Techno-Economic Analysis of a Proposed Nuclear Renewable Hybrid Energy System in Nome, AK

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Nome's Energy Status[1,2]

- Isolated microgrid
- Energy resources
  - 2.7 MW wind
  - 5.2 MW diesel
    - Potential 2 MW geothermal
    - Potential 5-10 MW nuclear
- Energy demand
  - 6 MW peak
  - 4 MW average

Alaska map[3]

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2019-20 Nome Energy Statistics[4]

Diesel Generated & Purchased [kWh]	Non-Diesel Generated & Purchased [kWh]	Total [kWh]
29,374,743	2,186,915	31,561,658

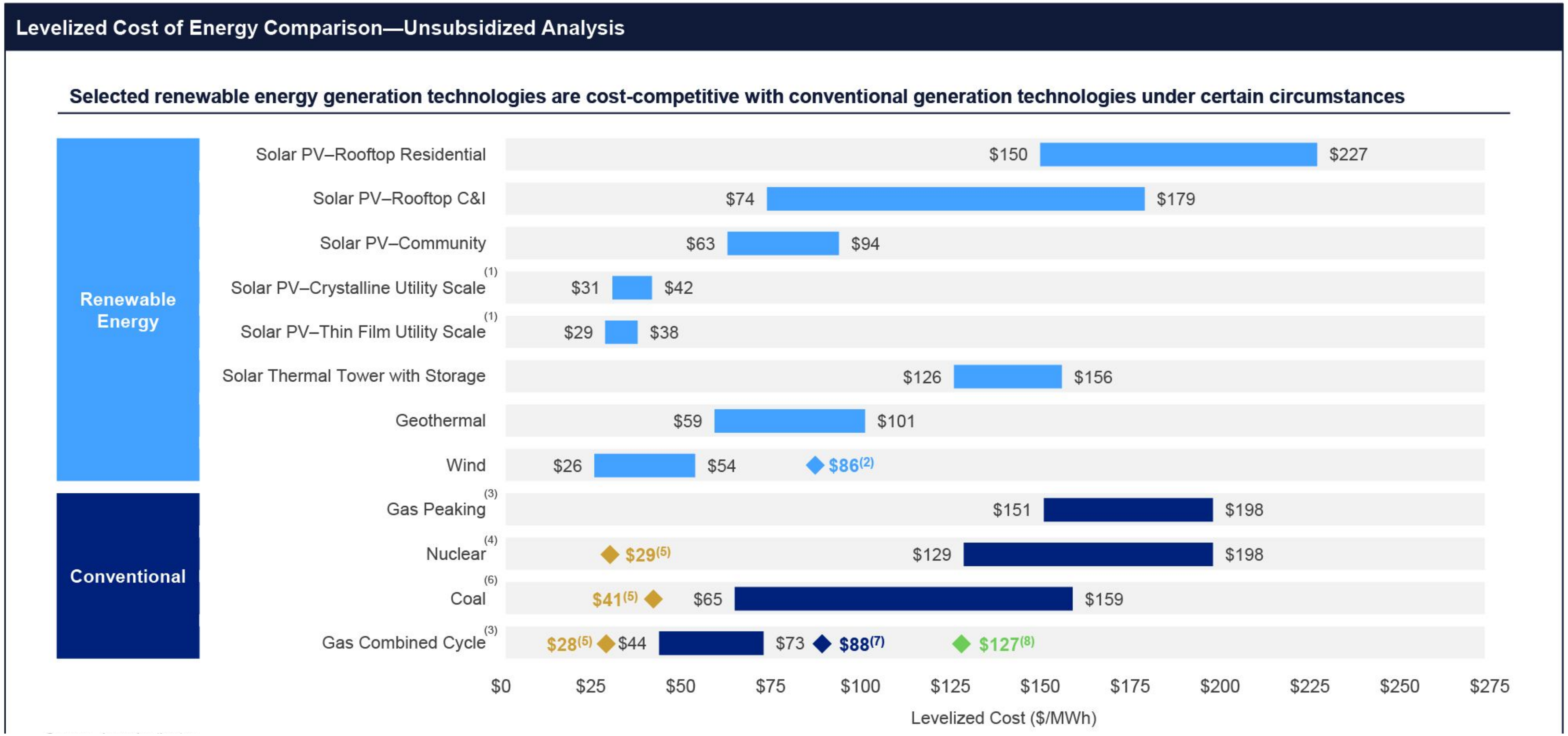
Annual Fuel Costs	Annual Non-Fuel Costs	Total
$4,512,210	$7,081,890	$11,594,100

