Case Study: Maximizing Value with a Solar Energy System
IST 652 Final Project

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Introduction

Energy costs in Hawaii are higher than anywhere else in the United States. As of August 2024, families are paying 44.28 cents per kilowatt hour (kWh), almost three times the national average of 15.45 cents[1]. The average gas price in Hawaii is $4.667 per gallon for regular unleaded fuel. This is again the highest in the nation and 35.5% higher than the national average[2]. Sustainable living is not just an environmental imperative, it is essential to be able to maintain a comfortable lifestyle.

This case study will examine a home with a newly installed solar electrical system. This system has five main components:

1) Photovoltaic (PV) panels. The PV panels generate electricity from the sun. This system is located on the western part of the island of Oahu. This area has very little cloud cover and only gets about 28 days of rain per year.

2) Batteries. Modern solar power systems may include one or more batteries to store and distribute electrical power when the sun is not shining or to serve as a backup in the event of a power outage that makes the power grid unavailable.

3) The electrical grid. The local utility company, Hawaiian Electric (HECO), provides electrical power when needed. HECO also buys back excess electricity produced by solar electric systems at a reduced rate[3].

4) The home. The home is the consumer of electricity. As part of this case study, all appliances and lawn equipment are electric with most drawing from the power provided by the solar electric system[4].

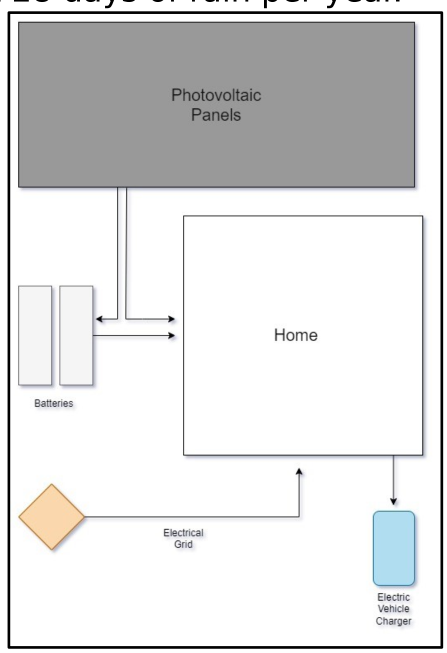

Fig. 1: Solar Electrical System

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[1] https://www.usatoday.com/money/homefront/deregulated-energy/electricity-rates-by-state/
[2] https://gasprices.aaa.com/state-gas-price-averages/; accessed August 14th
[3] https://www.hawaiianelectric.com/products-and-services/smart-renewable-energy-programs
[4] The hot water heater is connected to its own PV panels and not integrated with the system

5) Electric Vehicle (EV) charger. The EV charger provides power for one vehicle, offsetting the cost of fuel. However, the EV charger is the single greatest draw on the power system, quickly draining the batteries and forcing increased reliance on the electrical grid.

Study Questions

The purpose of this study is to use available data to answer the following questions:

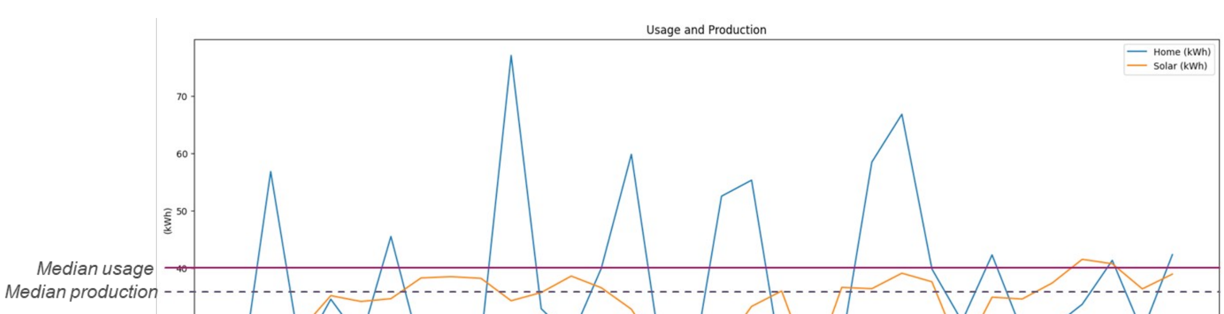
1) What is the energy capacity of the solar electrical system? (unit of analysis = kW or kWh)
2) Is it possible to optimize car charging to reduce reliance on the grid and retain enough charge in the batteries to power the home through the night? (unit of analysis = hours)
3) Can the system be removed from the grid and be completely self-reliant? (unit of analysis = kWh)
4) At what point will the system deliver a return on investment? (unit of analysis = U.S. dollars)

