Calculator for SPIR Kit

Cassidy Exum

Assumptions

- Number of 10x10s = 5, this corresponds to a 6.5kW solar array
- Number of Batteries = 6, this corresponds to 22800 Wh Battery Capacity
- 5 workstations are active 24/7, pulling 115 watts each
- Location: Huntington, NY (Location chosen due to versatility, i.e. experiences all 4 seasons)
- ECU active 24/7, pulling varying watts from 0 to a set maximum amount of watts according to delta from 70 deg +- 23. Outside of that range is pulling the max amount
- Generator Production is 5000 W
- Generator fuel consumption in 1 hour is 0.572 gallons (Obtained from 3.43 fuel capacity / 6 hour runtime at full load)

Data Explained

Data obtained from PVWatts site, with a 1kW array size. The AC Power Produced has been scaled to the appropriate array size, and battery capacity has been selected as 6 batteries, 22800 Wh.

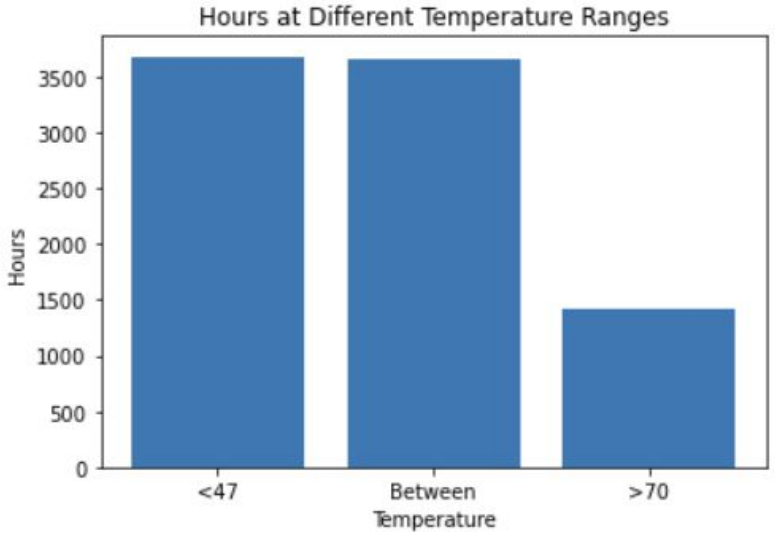
The output of the PVWatts site is a .csv file with hourly data including features like Date/Time, AC Power, Ambient Temperature. Using these three columns I generated multiple simulations with and without generators and ECU's. All time series graphs are plotted hourly across the whole year.

Hours in the year at certain temperature ranges

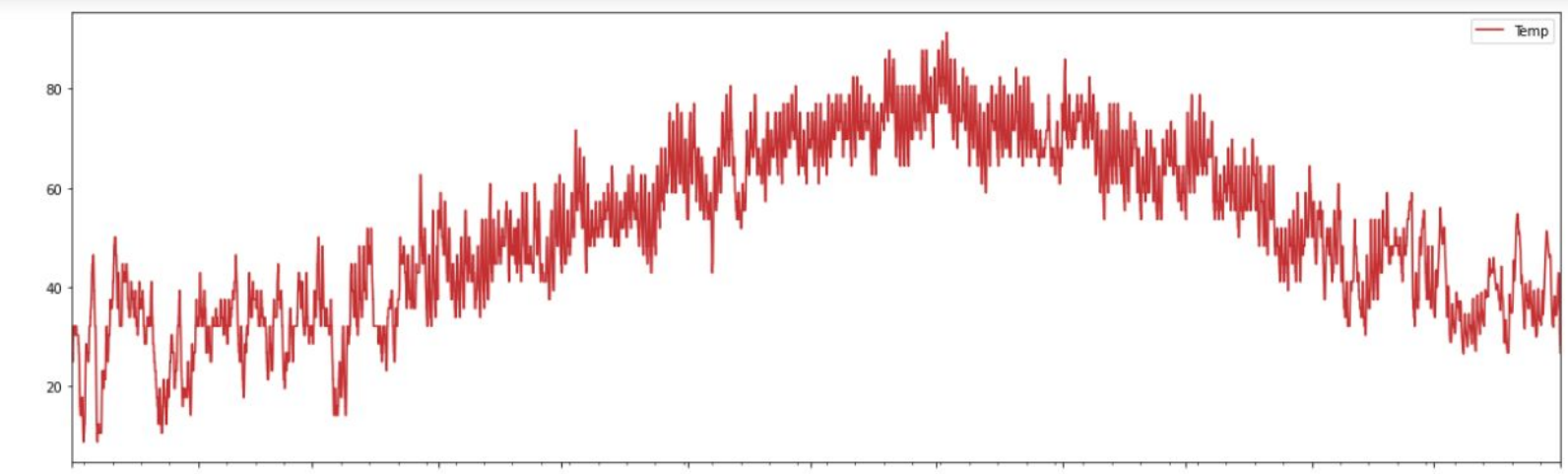
Hours below 47 degrees =	3681
Hours between 47 and 70 degrees =	3654
Hours above 70 degrees =	1425

