Home Energy Independence With Solar Power

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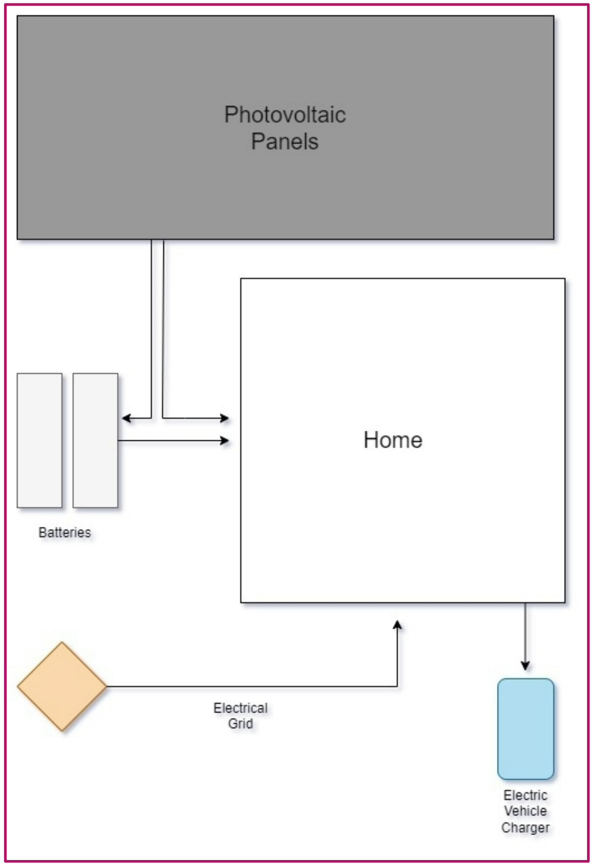
Introduction

- Average energy costs in Hawaii are $0.44 per kilowatt hour (kWh) almost 3x the national average
- Average gas price in Hawaii is $4.67, 35.5% over the national average
- This case study will examine a home with newly installed solar energy system.
- The purpose of the study is to determine energy capacity, optimization, self-reliance, and return on investment (ROI)



Solar Energy System

Problem Statement

- This study will use available data to answer the following questions:
  1. What is the energy capacity of the solar electrical system?
  2. Is it possible to optimize car charging to reduce reliance on the grid?
  3. Can the unit be completely self-reliant? (Removed from the grid)
  4. At what point will the system deliver a return on investment?

Data Overview

- Dataset 1: Solar Electrical System Data
  - 32 days of power generation/power usage
    - 5-minute interval “snapshot” of power generation/usage
- Dataset 2: Electric Vehicle (EV) Charging Data
  - ~60 days of EV charging data
    - Date, time, duration, energy used, estimated miles per charge, estimated value of charge
- Other Reference Data:
  - Fuel Cost Data
  - Inflation Indices
  - Hawaiian Electric (HECO) Rates Data

Data Preparation

- Data Cleaning
  - Date/Time sometimes used in separate columns, other times joined using datetime
  - Primarily numeric data; minimal cleaning needed for analysis
  - Data in kilowatts (kW) converted to kilowatt hours (kWh) to match EV charging and aid in pivoting and aggregation

Date_Time	Home (kW)	Powerwall (kW)	Solar (kW)	Grid (kW)
2024-08-01 00:00:00	0.4	0.3	0.0	0.0
2024-08-01 00:05:00	0.4	0.4	0.0	0.0
2024-08-01 00:10:00	0.4	0.3	0.0	0.0
2024-08-01 00:15:00	0.3	0.3	0.0	0.0
2024-08-01 00:20:00	0.3	0.3	0.0	0.0
2024-08-01 00:25:00	0.3	0.3	0.0	0.0
2024-08-01 00:30:00	0.4	0.4	0.0	0.0