Energy Costs in Perspective

- Residential rate[4]: 41¢/kWh
- Power Cost Equalization (PCE) rate[4]: 19¢/kWh
- PCE Subsidy: 22¢/kWh

- Alaska Housing Finance Corp[5]:
  - Nome, AK average annual energy cost 2.78x national average, 1.81x Alaska avg.

Levelized cost of Energy Comparison[6]



Motivation

- Find cheaper energy options for Nome
- Advanced nuclear needs to prove its economic competitiveness[7,8]
- Replace existing diesel with advanced nuclear
  - CO_2 emission goals
    - Nuclear-renewable hybrid energy systems (NRHESs)

Design Objective

- Determine if an NRHES deployed within an existing microgrid in Nome, Alaska is economically competitive with current fossil fuel-based energy generation technologies.
  - If not, determine how economic indicators must change in order for the NHRES to become viable.

Technical Approach

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To achieve the objectives of the Techno Economic Analysis, two types of software will be utilized: Renewable Energy Integration and Optimization (REopt), and System Advisor Module (SAM).

REopt:

- Estimate of the Size (MW)
- Dispatch Strategy of the Chosen Technologies

SAM:

- Key economic figures of merit such as Net Present Value(NPV), Levelized Cost Of Energy(LCOE), and internal rate of return(IRR)

Technical Approach (cont.)

$$LCOE = \frac{\sum_{i=0}^{N} \frac{Costs}{(1+d)^i}}{\sum_{i=0}^{N} \frac{Production}{(1+d)^i}}$$

$$NPV = \sum_{i=0}^{N} \frac{R_i}{(1+d)^i}$$

$$LCOE = \frac{\text{Sum of costs over plants lifetime}}{\text{Sum of electrical energy generated over plant lifetime}}$$

d=discount rate, R=net cash flow

IRR= annual growth rate for investment

Mock Excel Inputs

Inputs	Nuclear
Size	1
Capacity Factor	0.92
OCC	6200
Fixed O&M	101
Variable O&M	2
Fuel Costs	7
Wholesale Electricity Price	60
Discount Rate	0.04
Plant Lifetime	80
Outputs	
Capital Cost (C_o)	-$6,200,000
Year One Cash Flow	
Year One Power Production	8059.2
Year One Income	$483,552
Year One Fixed Expenditures	-$101
Year One Variable Expenditures	-$16,118.40
Year One Fuel Expenditures	-$56,414.40
Year One Net Cash Flow	$410,918
NPV (Capital Cost * SUM of years)	-$4,708,410
Payback Period	42
Internal Rate of Return	
LCOE	82

