Microgrid Feasibility Study: Considering Renewable Energy Technology in Eagle, Alaska

Josiah Alverts

Alaska Power and Telephone, Alaska Center for Energy and Power

Author Note

Correspondence should be addressed to Josiah Alverts by email: mjalverts@alaska.edu

Abstract

This paper is a summary of the model and results from a feasibility study of the microgrid in Eagle, Alaska. This feasibility study's purpose was to investigate if there is any potential economic benefit to adding a battery energy storage system (BESS) and increasing the solar penetration in the microgrid. Eagle is serviced by Alaska Power and Telephone (AP&T), which currently uses three diesel generators and a 24 kW solar array to provide power to the area. The current solar array accounts for approximately 1-2% of annual power generation in Eagle, so increasing the solar penetration is needed to see a large impact on fuel reduction. Reducing annual fuel consumption for the diesel generators is the key factor to compare against the capital expenses of adding renewable energy technology, because fuel heavily influences the cost of electricity for customers in Eagle. Due to the complexity of integrating an intermittent energy source like solar into a grid, a BESS needs to be installed in Eagle along with any additional solar generation capacity. A BESS has the capability to stabilize a grid similar to how a diesel generator does, which means solar power generation can be used to power the grid without worry of blackouts caused by instability. This feasibility study was conducted using the software XENDEE.

Keywords: solar, battery energy storage system, XENDEE

Microgrid Feasibility Study: Considering Renewable Energy Technology in Eagle, Alaska

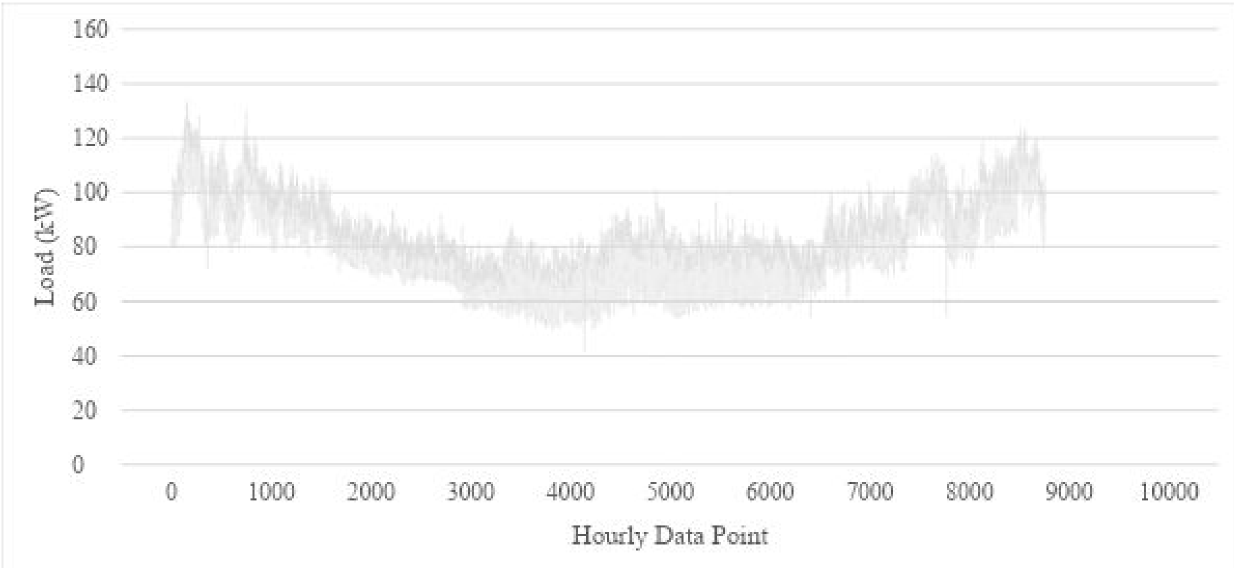
The process for this study involved three main steps: developing a baseline economic model of Eagle in the XENDEE platform as accurately as possible, estimating the variable costs and renewable technology sizes that were considered for the study, and executing optimization trials using XENDEE. Developing the baseline economic model involved gathering data from AP&T records and adjusting XENDEE until the output closely matched AP&T's data for Eagle's annual operating costs. Likewise, the different capital costs for technology used in the study were determined using AP&T's information as a starting point. Different sizes of solar generation were used in the study at 50 kW increments to serve as benchmarks for a wide range of power generation strategies. A more advanced analysis based on the technical needs of the system is needed to determine exact sizing if equipment is going to be installed. However, the size of the BESS in each trial was determined by the XENDEE software for optimal capacity.

