INL/MIS-25-83575

Microreactor Cost Basis Work Scope

2025 Microreactor Annual Review

March 2025

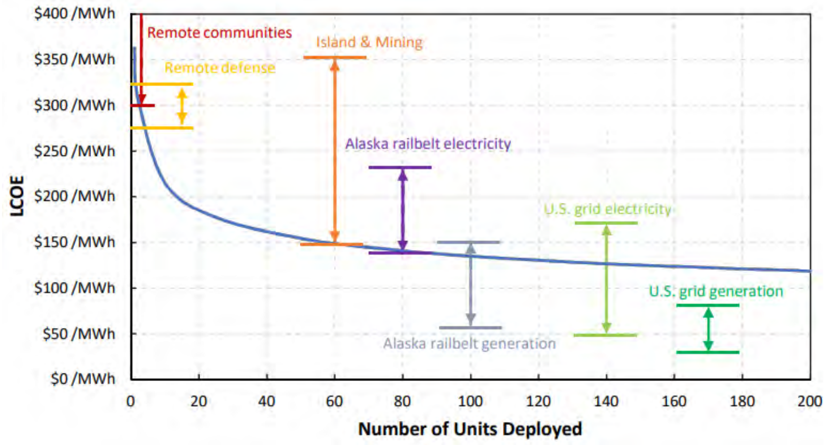
Botros N. Hanna, Khaldoon Al Dawood, **Abdalla Abou-Jaoude**

Background

- Motivation
  - Rising interest in the small/microreactors that can be deployed at a fraction of the cost and time (compared to the GW-scale reactors)
  - Economic competitiveness tied to mass production which is tied to demand → circular paradigm → need to unblock with techneconomic analysis
  - Need for detailed bottom-up assessment of microreactors costs for evaluating the competitiveness for several markets
- Opportunity
  - MARVEL cost data: only microreactor cost dataset available for detailed design, primary coolant system and fuel fabrication
  - Even through MARVEL is not built to be cost-competitive, MARVEL costs can still serve as a starting point for developing a microreactor cost model
- Scope
  - Develop alternate configurations of a microreactors using MARVEL as a starting point to derive a bottom-up cost estimate that is more representative of commercial concepts
  - Long-term: leverage cost data to consider other design parameters (e.g., TRISO fuel, HTGR)

Driving Question:

Can microreactors compete beyond niche markets?



(Abou-Jaoude, 2021)

MRP Microreactor Program

FY24 Summary and FY25 Plan

- FY24 Summary (accomplished)
  - Mapped MARVEL non-recurring costs
  - LMTR core design OpenMC model
  - BOP and Shielding Simplistic calculations
  - Developed a detailed FOAK & NOAK Cost model for a LMTR reactor
- FY25 Plan
  - Updating the MARVEL Cost (under development)
  - Reviewing/Improving the LMTR Cost model
  - Developed a detailed FOAK & NOAK Cost model for a CGMR reactor
  - Developing a comprehensive framework for detailed microreactor cost estimation (several designs, fuels, materials,..)
    - Optimization and parametric studies (under development)
    - Uncertainty calculation and propagation

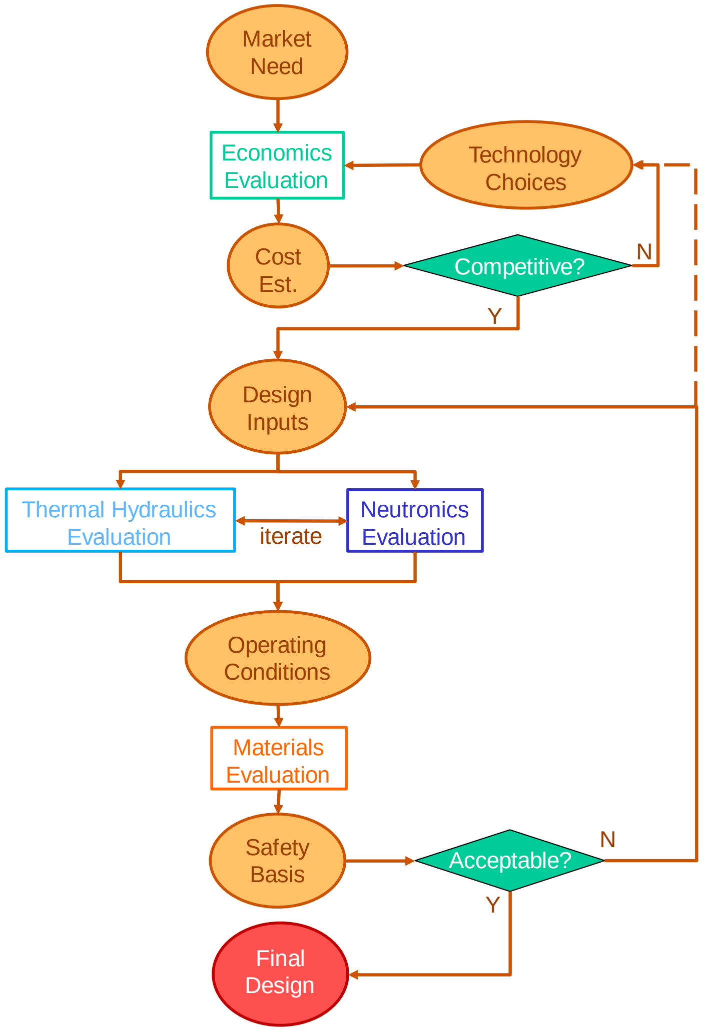
MRP Microreactor Program

(Abou-Jaoude, 2021)

Economics-by-Design Approach

- Follow 'economics-by-design' approach from SA&I
  - Will not be able to fully optimize design within current scope
  - Can put economics as guiding principle for analysis
- Ultimate target is:
  - Capital cost (excluding fuel) **<$5,000/kW** *(Buongiorno, Jacopo, et al. Energies (2021)*
- Mass production cost reductions previously assessed in: https://doi.org/10.1080/00295450.2023.2206779
  - 1x to 10x → 70% cost drop in factory costs
  - 10x to 100x → 50% cost drop in factory cost
- Task breakdown in this scope:
  - Conduct neutronics analysis to evaluate alternate configurations
  - Simple thermal hydraulics verifications
  - Source term evaluation
  - Cost estimation (leveraging MARVEL data)
  - Iterate

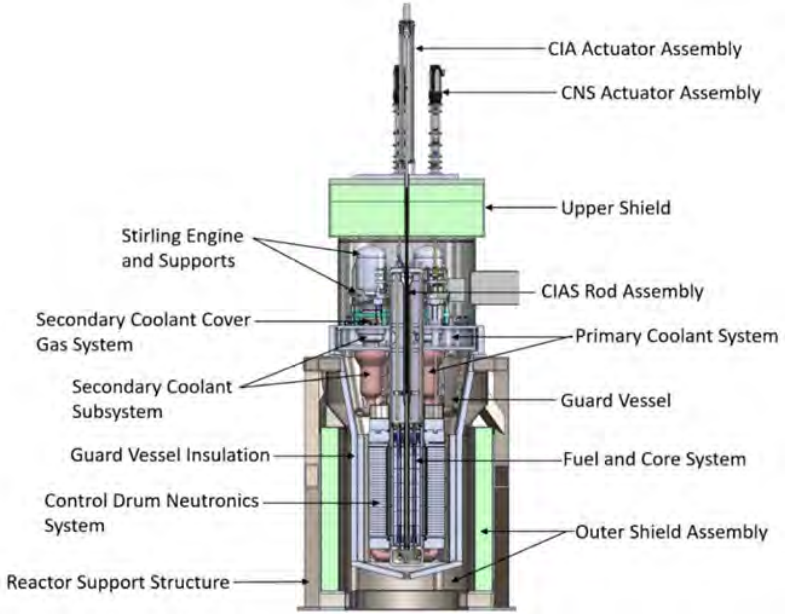
Economics-by-Design



MRP Microreactor Program

FY24 Scope: MARVEL Cost Mapping

- Class-3 cost estimate from the MARVEL team (February 2024), which has more than 2,000 items.
- The labor cost has been adjusted (40% less for the industry).
- Mapped to the INL-EPRI framework: Generalized Nuclear Code of Account (GN-COA)
- This facilitates cross-comparison with other technology types