Data Overview:

The analysis used three different sets of data: electrical system data covering 32 days of power generation and consumption measured at 5-minute intervals, approximately 60 days of EV charging data, and Hawaiian Electric Company (HECO) rates for both energy consumption and solar export. The data represented the home's energy usage, solar production, the impact of EV charging, and potential savings from selling solar energy back to the grid. Together, this information helped estimate the system's ROI and the feasibility of energy independence.

System Capacity

As seen in Figure 2, median daily solar production was 36.47 kWh. It was almost sufficient to cover the household's median daily requirement of 40 kWh. The batteries could provide up to an additional 27 kWh when charged at 100%. Excess demand would draw from the batteries until they were at 20%, then it would shift to drawing from the electrical grid. The days in which the EV was charged are represented by the spikes in home kWh usage, far exceeding the relatively consistent solar energy production.



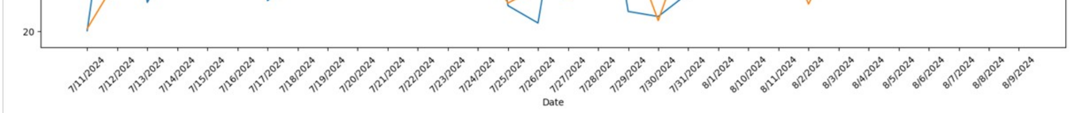


Fig. 2: System production and Usage

Figure 3 shows the battery minimum and maximum charge by day. The system is designed to maintain a minimum of 20% charge as a failsafe to keep the home powered in the event of a power outage.

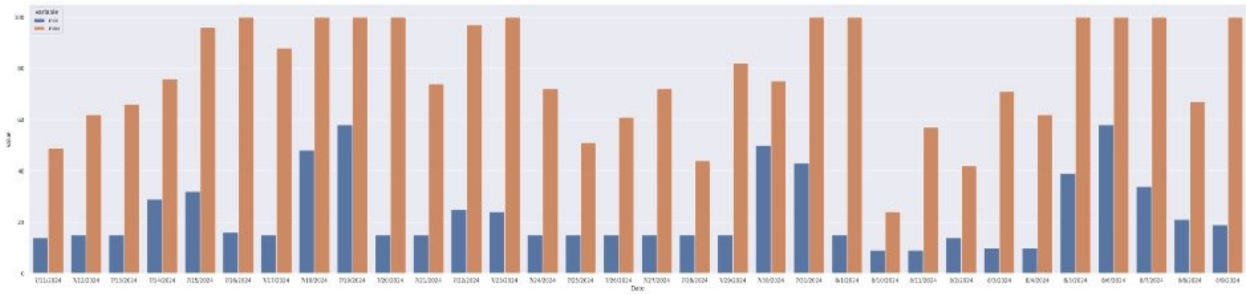


Figure 3. Battery Min/Max by Day

Home Energy Production and EV Charging Impact

EV charging had a significant impact on household energy usage. The daily energy consumed per charge averaged 21.8 kWh, with a peak of 39.95 kWh for a single charge. When EV charging was included, the total energy consumed by the household increased, often resulting in a shortfall that required support from the grid. Without EV charging, the solar system was able to handle the home’s energy load more effectively, occasionally producing excess energy.

The data showed that, without EV charging, the system often had adequate energy, allowing the home to operate independently of the grid on some days. However, on days when the EV was charged, energy demand exceeded solar production, making it difficult to avoid grid reliance.

