The Case for Micro Reactors as On-site Generators at Government Installations

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May 12, 2021

INSTITUTE FOR NUCLEAR ENERGY SYSTEMS

Our Study

- To determine whether micro-reactors can satisfy a need for resilient power at U.S. Government sites.
- To determine whether it would be practical to try to site micro-reactors at federal agency installations.
- To make recommendations to Department of Energy:
  - If DOE goes down this path, how might DOE proceed?

Study Tasks

Short-term: Assist DoE in developing program plan for micro-reactors at DoD sites.

(Task was completed in early 2019 and Draft report submitted)

Long-term:

1. Estimate size of market for new on-site secure power at federal agency installations.
2. Survey potential vendors of micro-reactors to elucidate their respective technologies.
3. Perform economic analysis: Under what conditions can micro-reactors compete with other technologies to provide on-site power (Diesels are baseline for on-site power)?
4. Regulatory issues: What are licensing options and issues that need to be addressed?
5. Decision whether to go forward: What are the acquisition options for micro-reactors?

How can this program be a bridge to commercial introduction of micro-reactors

Task 1: Estimate the Market

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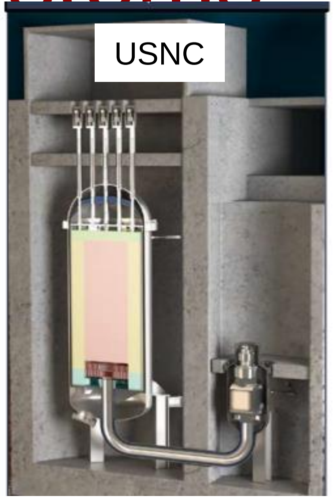
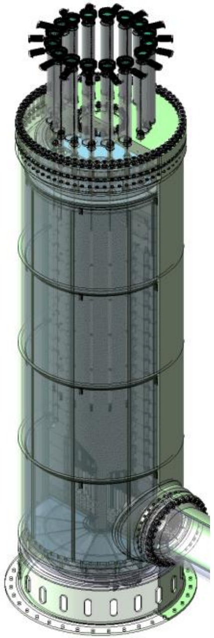
- FEMP provided an extensive range of energy use data.
- UW team surveyed the largest energy users in each civilian agency as well as their specific federal agency facilities (>200 facilities with >4MW energy usage).
- UW received detailed energy use data for selected facilities
- For these larger energy users:
  - All federal installations are connected to the grid;
  - 40-60% of energy is in form of electrical power;
  - Critical loads have many small local backups (buildings).
- Micro-grids will be a natural evolution for facility resilience with larger backups
- We estimate there are over 200 potential sites, assuming that it is reasonable to site at least a single micro-reactor with backup for redundancy.