Account		Cost (USD)
10	**Preconstruction Costs**	**5,216,860**
15	Plant Studies	5,216,860
20	**Capitalized Direct Costs**	**31,195,633**
21	Structures and Improvements	3,077,199
212	Reactor Island Civil Structures	2,851,662
214.7	Emergency and Startup Power Systems	225,537
22	Reactor System	17,811,509
221	Reactor Components	9,804,413
221.11	Reactor Support	1,196,316
	Reactor Frame Structure	454,126
	Other Support Structure (Including Installation)	742,190
221.12	Outer Vessel Structure	1,610,557
	Guard Vessel	941,382
	Guard Vessel–Related Structure & Installation	669,175
221.13	Inner Vessel Structure	317,648
221.21	Reactivity Control System	2,017,266
	B_4C-Control Poison	400,000
	Reactivity Control System Fabrication	1,294,603
	Installation	322,663
221.31	Reflector	4,259,687
	Outer Radial Reflector (BeO)	3,200,000
	Metallic Axial Neutron Reflector (Be)	850,000
	Installation	209,687
221.32	Shield Installation Cost	402,939
222	Main Heat Transport System	5,330,586
222.2	Reactor Heat Transfer Piping System	4,330,586
	Primary Coolant System (PCS)	1,691,583
	Primary Coolant System Structure Fabrication	2,431,871
	Other Structure Related to PCS	207,132
222.5	Initial Heat Transfer Fluid Inventory	1,000,000
226	Other Reactor Plant Equipment	775,876
227	Reactor Instrumentation and Control	1,897,554
228	Reactor Plant Miscellaneous Items	3,080
23	Energy Conversion System	132,044
232.1	Electricity Generation Systems	132,044
24	Electrical Equipment	33,657
244	Protective Systems Equipment	1,627
246	Power and Control Cables and Wiring	32,030
25	Initial Fuel Inventory	10,141,224
254	First Core Fuel Assembly Fabrication	10,141,224
	Fuel Production and Procurement	9,324,075
	Other Related Activities	817,149

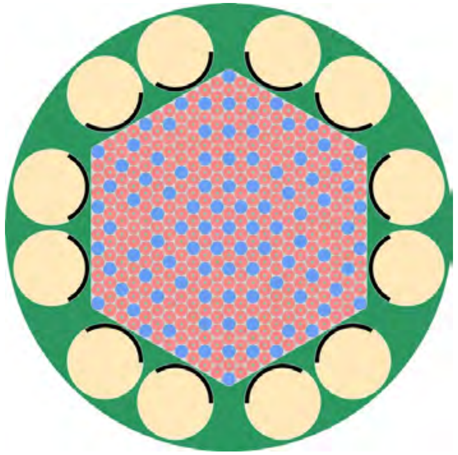
Account		Cost (USD
30	**Capitalized Indirect Services Cost**	**7,202,608**
31	Factory and Field Indirect Costs	1,656,640
317	Field Shops	1,656,640
33	Startup Costs	2,407,166
331.3	Initial Fuel Loading Operations	215,000
331.5	Test Runs	138,369
332	Demonstration Test Run	2,053,798
34	Shipping and Transportation Cost	1,923,914
341	Fuel Shipping and Transportation	1,899,493
345	Shipping and Transportation Costs	24,421
35	Engineering Services	797,929
351	Off-Site	307,221
352	On-Site	490,708
36	PM/CM Services	416,959
362	On-Site	416,959
40	**Capitalized Training Costs**	**4,169,765**
41	Staff Recruitment and Training	4,169,765
50	**Capitalized Supplementary Costs**	**16,408,782**
54	Decommissioning	16,408,782
60	**Capitalized Financial Costs**	**6,160,606**
61	Escalation	6,160,606
70	**Annualized O&M Cost**	**3,915,898**
71	O&M Staff	3,915,898

MRP Microreactor Program

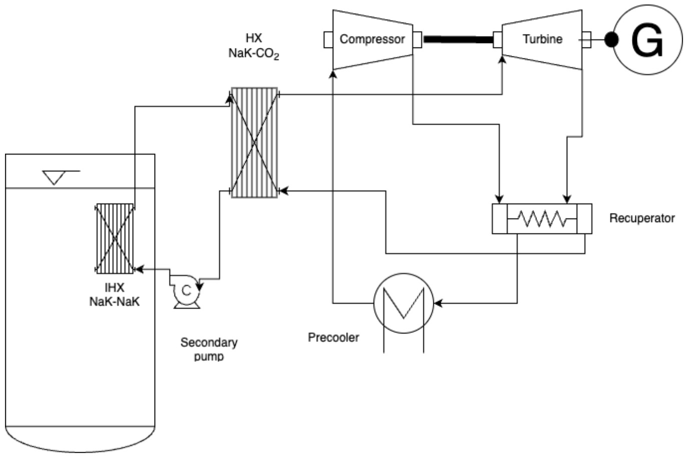
Scaled Design: Liquid-metal Thermal MicroReactor 20 (LTMR-20) Core Neutronics

- Studies using OpenMC:
  - Monte-Carlo method
  - Scriptable API makes it highly parametrizable
  - 2D-model for simplified analysis
- “MARVEL-like” core as starting point
- Parametric study to find condition of viability
  - E.g., criticality and heat flux
  - Kept at 20 MW_{th}
  - Refueling needs to be >> 2 years (5.9 years selected)

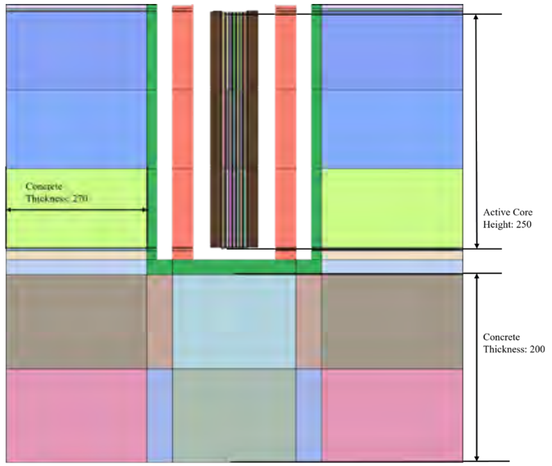
OpenMC



2D view of the core lattice arrangement



LTMR Balance of Plant

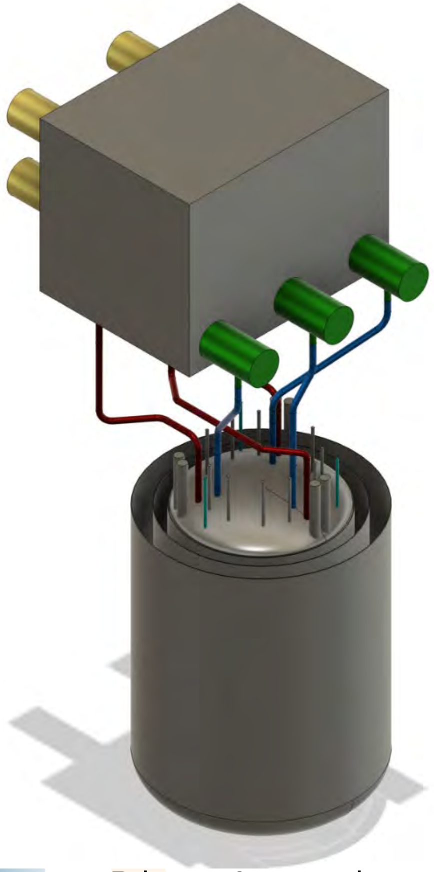


Shielding calculations

Reactor Specification	Value
Thermal Power	20 MWth
Power conversion cycle	S-CO_2 Brayton
Efficiency	31%
Electric Output	6.2 MWe
Av. Power	79 kWth/pin
Inlet/Outlet Temp.	430/520°C