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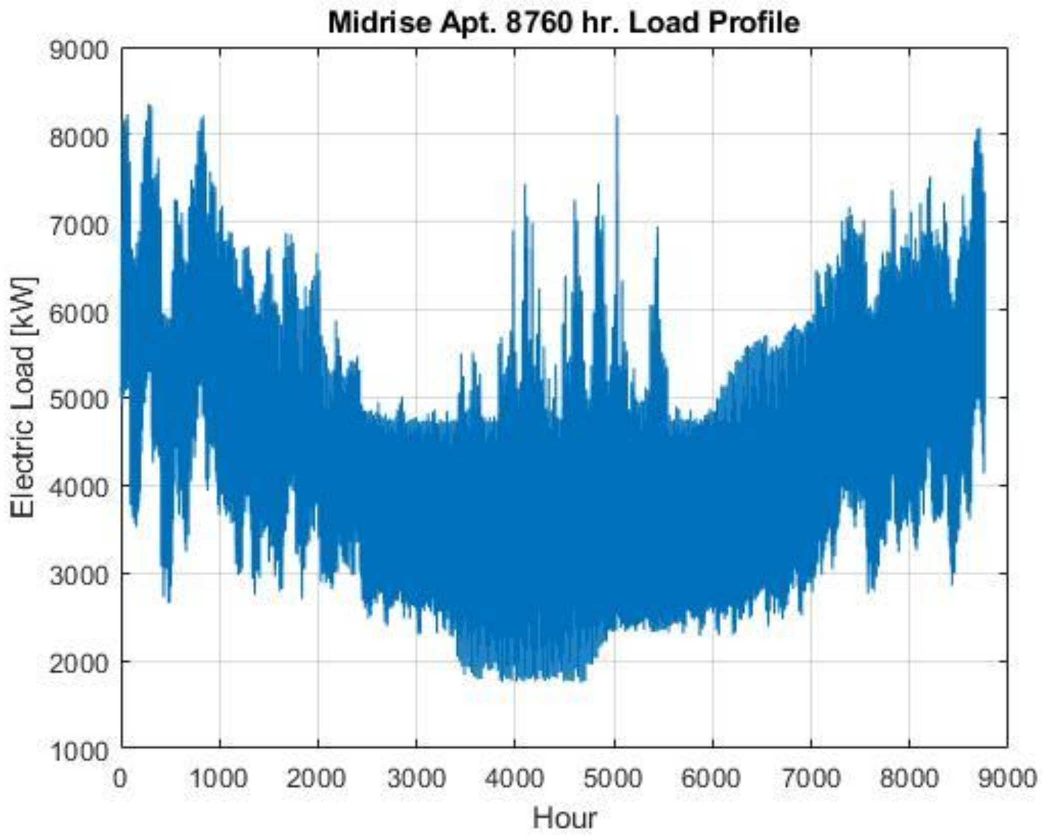
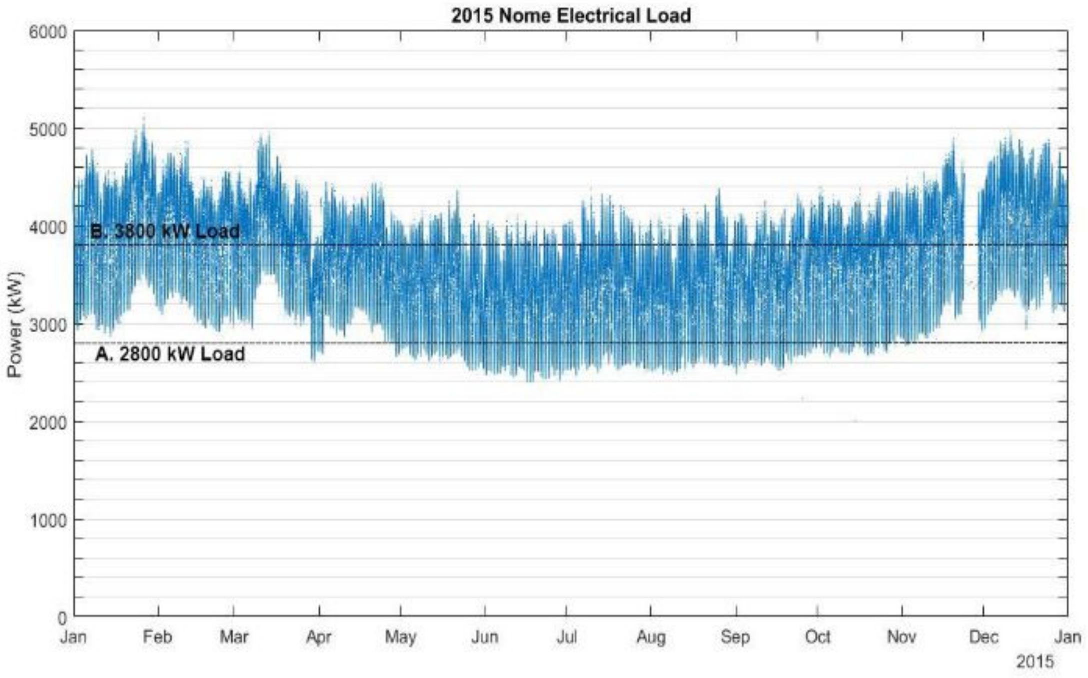
REopt

