Unlimited Energy: 24/7 Renewable Energy Source Report

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I. Abstract

The global energy landscape is shifting toward renewable sources to reduce reliance on fossil fuels and combat climate change. The demand for 24/7 renewable energy sources has emerged as a key focus to ensure a consistent and reliable power supply while minimizing reliance on non-renewable resources. Unfortunately, ensuring a 24/7 renewable energy supply presents challenges due to the intermittent nature of sources like solar and wind. To address this, integrating energy storage systems will be crucial to store and release excess renewable energy, requiring careful consideration of factors such as battery capacity, charge controllers, and solar panel efficiency. In this project, a small-scaled experimental PhotoVoltaic (PV) system was built, representing a 24/7 renewable source of energy. First, energy generation data from a home solar system and home energy consumption were analyzed to understand rechargeable battery requirements to supply 24/7 energy. Next, the analysis helped establish a process to determine the rechargeable battery capacity. Through thorough research, it was evident that a lead-acid battery was suitable for this project because it is safer, cheaper, and has a higher capacity. However, for this small-scale experiment, a lithium-ion battery had also been tested. This study provides valuable insights into small-scale PV systems, highlighting the practical implications for achieving reliable renewable energy generation.

II. Introduction

2.1 Background:

Solar energy and wind energy are both excellent examples of renewable energy sources that are naturally replenished and essentially do not run out, making them reliable in the long run. On the other hand, coal and petroleum are both examples of energy sources that are not renewable and are instead known as fossil fuels [1].

It is important to use renewable energy sources rather than fossil fuels because in the future, fossil fuels are going to be less available and there will be little-to-no access to them. Furthermore, fossil fuels create air pollution, leading to harmful effects on the Earth such as climate change. In simple terms, renewable energy sources are eco-friendly.

2.2 Solar Panels:

Solar panels consist of photovoltaic (PV) cells that need sunlight in order to generate electricity. Specifically, light shines on a crystal and energy is produced [10]. This occurs through a process known as the photoelectric effect, a physical phenomenon in which electrically charged particles are released from a material, typically a metal, after absorbing electromagnetic radiation [6]. The fuel source, sunlight, is completely free and available to every single person in the world, making photovoltaics (solar panels) one of the most accessible and elegant energy sources in the world.

A PV system only produces power when sunlight is available. So, to provide power during periods when sunlight is not available, another source is needed to supply that energy. The other most common type of power/energy is from an electrochemical process, in the form of a battery [7].

2.3 Electrochemical Cells:

Electrochemical cells are devices that can either generate electrical energy through a spontaneous process or consume electrical energy with the help of an external power source. There are two modes an electrochemical cell operates in: galvanic cells and electrolytic cells. Galvanic cells are spontaneous and can be used to provide energy for performing work, while electrolytic cells are non-spontaneous and require external energy input. The components of electrochemical cells include the anode, where oxidation takes place, and the cathode, where reduction occurs. The anode's positive or negative sign depends on the mode of the cell, with galvanic cells having a negative electrode and electrolytic cells having a positive electrode. The cathode has the opposite sign of the anode, with galvanic cells having a positive electrode and electrolytic cells having a negative electrode [5].

Electrodes in electrochemical cells can be either active or inert. Active electrodes participate in the half-reaction and must be solid, while inert electrodes are made of a substance that does not undergo oxidation or reduction. The electrolyte, a charged mobile ion, acts as a conducting medium, allowing for conductivity between the anode and cathode. The external circuit permits the flow of electrons from the anode to the cathode, enabling the generation or consumption of electrical energy. A salt bridge serves two main functions: completing the circuit and preventing charge build-up, which would disrupt the electron flow. Additionally, it acts as a semipermeable membrane, allowing electrolyte ions to migrate freely between half-cells while preventing ions involved in the redox reaction from crossing over entirely. In reality, however, some ions involved in the redox reaction do migrate through the salt bridge in practice [5]. This can potentially impact the efficiency and performance of the electrochemical cell, considering the fact that contamination, charge imbalance, and side reactions can occur.

Batteries are electrochemical cells composed of electrodes and an electrolyte. The electrodes store the electrochemical energy of the battery, while the electrolyte facilitates the movement of charges between the electrodes. The electrolyte acts as an ionic conductor, allowing the flow of ions rather than electrons. Additionally, a separator physically separates the anode and cathode electrodes within the electrolyte, enabling the ionic conductivity while preventing direct contact.

The specific combination of electrode materials and electrolyte chosen for a battery determines its unique characteristics and performance [2]. For example, the use of lithium-ion electrode materials paired with a liquid electrolyte in a battery enables high energy density and fast charging capabilities.

2.4 Two Types of Electrochemical Cells and Batteries:

There are two main types of electrochemical cells and batteries: primary (non-rechargeable) batteries and secondary (rechargeable) batteries. Primary batteries are typically inexpensive, lightweight, small, and convenient with low maintenance. Some examples of primary batteries include zinc-carbon, magnesium (Mg/MnO), mercury (Zn/HgO), alkaline (Zn/Alkaline/MnO_2), silver/zinc (Zn/Ag_2O), and various types of lithium batteries, including lithium/soluble cathode, lithium/solid cathode, and lithium/solid electrolyte [9]. However, for a 24/7 renewable energy project, a primary battery cannot be used as it needs a rechargeable option. Thus, a secondary battery is utilized.

Secondary batteries come in four major types: lead-acid, nickel-cadmium, nickel-metal hydride, and lithium-ion. Lead-acid batteries are the most popular and cost-effective option [4]. They also offer excellent performance and applications in energy storage, emergency power, electric vehicles, and communication systems. Nickel-cadmium batteries are reliable and durable, suitable for high discharge rates and a range of temperatures, but they can suffer from the "memory effect." This refers to the loss of battery capacity or the ability to hold a charge when the battery is repeatedly charged after being only partially discharged. Nickel-metal hydride batteries have higher specific energy and are commonly used in aerospace applications and portable electronics. Lithium-ion batteries are the most popular among consumers, providing high energy density, longer cycle life, slow self-discharge, and the ability to operate in various temperatures, making them suitable for the hot sun in a renewable energy project [9].

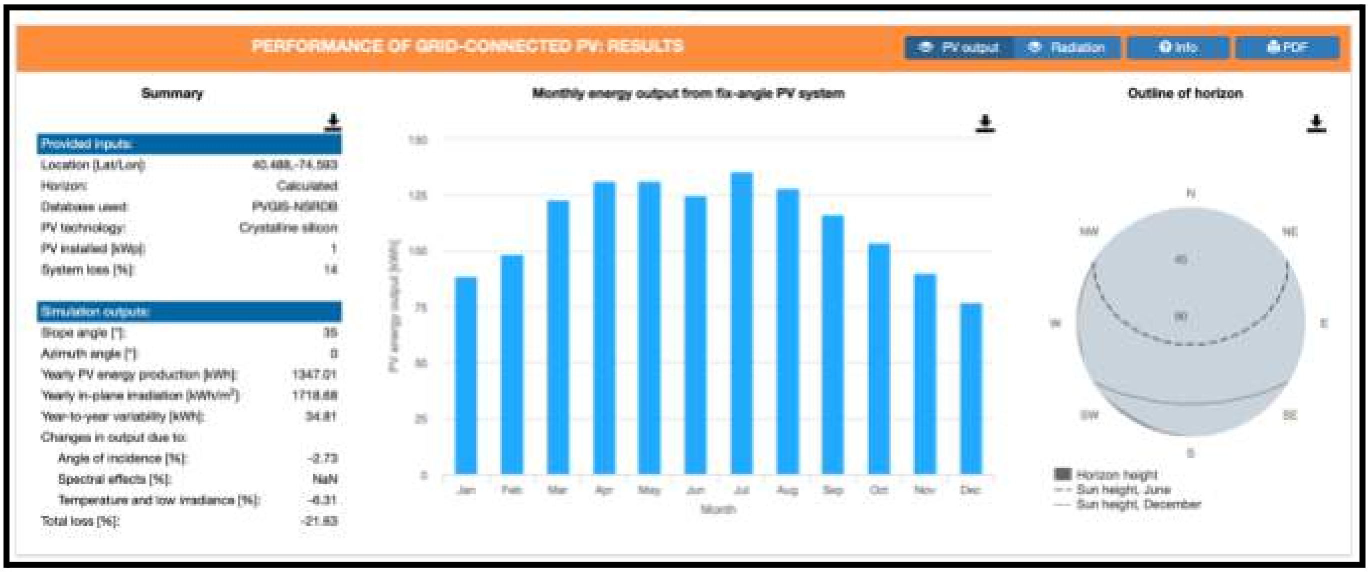
III. Methods

3.1 Solar System Charge Controller:

There were two choices: PWM (Pulse Width Modulation) Charge Controller and MPPT (Maximum Power Point Tracking) Charge Controller. Though any charge controller would suffice for this project, it was important to look at the differences of each. One thing that stands out the most is the price. The average price of PWM Charge Controllers is around $20-$60, whereas the average price of MPPT Charge Controllers is approximately $100-$729. While the cheaper prices of PWM Charge Controllers may be appealing to budget-conscious people, the MPPT Charge Controllers function better and, thus, the higher price would be reasonable. Diving deeper, it was understood that MPPT Charge Controllers tended to be more efficient than PWM Charge Controllers, which is why PWM Charge Controllers were said to be better utilized in small, not-so-complex solar systems, rather than larger, more-complex solar systems.

