The Feasibility of Microreactors for Copper Valley Electric Association

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Introduction

In alignment with Copper Valley Electric Association's (CVEA) goal to provide affordable, safe, and reliable power to its membership while striving to reduce their reliance on fossil fuel generation [1], this study is an investigation into the potential for future integration of nuclear microreactors into their service area. CVEA has already excelled in this goal as their two hydroelectric generation projects, Solomon Gulch and Allison Creek, provide nearly 100% of the power generated in the summer months (June - September), and about 75% of their total annual generation. This is due to the decline of hydroelectric power generation in the winter months. The cogeneration plant is the primary source backed up with their two diesel generator plants, Glennallen Diesel Plant and Valdez Diesel Plant. Due to CVEA's interests in clean and reliable energy, they have done extensive studies over the years of different renewable power generation sources such as wind, biomass, and solar. The wind and biomass feasibility studies both showed that these were not functionally or economically viable generation sources in the Copper River Basin [2], hence the desire to continue searching for new alternative energy solutions.

Nuclear Power

Challenges

As with any new technology, there are challenges that need to be addressed. This holds true with new nuclear generation technology, especially when it's not yet commercially available in the United States. Although there are many matters to consider when exploring the feasibility of nuclear power generation, the five major issues are [3]:

- Cost
- Regulation
- Safety risks
- Waste issues / management
- Risk of contributing to nuclear weapons development

Due to the smaller size and upgraded passive safety designs of microreactors, they are expected to significantly reduce the waste and proliferation risks as compared to traditional nuclear power plants and therefore those two issues will not be discussed in this report. In this feasibility study cost will be the main driver, as it usually is, with some discussion on assumed updated regulation and safety issues that would directly affect the siting of a microreactor in CVEA's service area.

As there are no microreactors yet on the market, doing an accurate cost analysis proves to be extremely difficult. However, the Nuclear Energy Institute (NEI) has developed a cost model, with input from several microreactor developers, that will be used in this report [4]. Even though actual costs won't be known yet, and could fluctuate based on manufacturer and design components, it is believed that this model should give an educated estimate at this current time. Marcus Nichol, Senior Director of New Reactor Deployment at NEI, believes that the cost model assumptions are conservative and therefore should give a good approximation of the range of cost for examining different microreactor technologies [8].

Cost Model

In the NEI cost model, calculating the cost is broken up into five categories:

- overnight capital cost ($/kWe)
- fixed operations and maintenance ($/kWe)
- fuel cost ($/MWh)
- decommissioning cost ($/MWh)
- cost per refueling ($)

Additionally, within each of these five categories they have given a nominal value as well as a range of values for best-case and worst-case scenarios, all of which were included in the cost analysis. Furthermore, they included a range of values when incorporating a learning curve between a First-of-a-Kind (FOAK) reactor and an Nth-of-a-Kind (NOAK) reactor (in their example, N = 50). The three learning curve rates applied are 5%, 10%, and 15% with the lowest learning curve rate applied to the highest initial overnight capital cost estimate, and the highest learning curve rate applied to the lowest initial overnight capital cost estimate to maximize the range of values. It should also be noted that these learning curve rates were only applied to the overnight capital cost, as this is the "main driver of costs for microreactors," as stated in the report [4]. Lastly, site engineering and NRC licensing, which are historically high costs, as well as the initial fuel cost, are all included in the overnight capital cost calculation. All this information can be more easily illustrated in the attached spreadsheet (Source: Master Variable Doc spreadsheet).

Micro-reactors

For this cost analysis, I have highlighted four different microreactors to see if they will be economically feasible for CVEA: Ultra Safe Nuclear – Micro Modular Reactor (MMR), Westinghouse eVinci reactor, Holos Reactor, and the Oklo reactor. These were chosen because of their nameplate capacity and because they were also highlighted in a U.S. Department of Energy factsheet on advanced reactor types [5]. The information needed on these reactors to run them through the NEI cost model are reactor size (kWe), plant life (years), and core life (years). Much more information on these reactors (i.e. thermal output (MWt), fuel format, load-follow capability, etc.) is included in the attached spreadsheet (Source: Master Variable Doc spreadsheet).

Cost Analysis

In Excel, I created a cost modeling tool based on the information above that speeds up and simplifies the process of running different simulations with different sensitivities. In order to use my tool, the user is only responsible for six different inputs: name of reactor (drop-down menu), number of reactors (drop-down menu), annual generation you'd like to produce in kWh (which the tool then also converts to MWh), the capacity factor, type of financing (drop-down menu), and type of ownership (drop-down menu). This allows the user to run a cost analysis very easily for different situations and circumstances. After all the inputs have been put in, the result is a $/kWh which allows you to see if the microreactor will be able to generate power for cheaper than what you can currently produce it for. The tool was reviewed by Ilya Turchaninov (another ACEP intern) and George Roe (my ACEP supervisor for this project), as well as Darin Sauls (my supervisor at CVEA).