Percentage of the year at each point:

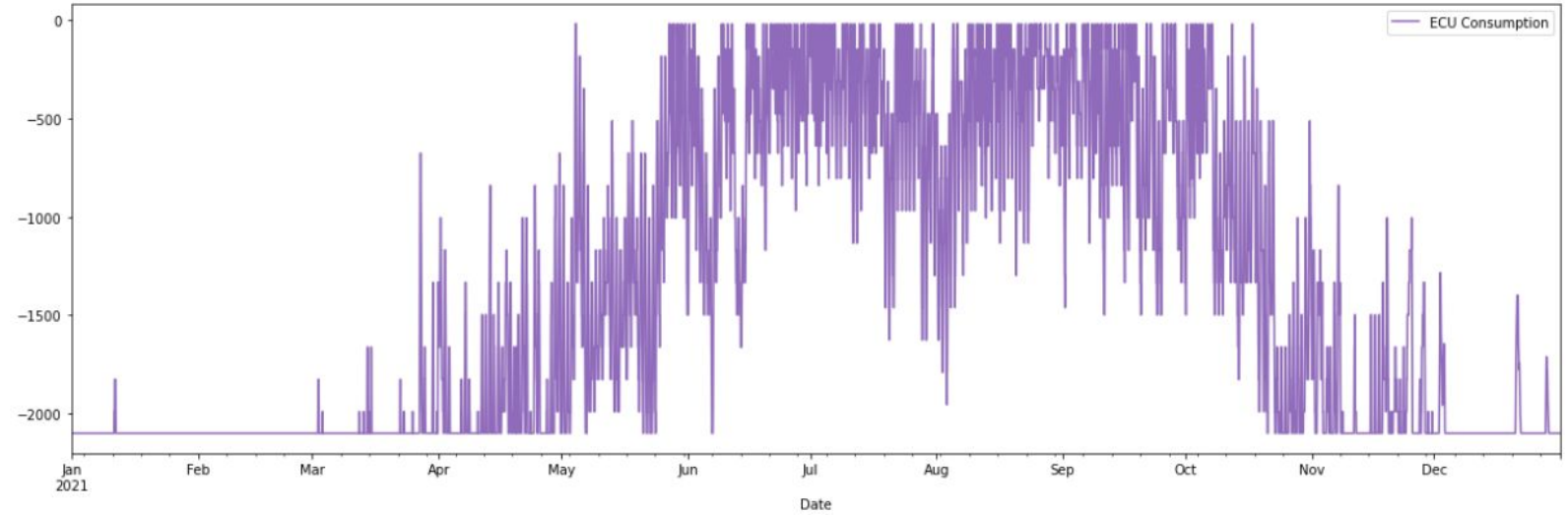
Percent under 47:	42%
Percent between 47 and 70:	42%
Percent over 65:	16%



Notes: Electric heat will vary in consumption depending on temperature under 47 degrees, but still note that 42% of the year would be electric heat.