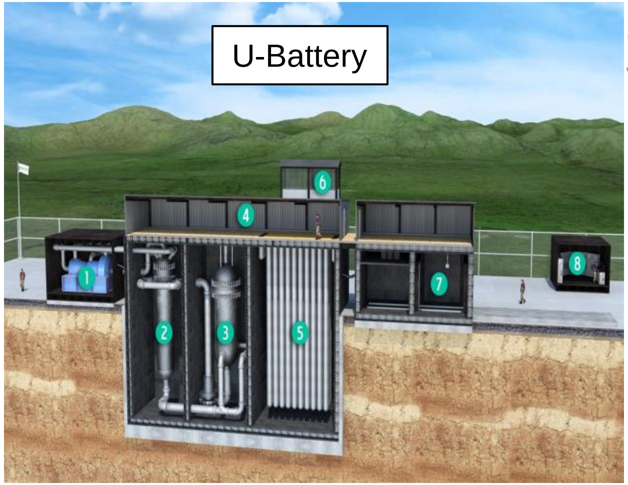
Task 2: Micro-reactor potential vendors

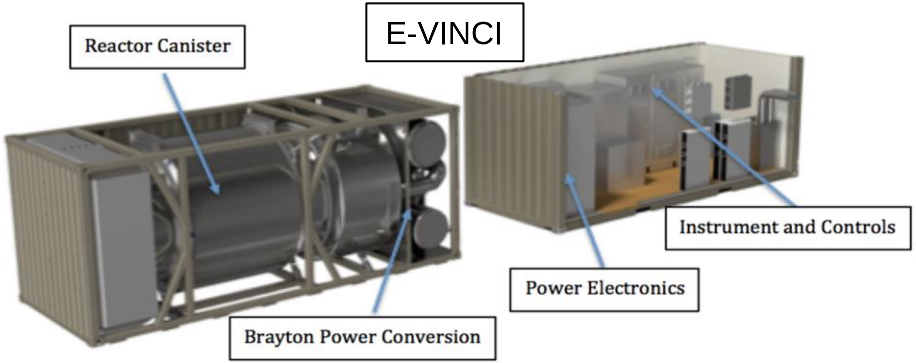
- There is a wide range micro-reactor design concepts available.
- Conceptual technical designs have details to be determined.
- Cost estimates exist only as proprietary data; i.e., FOAK estimates as well as required R&D development costs.
- UW contact with individual vendors did not provide any firm basis for stated cost estimates. A detailed methodology to estimate costs will be necessary to gain confidence in future.

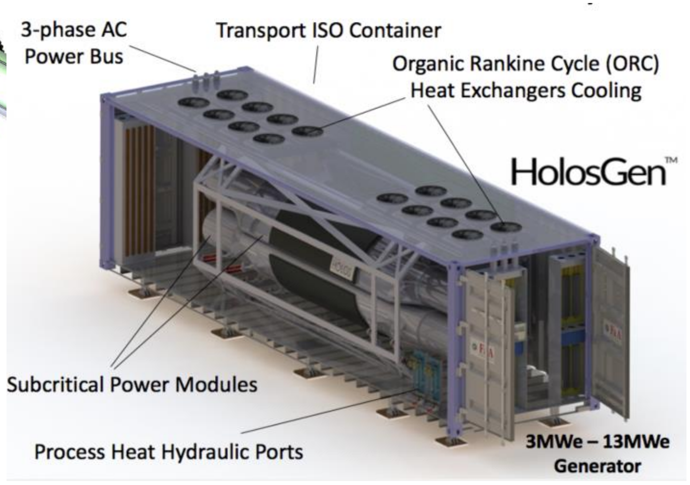
Micro-Rx Systems











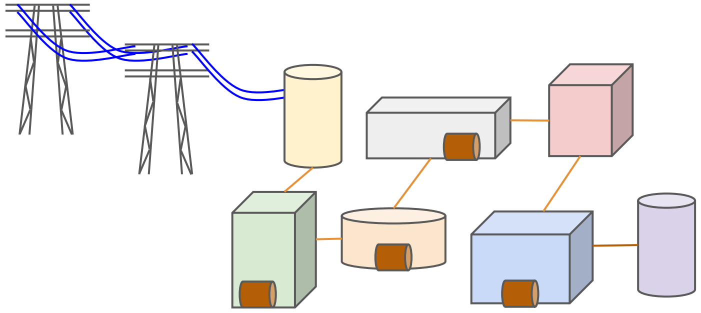
Task 3: Economic Analysis

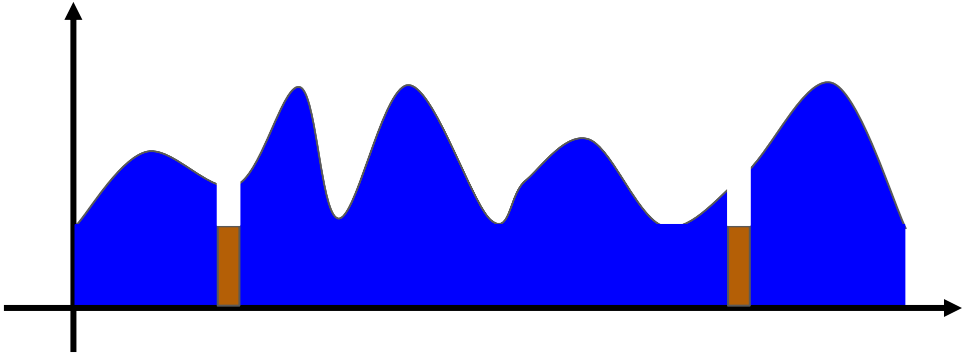
- Developed a set of cases to consider for analysis
  - Status quo
  - On-site generators for critical load with backup
  - On-site generators for whole facility load with backup
- Considered all energy technologies to supply power
  - (Diesel, Natural Gas, Micro-reactor, Renewables + Storage)
- Gathered cost inputs from variety sources (e.g., NREL, EIA)
- Analysis using simple tool and optimization tool (Homer)