- Solar
- Wind
- Wind & Diesel
- Wind, Diesel, Battery
- Nuclear

Site Location	-	Bethel, AK
Analysis Focus	Financial/Resilence	Financial
Annual Energy Cost	$/kWh	0.22
Demand Cost	$/kW/month	10
Net Metering Size Limit	kW	0.1
Type of Building Simulated	-	Midrise Apartment
Annual Energy Consumption	kWh	32475000
Load Adjustment	%	110
Adjusted Energy Consumption	kWh	36019500
Discount Rate	%	2
Electricity Escalation Rate	%	2
Annual Grid Emissions Factor	lbs CO2/ kWh	1.11
Solar Inputs		
System Capital Cost	$/kW	2400
Outputs		
Estimated Solar Size	kW	10158
Potential Life Savings	$	9,345,868

Load Profile[9]





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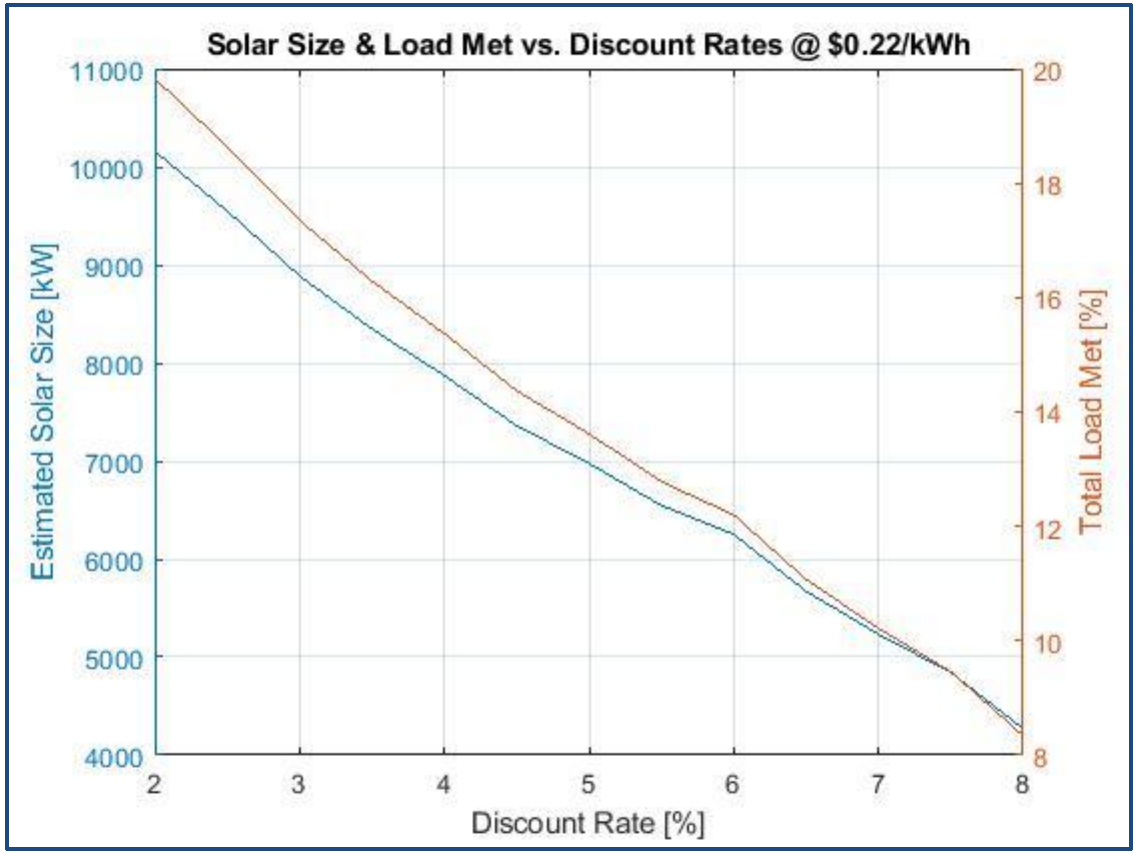
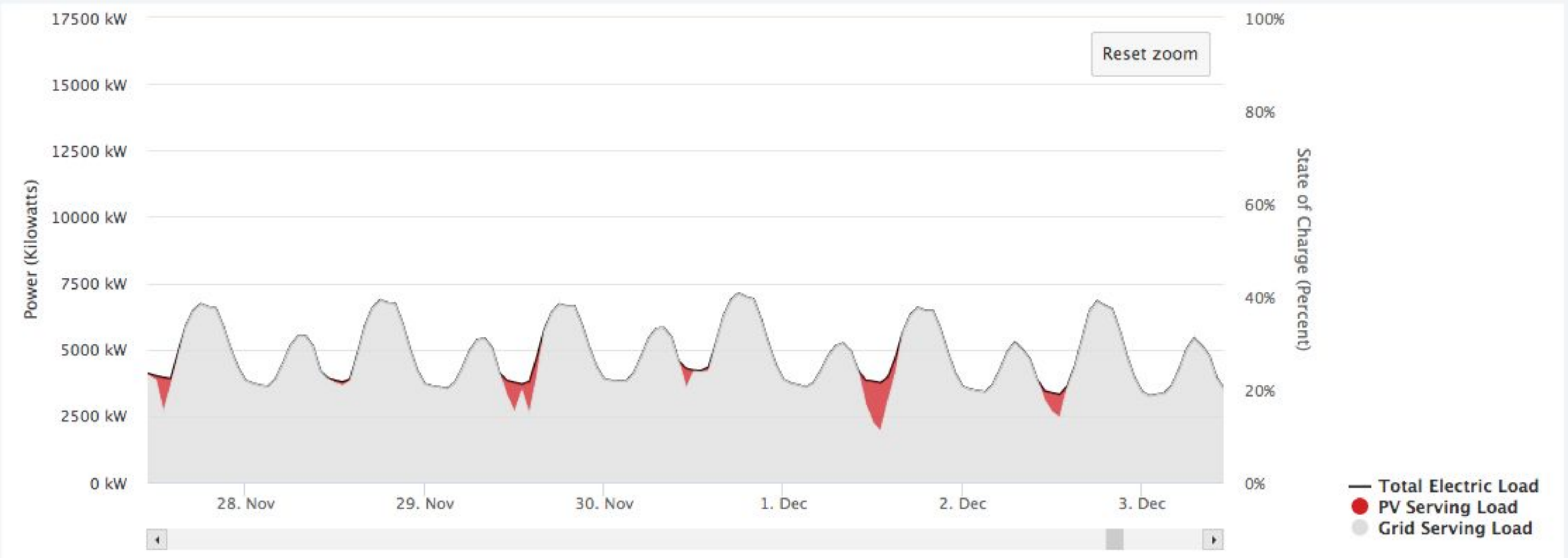
REopt Preliminary Results - Solar only



Preliminary Results - Solar (2%)