Microreactor Cost Tool

Safety

The Idaho National Laboratory (INL) is currently the only location that has been granted site use permits by the Department of Energy (DOE) for demonstrating advanced reactors - NuScale and Oklo. Since this is the only approved site for advanced reactors thus far, I will be using their siting evaluation criteria listed in two categories below - “must” and “want” [6]:

“Must” Criteria:

1. Must be located > 10 miles from an airport.
2. Must be in an area of < 0.5 G peak ground acceleration.
3. Must be located > 5 miles from surface faults and capable tectonic structures.
4. Must be located away from population centers of > 25,000 people.
5. Must be located > 5 miles from hazardous sites.
6. Must be located > 1 mile from a commercial rail line.
7. Must be located outside wetland areas.
8. Must be located outside of Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites.
9. Must be located outside of 100-year floodplain.
10. Must meet minimum reactor design requirements.

“Want” Criteria:

1. Avoid areas of surface-water flooding/ponding.
2. Maximize proximity to suitable sources of cooling water.
3. Minimize disturbance of the critical habitat of protected species
4. Avoid areas of high-predictive archaeology zones.
5. Minimize potential adverse interactions with existing programs.
6. Ensure appropriate security controls are available
7. Minimize distance from transportation routes.
8. Minimize distance to transmission lines.
9. Optimize use of Land Use planning zones.
10. Maximize use of updated seismic hazard analysis and site-specific characterization data.
11. Minimize proximity to faults and building on soil sites.

Beyond this siting criteria, large commercial nuclear power plants require a 10-mile safety perimeter whereas some of the microreactor manufacturers are claiming that they will only have a 300-400-yard safety perimeter [7]. If a microreactor were to become economically viable in CVEA’s grid, then this would be the initial criteria that would need to be met when looking for an appropriate site within their service area.

Recommendations/Conclusions

In conclusion, the analysis suggests that none of the four microreactors analyzed in the cost model will be economically viable for CVEA at this time. Currently, their load profile is too small, and their hydroelectric plants are too high yielding to justify spending the money on a microreactor to offset their diesel generation plants that only account for 6% of their annual generation. Although it doesn't seem that microreactors will be feasible for CVEA at this time, I do believe the study provides valuable insight on the conditions that need to be met in order to make them viable in CVEA's grid:

1. The microreactor would need to run constantly at a high capacity factor
2. There would need to be a use for the thermal energy
3. A best-case scenario situation would be the manufacturer of the microreactor running and operating the plant (as well as taking on all the risk) and going into a long-term contract with CVEA to purchase power at a rate less than what they pay now.

Currently, CVEA only generates about 6% of their power from their diesel plants which means if a microreactor were brought in it would not be running at a high capacity factor and would also be pretty much dormant during the summer because of the nearly 100% hydroelectric generation in those months. In this scenario, the capital cost and risk due to uncertainty of the microreactor would not be worth integrating into their grid. Here is a cost table for a single unit, running at 95% capacity factor, while only offsetting the diesel generation:

Microreactor	**Equivalent Uniform Annual Cost (EUAC)**	**$/kWh**
Ultra Safe	$5,570,454.20	$0.89
Westinghouse eVinci	$1,704,228.13	$0.27
Holos	$7,859,506.51	$1.26
Oklo	$2,004,789.15	$0.32

Additionally, here is a table which highlights the $/kWh for CVEA from 2019:

Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
0.2112	0.2272	0.2099	0.2006	0.1362	0.1188	0.1188	0.1188	0.1188	0.1188	0.1188	0.1891