Furthermore, most MPPT Charge Controllers were compatible with a mobile application that could be used to track data. For instance, the specific charge controller utilized in this experiment transferred data over to the ChargePro2.0 app. Using the mobile application, one is able to gain access to simple information, such as the current voltage of the system, as well as to more complex information, such as the historical data of the solar system's performance over the course of several months. Therefore, although PWM Charge Controllers are cheaper on average, MPPT Charge Controllers are better suited for this project (i.e. the measuring, recording, and tracking of energy generation and consumption). For these reasons, the MPPT Charge Controller was selected for this project.

3.2 Determining Rechargeable Battery Capacity:



Summary

Provided inputs:	
Location [Lat/Lon]:	40.488,-74.593
Horizon:	Calculated
Database used:	PVGIS-NSRDB
PV technology:	Crystalline silicon
PV installed [kWp]:	1
System loss [%]:	14

Simulation outputs:	
Slope angle [°]:	35
Azimuth angle [°]:	0
Yearly PV energy production [kWh]:	1347.01
Yearly in-plane irradiation [kWh/m²]:	1718.68
Year-to-year variability [kWh]:	34.81
Changes in output due to:	
Angle of incidence [%]:	-2.73
Spectral effects [%]:	NaN
Temperature and low irradiance [%]:	-6.31
Total loss [%]:	-21.63

Figure 1. Shows the PhotoVoltaic Geographical Information of My House

At first, we used the energy generation and consumption data of my home solar system to study battery size requirements. We then analyzed generations and consumptions in winter, spring, summer, and fall seasons from the past year.

For each season, an in-depth analysis was completed and a specific week (7-day period) was chosen during which the amount of sunlight and weather in that week represents the season as a whole. Figure 1 not only shows the estimated PV energy output (in kWh) per month [3], but it also shows the solar axis and sun's path in the months of June (beginning of summer) and December (beginning of winter). From Figure 1, it is evident that the PV energy output is lowest in the winter months and highest in the later spring and summer months.

We noted down solar energy generation (in kWh) for each hour of the week and home energy consumption (kWh) for each day of the week. From the weekly data, we were able to determine an averaged hourly generation for a 24-hour period and an average daily home consumption for that 7-day period.

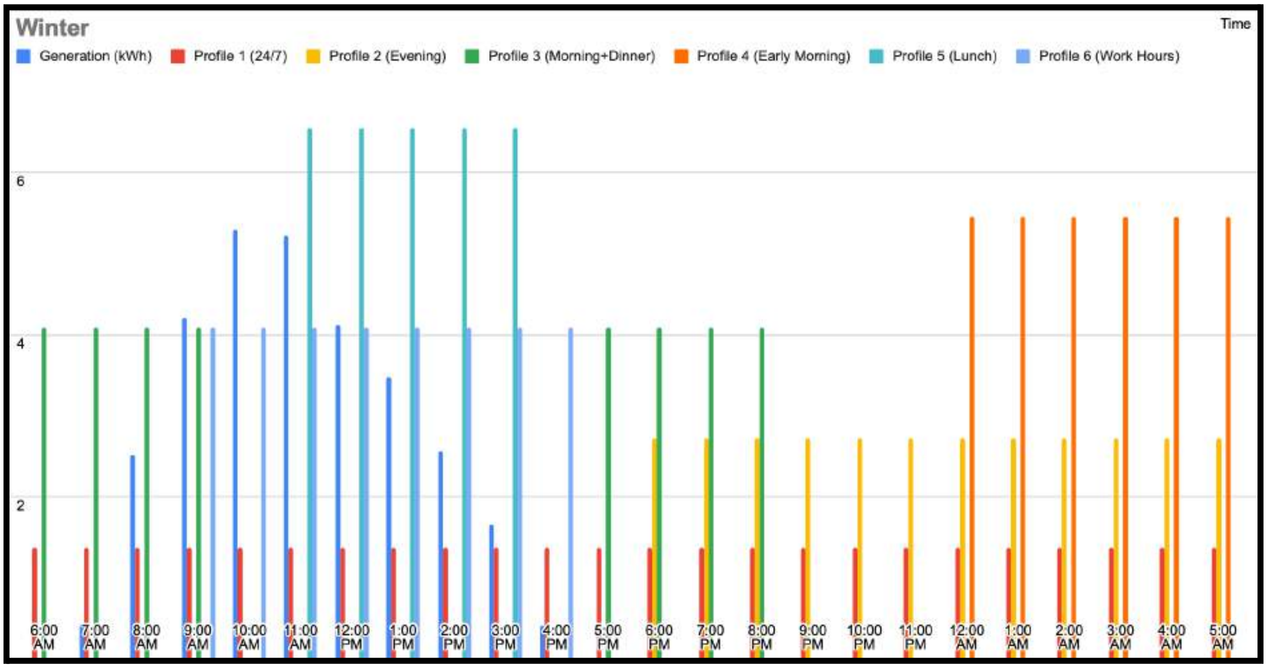


Figure 2. Shows the Generation (in kWh) and 6 Different Profiles for the Winter Season

An analysis of the winter season chart allows for a better understanding [Figure 2]. First, we determined an average daily home consumption from the chosen week using my solar system consumption report, which came out to be 32.7 kWh. Depending on how many hours each profile lasted, we divided 32.7 by that profile's hours. For example, the "Work Hours" profile has 8 hours (9:00 A.M. to 4:00 P.M.) so we divided 32.7 by 8 which is approximately 4.09 kWh. This means 32.7 kWh daily consumption is equally divided amongst the 8 hours. Hence, the average hourly consumption is 4.09 kWh for each of those 8 hours of the "Work Hours" profile.

The next step is to determine an average hourly solar generation over a 24-hour period using data from each hour of each day of the chosen week. Then, we have to compare the average hourly generation for the specific hours of the profile to 4.09 kWh (the expected consumption per profile hour).

Looking at the winter season graph of Figure 2, we see that from 9:00 A.M. to 12:00 P.M., the average hourly solar generation is greater than the 4.09 kWh of the "Work Hours" profile. The amount of energy produced by the solar system is enough for home consumption. In fact, the solar system is generating more energy than the home is consuming. Thus, the home will not need stored energy from the battery but, now, the surplus/excess energy will be used to (re)charge the battery. That stored energy in the battery can later be used when needed.

Work Hour	Winter Solar Generation (kWh)	Winter Home Consumption (kWh)	Surplus (kWh) to Charge Battery
9:00 AM	4.20	4.09	+0.11
10:00 AM	5.30	4.09	+1.21
11:00 AM	5.23	4.09	+1.14
12:00 PM	4.11	4.09	+0.02
Total			**+2.48**

Table 1. Hourly Surplus Energy to Charge Battery

Table 1 shows a total of 2.48 kWh excess energy is generated by the solar system during 9:00 A.M. to 12:00 P.M. If the battery is not at full charge, this excess energy will be used to charge the battery. However, if the battery is at full capacity, the excess charge will go to the electric grid.

Work Hour	Winter Solar Generation (kWh)	Winter Home Consumption (kWh)	Supplement (kWh) from Battery
1:00 PM	3.47	4.09	-0.62
2:00 PM	2.56	4.09	-1.53
3:00 PM	1.66	4.09	-2.43
4:00 PM	0.41	4.09	-3.68
Total			**-8.26**

Table 2. Hourly Supplemental Energy from Battery

Now, from 12:00 P.M. to 4:00 P.M., the average solar generation for each of those hours is less than 4.09 kWh. This means that the amount of energy produced by the solar system will not be enough to power the home, and additional/supplemental energy will be needed from the battery. We subtracted 4.09 kWh from the average hourly solar generation to determine how much supplemental energy would be required.

Table 2 shows a total 8.26 kWh required from the battery during 1:00 P.M. to 4:00 P.M and that becomes the battery size/capacity requirement for the “Work Hours” profile in the winter season. When the battery does not have enough energy stored, then the fall back option will be the grid to support the home consumption [8]. This means that the supplemental energy for the home consumption can also be taken from the grid. However, it is important to note that in our scaled-down experimental setup, we did not connect to the grid.