Baseline Model

Creating an accurate model of the current microgrid in Eagle is an important first step before executing optimization trials because it ensures a more meaningful comparison can be made with trial results. If the baseline model accurately represents the Eagle grid, then any promising results are more likely to carry over to success in real life. The first part building of the baseline model involved creating an annual load profile for Eagle from AP&T data. The load profile uses data points at intervals every hour, taken from AP&T's SCADA logs. The load profile was composed of data primarily from 2019, but some missing sections from connection outages were filled in with data from 2018.

Figure 1

Eagle Load Profile



Note. Hourly data starts at point 1 on January 1st 12:01am, and ends at point 8760 on December 31st 11:01pm.

The next part of baseline model development involved filling out the input that is requested by XENDEE in the software's interface. This includes fuel prices, specifications for each diesel generator, and specifications for the solar and battery technologies. The table shown below contains the fuel prices used for the baseline model. Current fuel prices are historically low, so the year 2019 was used to determine the baseline model prices because they reflect a more accurate historical average.

Table 1

Baseline Model Fuel Prices

Winter Fuel Prices ($/Gal)	Summer Fuel Prices ($/Gal)
2.77	2.77

Note. These prices are an annual average taken from AP&T invoices in 2019

Unlike the load profile and fuel prices, the input for the diesel generators was not based closely on data from AP&T. The only data from AP&T that was used for the engines was annual fuel consumption[1] and replacement cost for each. The standard diesel generator model that XENDEE provides is reasonably accurate; so only two input values were changed from the standard for each engine, the nameplate efficiency and the minimum load percentage. See Appendix A for the tables of complete diesel generator input. The nameplate efficiency was altered until the annual fuel consumption of the engines closely matched AP&T's data, and the minimum load percentage was adjusted to 25% to reflect as close to a realistic minimum load cutoff as possible without dropping below the lowest value in the load profile. The annual low load value in the load profile is 41.3 kW, which is uncharacteristically low but was left in the load profile to make sure any feasible solutions would be able to perform without failing for a wider range of situations. The replacement costs for the engines came from an estimate provided by an AP&T member, which includes the labor costs to install a new engine and redo fuel plumbing lines.

The model for the existing solar array in Eagle was based on a combination of AP&T data and XENDEE simulation. The solar panel specifications, like panel type, tilt angle, array type, and system losses shown in the table below were adjusted until the simulated solar performance in XENDEE matched the theoretical annual output of the 24 kW solar array. The theoretical annual output for the existing installation is 3.4%, which is above actual performance.[2] The component costs shown in the table were taken from the AP&T cost report for the project.[3] The solar price in $/kW was determined using the section of the report labeled "procurement costs" divided by the 24 kW that were purchased, while the installation cost was determined using the section labeled "installation."

Table 2

Solar Input For 24 kW Array

Panel Type	Standard	O&M ($/kW/month)	7.6
Tilt Angle (degrees)	65	Installation ($)	148439.68
Array Type	Fixed Axis	Existing Size (kW)	24
System Losses (%)	14	Existing Age (years)	5
Inverter Eff (%)	96.2	Investment Tax Credit (%)	26
Inverter ($/kW)	0	Amt Depreciable (%)	85
Inverter Life (years)	10	MACRS Years	5
Solar ($/kW)	3765.3	Technology Decision	Existing
Solar Life (years)	25	Available Space (sqft)	13984

Note. Inverter cost is included in the Solar cost

Operation and maintenance (O&M) costs for the solar array were determined from an AP&T presentation that reports only 20 hours of labor required to service the panels annually.[2] The available space value was determined by drawing on the XENDEE GIS interface, filling in the spaces that were considered for placement of the existing array but were not chosen. This parameter does not affect the baseline but was a factor to consider when additional solar generation was considered later.