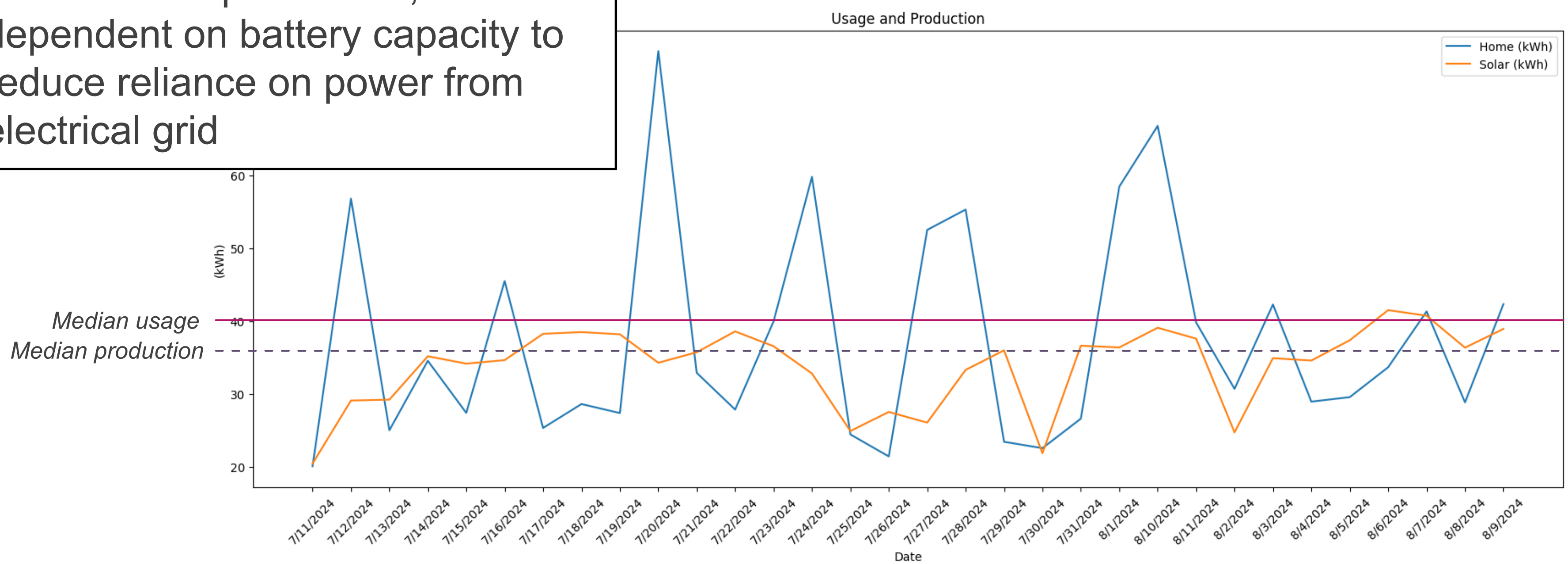
Date	Grid (kWh)	Home (kWh)	Powerwall (kWh)	Solar (kWh)
7/11/2024	5.275000	20.100000	-5.658333	20.466667
7/12/2024	25.758333	56.791667	1.908333	29.108333
7/13/2024	7.258333	25.033333	-11.475000	29.233333
7/14/2024	0.000000	34.558333	-0.741667	35.183333
7/15/2024	0.000000	27.416667	-6.825000	34.166667