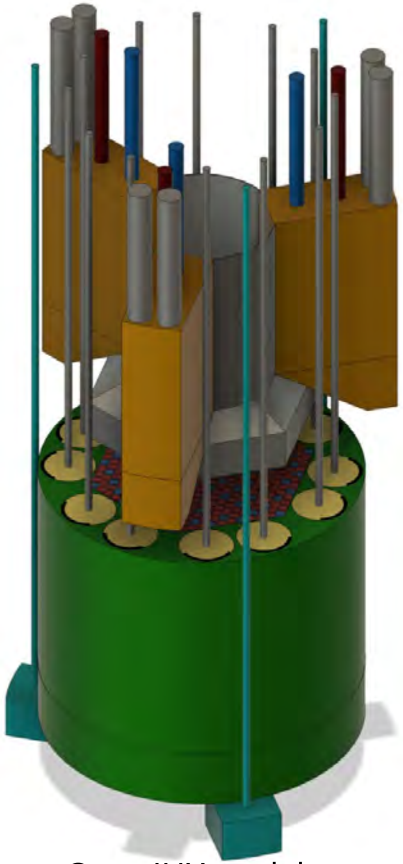
FY24: LTMR-20 Plant Physical Design Considerations

CAD Model Rendering



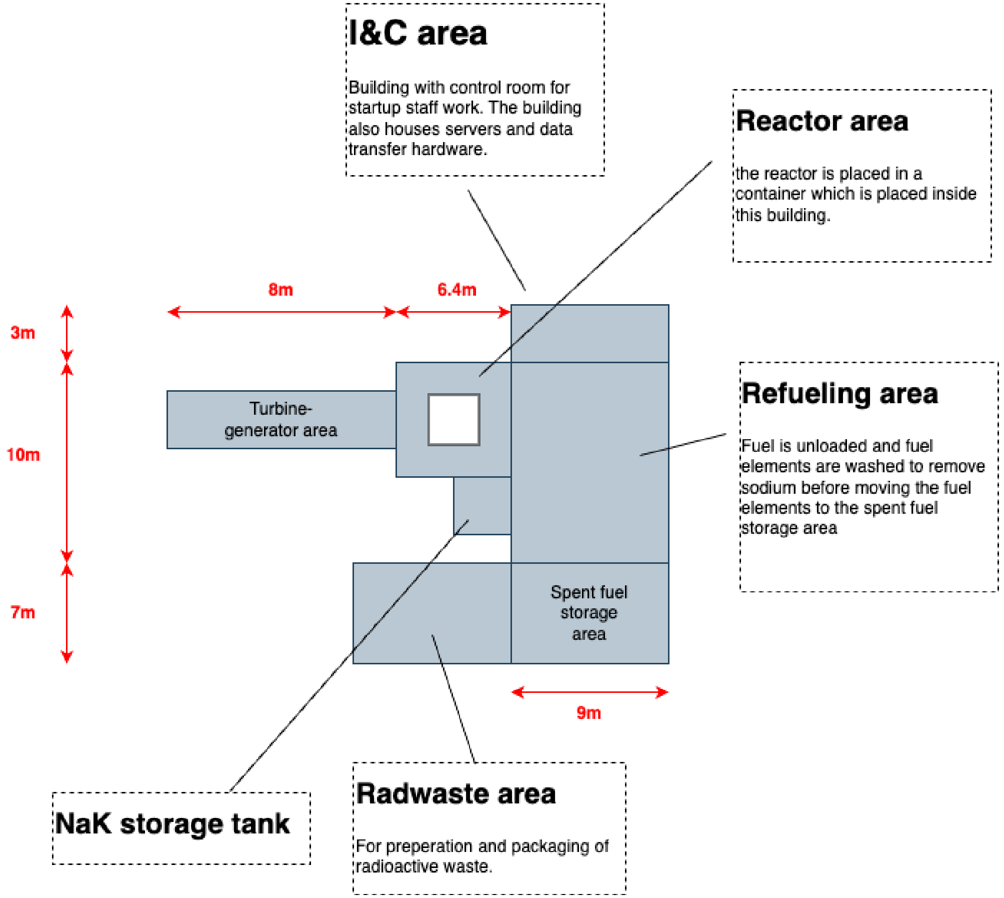
Primary & secondary coolant system

Vessel + Guard + RVAC



Core, IHX, and drums

Assumed Plant Layout



LTMR-20 Cost Breakdown

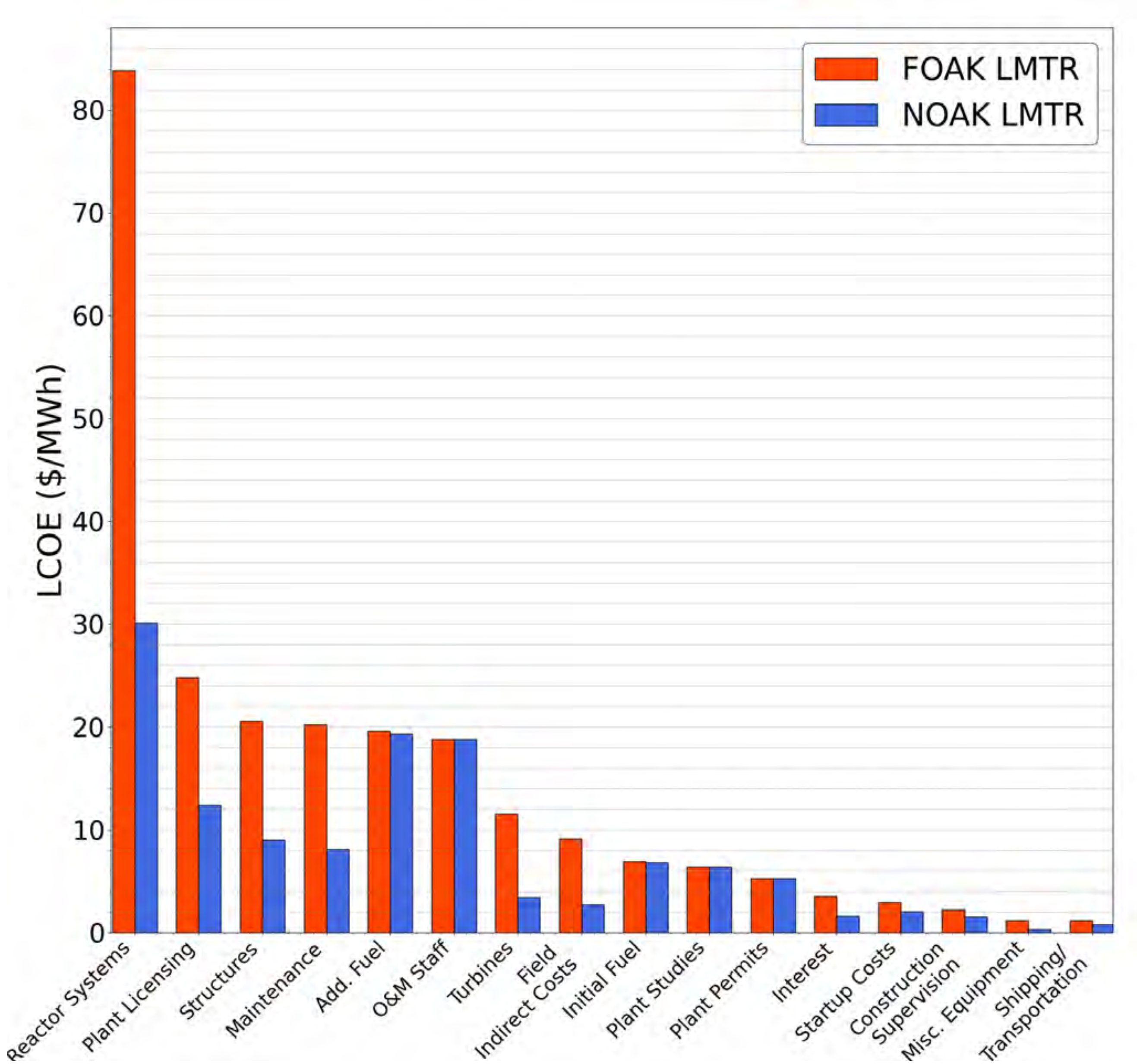
- FOAK = LTMR scaled costs based on MARVEL class 3 cost estimate
- NOAK = assume mass production rate of 10/year and apply cost adjustments