Equation 1 below is a summation equation, indicated by the summation sign (∑), for the total energy storage of the apparatus per day. $\boldsymbol{E_s}$ represents the energy storage, $\boldsymbol{t = 0}$ is the index of summation or starting point (the 0th hour), ***24*** is the stopping point (the 24th hour), and $\boldsymbol{E_d(t) - E_g(t)}$ is the typical element of the sequence which is being summed, in which $\boldsymbol{E_g(t)}$ (the energy generated for that hour) is being subtracted by $\boldsymbol{E_d(t)}$ (the energy demanded for that hour).

$$E_s = \sum_{t=0}^{24} E_d(t) - E_g(t) \qquad \textbf{Eqn. (1)}$$

A total of 6 profiles have been established per season including "Work Hours" we discussed above, along with 5 other additional profiles. Each of these profiles represents the potential hours of energy consumption. For example, for the "24/7" profile, the battery needs to provide energy to be consumed over all 24 hours compared to the "Work Hours" profile, which lasts a total of 8 hours (from 9:00 A.M. to 4:00 P.M.).

It was determined that in order to support the "Work Hour" profile, an 8.26 kWh battery capacity was needed. That is smaller compared to what is required for the "24/7" profile because there are 16 more hours to support home energy consumption and there is no sunlight all 24 hours of the day. This means that supplemental energy is needed to support home consumption and that would be coming from the battery.

Figure 8 in the Appendix shows a chart of the detailed calculations of all 6 profiles for the winter season. It demonstrates that the required max battery capacity for winter season is 32.70 kWh based on the "Evening" profile. However, it was thought that the "24/7" profile represents typical home energy consumption patterns, so it was concluded that the winter battery capacity would be around 20.96 kWh. The same steps were taken to determine the battery capacity for the spring, summer, and fall seasons. In fact, graphs showing representative daily generation and consumption profiles (similar to Figure 2) and charts showing detailed calculations (similar to Figure 8) for the spring, summer, and fall seasons are all included in the Appendix as well.

In general, the Summer "24/7" profile has the highest battery capacity requirement of 32.41 kWh amongst all seasons. Therefore, it was concluded that 35.0 kWh battery capacity is required for the home.

3.3 Experimental Setup:

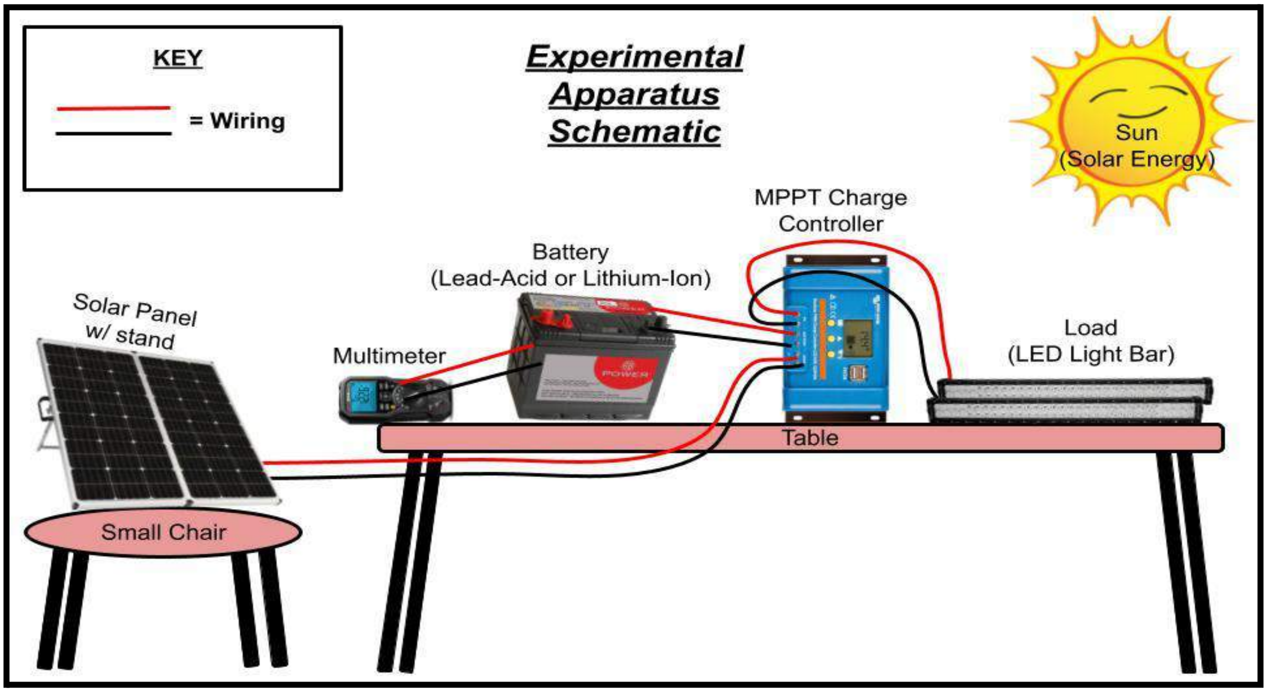


Figure 3. Shows the Apparatus Schematic Utilized in this Experiment

Figure 3 shows the set-up schematics with wiring connecting each component of the solar system. Table 3 shows the components/parts used to build the experimental system. One light bar has a 6 W consumption rating. The Lead-Acid Battery has a 84 Wh (12 V * 7 Ah) capacity, while the Lithium-Ion Battery has a 71.04 Wh (11.1 V * 6.4 Ah) capacity. A fully charged Lead-Acid Battery can power the LED bar for 14 hours (84 Wh / 6 W). Likewise, a fully charged Lithium-Ion Battery can power the LED bar for 11.84 hours (71.04 Wh / 6 W). This means that for the remaining 10-12 hours in the day, the load is relying on the solar power generation to be powered.

Parts List	Description
High-Efficiency Solar Panel Kit	12 V solar battery charger maintainer w/ a waterproof 10 W solar trickle charger
MPPT Charge Controller	20 Amp negative grounded controller w/ a bluetooth LCD display, 12 V/24 V DC input solar panel regulator for battery
Lead-Acid Battery	12 V, 7 Ah
Lithium-Ion Battery	11.1 V, 6.4 Ah
Load (Light Bars)	12 V, 6 W, 108 LEDs Strip Lights per Bar

Table 3. Shows the Parts List of Our Experimental Apparatus

Figures 4 and 5 show the working apparatus. Figure 4 displays the working apparatus outside with all the different components wired together (representing the schematic seen in Figure 3). Figure 5 shows a certain part of the apparatus — the display of the MPPT Charge Controller — that reveals the solar system functioning as it should.

Figure 4. Experimental Set-Up in Action

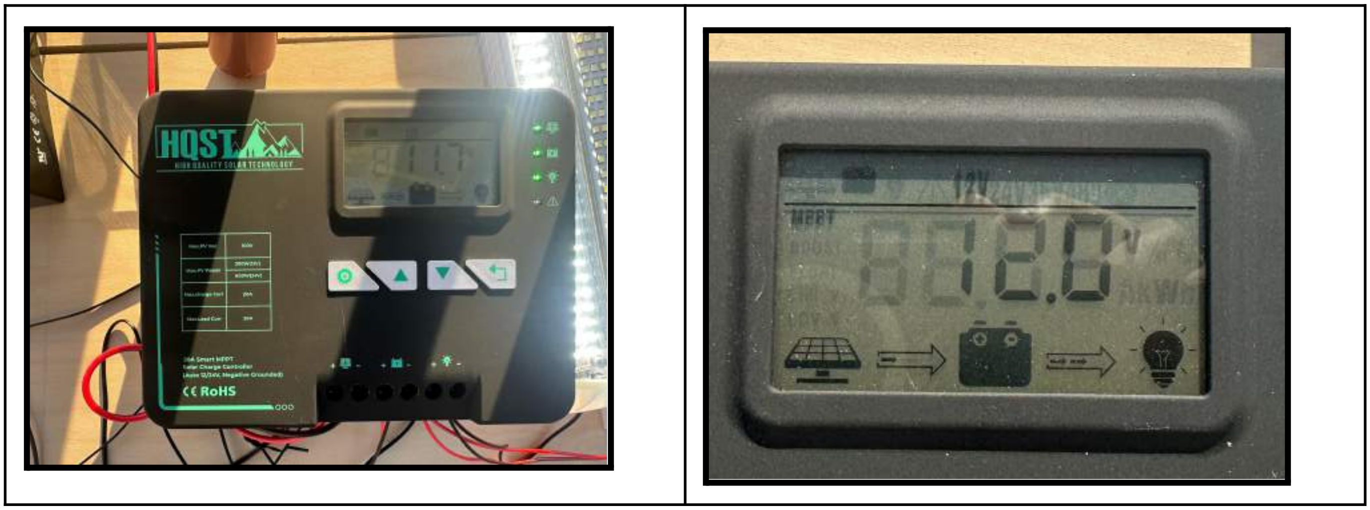


Figure 5. (Left) MPPT Charge Controller **(Right)** Arrows on the controller display from the solar panel to battery to light bulb (load) indicates that the solar system is working properly; solar generated energy is charging the battery and driving the load, i.e. turning the LED strip lights ON

In an ideal world, it is assumed that the solar panel used would have a 10 Wh generation capacity. This indicates that each hour, 6 W will be used to power the LED light, and the remaining 4 W will be used to charge the battery. If 10 hours of sunlight were considered, the solar system will have 40 Wh surplus generation which will be stored in the battery. Since the maximum capacity for each battery is almost two times more than 40 Wh, these two batteries found in the Parts List are more than enough for this experiment.