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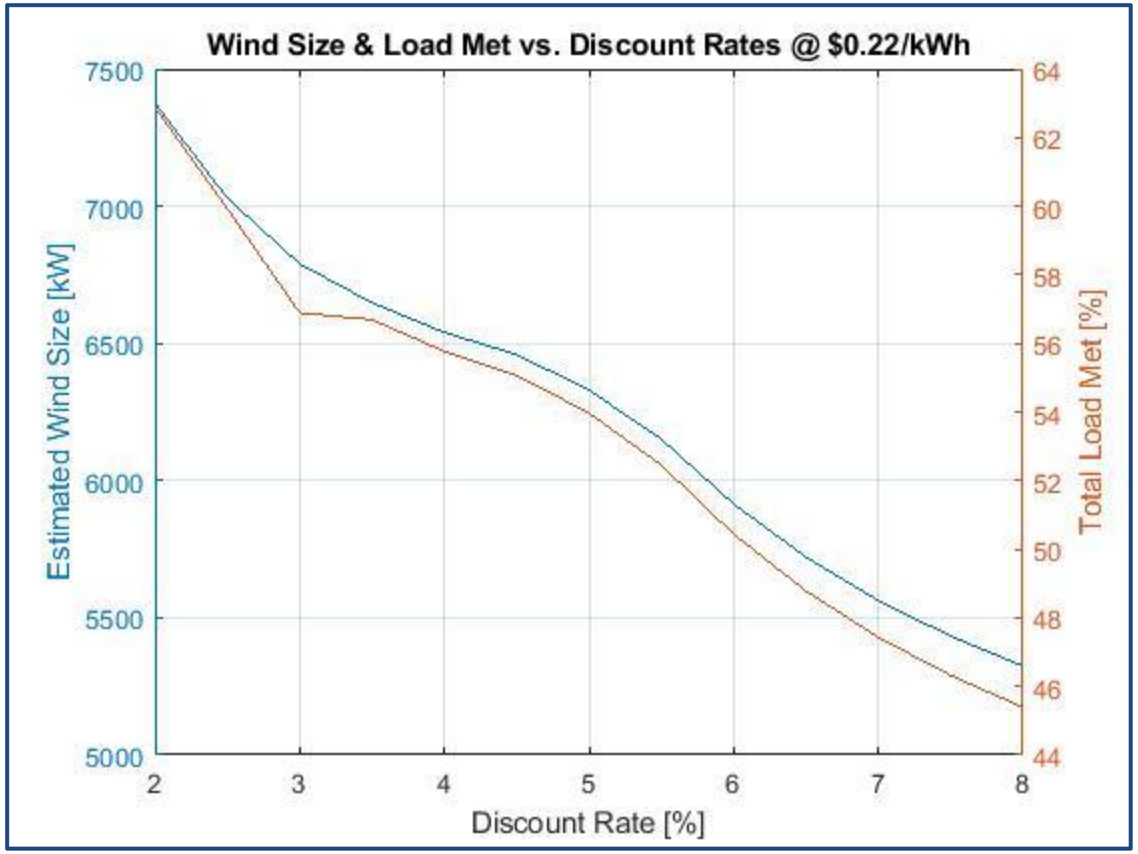
REopt Preliminary Results - Wind only



Next Steps

- Adjust the load profile to best fit Nome’s.
- Combine the different renewables as well as nuclear into the REopt runs.
- Carry over REopt results and input into SAM.

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Conclusion

- Noticeable trends between the discount rate and the life savings and size.
- A successful project will demonstrate that an NRHES is viable or the change needed in economic indicators for viability to occur.
- This work is important for the future of nuclear energy and for helping communities afford clean energy.

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Questions?