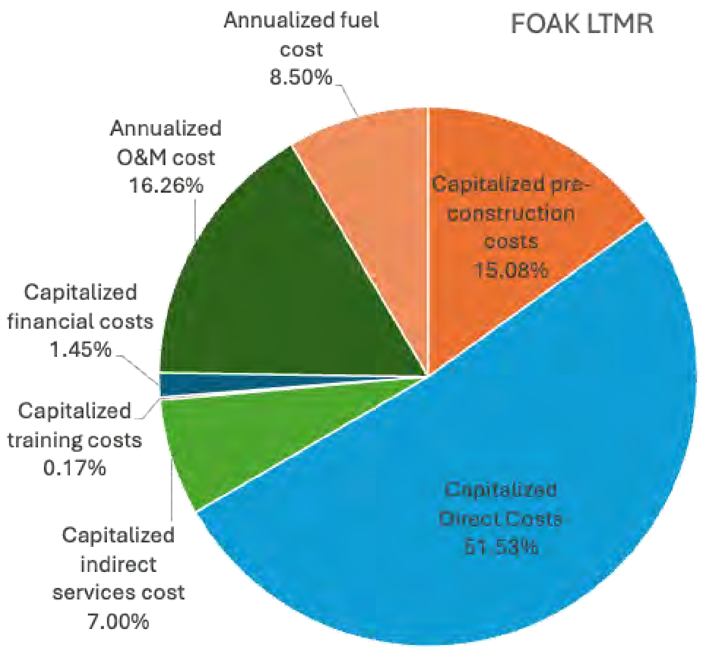
Bottom-up estimate results:

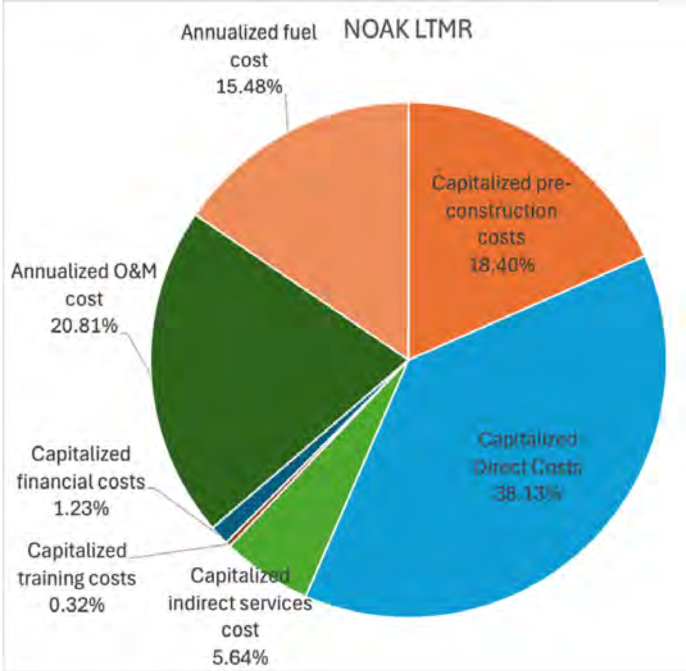
- OCC excluding fuel
  - ~$23,000/kWe for FOAK
  - ~$10,000/kWe for NOAK
- LCOE (assuming 6% financing costs):
  - $234/MWh for FOAK
  - $131/MWh for NOAK

Account ID	Title	FOAK LTMR [$]	NOAK LRMT [$]
10	**Capitalized pre-construction costs**	29,893,575	19,769,022
11	**land and rights**	71,136	71,136
12	**site permits**	64,673	64,673
13	**plant licensing**	20,249,106	10,124,553
14	**plant permit**	4,291,800	4,291,800
15	**plant studies**	5,216,860	5,216,860
20	**Capitalized Direct Costs**	102,156,869	40,952,189
21	**Structures and improvements**	16,806,927	7,392,949
22	**Reactor systems**	68,493,000	24,627,437
221	|__ Reactor components	60,255,161	21,548,266
221.1	|__ reactor vessel and accessories	7,514,825	4,325,415
221.11	|__ reactor support	917,400	366,960
221.12	|__ outer vessel structure	792,160	475,296
221.13	|__ inner vessel structure	5,805,265	3,483,159
221.2	|__ reactor control devices	14,007,498	5,602,999
221.21	|__ reactivity control system	14,007,498	5,602,999
221.3	|__ non-fuel internals	38,732,838	11,619,851
221.31	|__ reflector	5,584,965	1,675,490
221.32	|__ shield	32,584,126	9,775,238
221.33	|__ moderator	563,746	169,124
222	|__ Main heat transprt system	1,537,750	461,325
222.1	|__ fluid circulation drive system	31,911	9,573
222.2	|__ reactor heat transfer piping	155,000	46,500
222.3	|__ heat exchangers	1,350,838	405,251
223	|__ safety systems	2,026,064	1,215,638
223.5	|__ reactor cavity cooling system	2,026,064	1,215,638
226	|__ other plant equipment	814,938	244,481
227	|__ reactor instrumentation and control (i&c)	3,579,140	1,073,742
228	|__ reactor plant miscellaneous items	279,947	83,984
23	**Energy conversion system**	9,413,837	2,824,151
232	|__ energy applications	9,413,837	2,824,151
232.1	|__ electricity generation systems	9,413,837	2,824,151
24	**Electric equipment**	794,005	238,202
25	**Initial fuel inventory**	5,649,100	5,569,451
251	|__ initial fuel inventory material	5,649,100	5,569,451
26	**Miscellaneous equipment**	1,000,000	300,000
30	**Capitalized indirect services cost**	13,879,997	6,056,881
31	**Factory & field indirect costs**	7,464,367	2,239,310
32	**Factory and construction supervision**	1,831,619	1,282,133
33	**Startup costs**	2,407,166	1,685,016
34	**Shipping and transportation costs**	961,957	673,370
35	**Engineering services**	797,929	558,550
36	**PM/CM sevices**	416,959	291,871
40	**Capitalized training costs**	339,400	339,400
41	**staff recruitment and training**	339,400	339,400
60	**Capitalized financial costs**	2,879,778	1,321,417
62	**Interest**	2,879,778	1,321,417
70	**Annualized O&M cost**	1,994,834	1,382,788
71	**O&M staff**	951,086	951,086
75	**Capital plant expenditures**	1,021,569	409,522
78	**Annualized decommissioning costs**	22,180	22,180
80	**Annualized fuel cost**	1,042,840	1,028,866
81	**Refueling operations**	1,225	1,225
82	**Additional nuclear fuel**	991,070	977,097
83	**Spent fuel management**	50,545	50,545

LTMR-20 Cost Breakdown



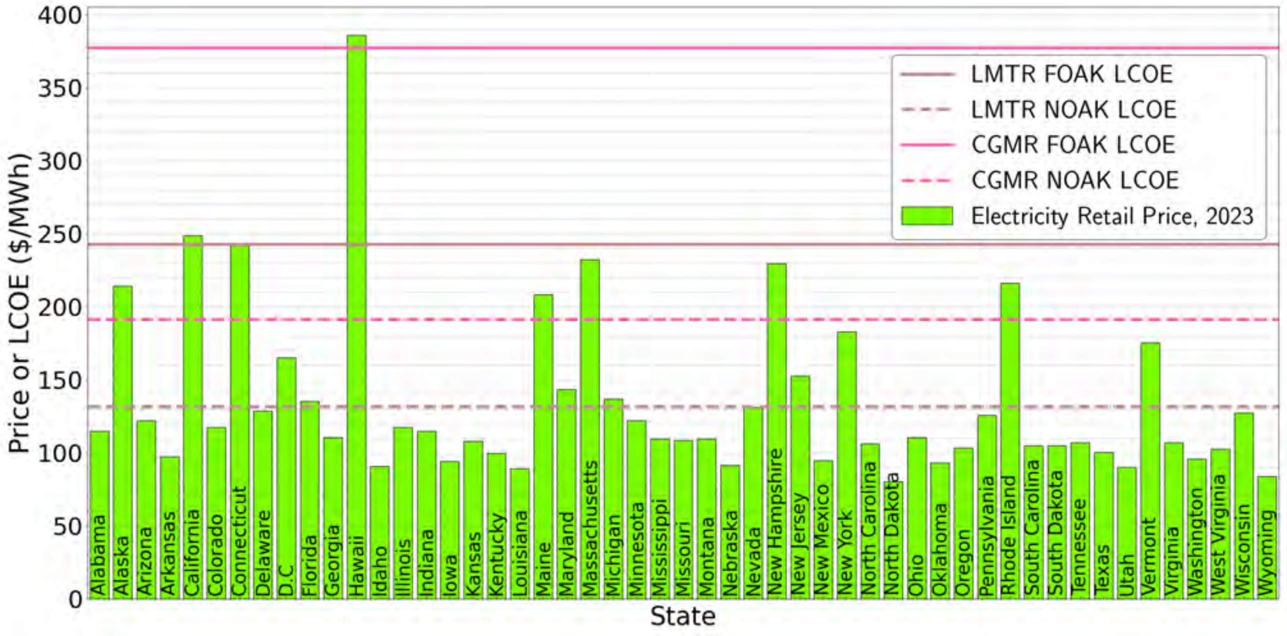




Costs in Perspective

Can microreactor compete beyond niche markets?