The 40 Wh stored energy in the battery can power the LED light bar for approximately 6 hours and 40 minutes (40 Wh / 6 W). Now, for 10 hours, we expect that one LED strip will be powered by solar energy, while for the remaining 6 hours and 40 minutes, the energy will come directly from the stored energy in the battery. So, we are expecting that LED strip to be emitting light for a total of 16 hours and 40 minutes. We can acknowledge that this is not sufficient enough for the "24/7" profile, but in a real-life scenario, not all lights will be on for 24 hours. We think that 16+ hours of "on-time" is reasonable enough to meet the realistic demand.

However, as stated above, that 10 Wh generation capacity is its nominal capacity only achieved under optimal test conditions in a lab. Realistically, the solar panel will always output less than 10 Wh; therefore, it is not right to assume the above information. There may be times, such as the peak of day, where the solar panel outputs 10 Wh, but it will never consistently output that amount of watts. The amount of sunlight determines the output energy of the solar panel, and as we all know, the strength of sunlight varies throughout the day. That being said, it is helpful to look at the actual data of the apparatus to observe the amount of power produced by the system. Figure 6 displays the actual battery power accumulation (representing solar energy output of the system) vs. sunlight hours during a week at the end of May 2023.

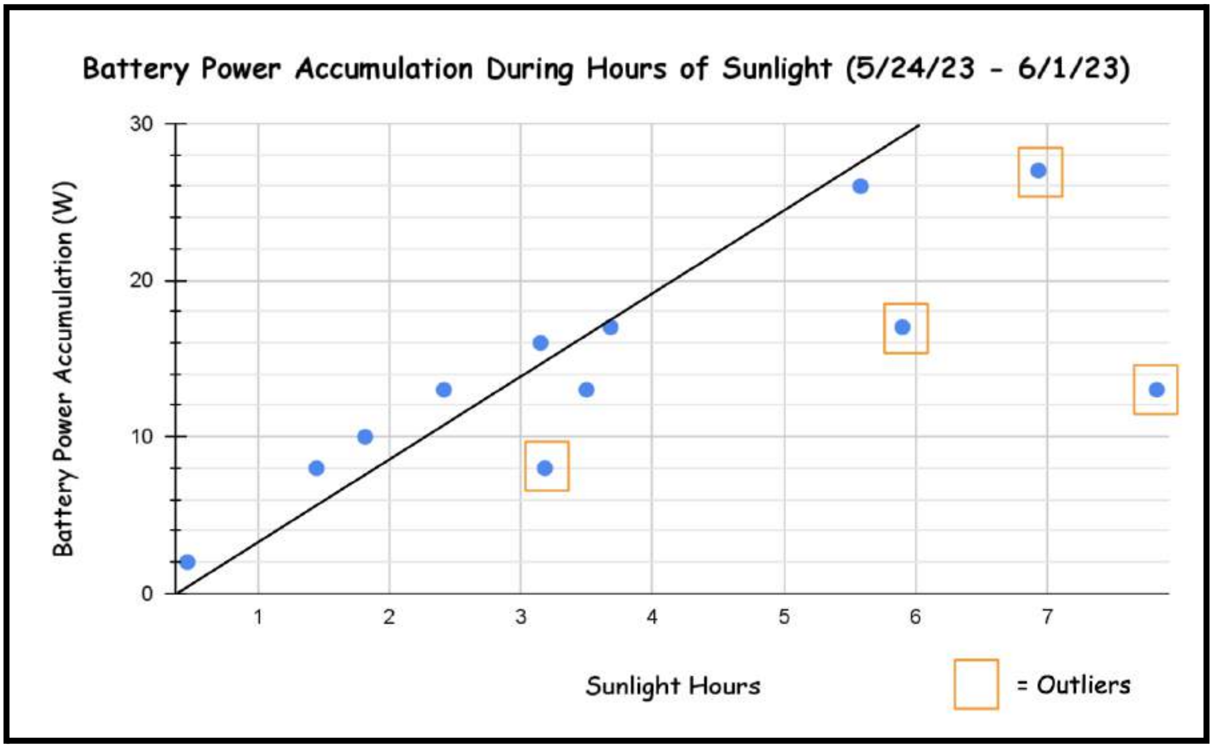


Figure 6. Shows the Battery Power Accumulation During Hours of Sunlight in a Week in the Month of May

As seen by the trendline in Figure 6, the average battery accumulation hovers around 4 Wh. This amount is expected to vary throughout the year, with a lower average battery accumulation during the winter months because of less sunlight hours. Furthermore, some data points on Figure 6 have been boxed in orange showing “outliers.” These “outlier” data points are primarily due to the fact that the sunlight was not consistent with the episodes of cloud covers. This reduced the amount of sunlight during the data collection periods, resulting in less energy production and hence, reducing the battery power accumulation.

3.4 Experimental Testing Procedure:

1. Build the system using the Lead-Acid Battery first and run tests for a couple of days.
    a. Monitor the system every couple of hours to ensure that the solar system is functioning properly and energy requirements are being met.
    b. If needed, adjust the position of the solar panel so that it gets more sunlight and maximum solar energy is generated.
2. Once the data has been collected with the Lead-Acid Battery, switch it out for the Lithium-Ion Battery and repeat the testing process.
3. If certain aspects of the experiments went wrong, identify the source of the problem and what resources are needed and/or what should be done next time in order to improve the outcome of the experiments.
4. After the tests are completed, determine which battery worked the best.
5. ****If some questions are still lingering and have not yet been answered, modify the design of the experiment in order to collect specific data to answer those questions!****

IV. Results and Discussion

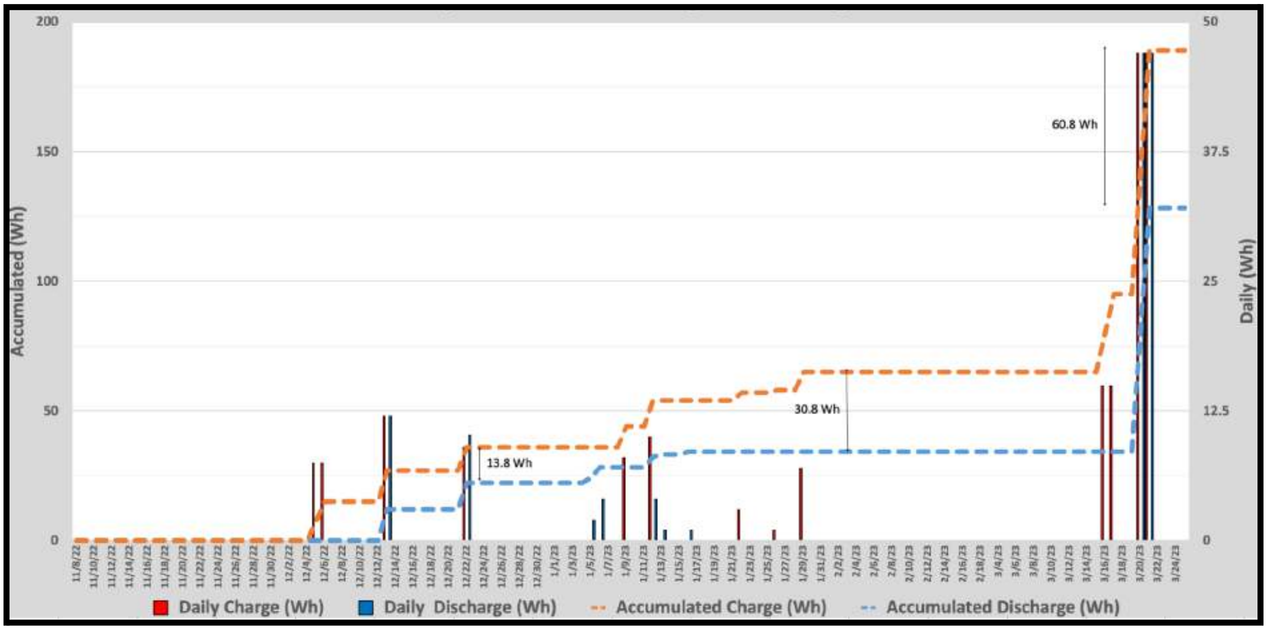


Figure 7. Shows the Daily and Accumulated Charge and Discharge of the Solar System

Figure 7 displays data collected from the experimental setup through the controller's Mobile App from November 2022 to the end of March 2023. (The data we exported from the apparatus to formulate Figure 7 above can be found in the Appendix.) It shows that the daily accumulated charge (Wh) has gradually risen from November to March. It shows that the amount of discharge is lower than the charge and also proportional as expected.