Exploratory Data Analysis

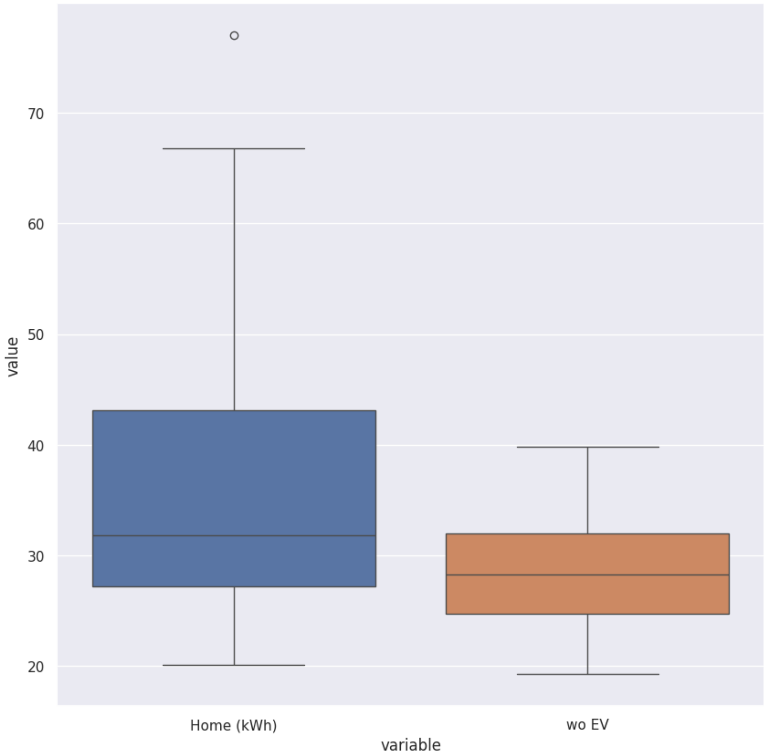
- Daily Usage vs. solar production
- Solar production is close to total usage most days
- EV charging causes usage to exceed solar production; dependent on battery capacity to reduce reliance on power from electrical grid

```
import statistics
Home_EV.head()
medianusage = statistics.median(Home_EV['Home (kWh)'])
print('typical (median) usage is ',"{:.2f}".format(medianusage),'kWh')
mediansolar = statistics.median(Home_EV['Solar (kWh)'])
delta = medianusage - mediansolar
print('typical (median) solar production is ',"{:.2f}".format(mediansolar),'kWh')
print('typical (median) daily shortfall is ',"{:.2f}".format(delta),'kWh')
```

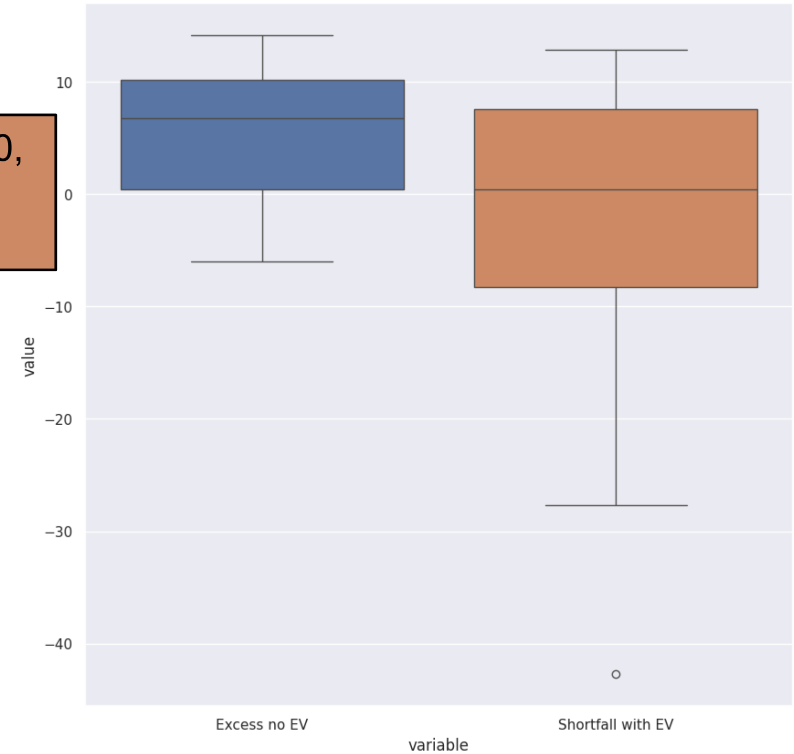
```
typical (median) usage is  39.89 kWh
typical (median) solar production is  36.47 kWh
typical (median) daily shortfall is  3.41 kWh
```