- **Wholesale electricity**: Using the publicly available data (EIA), the annual average electricity prices are < 60 $/MWh. Microreactors cannot compete.
- **Retail electricity**: FOAK LMTR in a few states, FOAK CGMR in one state While NOAK LMTR in ~ 16 states, NOAK CGMR In ~8 states
  - Requires 'behind the meter' arrangement being approved by public commissioners/regulators
  - Requires regulatory basis to embed microreactor with end-users
- **Beyond**: Potential for industrial heat applications for microreactors if natural gas prices are above $10/MMBTU, see recent study M. Vanata et. al 2024: https://doi.org/10.1038/s41560-024-01665-w



MRP Microreactor Program

FY25 Activities: Developing Reference Microreactor Costs

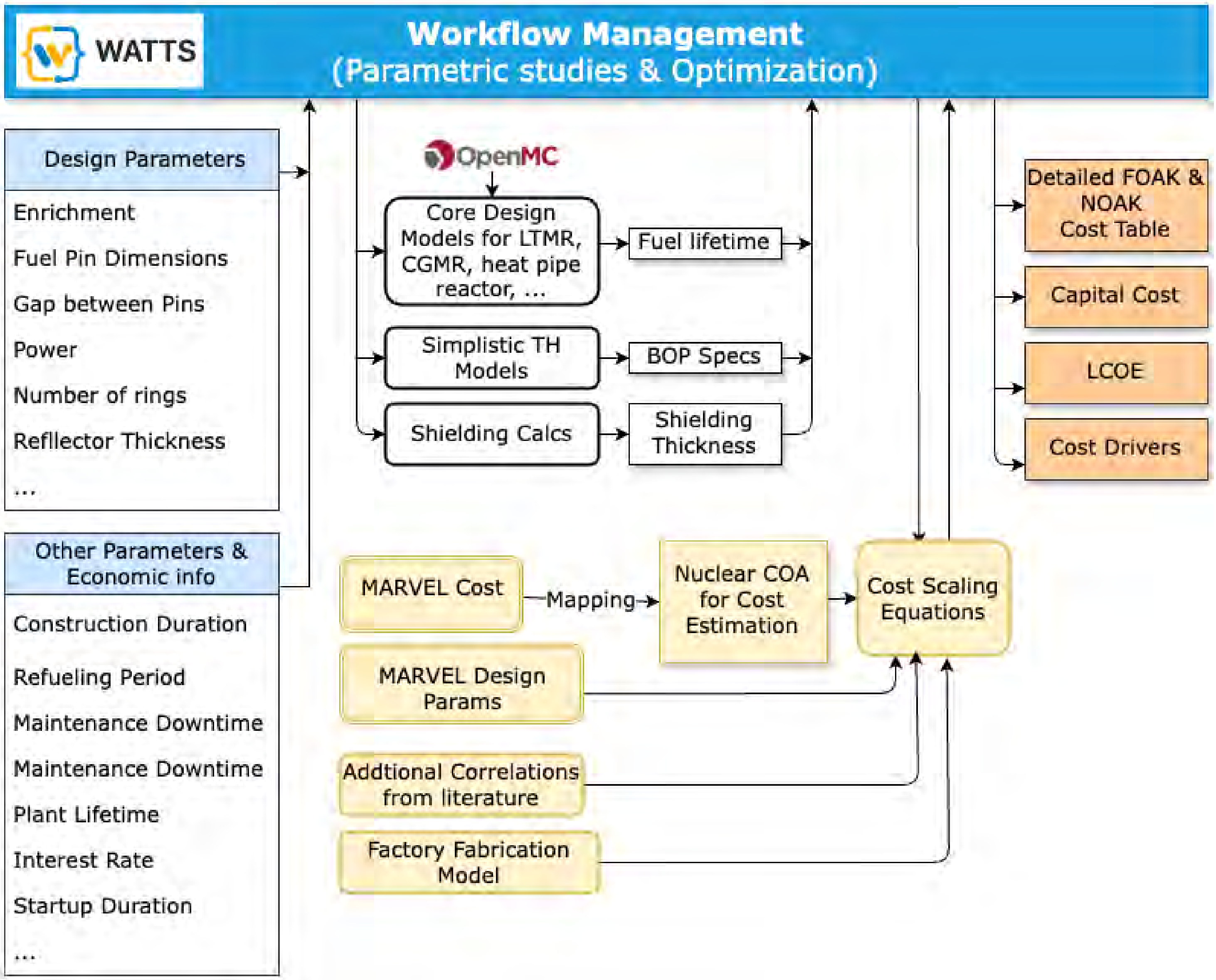
- Task 1: Develop reference microreactor costs to the GAIN program to use in 2025 update of ATB
  - Refined estimates for LTRM model
  - Evaluated estimates for a Gas Cooled Microreactor (GCMR) and reconciling cost models between two concepts (concept was obtained from separate effort)
- Task 2: develop framework for technoeconomic analysis of microreactors

Title	FOAK LTMR	NOAK LTMR	FOAK GCMR	NOAK GCMR
Overnight Capital Cost (OCC) [$]	146,269,841	67,117,492	215,523,136	98,756,526
OCC [$/kWe]	23,592	10,825	35,921	16,459
Total Capital Investment (TCI) [$]	149,149,619	68,438,910	219,766,382	100,700,856
Annualized Cost [$/year]	50,545	3,929,563	48,914	8,134,852
LCOE [$/MWe-hr]	243	131	378	192

TRISO-based microreactors are expected to be substantially more expensive than non-TRISO alternatives

FY25 Activities: Technoeconomic Framework for Microreactors

- **Proposing**: WATTS-based framework (using OpenMC)
- **Goal**: A comprehensive cost estimate for several designs of microreactors with variety of fuels, design parameters and economic parameters.
- **For Investors**: A database to investigate microreactor costs and their drivers
- **For engineers**: studying the impact of design parameters on the cost + optimization studies
- **For MRP**: provide framework to identify cost drivers and research priorities



Summary

- **FY24**: Developed microreactor cost model using MARVEL detailed estimates as the basis. Identified potential configuration that point to broader potential for microreactor to compete in retail electricity generation if possible to be embedded directly with end users.
- **FY25**: Refine previous cost estimates and develop flexible framework to consider different microreactor design paradigms (different fuel, coolant, enrichment). Intent is to provide useful tool to stakeholders.
- **Publications**:
  - B. Hanna et al., “Technoeconomic Evaluation of Microreactor Using Detailed Bottom-up Estimate”, Idaho National Laboratory, INL/RPT-24-80433, (2024), https://www.osti.gov/biblio/2447366/
  - B. Hanna et al., “Technoeconomic Evaluation of Microreactor Using Detailed Bottom-up Estimate”, Idaho National Laboratory, INL/RPT-24-80433, (2024), https://www.osti.gov/biblio/2447366/
  - I. N. de Candido et al., “Assessment of Technoeconomic Opportunities in Automation for Nuclear Microreactors”, Nuclear Science and Engineering, (2024), https://doi.org/10.1080/00295639.2024.2372511
  - K. Al Dawood et al., "Open-Source Microreactor Design Models for Technoeconomic Assessments “, Nuclear Engineering and Design, (in submission)
  - K. Al Dawood et al., “Review and Processing of MARVEL Cost Estimation and Economics Data”, Nuclear Technology (under preparation)

MRP Microreactor Program

Abdalla.AbouJaoude@inl.gov

Questions?