During the winter months from November to February, not only was the weather uncooperative and present challenges (in terms of the success of the experiment), but the sun's axis, or path it takes from dawn to dusk in these months, was much shorter than the warmer summer months. This demonstrates that there was less sunlight in November compared to the amount of sunlight present in March, supporting the increase in accumulated charge throughout these months. Overall, in these 5 months, while it was first determined that the Lead-Acid Battery was better suited for this apparatus, it can be concluded that both the batteries, regardless of which profile each one was utilized in, functioned the same. It is important to note that a different setting had to be set on the MPPT Charge Controller for the Lithium-Ion Battery to successfully function.

While some experiments were successful, producing the expected results in terms of solar generation, battery (re)charging and powering the load (LED light bar), other experiments were not that successful. At some instances, the battery died unexpectedly, leading to the load not emitting any light. We noticed that it mainly occurred when utilizing the "24/7" profile, along with times when the discharge rate was high compared to solar generation or the battery did not have enough charge to drive the load when there is no sunlight.

The main reason for these flaws can be explained due to one factor in particular: weather. Since the majority of these experiments were conducted (and the data was collected) in the peak of winter, the weather in the northeast of the United States was not ideal. Also, the amount of sunlight each day was very poor compared to a long summer day [3]. Obviously, with an insufficient amount of sunlight, there is not enough solar energy to power the system and/or store energy in the batteries to be used at night/early morning time.

It was noticed that at lower temperatures, solar generation was more efficient compared to higher temperatures, because at lower temperatures, there is less resistance on the wire connectors, thus reducing losses. This was also observed on our home solar system. In the scaled-down system, this did not play much of a factor, since the wires were not as big. Moreover, there were many topics that were out of scope of the project. This includes the solar panel efficiency of converting sunlight into electricity/energy, and going into more detail about how and why the charge controller itself requires power to function (that power is supplied by the solar generation or by the battery when there is no sunlight).

V. Conclusion

The successes of this small-scaled apparatus is very encouraging. It proves the point of sustainable renewable energy for a brighter and cleaner future. Bigger and better solar systems can be designed to benefit entire communities. Throughout this process, careful planning and design is required; this includes determining the specific energy needs, the particular type of renewable energy source (in this case solar energy), the necessary legal permits, having to monitor the system on a regular-basis to ensure proper functioning and, most importantly, incorporating the electric grid in the design as a fall back. While the entire design and maintenance procedures can be overwhelming, the benefits in the long run are extraordinary: a reliable source of clean energy is provided, energy costs are reduced, energy security can be improved, and environmental sustainability is promoted.

As the world continues to face the obstacles of energy security and climate change (greenhouse gas emissions), it is imperative for humans to discover new and improved ways to generate and use energy in a healthier manner. Utilizing renewable energy sources, not only through solar energy, but by wind, hydropower, biomass, and geothermal, we humans can gradually reduce our use and dependence on fossil fuels and transition toward a cleaner future to alleviate the effects of climate change. Although building a 24/7 renewable energy source is just one way to progress toward a greener, more eco-friendly future, it is one step in the positive direction that we can all contribute to in order to make a greater impact on the Earth, the place we all call home.

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Appendix

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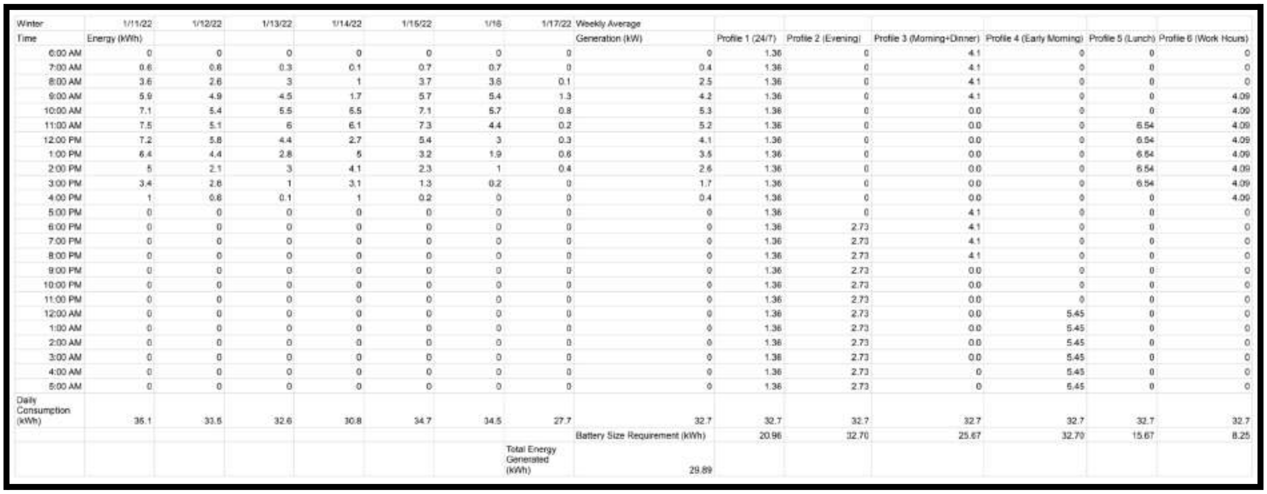


Winter	1/11/22	1/12/22	1/13/22	1/14/22	1/15/22	1/16	1/17/22	Weekly Average						
Time	Energy (kWh)							Generation (kW)	Profile 1 (24/7)	Profile 2 (Evening)	Profile 3 (Morning+Dinner)	Profile 4 (Early Morning)	Profile 5 (Lunch)	Profile 6 (Work Hours)
6:00 AM	0	0	0	0	0	0	0	0	1.36	0	4.1	0	0	0
7:00 AM	0.6	0.6	0.3	0.1	0.7	0.7	0	0.4	1.36	0	4.1	0	0	0
8:00 AM	3.6	2.6	3	1	3.7	3.6	0.1	2.5	1.36	0	4.1	0	0	0
9:00 AM	5.9	4.9	4.5	1.7	5.7	5.4	1.3	4.2	1.36	0	4.1	0	0	4.09
10:00 AM	7.1	5.4	5.5	6.5	7.1	5.7	0.8	5.3	1.36	0	0.0	0	0	4.09
11:00 AM	7.5	5.1	6	6.1	7.3	4.4	0.2	5.2	1.36	0	0.0	0	6.54	4.09
12:00 PM	7.2	5.8	4.4	2.7	5.4	3	0.3	4.1	1.36	0	0.0	0	6.54	4.09
1:00 PM	6.4	4.4	2.8	5	3.2	1.9	0.6	3.5	1.36	0	0.0	0	6.54	4.09
2:00 PM	5	2.1	3	4.1	2.3	1	0.4	2.6	1.36	0	0.0	0	6.54	4.09
3:00 PM	3.4	2.6	1	3.1	1.3	0.2	0	1.7	1.36	0	0.0	0	6.54	4.09
4:00 PM	1	0.6	0.1	1	0.2	0	0	0.4	1.36	0	0.0	0	0	4.09
5:00 PM	0	0	0	0	0	0	0	0	1.36	0	4.1	0	0	0
6:00 PM	0	0	0	0	0	0	0	0	1.36	2.73	4.1	0	0	0
7:00 PM	0	0	0	0	0	0	0	0	1.36	2.73	4.1	0	0	0
8:00 PM	0	0	0	0	0	0	0	0	1.36	2.73	4.1	0	0	0
9:00 PM	0	0	0	0	0	0	0	0	1.36	2.73	0.0	0	0	0
10:00 PM	0	0	0	0	0	0	0	0	1.36	2.73	0.0	0	0	0
11:00 PM	0	0	0	0	0	0	0	0	1.36	2.73	0.0	0	0	0
12:00 AM	0	0	0	0	0	0	0	0	1.36	2.73	0.0	5.45	0	0
1:00 AM	0	0	0	0	0	0	0	0	1.36	2.73	0.0	5.45	0	0
2:00 AM	0	0	0	0	0	0	0	0	1.36	2.73	0.0	5.45	0	0
3:00 AM	0	0	0	0	0	0	0	0	1.36	2.73	0.0	5.45	0	0
4:00 AM	0	0	0	0	0	0	0	0	1.36	2.73	0	5.45	0	0
5:00 AM	0	0	0	0	0	0	0	0	1.36	2.73	0	5.45	0	0
Daily Consumption (kWh)	36.1	33.5	32.6	30.8	34.7	34.5	27.7	32.7	32.7	32.7	32.7	32.7	32.7	32.7
								Battery Size Requirement (kWh)	20.96	32.70	25.67	32.70	15.67	8.25
							Total Energy Generated (kWh)	29.89						