Impact of EV Charging



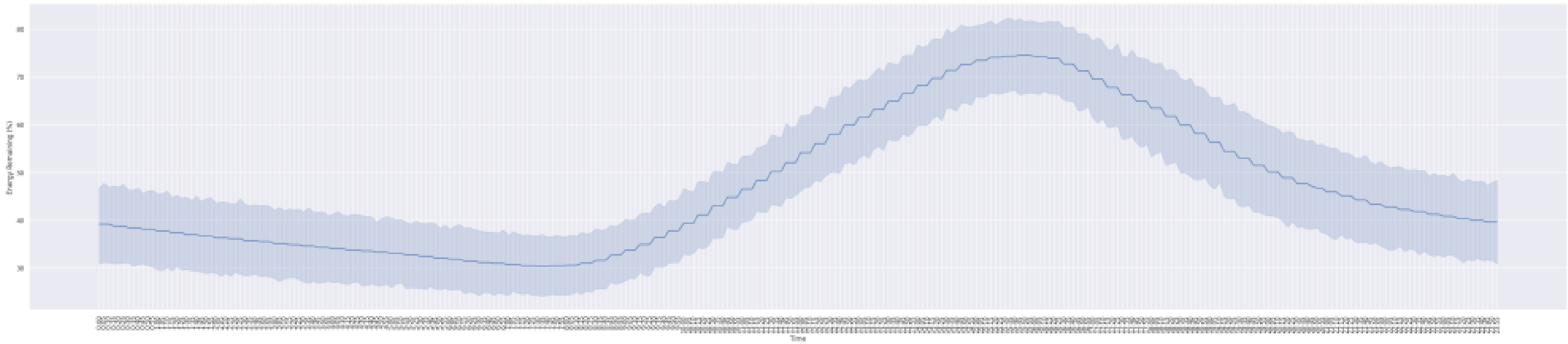
Where y = 0, usage = production



Usage with and without EV Charging

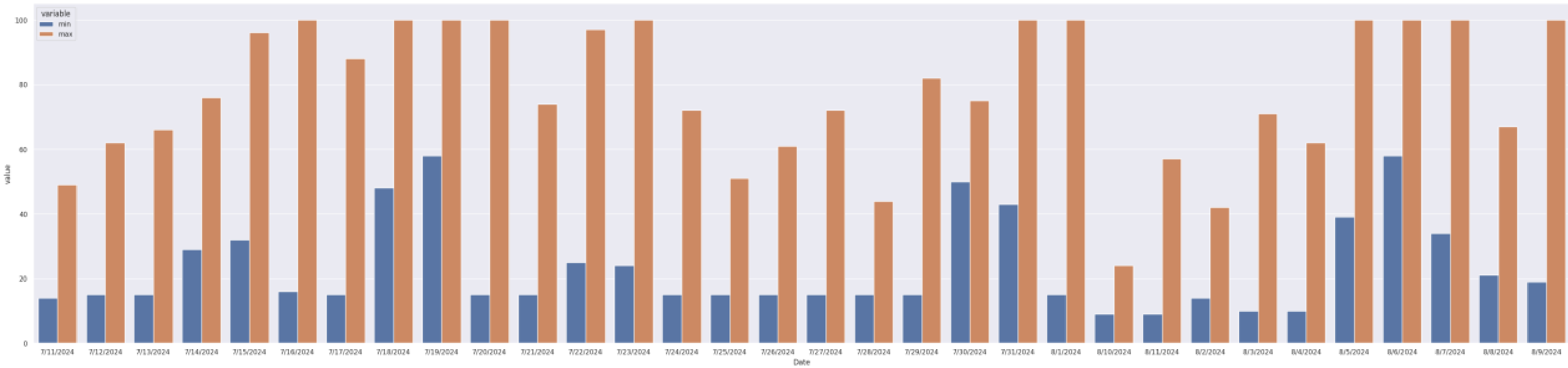
Energy Excess and Shortfall

Can the System Go Off-Grid?



- Battery availability is the most important factor to limiting grid usage
- Graph shows the ‘% energy remaining’ distribution at 5-minute intervals
- The battery is at its maximum charge around 4pm each day; this is the time that the solar production starts to taper off
- The battery is used overnight to maintain power; it is at its lowest around 8am, just prior to the solar production starting each day

Can the System Go Off-Grid? (cont.)