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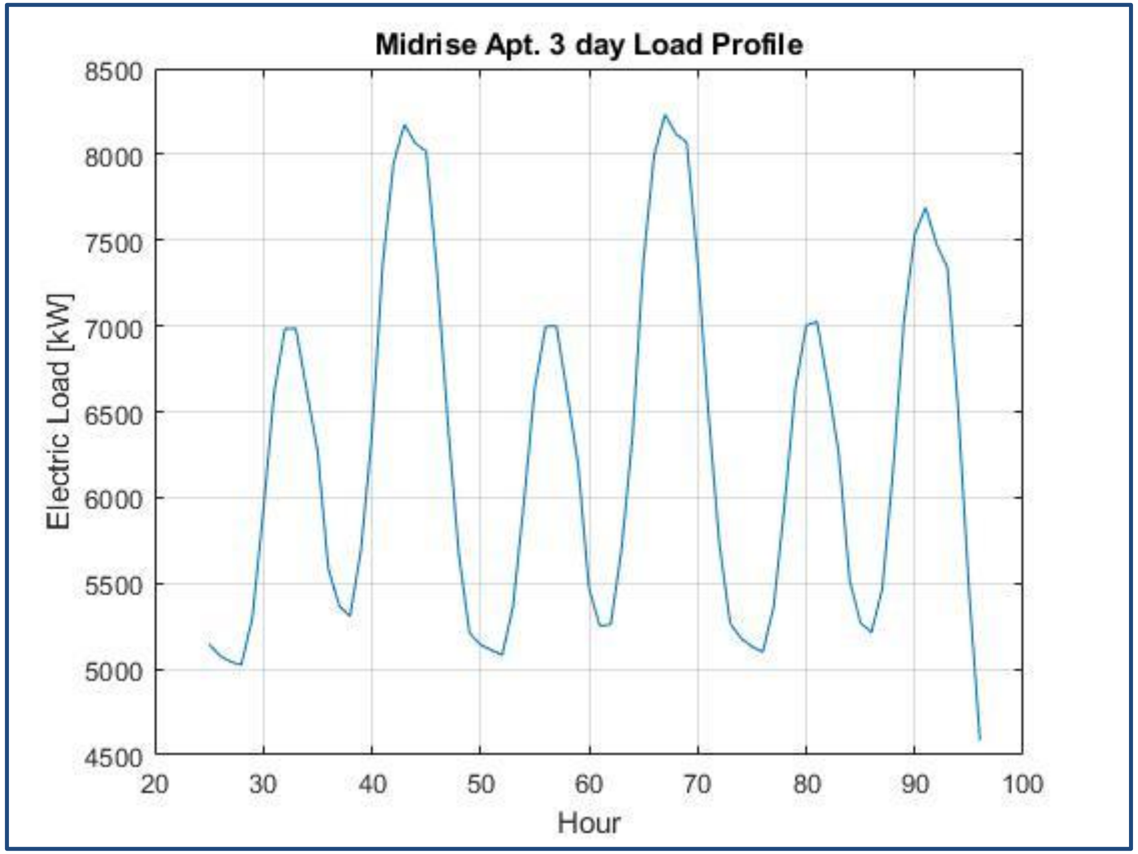
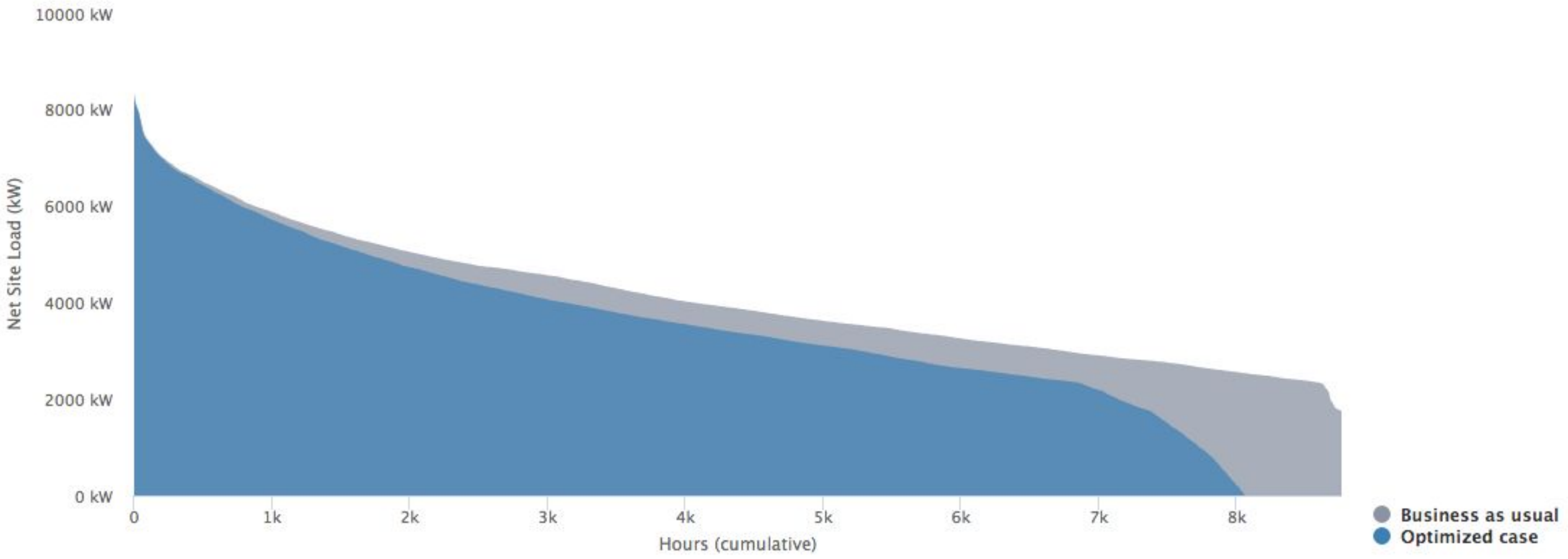
Appendix A: Three Day Load Profile