Scenarios Considered in Economic Analysis

Scenario #1: Status Quo

- Utility as primary supply of all electricity
- Diesel or fossil gas backup units for critical load



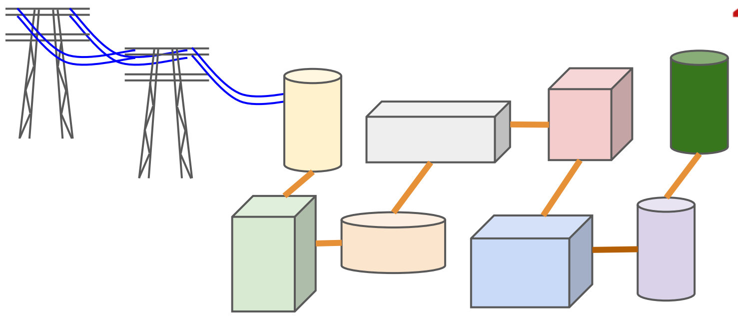


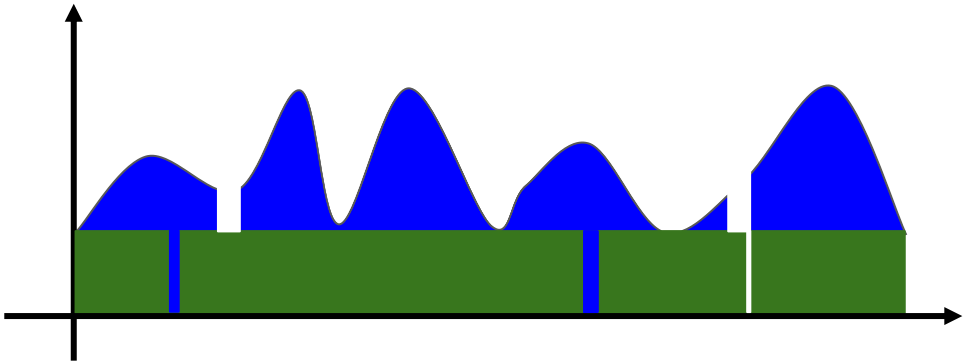
4 MWe average load
2 MWe critical load

Scenarios Considered in Economic Analysis

Scenario #2: Partially Decoupled

- On-site power for critical load
- Utility provides variable load
- Utility provides backup for critical load



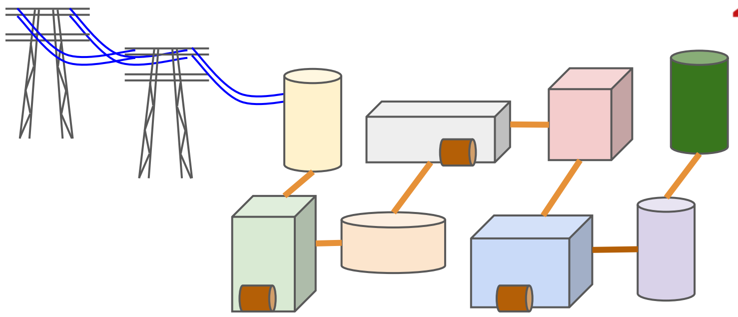


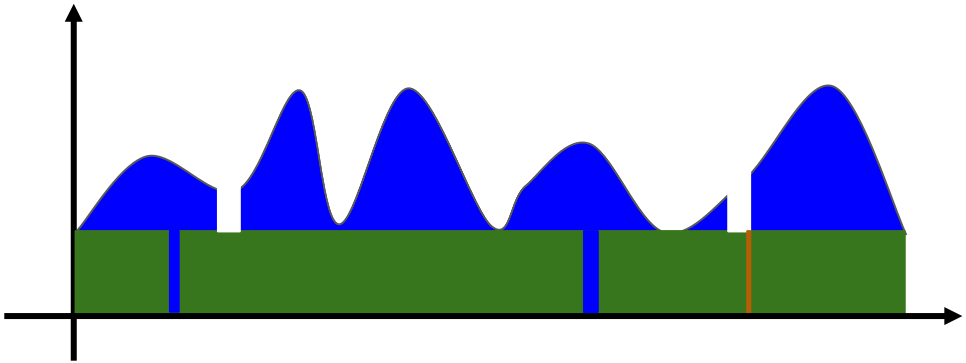
4 MWe average load
2 MWe critical load

Scenarios Considered in Economic Analysis

Scenario #3: High-reliability

- On-site power for critical load
- Utility provides variable load
- Utility provides backup for critical load
- Additional onsite backup