- Battery is set to start pulling from the grid if it goes below 20% (however, this was not the case during the period shown)
- Battery must be at ~81% remaining when solar production stops for the day to ensure adequate capacity to prevent drawing on the grid overnight

```
#battery descriptive statistics; all in percent available;
#will use the median for analysis

minMin = min(minmaxbattery['min'])
maxMin = max(minmaxbattery['min'])
minMax = min(minmaxbattery['max'])
maxMax = max(minmaxbattery['max']) #100
medianMin = statistics.median(minmaxbattery['min'])
medianMax = statistics.median(minmaxbattery['max'])
meanMin = statistics.mean(minmaxbattery['min'])
meanMax = statistics.mean(minmaxbattery['max'])
modeMin = statistics.mode(minmaxbattery['min'])
modeMax = statistics.mode(minmaxbattery['max'])

print("median Min: ", medianMin)

print("median Max: ",medianMax)

print("median delta: ",medianMax-medianMin)
```

```
median Min:  15.0
median Max:  75.5
median delta:  60.5
```

Return on Investment: Component Value

```
cost_summaries_by_day = powerwall_data.pivot_table(values =
 ['Cost', 'ValueOfConsumedPower','Production'], index = 'Date', aggfunc = 'sum')

GridCost = float(cost_summaries_by_day['Cost'].sum())
ProdValue = float(cost_summaries_by_day['Production'].sum())
ValueofConsumed = float(cost_summaries_by_day['ValueOfConsumedPower'].sum())


#include export value
export_value_total = float(powerwall_data['Grid Export Value'].sum())

PowerBill = export_value_total + GridCost
CapitalCost = (32*-11.666667)
EnergyExpenses = CapitalCost + PowerBill
CostDelta = ValueofConsumed + EnergyExpenses

#Cost Components
print("Production = ", f"${ProdValue:,.2f}")
print("Value of consumed energy = ", f"${ValueofConsumed:,.2f}")
print("Grid Usage Cost = ", f"${GridCost:,.2f}")
print("Total Export Value = ", f"${export_value_total:,.2f}")

#Summary
print("Power Bill for the Month = ", f"${PowerBill:,.2f}")
print("Total Energy Expenses = ", f"${EnergyExpenses:,.2f}")
print("Cost Avoidance = ", f"${CostDelta:,.2f}")
```

```
Production =  $429.10
Value of consumed energy =  $473.33
Grid Usage Cost =  $-91.99
Total Export Value =  $8.94
Power Bill for the Month =  $-83.05
Total Energy Expenses =  $-456.38
Cost Avoidance =  $16.95
```

- Calculate value of energy used in the home
- Calculate value of the energy used to charge EV
- Calculate fixed and variable costs (capital cost + electric bill)