Figure 8. Chart Showing the Detailed Calculations of All 6 Profiles in the Winter Season

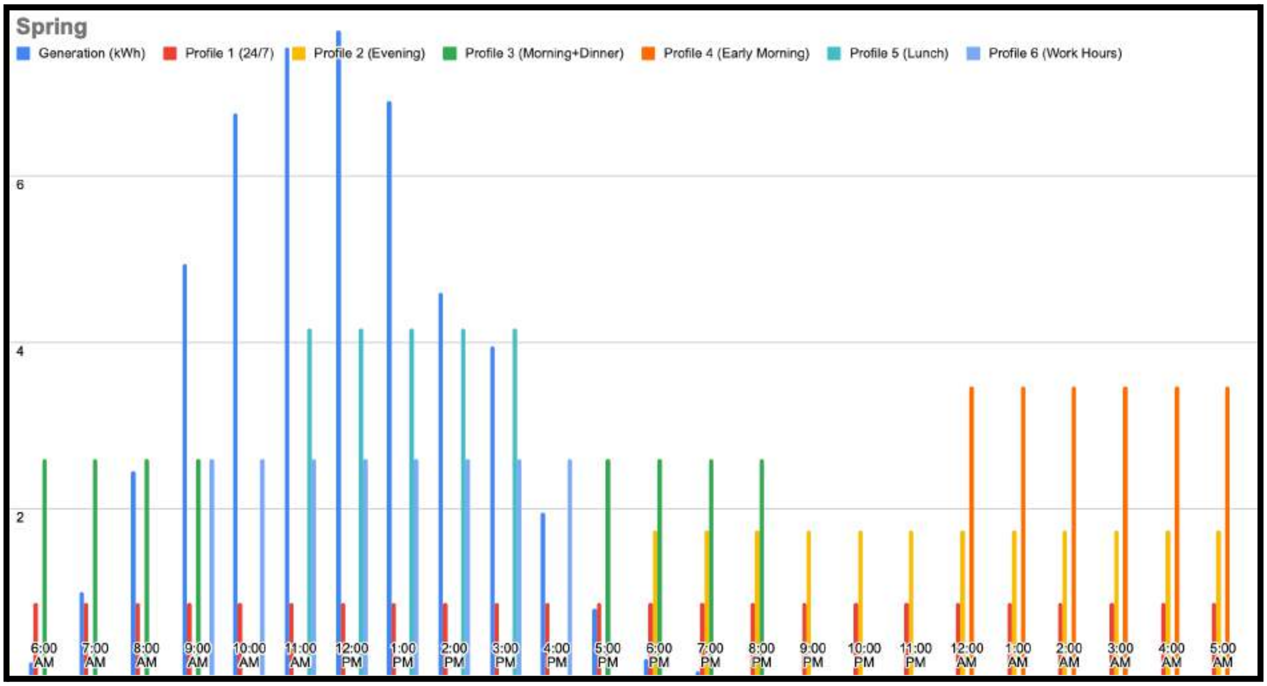
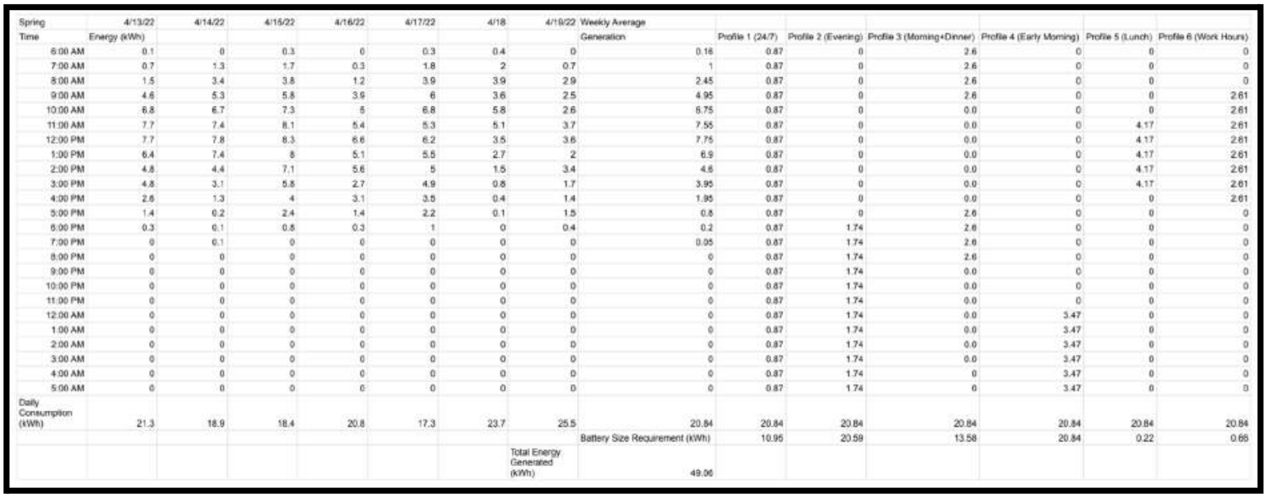


Figure 9. Shows the Generation (in kWh) and 6 Different Profiles for the Spring Season



Spring	4/13/22	4/14/22	4/15/22	4/16/22	4/17/22	4/18	4/19/22	Weekly Average						
Time	Energy (kWh)							Generation	Profile 1 (24/7)	Profile 2 (Evening)	Profile 3 (Morning+Dinner)	Profile 4 (Early Morning)	Profile 5 (Lunch)	Profile 6 (Work Hours)
6:00 AM	0.1	0	0.3	0	0.3	0.4	0	0.16	0.87	0	2.6	0	0	0
7:00 AM	0.7	1.3	1.7	0.3	1.8	2	0.7	1	0.87	0	2.6	0	0	0
8:00 AM	1.5	3.4	3.8	1.2	3.9	3.9	2.9	2.45	0.87	0	2.6	0	0	0
9:00 AM	4.6	5.3	5.8	3.9	6	3.6	2.5	4.95	0.87	0	2.6	0	0	2.61
10:00 AM	6.8	6.7	7.3	5	6.8	5.8	2.6	6.75	0.87	0	0.0	0	0	2.61
11:00 AM	7.7	7.4	8.1	5.4	5.3	5.1	3.7	7.55	0.87	0	0.0	0	4.17	2.61
12:00 PM	7.7	7.8	8.3	6.6	6.2	3.5	3.6	7.75	0.87	0	0.0	0	4.17	2.61
1:00 PM	6.4	7.4	8	5.1	5.5	2.7	2	6.9	0.87	0	0.0	0	4.17	2.61
2:00 PM	4.8	4.4	7.1	5.6	5	1.5	3.4	4.6	0.87	0	0.0	0	4.17	2.61
3:00 PM	4.8	3.1	5.8	2.7	4.9	0.8	1.7	3.95	0.87	0	0.0	0	4.17	2.61
4:00 PM	2.6	1.3	4	3.1	3.5	0.4	1.4	1.95	0.87	0	0.0	0	0	2.61
5:00 PM	1.4	0.2	2.4	1.4	2.2	0.1	1.5	0.8	0.87	0	2.6	0	0	0
6:00 PM	0.3	0.1	0.8	0.3	1	0	0.4	0.2	0.87	1.74	2.6	0	0	0
7:00 PM	0	0.1	0	0	0	0	0	0.05	0.87	1.74	2.6	0	0	0
8:00 PM	0	0	0	0	0	0	0	0	0.87	1.74	2.6	0	0	0
9:00 PM	0	0	0	0	0	0	0	0	0.87	1.74	0.0	0	0	0
10:00 PM	0	0	0	0	0	0	0	0	0.87	1.74	0.0	0	0	0
11:00 PM	0	0	0	0	0	0	0	0	0.87	1.74	0.0	0	0	0
12:00 AM	0	0	0	0	0	0	0	0	0.87	1.74	0.0	3.47	0	0
1:00 AM	0	0	0	0	0	0	0	0	0.87	1.74	0.0	3.47	0	0
2:00 AM	0	0	0	0	0	0	0	0	0.87	1.74	0.0	3.47	0	0
3:00 AM	0	0	0	0	0	0	0	0	0.87	1.74	0.0	3.47	0	0
4:00 AM	0	0	0	0	0	0	0	0	0.87	1.74	0	3.47	0	0
5:00 AM	0	0	0	0	0	0	0	0	0.87	1.74	0	3.47	0	0
Daily Consumption (kWh)	21.3	18.9	18.4	20.8	17.3	23.7	25.5	20.84	20.84	20.84	20.84	20.84	20.84	20.84
								Battery Size Requirement (kWh)	10.95	20.59	13.58	20.84	0.22	0.66
							Total Energy Generated (kWh)	49.06						

