Initial Modelling Report

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Goals:

In ENGN 4440 students are tasked with creating an energy storage solution for a house that is 99% powered by renewables and is located on Prince Edward Island (PEI). This presents many challenges. Seasonal variance in power generation, seasonal variance in load requirements, potential energy storage mechanisms, and producing a Levelized Cost of Energy (LCoE) that is competitive with what is offered by Maritime Electric, the local utility company, are some of the challenges. This is the first report in a series of three reports that will outline the creation of a functional prototype. It will focus on creating rationalized and reasonable requirements for the capacity and energy generation.

For the capacity requirement of this product there is an important distinction to be made between thermal and electric storage. These are the two primary energy storage methods for a house on PEI. There is minimal cold storage required as there are relatively few days that require cooling as compared to heating. (Figure 1) The cold storage was rationalized as part of the electrical requirement for the home because of this. Should this house be located in a warmer climate, cold and warm storage could be inversed.

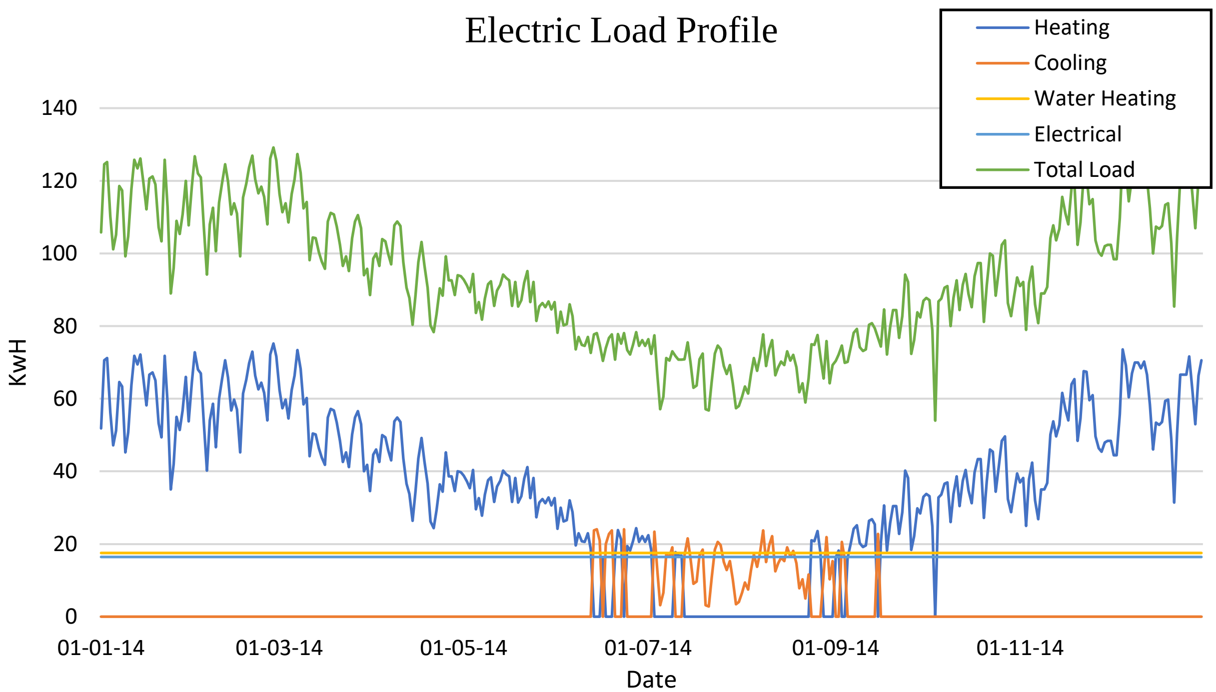

Figure 1. Grid Load Profile Over 2014 for an Average House in PEI

Figure 1 was created using average electric loads for a Canadian household from Statistics Canada[1] and degree days sourced from Environment Canada[2] to model the warm storage and cold storage by comparing it to room temperature. The total energy consumption was 28MW, the average for PEI. Something else that is interesting to note is that a majority of this storage is used by the thermal storage, and only a small portion is required to be an electrical battery. Using this data, sizing of renewables required per house and capacity of storage was rationalized. These were rationalized first using HOMER and second using MATLAB.

To accurately model the situation given in HOMER real world renewables data is required. This is data would be accurate to the local area and reliable. From work completed by A. Swingler [3], this was available for wind generation on PEI. This data was from 2014 and was supplemented with solar data simulated in HOMER to create an accurate portrayal of the conditions that this house would experience. The timestep of these datasets was 15min intervals from January 1st 2014, to Dec 31st 2014.