MRP Microreactor Program

Mass Production Cost Reduction

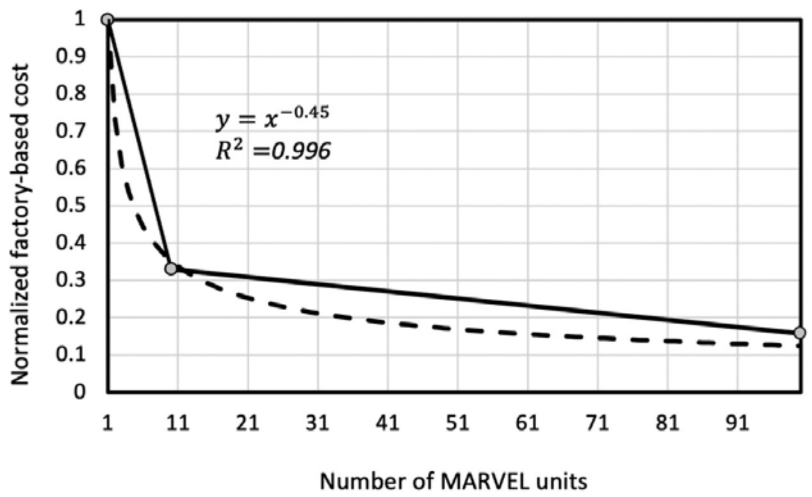
- In previous work, the factory fabrication and the mass production of microreactors were assessed
- MARVEL as use-case; assuming findings are applicable to MARVEL-20
- Main findings:
  - Shifting from stick-built to 10 units/year production can decrease costs by ~70%
  - Non-fuel CAPEX so far: 12,879$/kWe → ~3,863 $/kWe
  - Still within the bounds of the target by (Buongiorno 2021)

NUCLEAR TECHNOLOGY · VOLUME 209 · 1697–1732 · NOVEMBER 2023
DOI: https://doi.org/10.1080/00295450.2023.2206779
Check for updates

Assessment of Factory Fabrication Considerations for Nuclear Microreactors

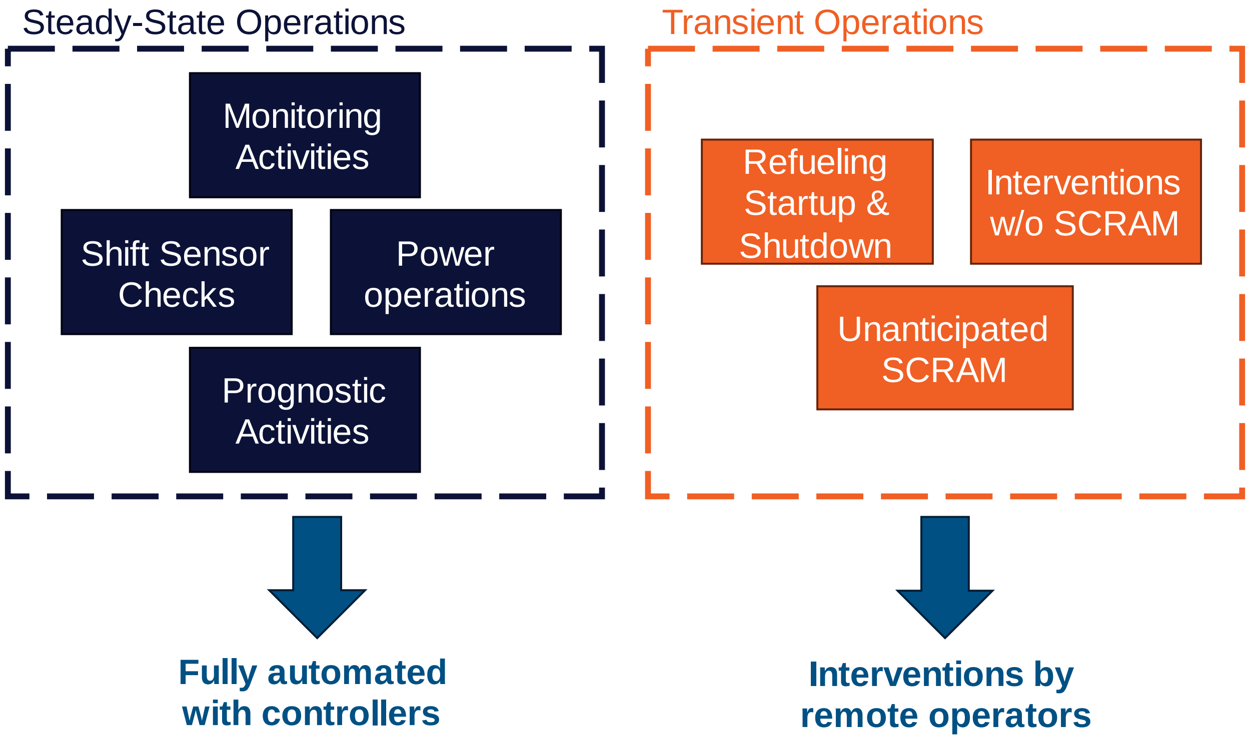
Abdalla Abou-Jaoude,[a]* Yasir Arafat,[a] Chandrakanth Bolisetti,[a] Botros Hanna,[a] Joshua Belvedere,[b] James Blocker,[b] Brandon Cooper,[b] Shanda Harmon,[b] and Dan McCarthy[b]
[a]*Idaho National Laboratory, Nuclear Science & Technology Directorate, Idaho Falls, Idaho*
[b]*Munro & Associates Inc., Auburn Hills, Michigan*

Received January 31, 2023
Accepted for Publication April 20, 2023



Framework for Automated Operation Assessment

- *Do additional capital costs for controller outweigh on-site staffing costs?*
- Frameworks for users to estimate cost reductions from automation
- Sensor-based approach:
  - Use # of sensors to determine number of FTEs needed per reactor
  - Use # of sensors to calculate controller hardware costs during steady state operations
  - Conduct differential analysis
- Automation:
  - Only for steady-state operations
  - Transient ops are assumed to require remote intervention



$$U = \sum_{i=1}^{N_s} f_{m,i}\left(t_{mp,i} + t_{m,i}\right)$$

$$\Delta C = U_M P - \left[(N_s C_c \times CRF) + U_T P + C_w\right]$$

U	Utilization (% of time) for operation
U_M	Utilization (% of time) for fully manual operation
U_T	Utilization during transients for autonomous ops
$f_{m,i}$	Frequency of sensor i operation demand (Hz)
$t_{m,i}$	Duration of sensor i operation measurement
$t_{mp,i}$	Processing time of sensor i operation
N_s	Number of sensors
C_c	Controller cost per sensor ($)
C_w	Wireless transmission costs ($)
CRF	Capital Recovery Factor
P	Cost per FTE ($)

Automation Framework Usecase

- Inputs based on MITR (6 MWt) as a use case
- Framework levers (inputs & assumptions) can be parameterizable
- Cost savings from full automation **~90%**
- Remote intervention of staff during transient operations are **trivial**. Anticipating each staff can cater to ***19 reactors*** under current assumptions

Inputs	Values
Total # of sensors	249
# of power sensors	76
# actuators	55
# load following ops	2
Ramp rate (%P/mins)	20%