Figure 10. Chart Showing the Detailed Calculations of All 6 Profiles in the Spring Season

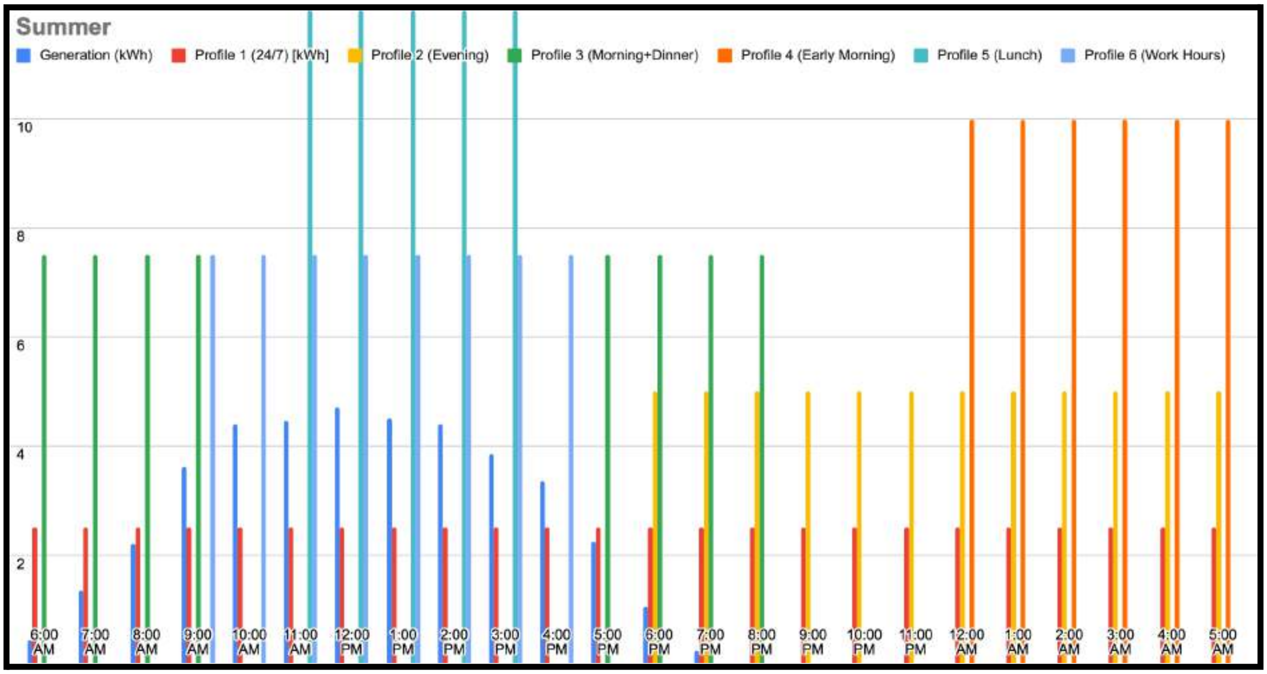
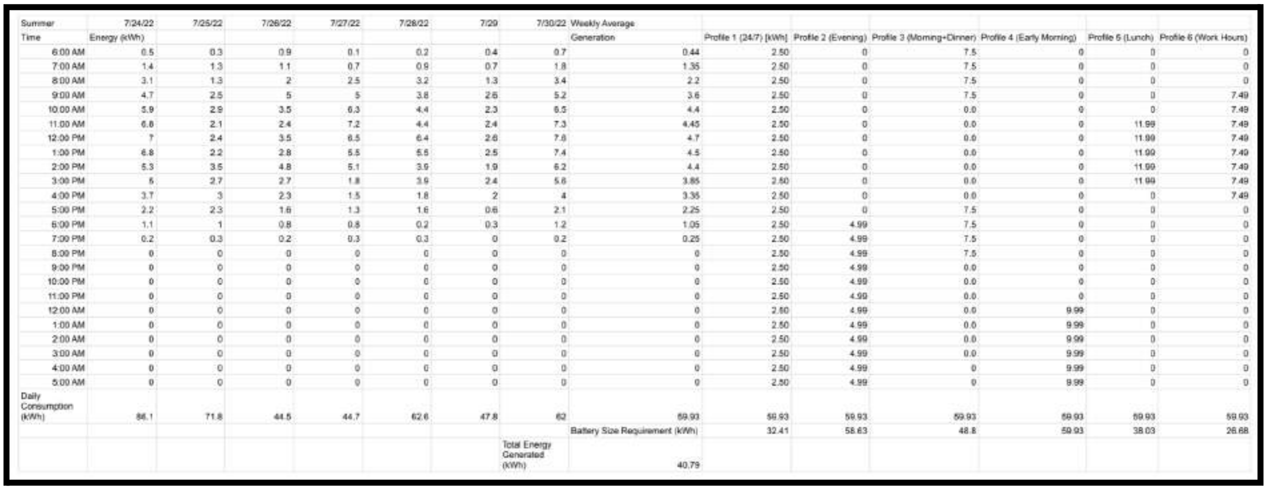


Figure 11. Shows the Generation (in kWh) and 6 Different Profiles for the Summer Season



Summer	7/24/22	7/25/22	7/26/22	7/27/22	7/28/22	7/29	7/30/22	Weekly Average						
Time	Energy (kWh)							Generation	Profile 1 (24/7) [kWh]	Profile 2 (Evening)	Profile 3 (Morning+Dinner)	Profile 4 (Early Morning)	Profile 5 (Lunch)	Profile 6 (Work Hours)
6:00 AM	0.5	0.3	0.9	0.1	0.2	0.4	0.7	0.44	2.50	0	7.5	0	0	0
7:00 AM	1.4	1.3	1.1	0.7	0.9	0.7	1.8	1.35	2.50	0	7.5	0	0	0
8:00 AM	3.1	1.3	2	2.5	3.2	1.3	3.4	2.2	2.50	0	7.5	0	0	0
9:00 AM	4.7	2.5	5	5	3.8	2.6	5.2	3.6	2.50	0	7.5	0	0	7.49
10:00 AM	5.9	2.9	3.5	6.3	4.4	2.3	6.5	4.4	2.50	0	0.0	0	0	7.49
11:00 AM	6.8	2.1	2.4	7.2	4.4	2.4	7.3	4.45	2.50	0	0.0	0	11.99	7.49
12:00 PM	7	2.4	3.5	6.5	6.4	2.6	7.6	4.7	2.50	0	0.0	0	11.99	7.49
1:00 PM	6.8	2.2	2.8	5.5	5.6	2.5	7.4	4.5	2.50	0	0.0	0	11.99	7.49
2:00 PM	5.3	3.5	4.8	5.1	3.9	1.9	6.2	4.4	2.50	0	0.0	0	11.99	7.49
3:00 PM	5	2.7	2.7	1.8	3.9	2.4	5.6	3.85	2.50	0	0.0	0	11.99	7.49
4:00 PM	3.7	3	2.3	1.5	1.8	2	4	3.35	2.50	0	0.0	0	0	7.49
5:00 PM	2.2	2.3	1.6	1.3	1.6	0.6	2.1	2.25	2.50	0	7.5	0	0	0
6:00 PM	1.1	1	0.8	0.8	0.2	0.3	1.2	1.05	2.50	4.99	7.5	0	0	0
7:00 PM	0.2	0.3	0.2	0.3	0.3	0	0.2	0.25	2.50	4.99	7.5	0	0	0
8:00 PM	0	0	0	0	0	0	0	0	2.50	4.99	7.5	0	0	0
9:00 PM	0	0	0	0	0	0	0	0	2.50	4.99	0.0	0	0	0
10:00 PM	0	0	0	0	0	0	0	0	2.50	4.99	0.0	0	0	0
11:00 PM	0	0	0	0	0	0	0	0	2.50	4.99	0.0	0	0	0
12:00 AM	0	0	0	0	0	0	0	0	2.50	4.99	0.0	9.99	0	0
1:00 AM	0	0	0	0	0	0	0	0	2.50	4.99	0.0	9.99	0	0
2:00 AM	0	0	0	0	0	0	0	0	2.50	4.99	0.0	9.99	0	0
3:00 AM	0	0	0	0	0	0	0	0	2.50	4.99	0.0	9.99	0	0
4:00 AM	0	0	0	0	0	0	0	0	2.50	4.99	0	9.99	0	0
5:00 AM	0	0	0	0	0	0	0	0	2.50	4.99	0	9.99	0	0
Daily Consumption (kWh)	86.1	71.8	44.5	44.7	62.6	47.8	62	59.93	59.93	59.93	59.93	59.93	59.93	59.93
								Battery Size Requirement (kWh)	32.41	58.63	48.8	59.93	38.03	26.68
							Total Energy Generated (kWh)	40.79						