Variable Costs and System Sizes

The scope of this feasibility study is very broad, since economically feasible prices and the desired renewable technology sizes are both unknowns. In order to have effective optimization trials that systematically investigated a wide possibility of solutions, a set of variables was created for use in the trials. The first group of variables consisted of prices for fuel, solar, and BESS components.

Table 3

Variable Costs

Gas Prices ($/gal)	Solar Prices ($/kW)	BESS Prices ($/kWh)
2.77	3765.3	2500
3	3000	2000
3.5	2500	1500
-	2000	-

The price value for gas and solar starts at the same point that was used for the baseline model, and then incrementally approaches prices that might be possible in the future and would be more likely to result in a feasible solution. The BESS price starts at a value that is an average of several quotes AP&T received for another project. It is worth noting that some of the quotes used in the average included climate controlled units for the BESS and some did not, but inverters are assumed to be included in all.

In addition to considering several different price points for fuel, solar, and a BESS, a set of variables for different sizes of diesel generators and solar arrays was used for the trials. The different generator size is a variable because a smaller generator would use less fuel and integrate better into running simultaneously with solar power generation. However, the cost of resizing the generator was not considered in the study. The table below shows the different technology sizes that were used for the optimization trials.

Table 4

Variable Technology Sizes

Generator Capacity (kW)	Total Solar Capacity (kW)
175	50
125	100
-	150
-	200

Note. The cost of resizing a 125 kW from the existing 175 kW generators was not considered

Also, the capacity of the BESS system was not considered as a variable because it was selected as a variable within XENDEE to be optimized by the XENDEE engine. The input for the BESS used most of the standard values provided by XENDEE. The exceptions are the system lifetime, which used twenty years so that replacing the BESS was not a factor in the twenty year period used for the optimization. A twenty year lifetime is also consistent with some of the quotes AP&T received, although the inverter lifetime may be less in reality. The input used in XENDEE for BESS consideration is shown below.

Table 5

BESS Input

System Life (years)	20	Discharge Efficiency (%)	90
Li-ion or Flow	Li-ion	Discharge C Rating	0.3
System Installation ($)	-	Discharge SOC (%)	5
Inverter Cost ($/kW)	-	Existing Size (kWh)	-
Energy Modules ($/kWh)	N/A	Age (years)	-
Discrete Module Size (kWh)	1	Max New Size (kWh)	-
O&M ($/kWh/month)	0.836	Investment Tax Credit (%)	26
Charging Efficiency (%)	90	Amount Depreciable (%)	85
Charge C Rating	0.3	MACRS Years	5
Charge Max SOC (%)	100	Technology Decision	Consider

Note. Energy Modules price changed for each trial since it is a variable for the study

Optimization Trials

With every possible value for each of the variables just described, there are a total of 288 unique trials. As a result, the trials were started from prices that were most likely to result in feasible solutions in order to conduct the study efficiently. Starting from the scenarios with the cheapest technology costs and highest fuel costs, optimization trials were run in groups of eight to include all solar capacity sizes run with each diesel generator size option. The XENDEE optimization program was left to determine the optimal BESS capacity as the final parameter.

The figures below show an example of the results for trial one. See the Appendix B for figures of the rest of the trials. The optimization trials were run until the point of breakeven costs.