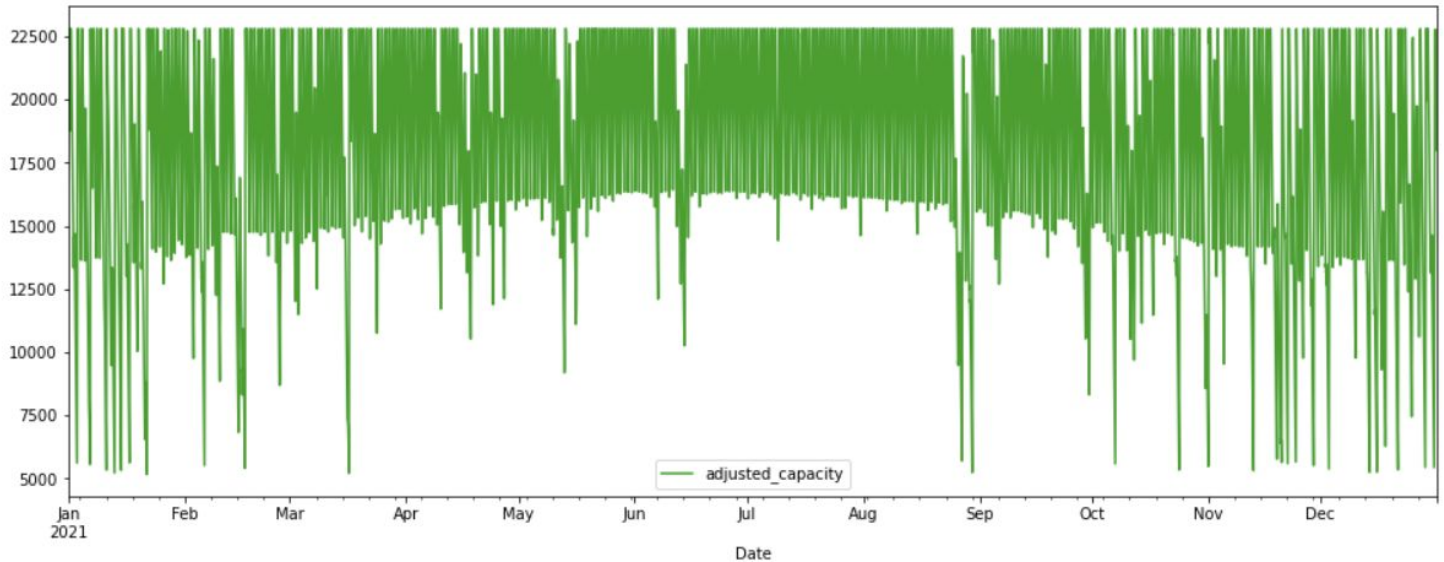
Temp and Power Consumption of the ECU



Please take note the Y-axis for the ECU Power Consumption plot

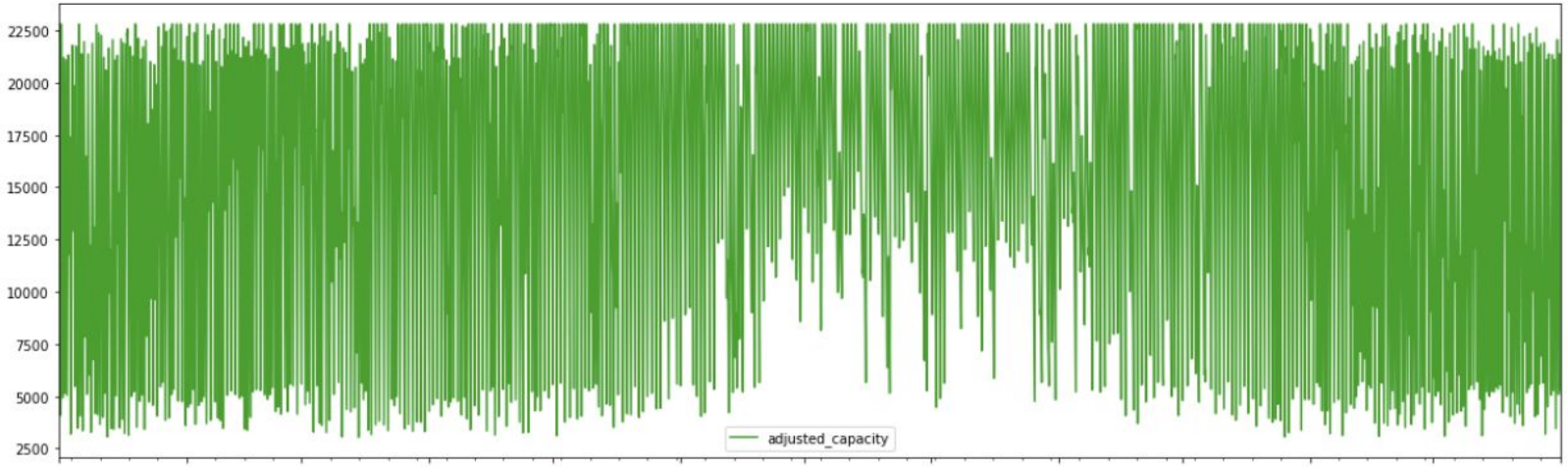
Without ECU

- With no ECU, battery storage is generally near maximum capacity
- Generator only needs to be on for 98 hours of the year
- Graph shows Battery Capacity over the course of the year with 5 workstations pulling 575 watts