HOMER:

The HOMER models that were created can be seen in Figure 2, and there were some more considerations that were included in these models for the financial simulation. These were that the Solar and Wind cost was $1000/kW and the battery cost was $25/kW

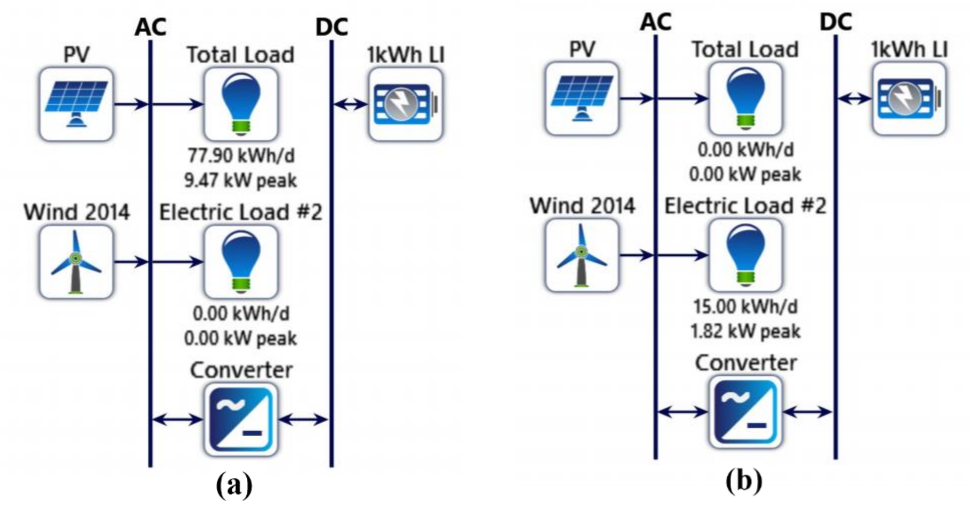

Figure 2. (a) Schematic Diagram of HOMER Simulation for Full House Load
(b) Schematic Diagram of HOMER Simulation for Only Electrical Load

As can be seen in Figure 2 there were two simulations that were optimized. First to see the total load from the house and the combined thermal and electric capacity required. Second, to see only the electric storage capacity required. This will give insight into pricing of the storage unit as there is a larger cost per kWh associated with the electrical storage. The scaling factor of wind and solar were changed until the smallest amount of storage would be feasible for both scenarios. A plot created in HOMER showing wind versus solar generation year-round can be seen in Figure 3.

The total storage was found to be 450kWh, while the electrical storage was found to be 10kWh. This means that the thermal storage capacity required, which was known to be the primary load, is 440kWh. Achieving these results was accomplished by using wind generation scaled to 12kWh and solar scaled to 5kWh. The optimization was used in relative proportion shown in research by A. Swingler [3]. Here it is reasoned that a 70-30 split between wind and solar has the benefits of more consistent energy generation, without a reduction in the drawback of less overall energy generation.

The LCoE for these scenarios was low compared to the current rate provided on PEI from Maritime Electric. For these simulations LCoE was 0.0779$/kWh, compared to the 0.143$/kWh offered by Maritime

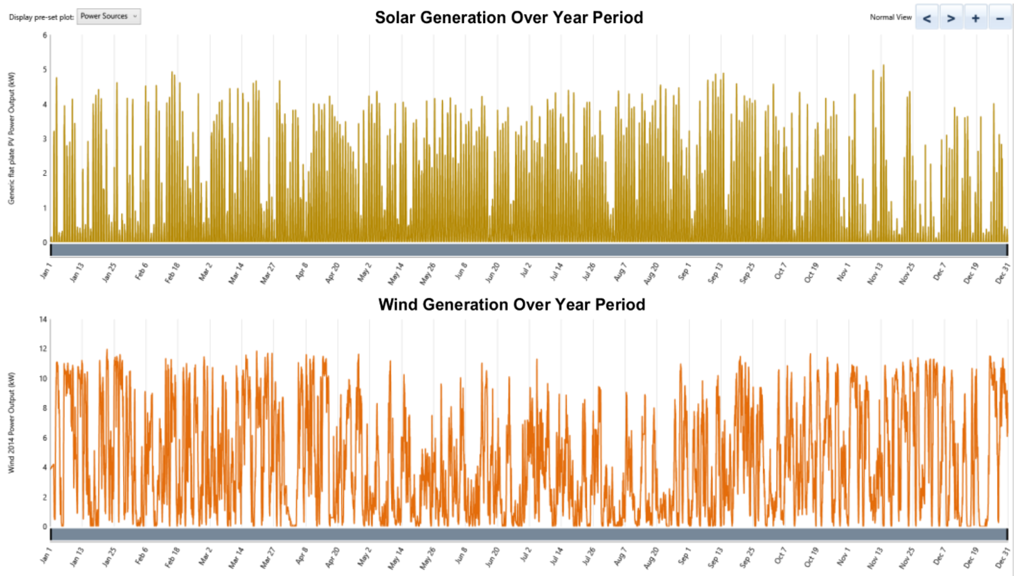

Figure 3. PV and Wind Generation Plots from HOMER for 2014 Dataset

Electric [4]. This has value and shows that on a large scale this technology is very competitive with the market standard. This hinges off of a price-point for energy storage of $25/kWh.