Figure 2

Trial #1: Total Savings Relative to Baseline at 2000 $/kW Solar Cost

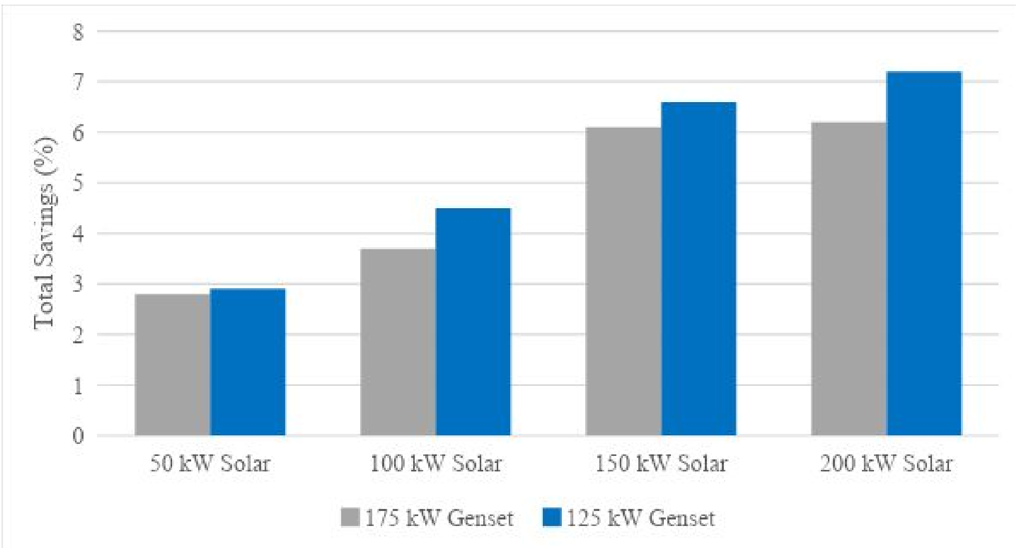
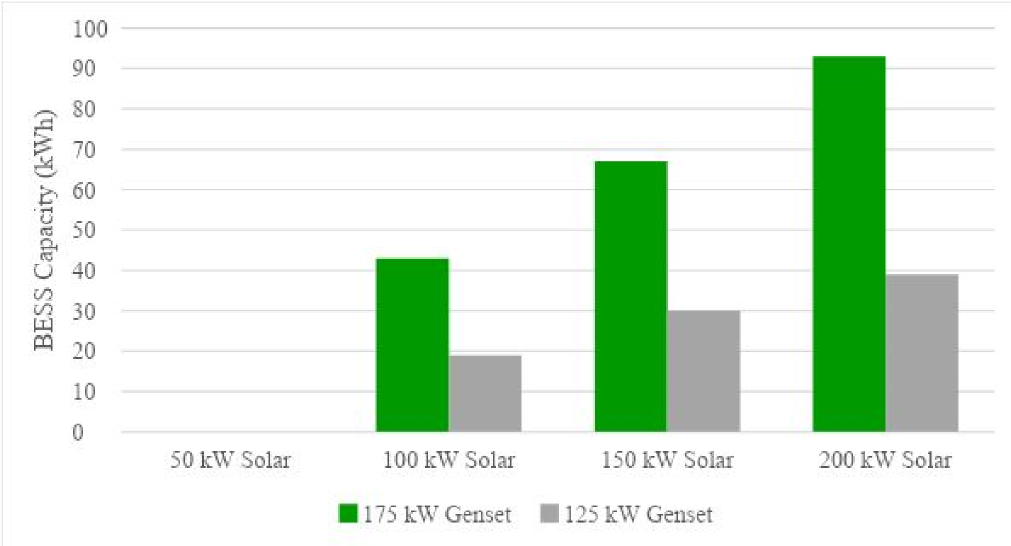


Figure 3

Trial #1: BESS Capacity Results at 1500 $/kWh Cost



Note. The 50 kW Solar size trial optimized with no BESS

Based on the figures for trial number one, the total savings compared to the baseline model plateau once 150 kW of solar has been installed. This can be seen in the results for all the different trials as well. Another trend is that the savings are higher, and the optimized BESS capacity is smaller, for all results with the 125 kW generator option. The higher savings is likely due to the reduced fuel consumption from the smaller sized engine, while the smaller BESS capacity is likely from ability of the smaller generator to run at lower kW values before reaching a minimum load cutoff. Results for trial number four showed a dramatic jump in savings for the larger solar capacity options, this is because the flat installation fee that was included in that trial was not adjusted for the larger arrays to be the same amount relative to the size of the solar array.

Conclusion

While the figures from the results did show that there were savings from investments for each technology size and option, none of the solutions are realistically feasible. First, the fuel price used for the optimization was $3.50/gal. While the optimization was for a twenty year period, which does leave time for fuel prices to increase in the future, $3.50/gal does not reflect current fuel prices closely. The renewable technology prices used in the study are also lower than current prices available for Alaska. According to a study from the National Renewable Energy Laboratory prices for utility scale battery storage could decrease up to 52% by 2025, which would likely bring prices into the realm of feasibility (Cole & Frazier, 2019). But it is yet to be seen if prices will decrease this dramatically.