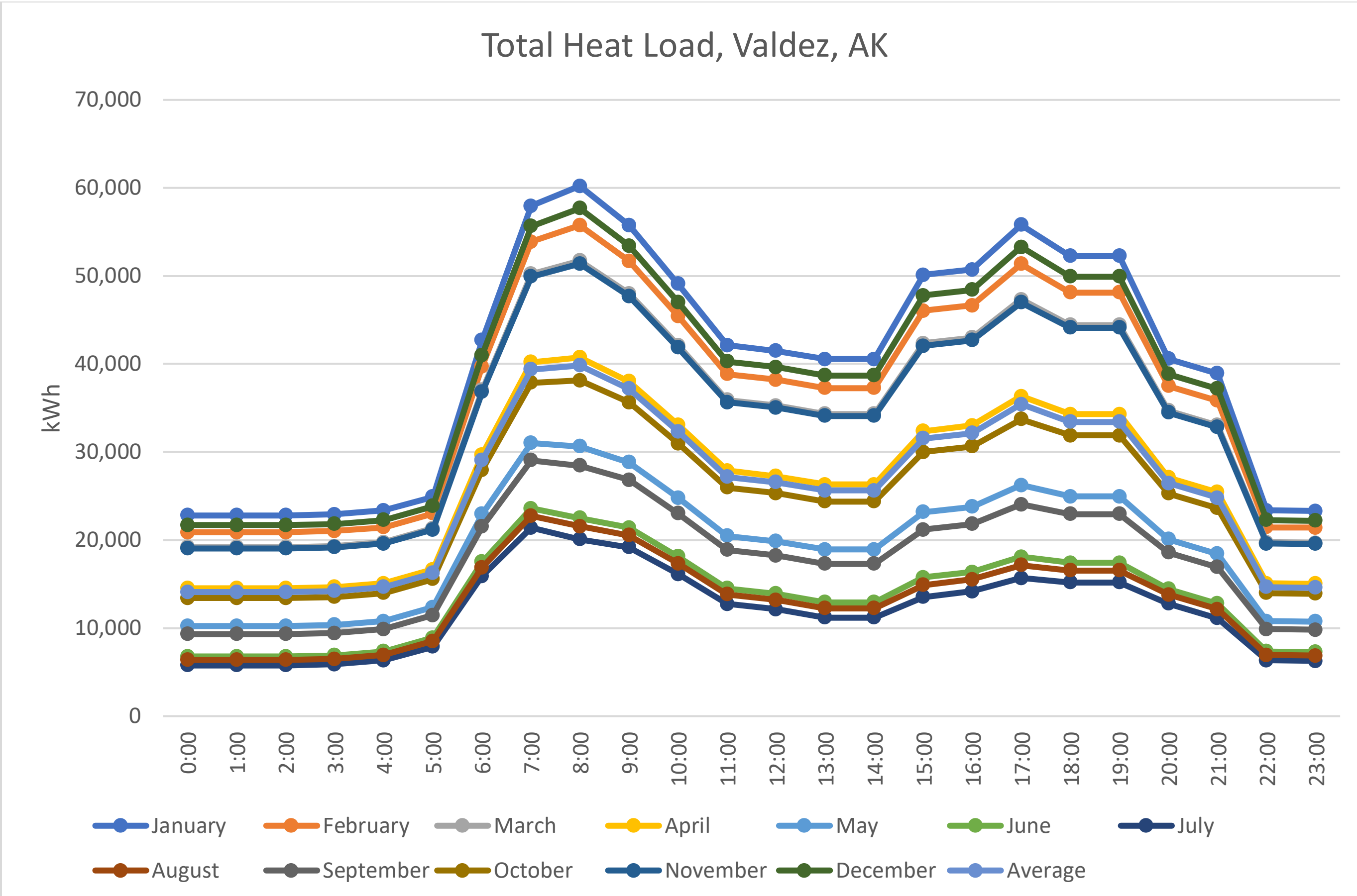
As you can see, for all four microreactors the $/kWh is still too high for the amount of kWh generated in order to make the cost feasible. Although the microreactor would offset the kWh generated from the diesel plants, it would only offset a small portion of the existing costs because these rates include the costs to operate and maintain generation and transmission facilities across CVEA's system; a nuclear project would add additional facilities without removing a comparable existing facility. Additionally, there would need to be a use for the thermal energy, nuclear power generation creates valuable heat and without a use for that heat, the integration of a microreactor does not make sense and CVEA does not currently have a use for that thermal energy. Finally, as mentioned above, in order to mitigate the risk involved with a new technology the best-case scenario for CVEA would be an outside party owning and operating the microreactor plant and selling them power for cheaper than they could produce it themselves. Another similar scenario would be a cogeneration plant agreement between a microreactor manufacturer, an industrial customer (that could use the thermal energy), and a local utility which would also reduce risk for the utility.

At this time, I recommend CVEA continue to watch the development of microreactors especially when the demonstration reactors at INL begin operation. Also, they should continue to keep an eye on regulations from the NRC as they are updated to fit microreactors. Lastly, I would suggest that they revisit the cost analysis for microreactors when/if some large industrial consumers come online in the area.

Thermal Load Profile

Due to the discovery that in order to make the cost of a microreactor sensible for CVEA there would need to be a use for the thermal energy, the next step was to develop a thermal load profile. This was done by utilizing a methodology outlined by George Roe [9]. To summarize this methodology, the thermal load is broken down into three categories: space heating, hot water, and wastewater. Furthermore, the space heating and hot water data is split up even further into residential and non-residential requirements. Data such as residential and non-residential heating fuel consumption, number of residential and non-residential buildings, and percent of residential heating fuel consumption per type is taken from the Alaska Affordable Energy Model (AAEM) [10] and used in the model. Additional information from the Alaska Energy Authority End Use Study: 2012 [11] is also used in estimating space heating and water heating requirements. It is important to note that the end use study is obviously from 2012 whereas data taken from the AAEM is from 2010 however it is the only information that was accessible for determining the thermal load. Our assumption is that since there hasn't been a huge shift in population and there aren't any new, large industrial customers that would greatly affect the load the values that we used should still give us an accurate estimate to work with. Below is a graph of the thermal load profile as well as an attached spreadsheet of the model.

CVEA Thermal Load Profile



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Resources

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