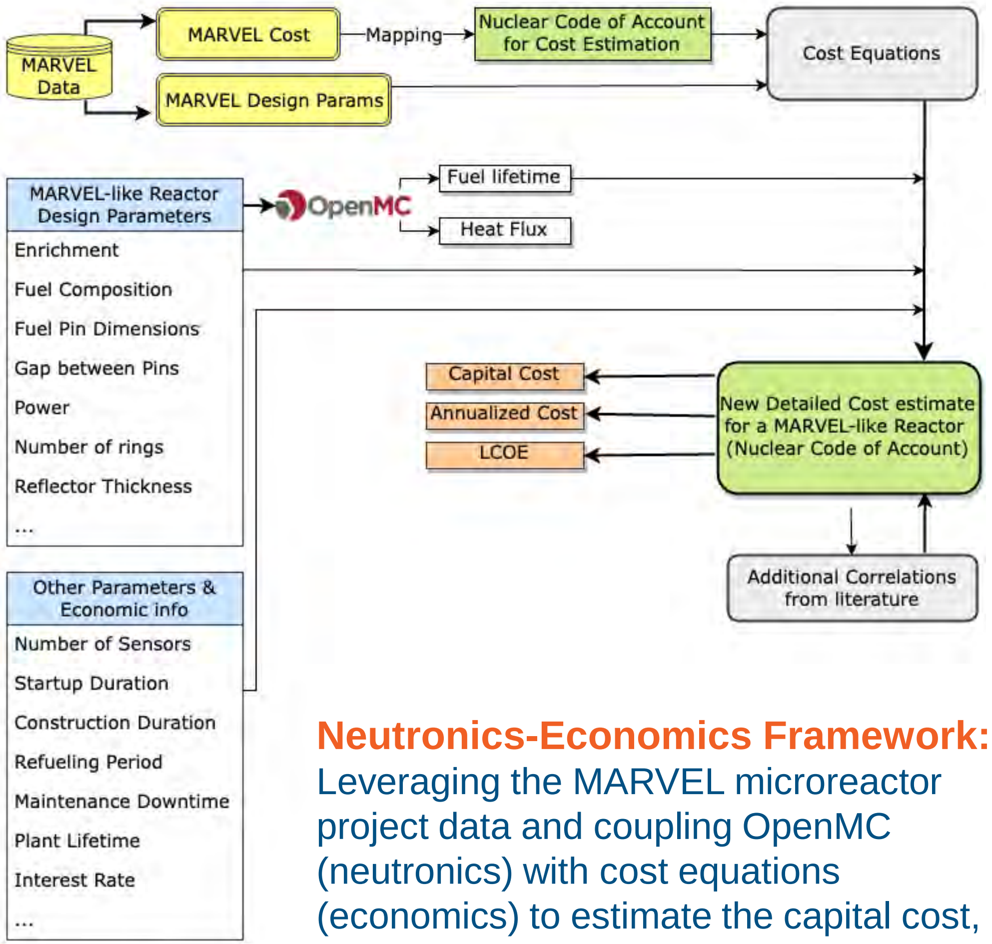
\+

Assumptions	Values
# sensor checks per shift	2
% sensor checks for power ops	30%
# sensor monitoring per day	1
# of prognostics per week	1
Startup/shutdown ops duration	8h
Unanticipated SCRAMs	0.5/yr
Unanticipated interventions	24/yr
FTE Cost	$250k/yr
Controller cost per IO	$5k
I&C lifetime	10 yr
Assumed WACC	8%
Secure information transfer fee	$60k/yr

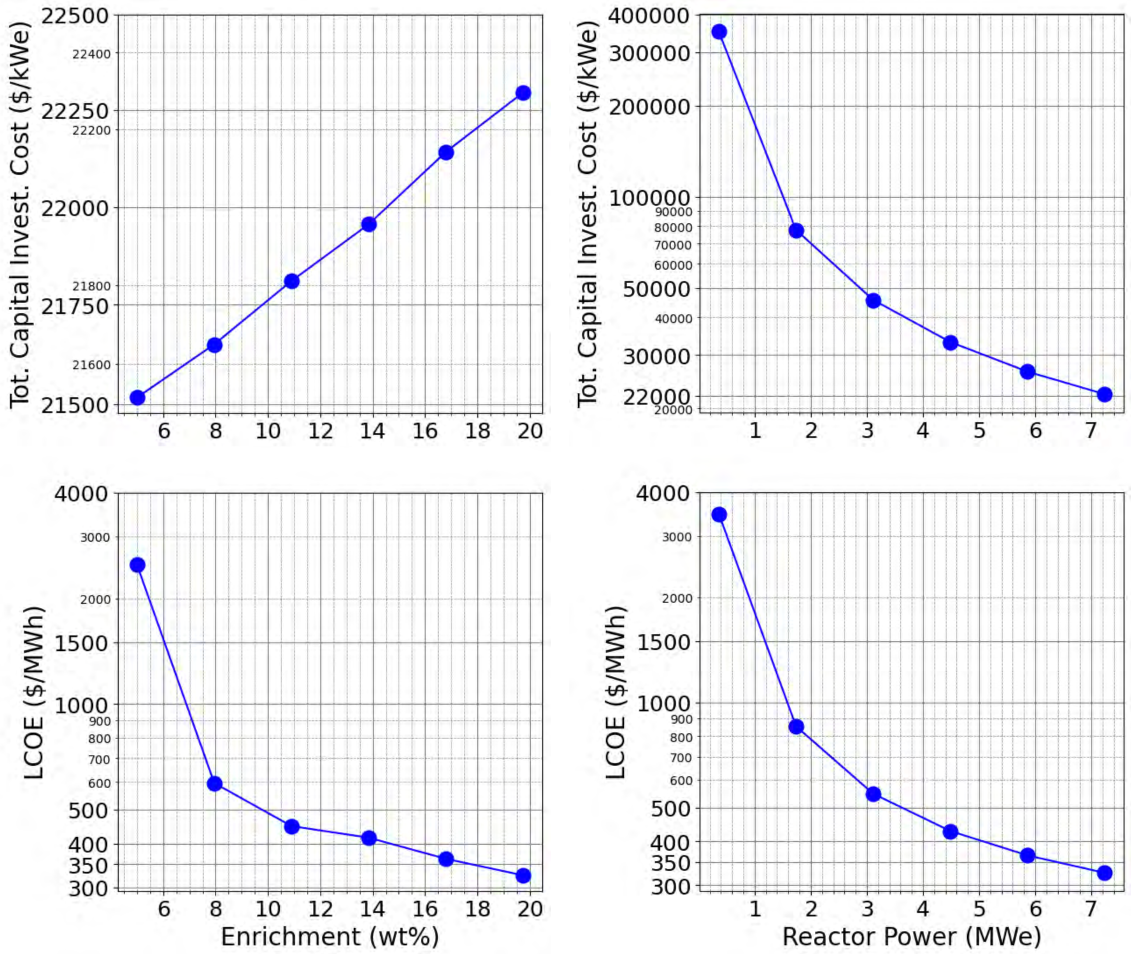
Results	Values
Fully manual staffing costs	$2.7M/yr
Levelized I&C costs	$233k/yr
Transient intervention costs	$13k/yr
% cost savings	**-89%**

MRP Microreactor Program

Framework to Evaluate Pathways for Competitive Microreactors



Neutronics-Economics Framework:
Leveraging the MARVEL microreactor project data and coupling OpenMC (neutronics) with cost equations (economics) to estimate the capital cost, annualized cost, and LCOE of an LTMR reactor.