Figure 12. Chart Showing the Detailed Calculations of All 6 Profiles in the Summer Season

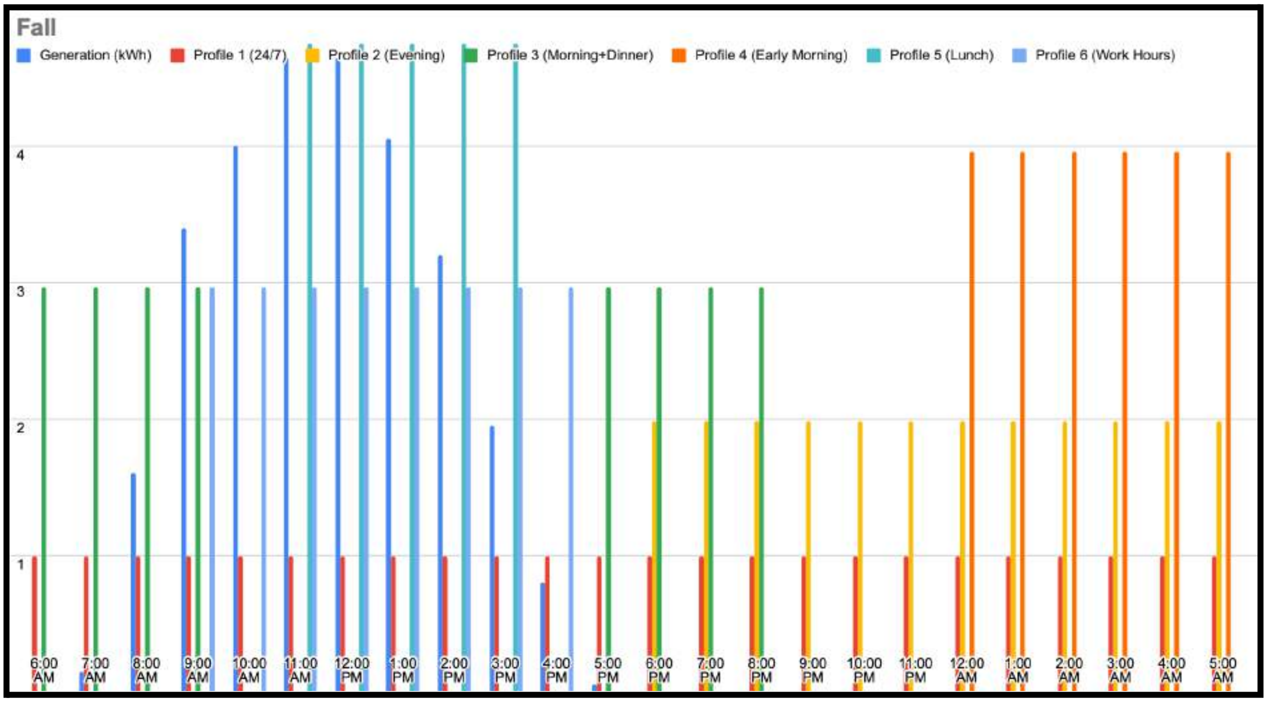
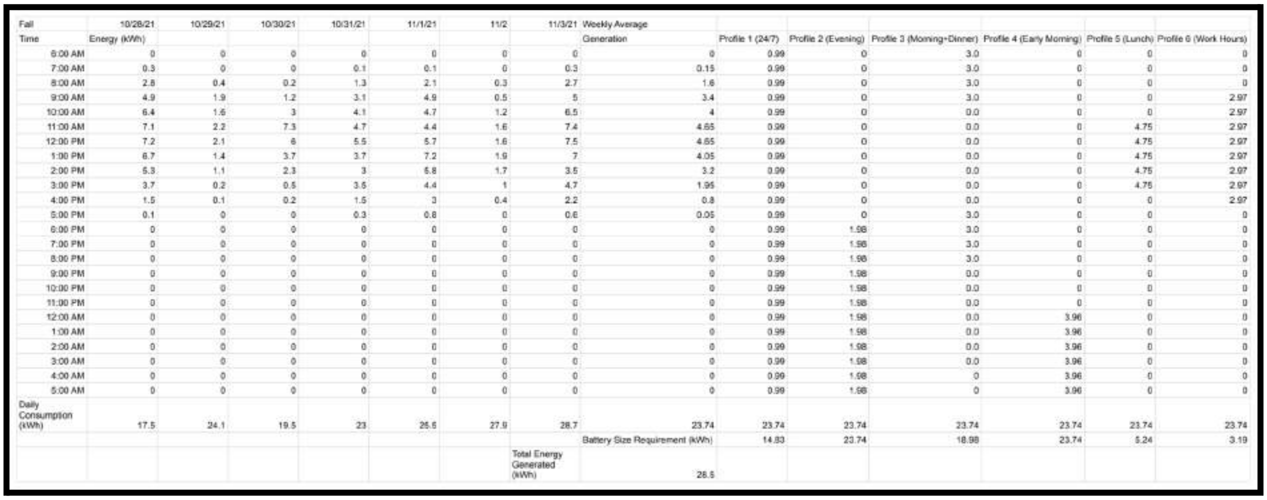


Figure 13. Shows the Generation (in kWh) and 6 Different Profiles for the Fall Season



Fall	10/28/21	10/29/21	10/30/21	10/31/21	11/1/21	11/2	11/3/21	Weekly Average						
Time	Energy (kWh)							Generation	Profile 1 (24/7)	Profile 2 (Evening)	Profile 3 (Morning+Dinner)	Profile 4 (Early Morning)	Profile 5 (Lunch)	Profile 6 (Work Hours)
6:00 AM	0	0	0	0	0	0	0	0	0.99	0	3.0	0	0	0
7:00 AM	0.3	0	0	0.1	0.1	0	0.3	0.15	0.99	0	3.0	0	0	0
8:00 AM	2.8	0.4	0.2	1.3	2.1	0.3	2.7	1.6	0.99	0	3.0	0	0	0
9:00 AM	4.9	1.9	1.2	3.1	4.9	0.5	5	3.4	0.99	0	3.0	0	0	2.97
10:00 AM	6.4	1.6	3	4.1	4.7	1.2	6.5	4	0.99	0	0.0	0	0	2.97
11:00 AM	7.1	2.2	7.3	4.7	4.4	1.6	7.4	4.65	0.99	0	0.0	0	4.75	2.97
12:00 PM	7.2	2.1	6	5.5	5.7	1.6	7.5	4.65	0.99	0	0.0	0	4.75	2.97
1:00 PM	6.7	1.4	3.7	3.7	7.2	1.9	7	4.05	0.99	0	0.0	0	4.75	2.97
2:00 PM	5.3	1.1	2.3	3	6.8	1.7	3.5	3.2	0.99	0	0.0	0	4.75	2.97
3:00 PM	3.7	0.2	0.5	3.6	4.4	1	4.7	1.95	0.99	0	0.0	0	4.75	2.97
4:00 PM	1.5	0.1	0.2	1.5	3	0.4	2.2	0.8	0.99	0	0.0	0	0	2.97
5:00 PM	0.1	0	0	0.3	0.8	0	0.6	0.05	0.99	0	3.0	0	0	0
6:00 PM	0	0	0	0	0	0	0	0	0.99	1.98	3.0	0	0	0
7:00 PM	0	0	0	0	0	0	0	0	0.99	1.98	3.0	0	0	0
8:00 PM	0	0	0	0	0	0	0	0	0.99	1.98	3.0	0	0	0
9:00 PM	0	0	0	0	0	0	0	0	0.99	1.98	0.0	0	0	0
10:00 PM	0	0	0	0	0	0	0	0	0.99	1.98	0.0	0	0	0
11:00 PM	0	0	0	0	0	0	0	0	0.99	1.98	0.0	0	0	0
12:00 AM	0	0	0	0	0	0	0	0	0.99	1.98	0.0	3.96	0	0
1:00 AM	0	0	0	0	0	0	0	0	0.99	1.98	0.0	3.96	0	0
2:00 AM	0	0	0	0	0	0	0	0	0.99	1.98	0.0	3.96	0	0
3:00 AM	0	0	0	0	0	0	0	0	0.99	1.98	0.0	3.96	0	0
4:00 AM	0	0	0	0	0	0	0	0	0.99	1.98	0	3.96	0	0
5:00 AM	0	0	0	0	0	0	0	0	0.99	1.98	0	3.96	0	0
Daily Consumption (kWh)	17.5	24.1	19.5	23	25.5	27.9	28.7	23.74	23.74	23.74	23.74	23.74	23.74	23.74
								Battery Size Requirement (kWh)	14.83	23.74	18.98	23.74	5.24	3.19
							Total Energy Generated (kWh)	28.5						

Figure 14. Chart Showing the Detailed Calculations of All 6 Profiles in the Fall Season