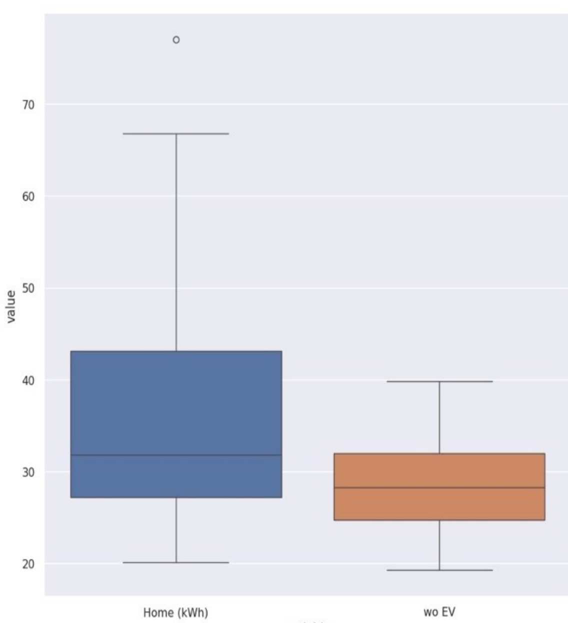


Figure 4. Energy Usage with and without EV Charging

Figure 4 compares total daily energy consumption with and without EV charging. When EV charging is included, the total energy consumed by the household increases substantially, pushing the home closer to its energy production capacity. Without EV charging, the system’s load is significantly lighter, allowing for more efficient energy usage and less reliance on the grid.

Figure 5 illustrates the daily energy balance, showing a clear contrast between days without EV charging and days with it. On days without EV charging, there is generally an excess of solar energy, sometimes allowing the home to rely solely on solar power. However, when EV charging is included, the energy demand increased, often leading to a shortfall, requiring support from the grid to meet the household's needs.

Self-Reliance

Figure 6 visualizes the percentage of energy remaining, taken in 5-minute intervals, in the Powerwall battery throughout the day.

The Powerwall battery's availability was critical in limiting grid usage. The battery typically reached full charge by 4 PM as solar production tapered off, and it was depleted by around 8 AM before solar generation started again. To cover the overnight energy requirements—especially when factoring in EV charging—the battery needed to maintain a charge of at least 81% before solar production stopped for the day.

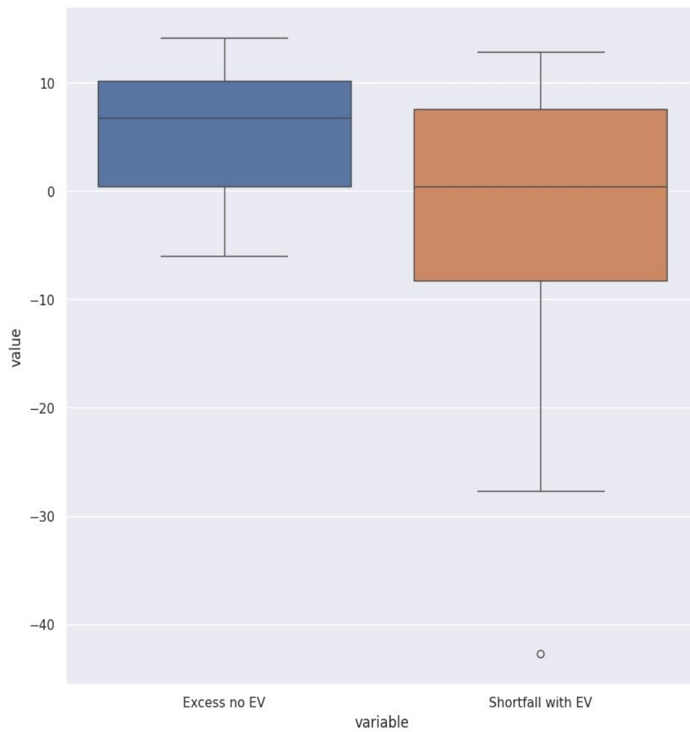


Figure 5. Energy Excess and Shortfall

The data revealed that going fully off-grid was unlikely, particularly when EV charging was involved. While there were some days when the system produced more energy than the home needed, the battery often depleted overnight, especially on days