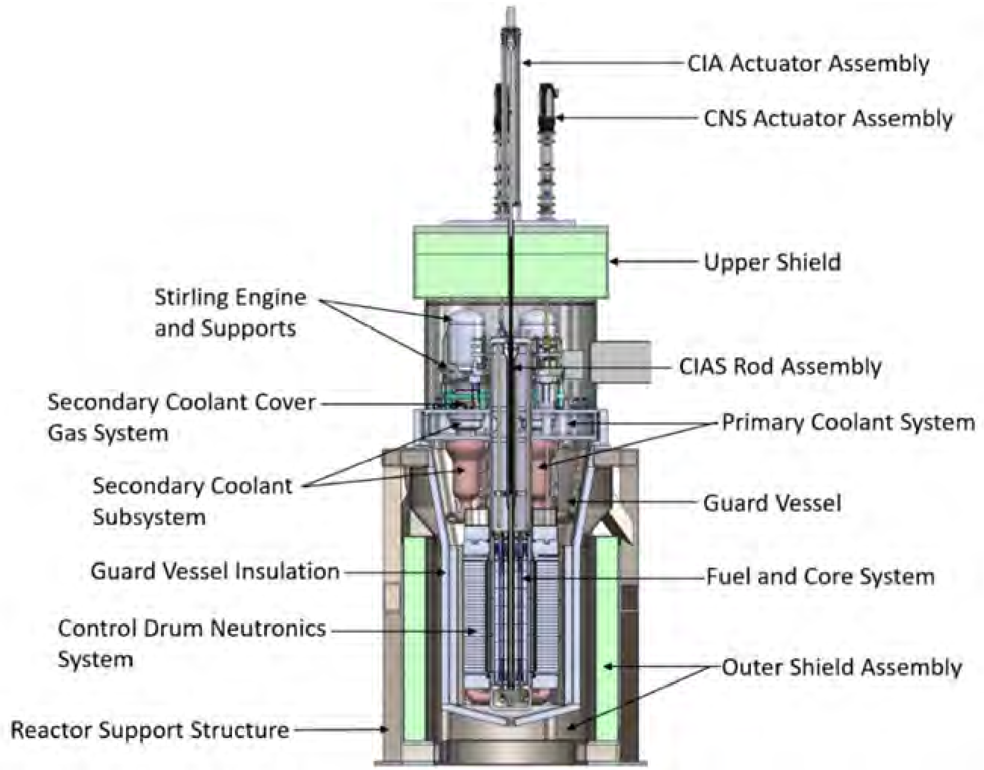


Economic figures of merit dependence on enrichment and reactor power

MRP Microreactor Program

MARVEL Project Cost Mapping

- The MARVEL project costs were taken from the following sources.
  - Class-3 cost estimate from the MARVEL team (February 2024), which has more than 2,000 items.
  - MARVEL team directly communicated the costs of some significant components
  - The actual spent costs up to FY 2023
  - Costs associated with MARVEL but intended to remain a part of TREX-C for future use
- The labor cost has been adjusted (40% less for the industry).
- Nonrecurring costs were excluded
- Some costs are missing e.g., the cost of the shielding in the pit, the Beryllium oxide(BeO) for the control drums, and the fuel mining and enrichment



MARVEL microreactor cutaway view

MRP Microreactor Program

MARVEL Project Cost Scaling

To leverage these cost data for the cost estimation of other microreactors, scaling parameters were selected for each cost item and the cost per unit (e.g., $/kg) was calculated.

Account		Scaling			Unit Cost	
		Scaling Variable	Base Value	Unit	Value	Unit
10	**Capitalized Preconstruction Costs**	—	—	—	—	—
15	Plant Studies	Assuming that this cost does not significantly change for microreactors with larger capacities.				
20	**Capitalized Direct Costs**	—	—	—	—	—
21	Structures and Improvements	—	—	—	—	—
212	Reactor Island Civil Structures					
214.7	Emergency and Startup Power Systems	Power (MWe)	0.03	MWe	7,517,900	$/MWe
22	Reactor System	—	—	—	—	—
221	Reactor Components	—	—	—	—	—
221.11	Reactor Support	Guard Vessel Mass	1587	kg	754	$/kg
	Reactor Frame Structure				286	$/kg
	Other Support Structure (Including Installation)				468	$/kg
221.12	Outer Vessel Structure				1015	$/kg
	Guard Vessel				593	$/kg
	Guard Vessel–Related Structure Including Installation				422	$/kg
221.13	Inner Vessel Structure				210	$/kg
221.21	Reactivity Control System	—	—	—	—	—
	B_4C-Control Poison	Mass of Rod Poison (in both the drums and control rod)	28	kg	14286	$/kg
	Reactivity Control System Fabrication	—	—		—	—
	Installation	—	—		—	—
221.31	Reflector	—	—	—	—	—
	Outer Radial Reflector (BeO)	Mass of BeO Reflector	318	kg	10063	$/kg
	Metallic Axial Neutron Reflector (Be)	Mass of Be	18.9		44,903	$/kg
	Installation	—	—		—	—
221.32	Shield Installation Cost	—	—	—	—	—
222	Main Heat Transport System	—	—	—	—	—
222.2	Reactor Heat Transfer Piping System	—	—	—	—	—
	PCS	Mass of PCSs (SS316H)	860	kg	1967	$/kg
	Primary Coolant System Structure Fabrication				2828	$/kg
227	Reactor I&C	Number of sensors	277	sensors	6850	$/sensor
228	Reactor Plant Miscellaneous Items	—	—	—	—	—
23	Energy Conversion System	—	—	—	—	—
232.1	Electricity Generation Systems	For larger microreactors, the Stirling engines are not used.			—	—
24	Electrical Equipment	—	—	—	—	—
244	Protective Systems Equipment	Assuming that this cost does not significantly change for microreactors with larger capacities.				
246	Power and Control Cables and Wiring					
25	Initial Fuel Inventory	—	—	—	—	—
254	First Core Fuel Assembly Fabrication	—	—	—	—	—
	Fuel Production and Procurement	Mass of the fuel (UZrH)	145.3	kg	83,423	$/kg

GCMR Cost Breakdown

- FOAK = GCMR scaled costs based on MARVEL class 3 cost estimate
- NOAK = assume mass production rate of 10/year and apply cost adjustments

Bottom-up estimate results:

- OCC excluding fuel
  - $34,000/kWe for FOAK
  - $15,000/kWe for NOAK
- LCOE:
  - $378/MWh for FOAK
  - $192/MWh for NOAK

Title	FOAK GCMR	NOAK GCMR
Overnight Capital Cost (OCC) [$]	215,523,136	98,756,526
OCC [$/kWe]	35,921	16,459
Total Capital Investment (TCI) [$]	219,766,382	100,700,856
Annualized Cost [$]	48,914	8,134,852
LCOE [$/MWe-hr]	378	192

Account ID	Title	FOAK GCMR [$]	NOAK GCMR [$]
10	Capitalized pre-construction costs	29,889,477	19,765,930
11	land and rights	71,136	71,136
12	site permits	62,587	62,587
13	plant licensing	20,247,093	10,123,547
14	plant permit	4,291,800	4,291,800
15	plant studies	5,216,860	5,216,860
20	Capitalized Direct Costs	166,952,710	70,734,627
21	Structures and improvements	16,483,594	8,135,249
22	Reactor systems	129,946,954	53,123,524
221	|__ Reactor components	121,156,459	49,765,269
221.1	|__ reactor vessel and accessories	34,225,371	19,062,330
221.11	|__ reactor support	7,364,462	2,945,785
221.12	|__ outer vessel structure	-	-
221.13	|__ inner vessel structure	26,860,908	16,116,545
221.2	|__ reactor control devices	46,236,122	18,494,449
221.21	|__ reactivity control system	46,236,122	18,494,449
221.3	|__ non-fuel internals	40,694,966	12,208,490
221.31	|__ reflector	39,685,812	11,905,744
221.32	|__ shield	194,405	58,321
221.33	|__ moderator	814,749	244,425
222	|__ Main heat transprt system	1,712,782	513,835
222.1	|__ fluid circulation drive system	27,982	8,395
222.2	|__ reactor heat transfer piping	180,000	54,000
222.3	|__ heat exchangers	1,504,800	451,440
223	|__ safety systems	2,403,688	1,442,213
223.5	|__ reactor cavity cooling system	2,403,688	1,442,213
226	|__ other plant equipment	814,938	244,481
227	|__ reactor instrumentation and control (i&c)	3,579,140	1,073,742
228	|__ reactor plant miscellaneous items	279,947	83,984
23	Energy conversion system	9,155,083	2,746,525
232	|__ energy applications	9,155,083	2,746,525
232.1	|__ electricity generation systems	9,155,083	2,746,525
24	Electric equipment	794,005	238,202
25	Initial fuel inventory	9,573,073	6,191,128
251	|__ initial fuel inventory material	9,573,073	6,191,128
26	Miscellaneous equipment	1,000,000	300,000
30	Capitalized indirect services cost	18,401,049	7,976,069
31	Factory & field indirect costs	12,261,663	3,678,499
32	Factory and construction supervision	1,555,375	1,088,763
33	Startup costs	2,407,166	1,685,016
34	Shipping and transportation costs	961,957	673,370
35	Engineering services	797,929	558,550
36	PM/CM sevices	416,959	291,871
40	Capitalized training costs	279,900	279,900
41	staff recruitment and training	279,900	279,900
60	Capitalized financial costs	4,243,246	1,944,331
62	Interest	4,243,246	1,944,331
70	Annualized O&M cost	2,642,077	1,679,897
71	O&M staff	951,086	951,086
75	Capital plant expenditures	1,669,527	707,346
78	Annualized decommissioning costs	21,464	21,464
80	Annualized fuel cost	2,226,199	1,457,575
81	Refueling operations	1,586	1,586
82	Additional nuclear fuel	2,175,698	1,407,074
83	Spent fuel management	48,914	48,914

GCMR Cost Breakdown