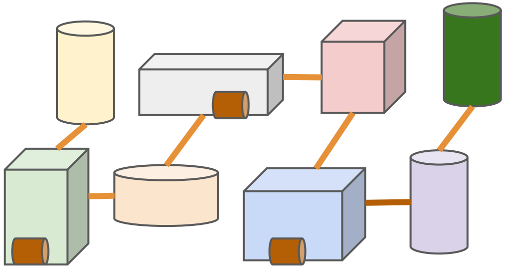


4 MWe average load
2 MWe critical load

Scenarios Considered in Economic Analysis

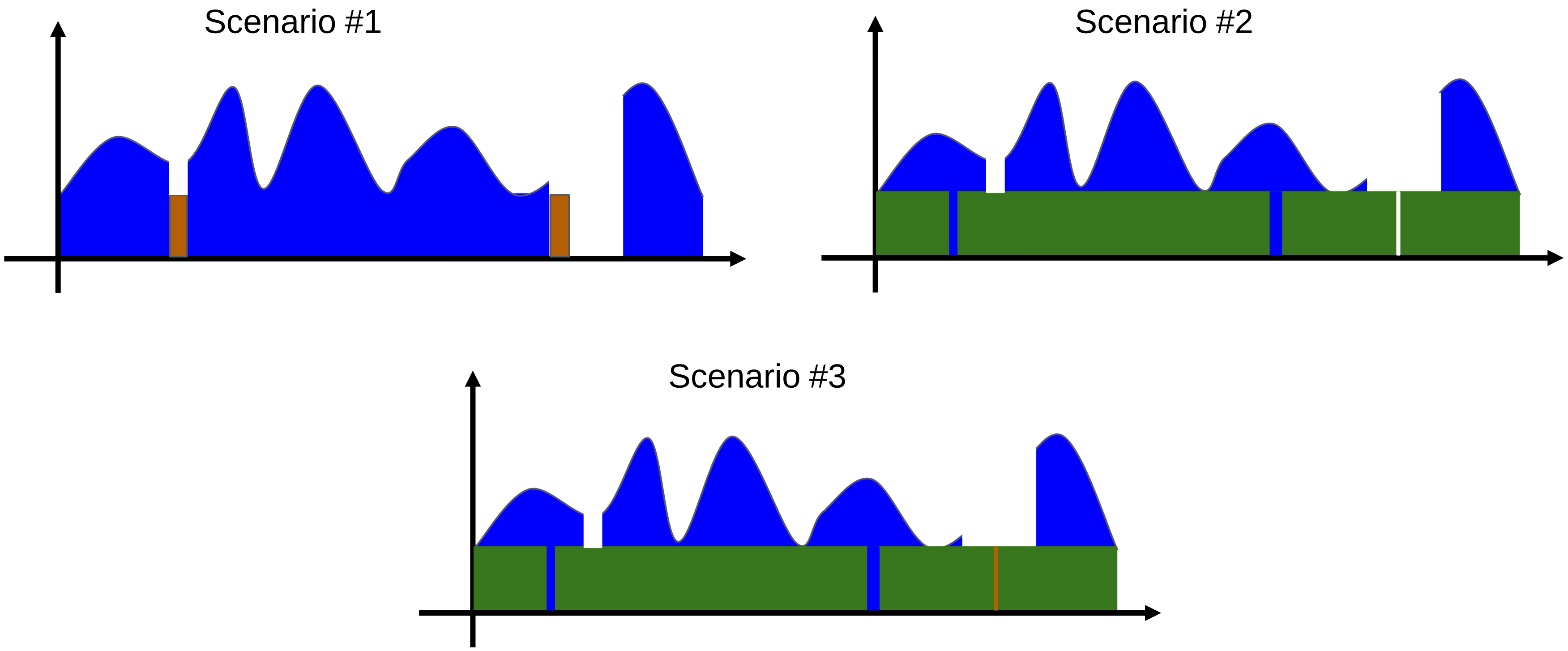
Scenario #4: Off-Grid

- On-site power for all load
- On-site backup power for critical load