Another consideration of this study is that most of the trials did not include installation costs. Trial number four did include installation costs to examine more realistic capital expenses, but the installation cost was still lower than a true installation project. Other economic metrics in the XENDEE results like return on investment, internal rate of return, and net present value usually showed negative values until about the 20th year as well. Even with the very generous pricing used for the trials in this study, no solution was found that would be a clear, reliable, or wise investment in the real world.

In order for an investment in renewable energy components to be feasible, the target price for the technology components should account for the cost to install the project. Based on trends from the results of this study, prices need to be below 1500 $/kW for solar components and 1500 $/kWh for BESS components for a project in Eagle to be considered.

Acknowledgements

This study was conducted with support from the Alaska Center for Energy and Power, the University of Alaska Fairbanks, and Alaska Power and Telephone through the ACEP Utility Internship program. I would like to thank my supervisors from ACEP and AP&T who provided insight and feedback that greatly assisted the research.

I would also like to thank Mickey Henton, Jeff Rice, and David Chamberlain for providing information from AP&T relevant to the study.

References

Cole, W., Frazier A. W. (2019). Cost Projects for Utility-Scale Battery Storage. *National Renewable Energy Laboratory*, 13. https://www.nrel.gov/docs/fy19osti/73222.pdf

Footnotes

1. See "2019 Eagle Fuel Invoices.pdf"
2. See "2016 REC Eagle Solar.pdf"
3. See "Eagle Solar EAS1301-1304 Total Costs.pdf"

Appendix A

Table A1

Cummins L10A10-C Input

Nameplate Efficiency (%)	29	Activation Demand (kW)	-
Sprint Rating (kW)	175	Min Up/Down Time (hrs)	-
Sprint Hours (hrs)	-	Emissions (kgNOx/kWh)	0.0068
Min Annual Hours (hrs)	-	Nox Treatment Cost ($/kW)	-
Max Annual Hours (hrs)	8760	# Generators	1
Min Load (%)	25	Existing Age (yrs)	4
Variable O&M Costs ($/kWh)	0.012	Lifetime (yrs)	35
Fixed O&M Costs ($/kW)	-	Purchase Price ($)	90020
Ramp Up Rate (%/min)	1.7	Capacity Rating (kW)	175
Ramp Down Rate (%/min)	1.7	Technology Decision	Existing

Table A2

Cummins L10A10-G Input

Nameplate Efficiency (%)	29	Activation Demand (kW)	-
Sprint Rating (kW)	175	Min Up/Down Time (hrs)	-
Sprint Hours (hrs)	-	Emissions (kgNOx/kWh)	0.0068

Min Annual Hours (hrs)	-	Nox Treatment Cost ($/kW)	-
Max Annual Hours (hrs)	8760	# Generators	1
Min Load (%)	25	Existing Age (yrs)	10
Variable O&M Costs ($/kWh)	0.012	Lifetime (yrs)	35
Fixed O&M Costs ($/kW)	-	Purchase Price ($)	90020
Ramp Up Rate (%/min)	1.7	Capacity Rating (kW)	175
Ramp Down Rate (%/min)	1.7	Technology Decision	Existing

Table A3

John Deere 6101AF010 Input

Nameplate Efficiency (%)	29	Activation Demand (kW)	-
Sprint Rating (kW)	180	Min Up/Down Time (hrs)	-
Sprint Hours (hrs)	-	Emissions (kgNOx/kWh)	0.0068
Min Annual Hours (hrs)	-	Nox Treatment Cost ($/kW)	-
Max Annual Hours (hrs)	8760	# Generators	1
Min Load (%)	25	Existing Age (yrs)	8
Variable O&M Costs ($/kWh)	0.012	Lifetime (yrs)	35
Fixed O&M Costs ($/kW)	-	Purchase Price ($)	90020
Ramp Up Rate (%/min)	1.7	Capacity Rating (kW)	180
Ramp Down Rate (%/min)	1.7	Technology Decision	Existing