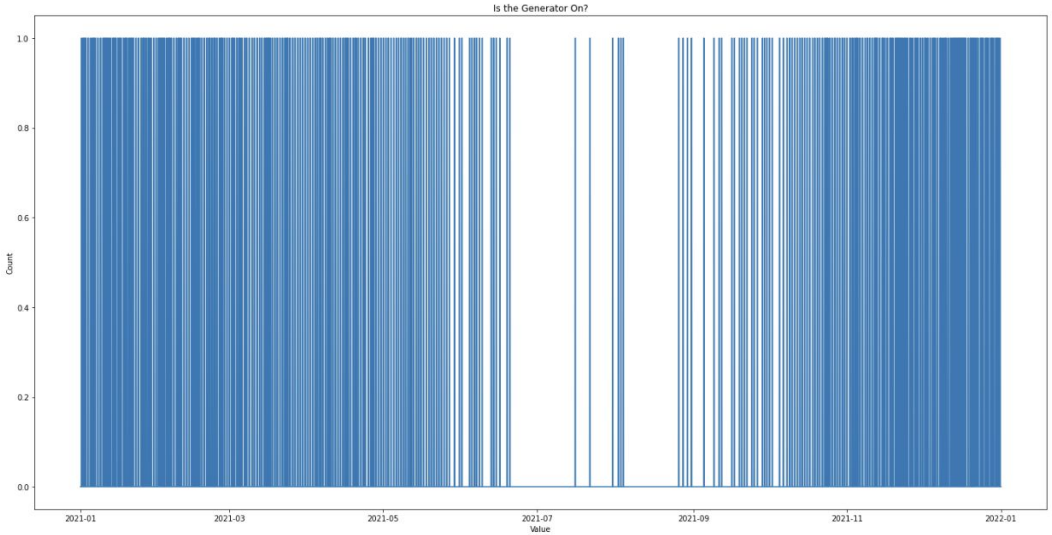
With ECU

- With the ECU, battery capacity levels fluctuate much more
- Generator needs to be on for 2122 hours in the year (24.22%)
- Graph shows Battery Capacity over the course of the year with 5 workstations pulling 575 watts, and the ECU pulling between 0 and 2100 watts, varying with temperature difference from 70 and maxing out delta = 23 degrees



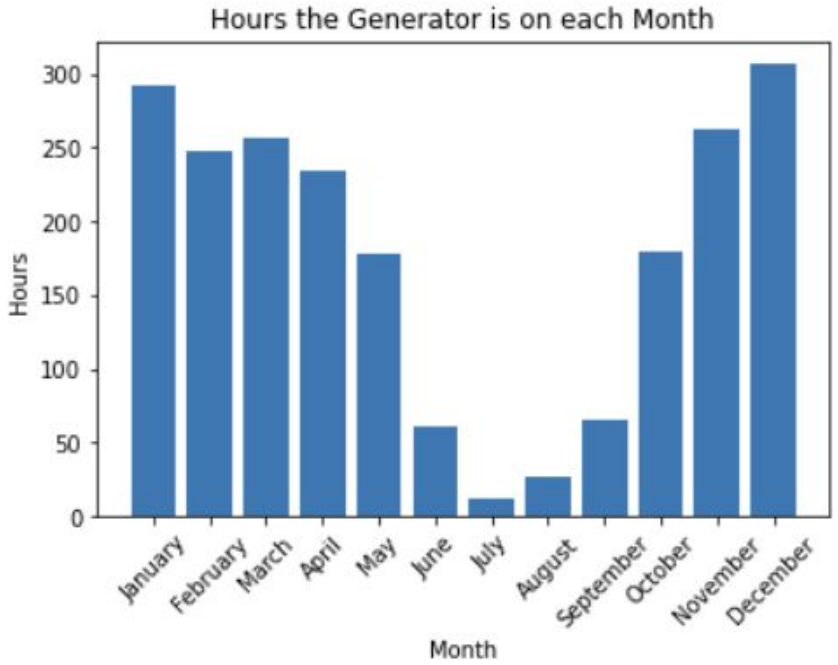
Generator Notes

- Generator needs to be on for 2122 hours in the year (24.22%)
- Consumes 1213.08 gallons of fuel
- Graph of generator On / Off vs time
- Generator is used much less from end of June to early September



Hours Generator is on, by Month

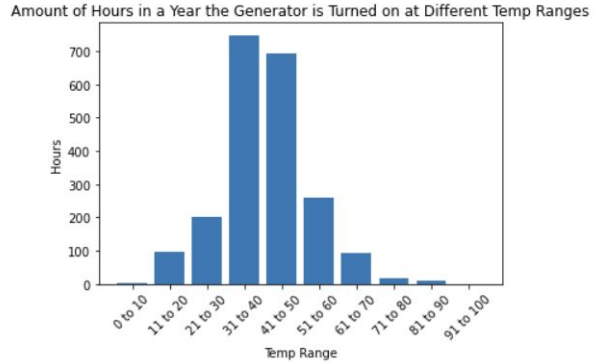
- January: 292
- February: 248
- March: 256
- April: 234
- May: 178
- June: 61
- July: 12
- August: 27
- September: 65
- October: 179
- November: 263
- December: 307