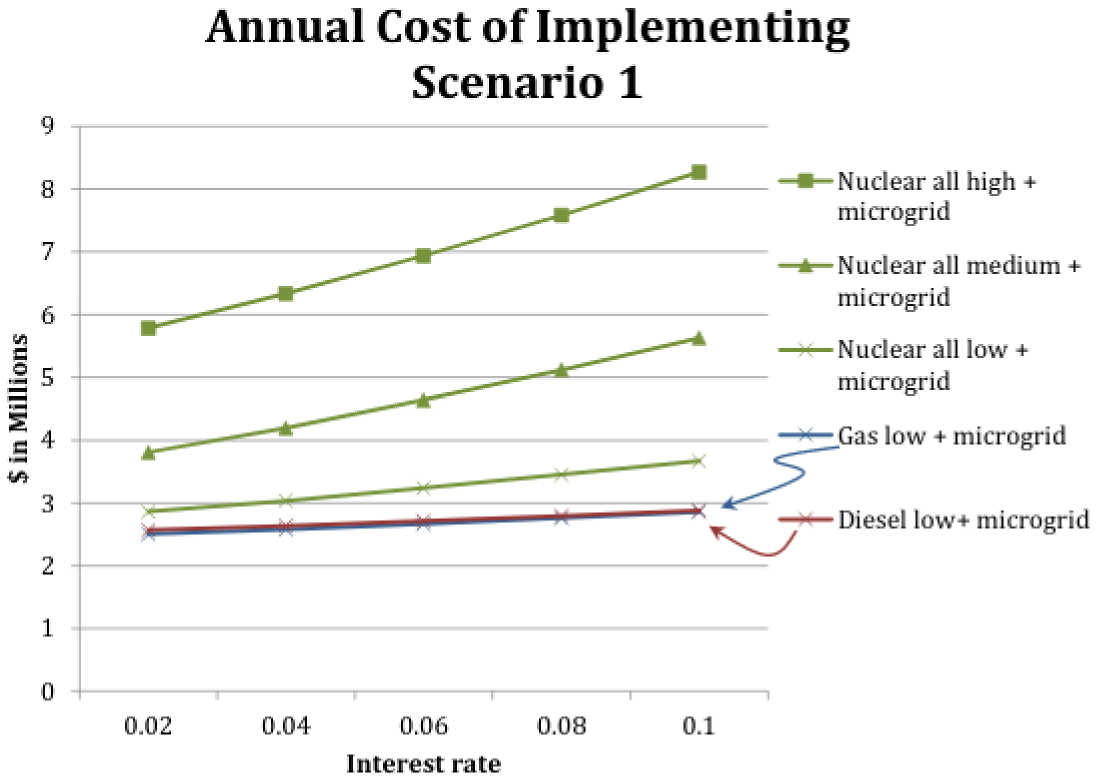


4 MWe average load
2 MWe critical load

Long Duration Outages

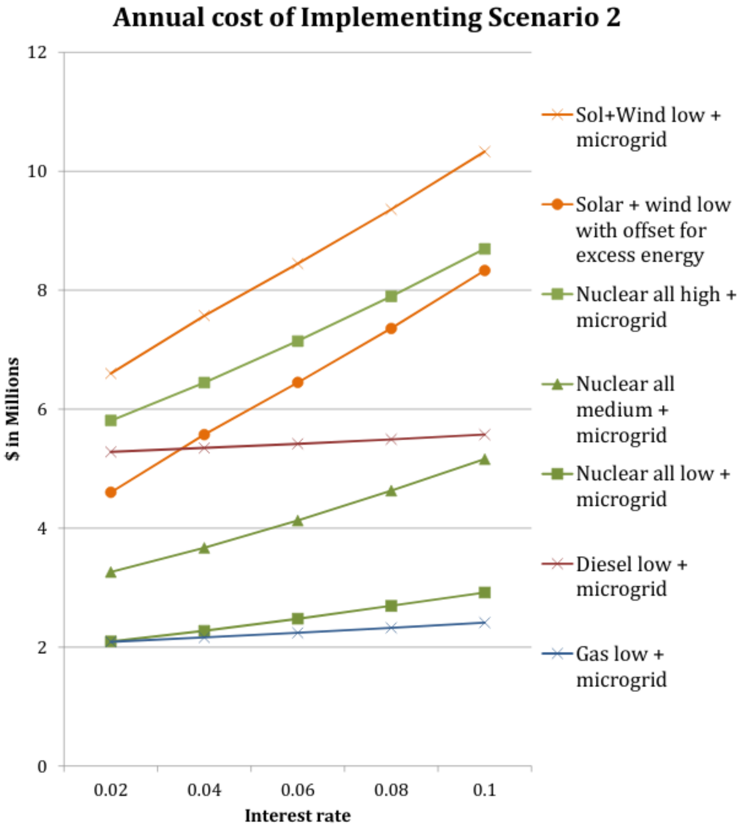


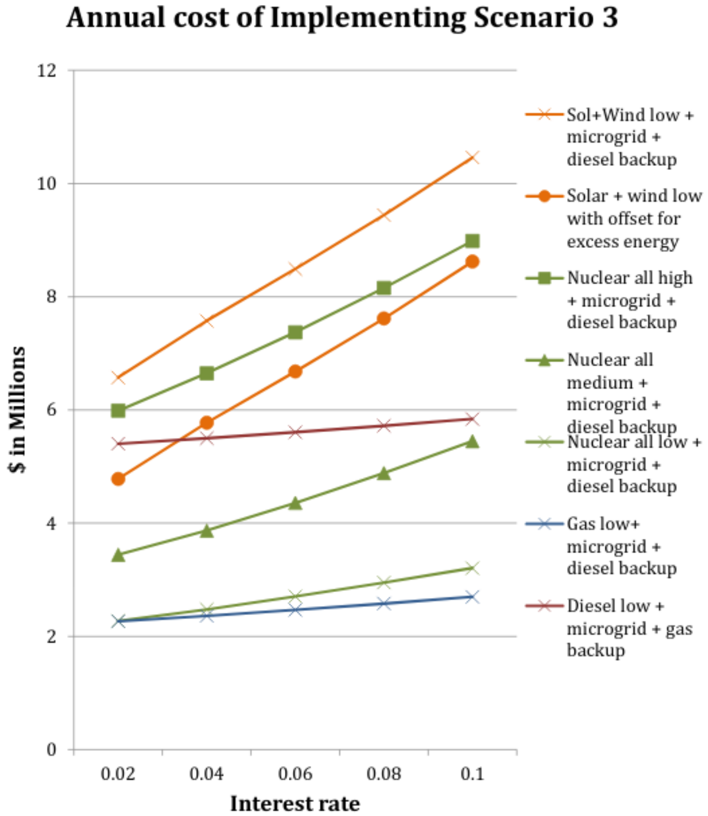
Scenario #1



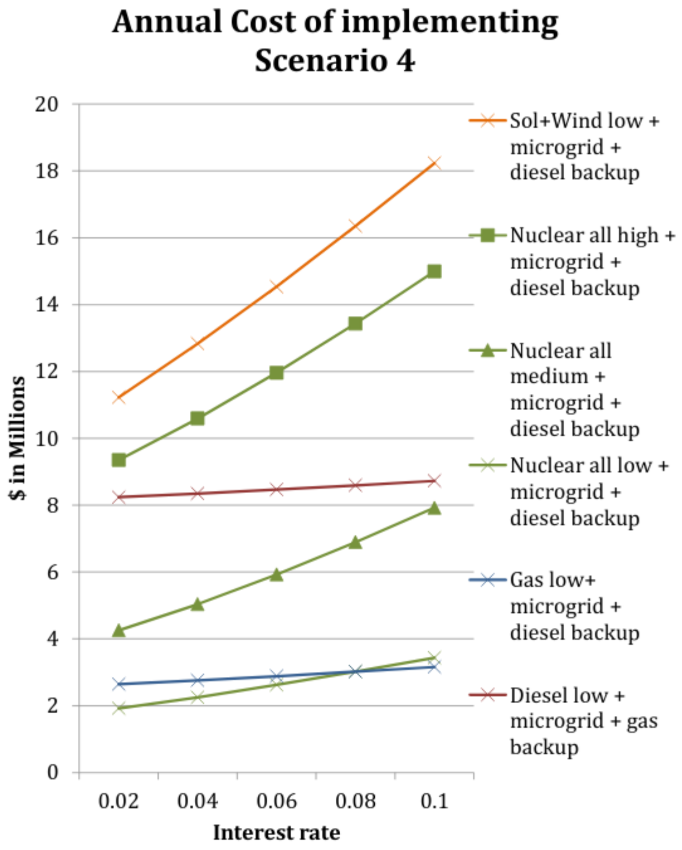
Annual Cost of Implementing Scenario 1
9
8
7
6
5
4
3
2
1
0
$ in Millions
0.02
0.04
0.06
0.08
0.1
Interest rate
Nuclear all high + microgrid
Nuclear all medium + microgrid
Nuclear all low + microgrid
Gas low + microgrid
Diesel low+ microgrid