Appendix B

Figure B1

Trial #2: Total Savings Relative to Baseline at 2000 $/kW Solar Cost

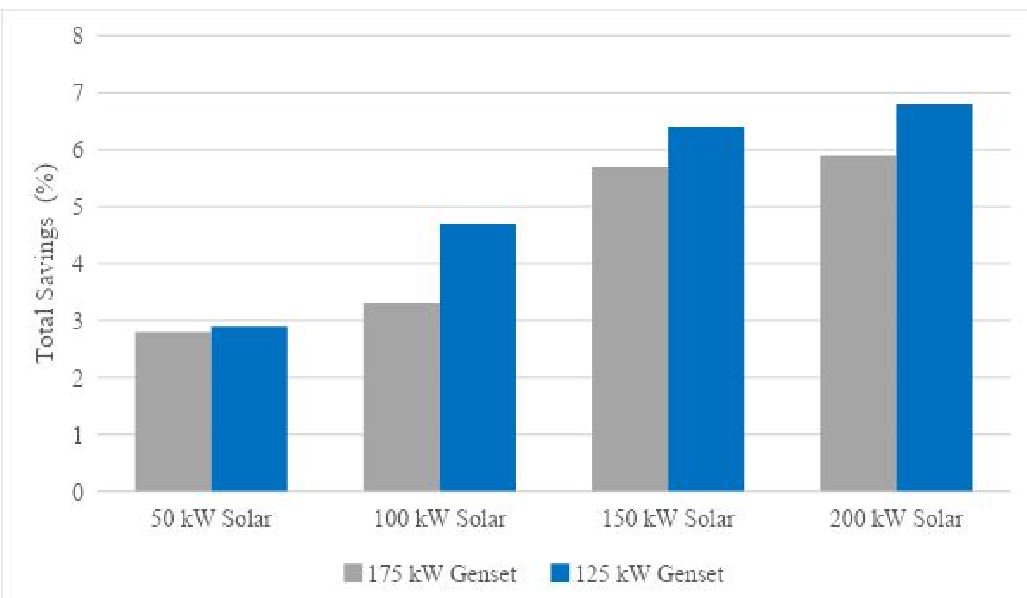
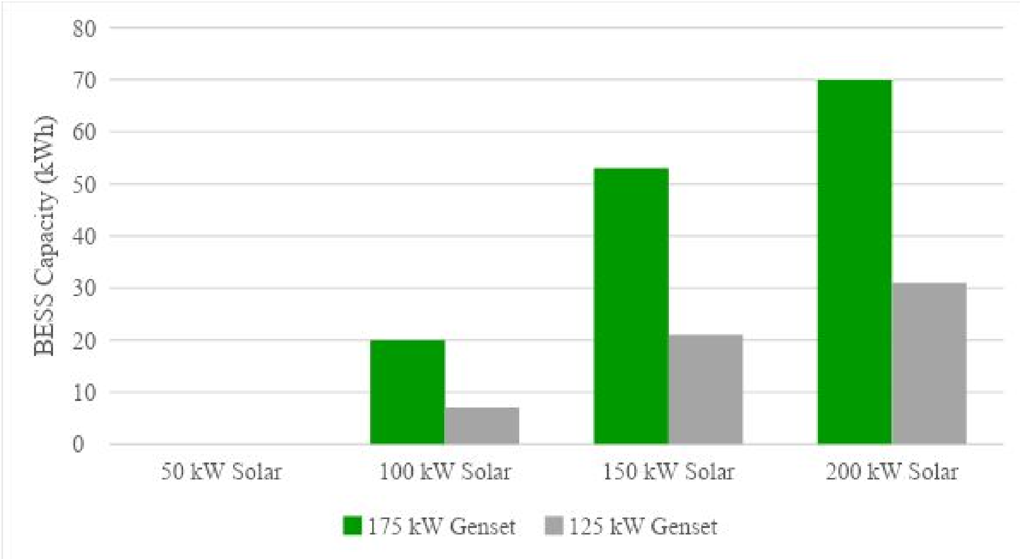