Appendix B: Sample REopt Output Deck



Appendix B: Sample REopt Output Deck

	Business As Usual	Financial
System Size		
PV Size	0 kW	10,158 kW
Energy Production and Fuel Use		
PV Energy Production	0 kWh	7,142,804 kWh
Original Average Annual Energy Supplied from Grid	32,745,000 kWh	N/A
Adjusted Average Annual Energy Supplied from Grid	36,019,500 kWh	29,977,688 kWh
Summary Generation Metrics		
Annual Energy from Renewable Energy	N/A	20%
CO_2 Emissions		
On-Site Fuels CO_2 Emissions in Year 1	0 tons	0 tons
Grid Electricity CO_2 Emissions in Year 1	19,991 tons	16,638 tons
Total CO_2 Emissions in Year 1	19,991 tons	16,638 tons
Percent Reduction in CO_2 Emissions from BAU	N/A	17%

Appendix B: Sample REopt Output Deck

Year 1 Utility Electricity Cost — Before Tax		
Utility Energy Cost	$7,924,290	$6,595,091
Utility Demand Cost	$852,209	$813,303
Utility Fixed Cost	$0	$0
Utility Minimum Cost Adder	$0	$0
Total Year 1 Utility Cost - Before Tax	$8,776,499	$7,408,395
Life Cycle Utility Electricity Cost — After Tax		
Utility Energy Cost	$146,599,365	$122,009,191
Utility Demand Cost	$15,765,858	$15,046,112
Utility Fixed Cost	$0	$0
Utility Minimum Cost Adder	$0	$0
Total Life Cycle Utility Cost - After Tax	$162,365,223	$137,055,302

Appendix C: Regression Outputs - Solar Size

```
Linear regression model:
    y ~ 1 + x1

Estimated Coefficients:
                   Estimate      SE       tStat       pValue
                   ________    ______    _______    __________

    (Intercept)      11775     108.29     108.74    4.9753e-18
    x1             -940.12     20.284    -46.347    5.7744e-14


Number of observations: 13, Error degrees of freedom: 11
Root Mean Squared Error: 137
R-squared: 0.995,  Adjusted R-Squared: 0.994
F-statistic vs. constant model: 2.15e+03, p-value = 5.77e-14
>>
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Appendix C: Regression Outputs - Wind Size

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Linear regression model:
    y ~ 1 + x1

Estimated Coefficients:
                   Estimate      SE        tStat        pValue
                   ________    ______    _______    __________

    (Intercept)     7874.8      59.94     131.38    6.2209e-19
    x1             -324.54     11.228    -28.905    9.9887e-12


Number of observations: 13, Error degrees of freedom: 11
Root Mean Squared Error: 75.7
R-squared: 0.987,  Adjusted R-Squared: 0.986
F-statistic vs. constant model: 835, p-value = 9.99e-12
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