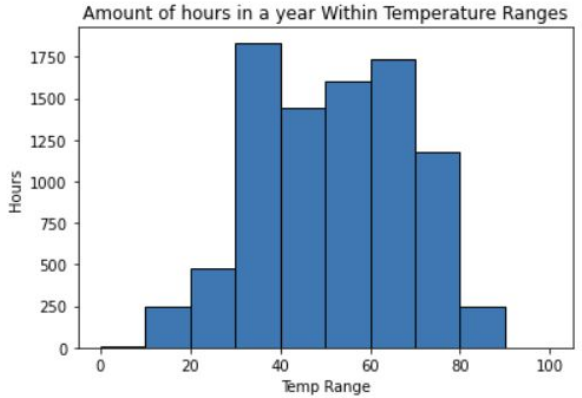


Notes: This data was obtained at max_watts = 2100

Hours Generator is on, sorted by Temperature Range

- 0 to 10: 3
- 11 to 20: 97
- 21 to 30: 202
- 31 to 40: 748
- 41 to 50: 691
- 51 to 60: 261
- 61 to 70: 92
- 71 to 80: 19
- 81 to 90: 9
- 91 to 100: 0





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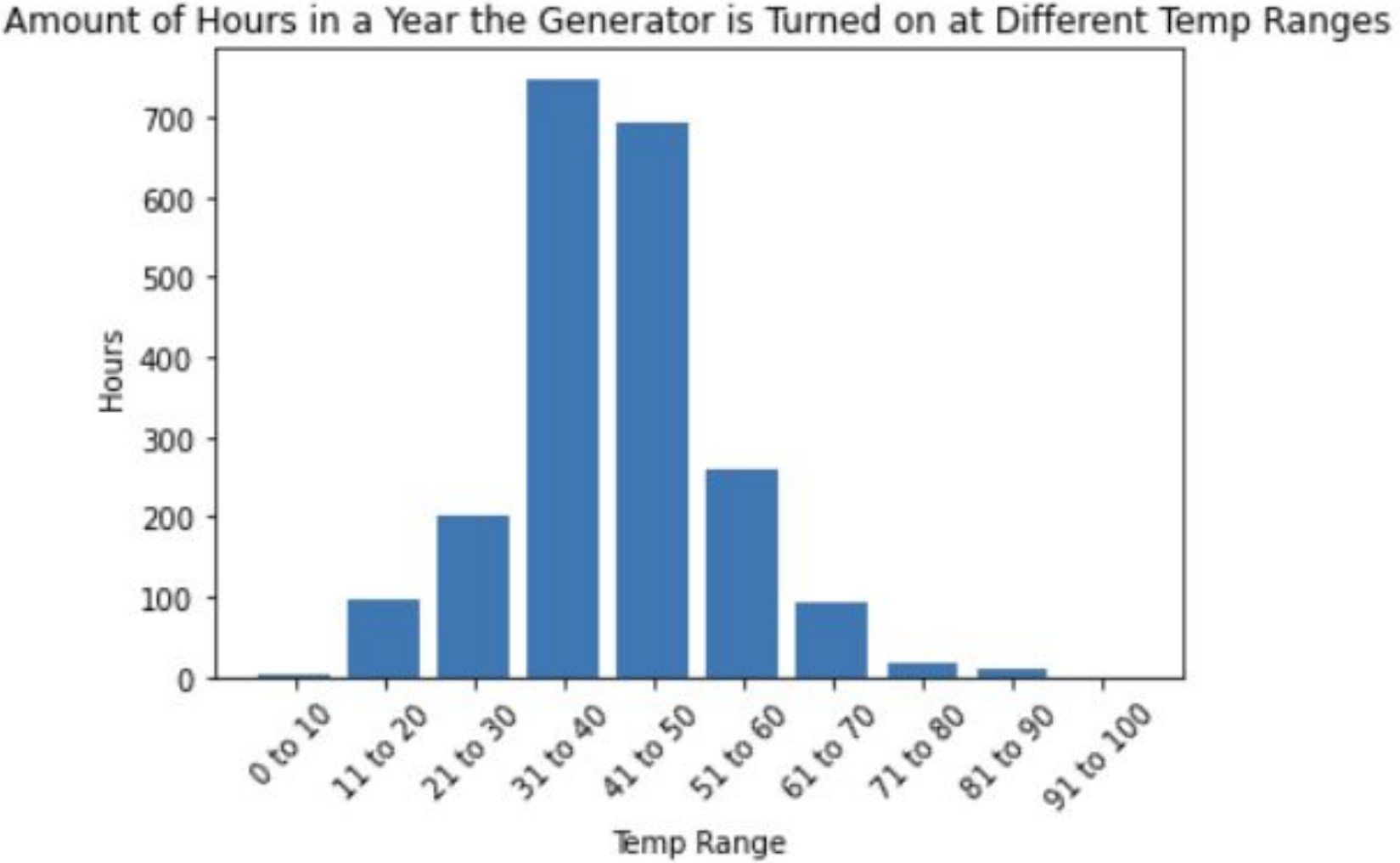
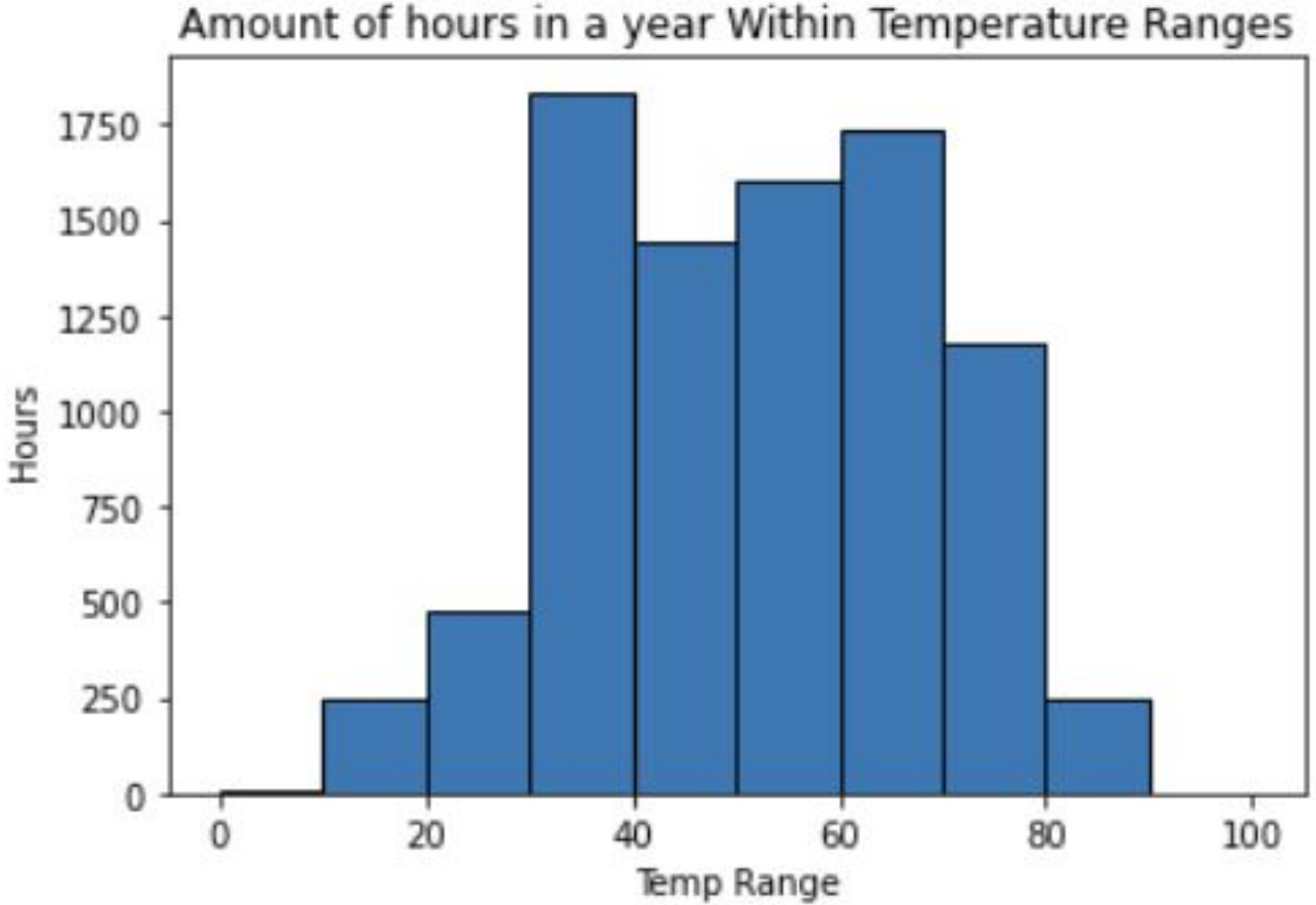
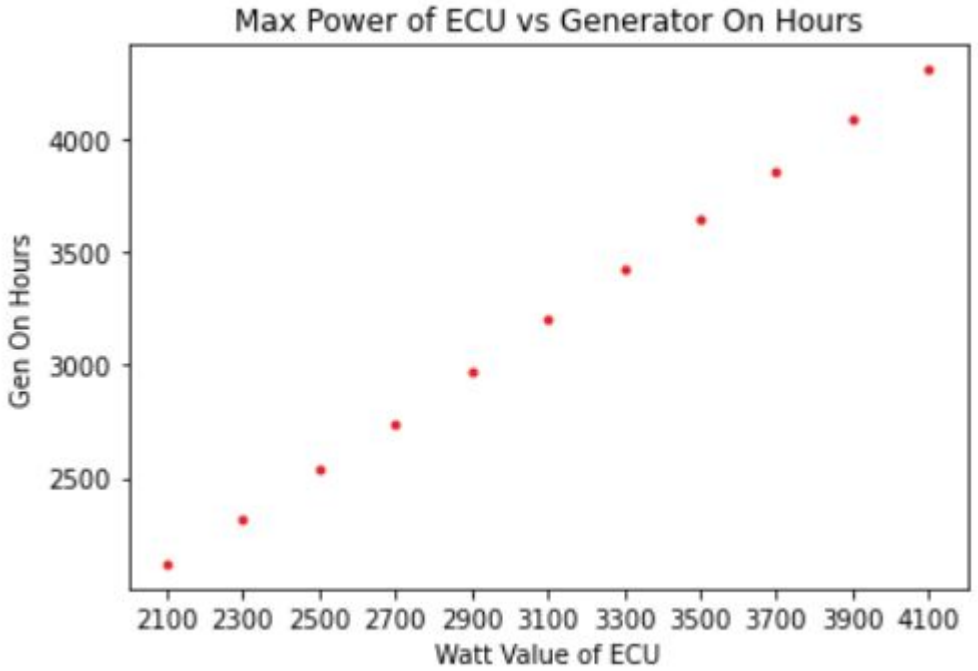