Figure B2

Trial #2: BESS Capacity Results at 2000 $/kWh Cost



Note. The 50 kW Solar size trial optimized with no BESS

Figure B3

Trial #3: Total Savings Relative to Baseline at 2500 $/kW Solar Cost

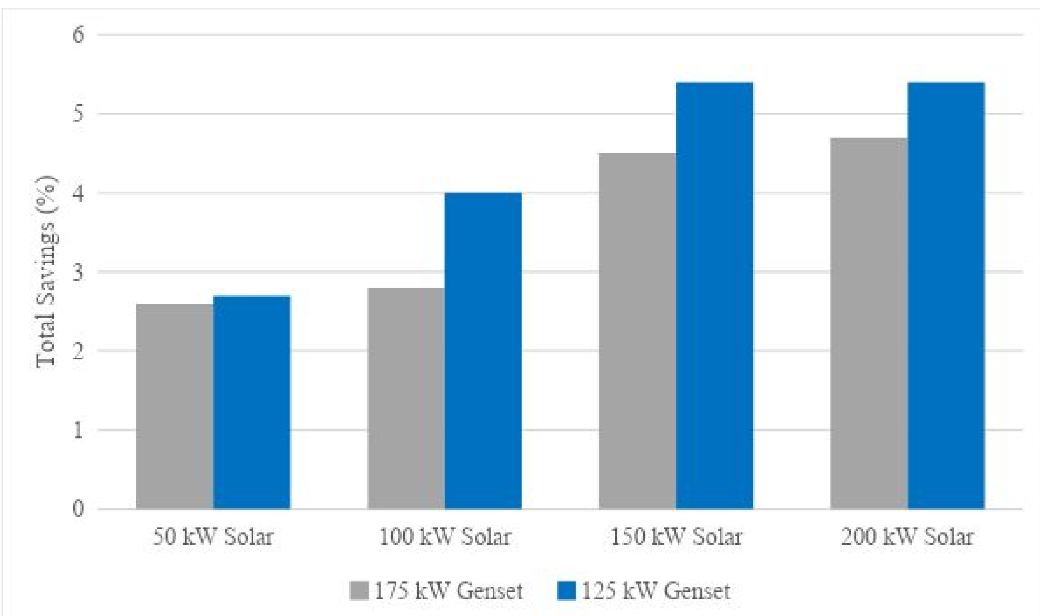
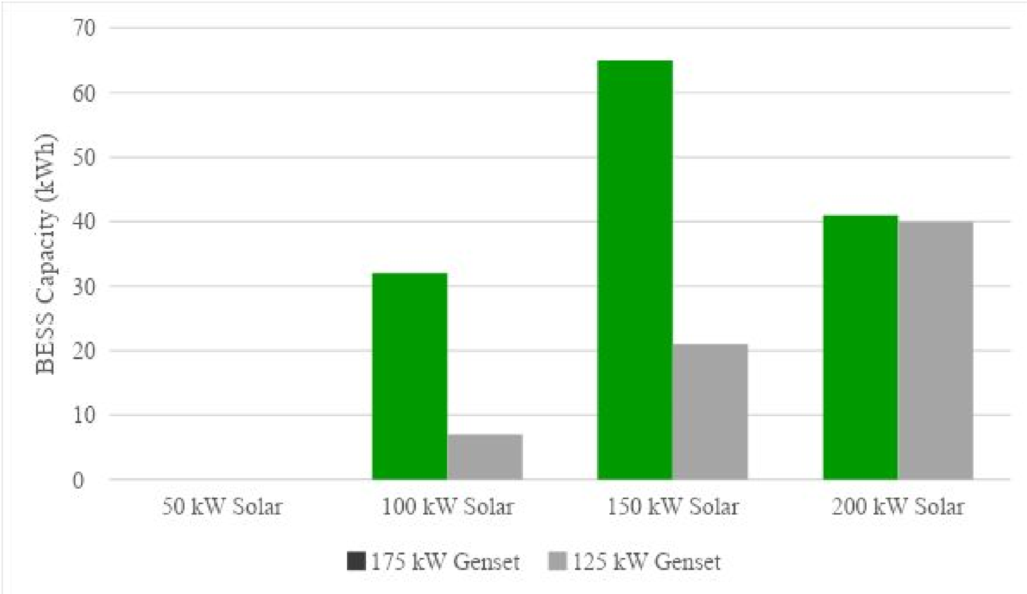


Figure B4

Trial #3: BESS Capacity Results at 2000 $/kWh Cost



Note. The 50 kW Solar size trial optimized with no BESS

Figure B5

Trial #4: Total Savings Relative to Baseline at Solar Cost (2500 $/kW + $150,000 Installation)