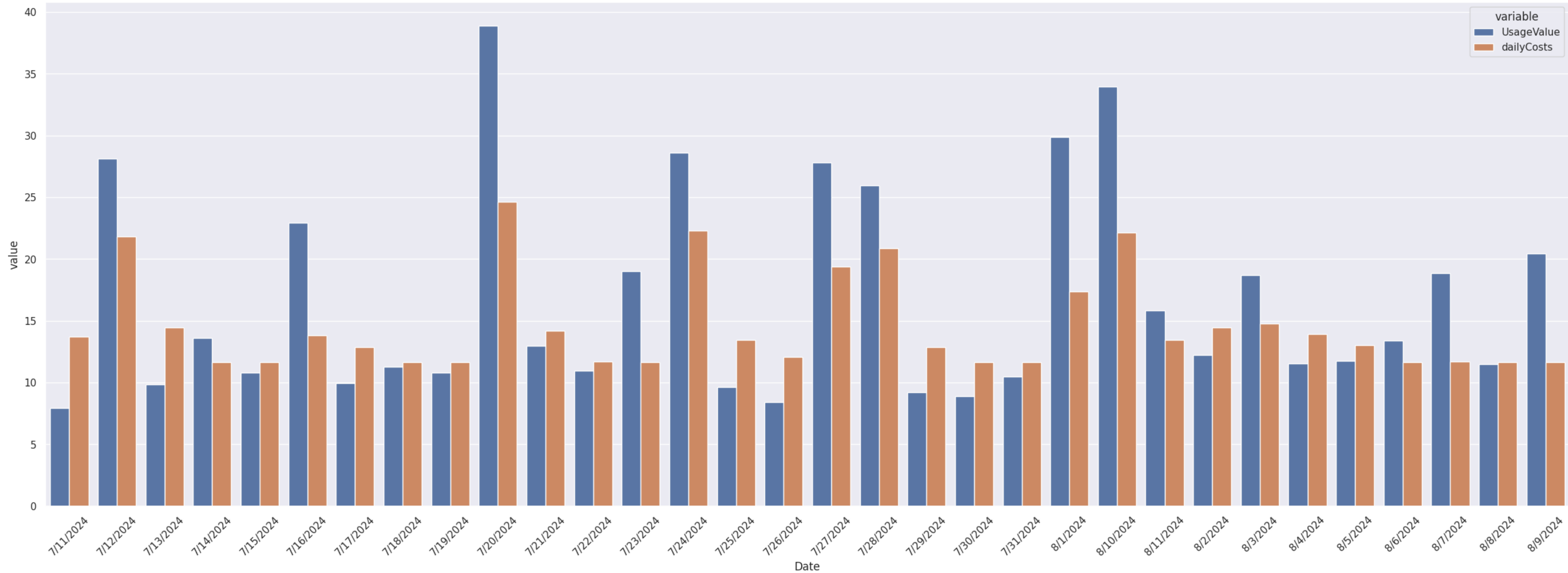
```
ev_charging_data_month = ev_charging_data[0:12]
ev_charging_data_month
GasEquivalent_total = float(ev_charging_data_month['Gas Value'].sum())
CostEquivalent_total = float(ev_charging_data_month['Cost'].sum())
EVDelta = GasEquivalent_total - CostEquivalent_total

print("Value of an equivalent amount of Gas= ", f"${GasEquivalent_total:,.2f}")
print("Value of EV Charge= ",f"${CostEquivalent_total:,.2f}")


print("Cost Avoidance for EV =" , f"${EVDelta:,.2f}")
```

```
Value of an equivalent amount of Gas=  $174.55
Value of EV Charge=  $104.68
Cost Avoidance for EV = $69.87
```

Return on Investment: Composite Value




```
TotalUsageValue = float(Value['UsageValue'].sum())
TotaldailyCosts = float(Value['dailyCosts'].sum())
ValueDelta = TotalUsageValue - TotaldailyCosts
savings = ((TotalUsageValue/TotaldailyCosts)-1)*100

print("Combined home and EV Usage Value = ", f"${TotalUsageValue:,.2f}")
print("Monthly Cost = ", f"${TotaldailyCosts:,.2f}")
print("True Cost Avoidance = ", f"${ValueDelta:,.2f}")
print("% cost avoidance = ", f"{savings:,.2f}%")
```

```
Combined home and EV Usage Value =  $533.94
Monthly Cost =  $465.32
True Cost Avoidance =  $68.62
% cost avoidance =  14.75%
```

- Net cost avoidance = 15% over electrical grid usage and a vehicle with an Internal Combustion Engine (ICE)
- Higher fixed costs will reduce the impact on energy prices caused by inflation; value will increase over time

Conclusion

- The Solar Electric System's capacity is sufficient to power the home but not the EV without grid usage
- The home with EV charging cannot be self-sustaining (i.e. 'off the grid') without a significant reduction in other energy usage
- However, the value of charging the EV on the solar electric system far exceeds the additional cost of drawing from the grid each month
- Charging the EV earlier in the day, more often, and for shorter periods would help with battery management; it would reduce but not eliminate the reliance on energy from the electrical grid