Scenarios #2 & #3





Scenario #4


Annual Cost of implementing Scenario 4
$ in Millions
20
18
16
14
12
10
8
6
4
2
0
0.02
0.04
0.06
0.08
0.1
Interest rate
Sol+Wind low + microgrid + diesel backup
Nuclear all high + microgrid + diesel backup
Nuclear all medium + microgrid + diesel backup
Nuclear all low + microgrid + diesel backup
Gas low+ microgrid + diesel backup
Diesel low + microgrid + gas backup

"Green Site" Analysis

- Carbon-free off-grid (Scenario #4)
  - Allowed technologies: wind, solar PV, batteries, nuclear microreactor
- HOMER Microgrid Energy System Optimization Tool
  - Developed at NREL
  - Finds lowest cost combination of technologies to meet time-varying energy demand
  - Implemented microreactor module & dispatch algorithm
- UW-Madison load shape and climate conditions

"Green Site" Analysis

	Inputs		Outputs				
Case No.	Nuclear Costs	PV-Battery Costs	Nuclear Size (MWe)	PV Solar Size (MWe)	Battery Size (kWh)	Annual Level. Cost [A] ($ Mill/yr)	Levelized Cost of Electricity ($/MWh)
1	No nuclear	Best	0	122	220,000	17.8	510
2	Best [B]	Best	6.0	0	0	1.73	49
3	Medium [B]	Best	5.0	10.92	235	4.56	130
4	Medium [C]	Best	5.5	14.45	94	4.11	117
5	Medium [B]	Medium	5.5	0.83	7	4.83	138
6	Medium [B]	Worst	5.5	0.46	9	4.81	137
7	Worst [B]	Best	5.0	14.46	94	9.30	266

Note A: Annual Levelized cost of generation at 2% interest without Microgrid or Backup Costs included
Note B: Capital Cost Method for Nuclear Fuel Model – This is explained in Appendix I.
Note C: Continuous Feed Model for Nuclear Fuel Model – This is explained in Appendix I.

Task 4: Regulatory Issues

- Micro-reactor licensing likely to use NRC regulations
  - 10CFR 50 (CP + OL) or 10CFR 52 (DC + COL) could be used
- NEIMA required new license approach (Part 53) ongoing
  - Provide licensing flexibility: Traditional, Risk-informed, MCA bound
- There are current policy issues under consideration
  - Staffing requirements for operations/monitoring on-site or remote
  - External man-made hazards that need to be considered
  - Physical security requirements for the micro-reactor
  - Siting requirements near population centers
- Prototypes can demonstrate operability and safety

Task 5: Program Recommendations

- Milestone based research program with reasonable timeline that would result in confidence that a FOAK plant could be built for about $12,000/kWe
- A policy to coordinate building one or more FOAK demonstrations when there is confidence that the cost would be around $12,000/kWe
- Requires ability of Government to independently assess viability of achieving cost targets

Task 5: Program Recommendations

- If FOAK construction program indicates that NOAK costs of ~$4,000/kWe are achievable, Government should develop
  - An organizational approach that could manage the construction and operation of a large number of micoreactors
  - An appropriate financing mechanism that would provide the ability to recover revenues

- Even at low cost target, low financing costs are important
  - May require government ownership

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Questions?

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https://uwmadison.box.com/v/wi-microreactor-government

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