MRP Microreactor Program

Why it matters | Part 2 – Technical Findings (subject to markets)

1. Ability to be “right-sized” for location, population size, and energy usage. Ability to stack reactors to add capacity.
2. Transportability to areas with limited access and infrastructure.
3. Co-produce electricity and heat (2-40 MWth).
4. Reliable with high-capacity factors (90-98%, high TRLs)
5. Limited capital at-risk ($10K- $20K/kWe)
6. Cost competitive in local energy market (O&M, fuel).

MRP Microreactor Program

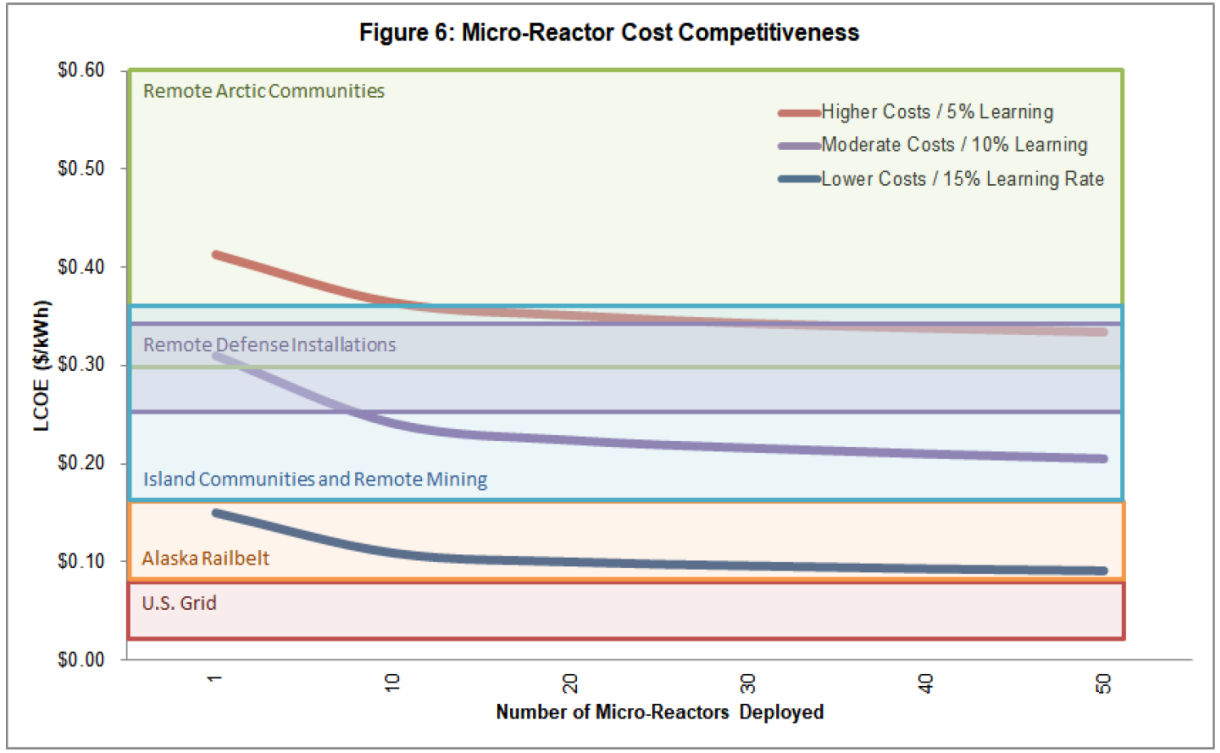
Why it matters | Part 3 – Technical Findings (subject to markets)

7. No offsite power required, little hard or soft infrastructure needs (e.g., labs, SNF storage)
8. Local access to trades/on-site construction.
9. Rapid initial deployment, mobility to redeploy to new site, minimum site preparations.
10. Long lived fuel with long refueling cycles (>3 years), independent of a fuel supply chain.
11. Flexible power conversion system, scale to meet changing loads over time, multiple voltage outputs.
12. Operate independently from the electric grid to supply highly resilient power for critical loads.

MRP Microreactor Program

Why it matters | Part 4 – Economic Findings

- Microreactors can be cost competitive when compared to remote diesel power and imported LNG, provided costs match the market.
- Minimal on-site construction would support quick reactor installations, but potentially limits the local economic uptake.
- Microreactors provide clean energy and can help to create economic growth (versus just replacement power).



MRP Microreactor Program

Additional Considerations

- Operational requirements (local skill sets) and local capabilities (used fuel storage);
- Lifecycle processes, including refueling, routine maintenance, and remediation and the ease of conducting them in remote areas;
- Adaptability or flexibility for changing energy systems (e.g., move reactors between mines);
- Community acceptance and perceptions over local control of energy systems, generally more positive than large reactors, particularly at military bases. The large number of unknowns influence perception at the technical level and among the general public.
- Resilience from supply chain disruption and other forces which could impact energy services;
- Local investment in energy system and community advocates;
- Availability of support networks to provide technical assistance throughout the life of the reactor.

MRP Microreactor Program

What's next for FY-22?

- Possible Topics:
  - Consideration of new microreactor applications including mini- and micro-grids in international markets, remote operations, disaster relief, in urban environments, and for mobile/marine applications.
  - Implications on microreactor technical requirements from specific market conditions in terms of specifications on size, competitive costs, transportability, coproduction of heat, reliability, infrastructure requirements, flexibility, etc.
  - Economic benefits from resilient microreactor designs?

MRP Microreactor Program

MRP Microreactor Program