Amount of Hours in a Year the Generator is Turned on at Different Temp Ranges
Hours
0
100
200
300
400
500
600
700
0 to 10
11 to 20
21 to 30
31 to 40
41 to 50
51 to 60
61 to 70
71 to 80
81 to 90
91 to 100
Temp Range


Amount of hours in a year Within Temperature Ranges
Hours
1750
1500
1250
1000
750
500
250
0
0
20
40
60
80
100
Temp Range

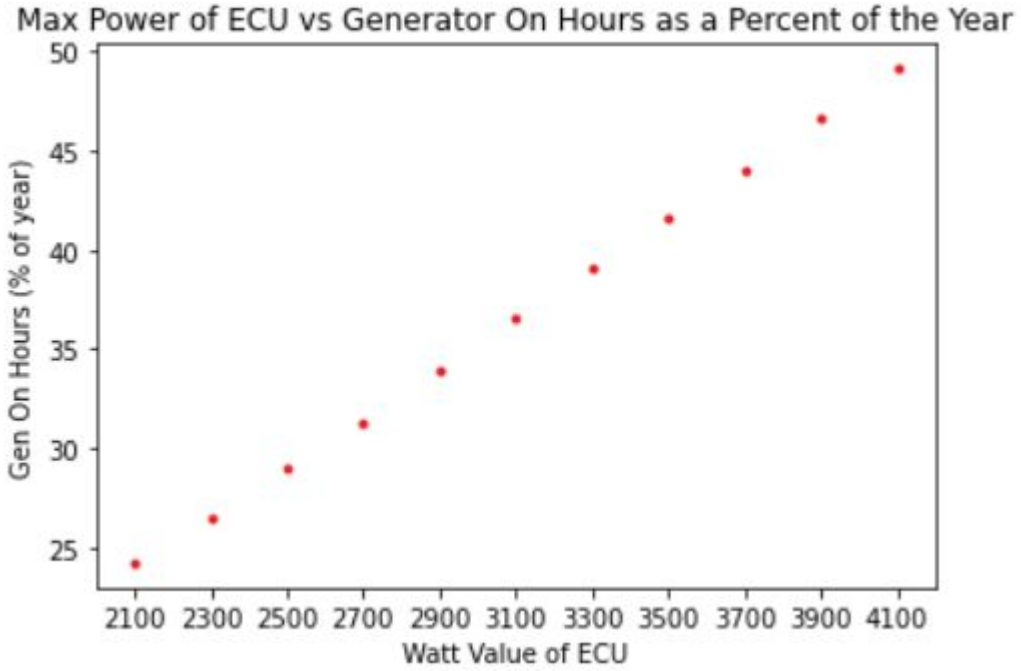
Max Power value of ECU vs Generator On Hours