There is no technology on the market that could store electric energy at a price point of 25$/kWh, this is one of the key reasons that creating a thermal storage solution is required for this project.

MATLAB:

With the load and generation data exported from HOMER, it was organized into 6 row vectors that were imported into MATLAB to simulate the scenario again and validate the model with more granular control. (Figure 4)

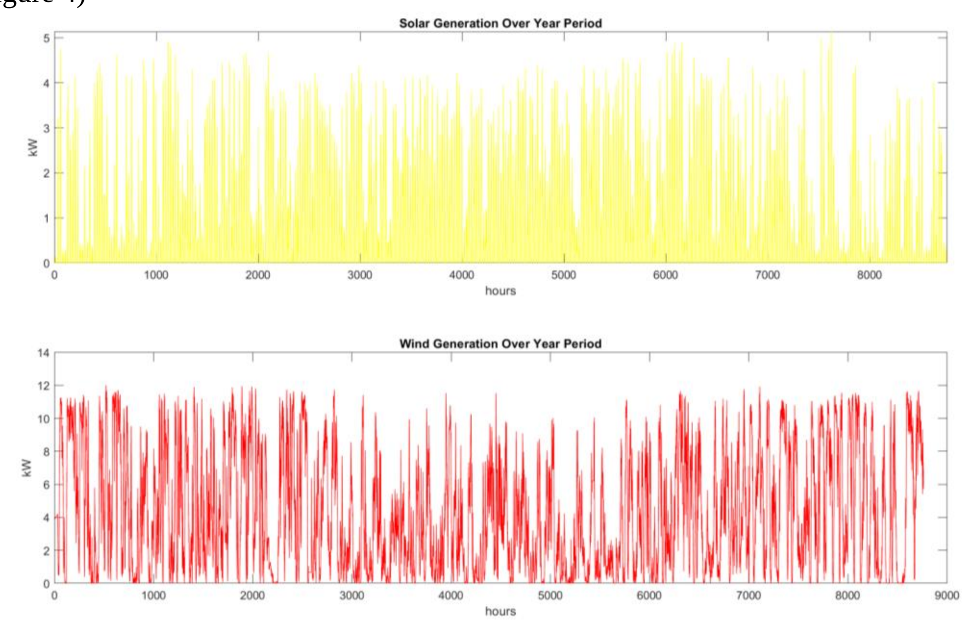

Figure 4. PV and Wind Generation Plots from MATLAB for 2014 Dataset

The results from the MATLAB plots confirm the results found in the HOMER model. That roughly 450kWh of storage are required for the loads from a house. This MATLAB model does not include the financial analysis that HOMER automatically does so no claims to the LCoE from this model can be made.

Conclusions

From these results the conclusion has been made that a total storage of 450kWh should be created for a 99% renewable powered house on PEI. 10kWh of which should be electric storage, electro-chemical battery, and 440kWh of thermal storage. These findings were created by simulating varying loads based on real world weather data and pairing them with real-world generation data for the same year. Using these two high resolution datasets a realistic picture of the energy requirements from a home for a one year was created.

Moving forward development into a thermal storage system that will cost 25$/kWh or less should begin to reach the final deliverable of a function prototype for the course.

References

[1] - "Household energy consumption, Canada and provinces", *Statistics Canada*, 2019. [Online]. Available: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=2510006001. [Accessed: 26- Oct- 2019].

[2] - "Charlottetown Historical Heating Degree Days (18°C)", *Amateur Weather Statistics for Charlottetown, Prince Edward Island*, 2019. [Online]. Available: https://charlottetown.weatherstats.ca/metrics/hdd.html. [Accessed: 26- Oct- 2019].

[3] - M. Hall and A. Swingler, "Initial perspective on a 100% renewable electricity supply for Prince Edward Island", *International Journal of Environmental Studies*, vol. 75, no. 1, pp. 135-153, 2017. Available: 10.1080/00207233.2017.1395246 [Accessed 26 October 2019].

[4] - "Charlottetown Historical Heating Degree Days (18°C)", *Amateur Weather Statistics for Charlottetown, Prince Edward Island*, 2019. [Online]. Available: https://charlottetown.weatherstats.ca/metrics/hdd.html. [Accessed: 26- Oct- 2019].