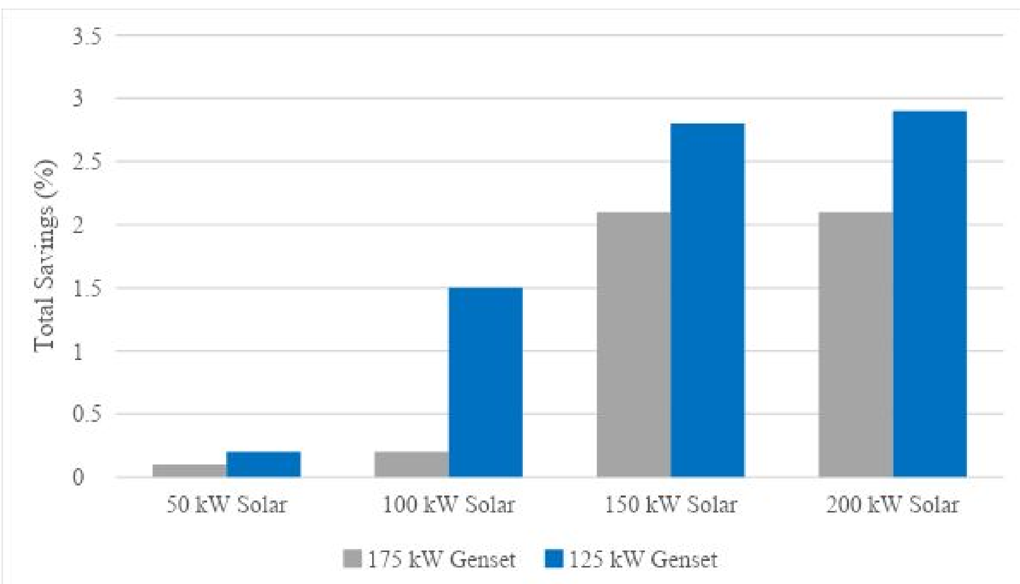
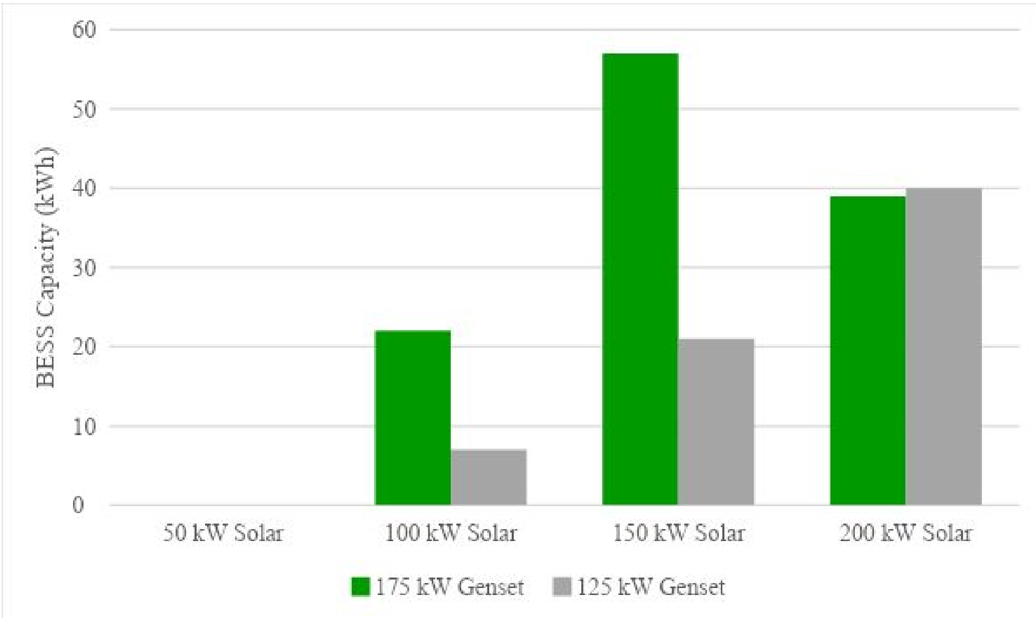


Figure B6

Trial #4: BESS Capacity Results at 2000 $/kWh Cost



Note. The 50 kW Solar size trial optimized with no BESS