Very linear relationship between ECU Max Power Consumption and Generator On Hours



Max Power Consumption of ECU vs Generator On Hours (%)

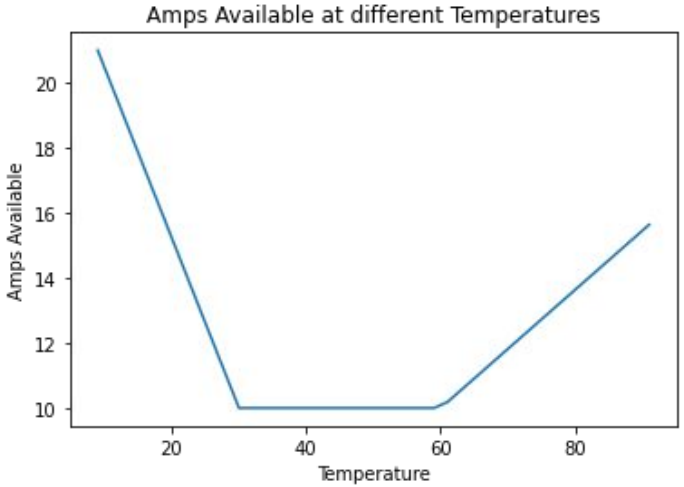
- 2100 W : 24.22 %
- 2300 W : 26.43 %
- 2500 W : 29.00 %
- 2700 W : 31.24 %
- 2900 W : 33.95 %
- 3100 W : 36.61 %
- 3300 W : 39.09 %
- 3500 W : 41.61 %
- 3700 W : 43.96 %
- 3900 W : 46.64 %
- 4100 W : 49.12 %



Watt Values	Hours Gen is on (yrly)	Percent of Year Gen is on	Yearly Fuel Consumption
2100.0	2122.0	24.223744	1213.076667
2300.0	2315.0	26.426941	1323.408333
2500.0	2540.0	28.995434	1452.033333
2700.0	2737.0	31.244292	1564.651667
2900.0	2974.0	33.949772	1700.136667
3100.0	3207.0	36.609589	1833.335000
3300.0	3424.0	39.086758	1957.386667
3500.0	3645.0	41.609589	2083.725000
3700.0	3851.0	43.961187	2201.488333
3900.0	4086.0	46.643836	2335.830000
4100.0	4303.0	49.121005	2459.881667

Amps Available

- Next to this is a plot for Amps Available.
- Created using a stepwise function that returns:
  - 21 amps at the lowest temperature
  - 10 amps between 30 and 60 degrees
  - 16 amps at the highest temperature.
  - Amp values between those are linearly interpolated
- Those values were selected from a previously generated table where:
  - 2100 watts / 208 volts = roughly 10 amps
  - 4100 watts / 208 volts = roughly 20 amps
  - 2100 is the power consumption of the current 24k BTU unit
- For a 3-Ton unit off the shelf we would expect around 2700 watts, so having the current draw be between 10 and 21 on a custom and specially designed efficient ecu seems fair (4100 watts is probably too high and we can refine these values hence why I felt this was too arbitrary), but there is some ambiguity in there and it may just be impossible for it to pull only 10 amps



What is Air Innovations looking for?

- “Amps available to their system at different temperature.”

To give relevant background information, the purpose of the solar kit we supply to the military is to replace energy from generators with solar energy. A generator is a requirement because solar energy is inconsistent, therefore minimizing generator runtime is essential. The formula used in these simulations for ECU Power draw is, where max_watts is the designated max pull of the system is given below:

- Watts = max_watts * ((temp - 70) / (47 - 70)) if temp <= 70 else max_watts * ((temp - 70) / (93 - 70))

If you refer to the ‘Hours Generator is on, sorted by Temperature Range’ slide, you can see in the first graph that the generator is overwhelmingly used between 31 and 60 degrees fahrenheit. This was recorded at max_watts = 2100, but the trend is the same at all tested values of max_watts. Maximizing ECU efficiency in this range is critical.

Possible Next Steps / Improvements

1. Recreate the simulation using a more refined formula for ECU Consumption
2. Compare the simulation results from the current 5, 10x10 array setup vs other configurations (4 and 6 specifically)
3. Try different locations (Hotter climate vs Cooler climate)