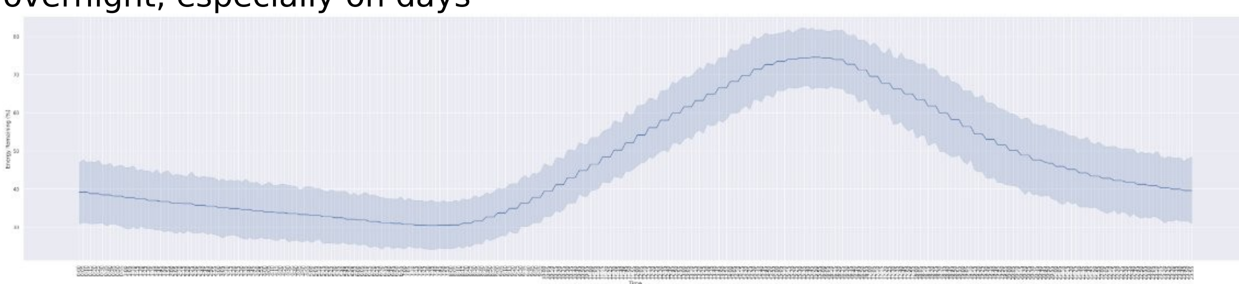


Figure 6. Battery Availability Over 24 Hours

with EV charging. Without EV charging, the battery generally provided enough power to meet the home's overnight needs, but grid support was still necessary on occasion.

Return on Investment (ROI)

The solar system yielded considerable cost savings over the 32-day analysis period. The total production value of solar energy generated was $429.10. Although grid usage incurred an additional $91.99 in costs, selling surplus energy back to the grid generated $8.94, resulting in a net cost avoidance of $68.62. This equated to a 14.75% reduction in energy expenses when compared to relying entirely on grid power.

Additionally, EV charging provided further cost benefits. Charging the EV using solar energy saved the household $69.87 over the month, as shown in Figure 6. This reflects a significant reduction in costs when compared to using gasoline to drive the same number of miles, further contributing to the overall savings from the solar system.

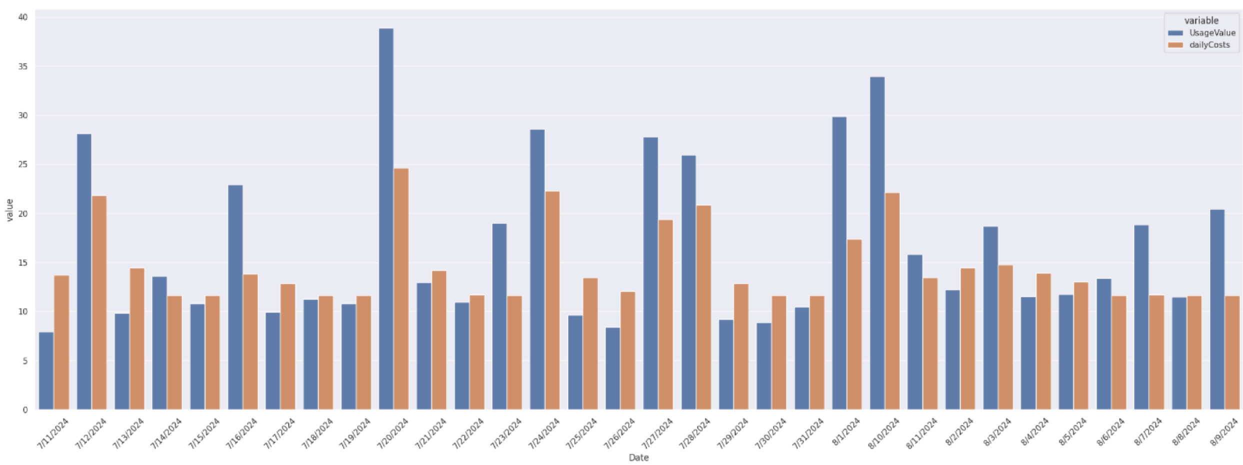


Figure 7. Usage Value and Daily Costs

In Figure 7, the comparison between Usage Value and Daily Costs shows the consistent savings achieved by using solar energy. On days with higher energy consumption, particularly due to EV charging, the household still benefited from cost avoidance, with Usage Value exceeding the Daily Costs. This further illustrates the system's effectiveness in reducing reliance on the grid while providing financial advantages.

Conclusions

The solar energy system performed well in supporting household energy needs but was insufficient for full energy independence, especially when EV charging was considered. While the system allowed for significant savings, full energy self-reliance was out of reach due to the limitations of battery capacity and the increased load from EV charging. However, there were clear cost benefits in both energy consumption and vehicle charging, contributing to a 14.75% overall cost avoidance.

With further optimizations, such as increasing battery storage or shifting EV charging to times of peak solar production, the system's effectiveness could be improved. For households in high-cost energy regions like Hawaii, solar power remained a highly viable option for reducing energy expenses.