Electric Vehicle Energy Storage as a Solution to the Duck Curve Problem

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Outline

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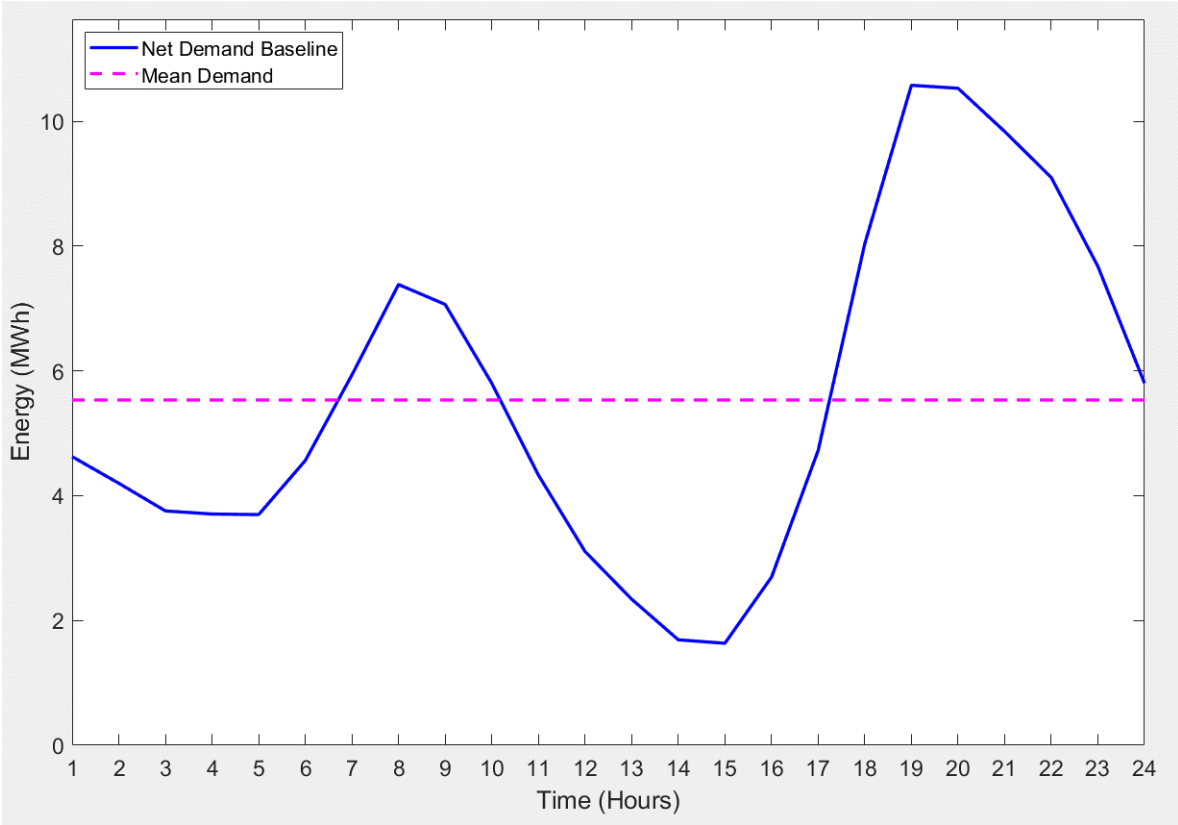
- Objectives
- Approach
- Results
- Discussion
- Conclusion

Background

- Renewable energy sources are intermittent.
- Daily demand for residential buildings with PV cells is not consistent.
- This presents a problem for slow responding power grids lacking energy storage.
- Energy storage solutions that could be adopted by the grid are expensive.



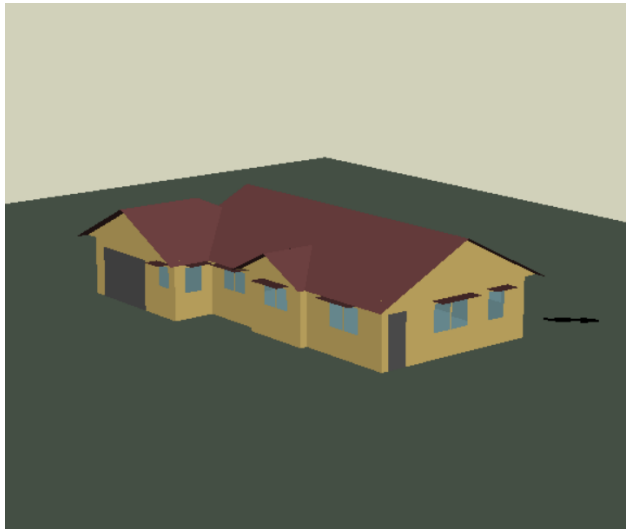
Objectives

- The main objective of this study is to look at vehicle to grid technology as a mean to balance the grid.
- The study also aims to quantify the cost of V2G on the EV owner.
- The study will propose an off/on peak utility schedule to offset the calculated V2G adoption costs.
- The cost will take into account the battery degradation over time.
- The cost will also consider the upfront cost of adding an inverter.

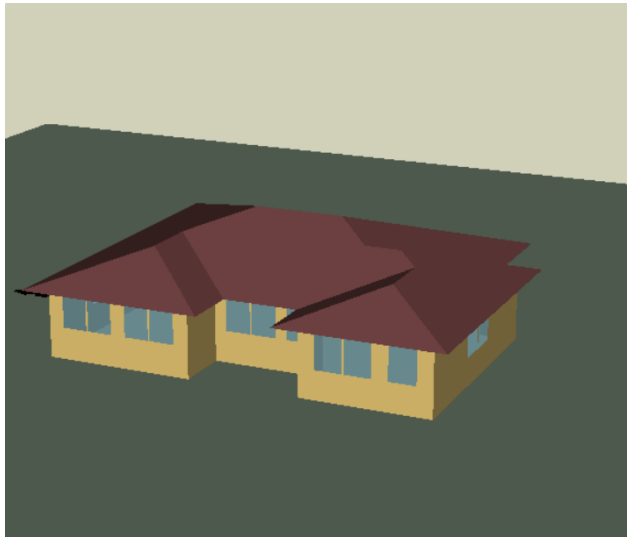
Approach: Simulation of Residential Units

Assumptions for the simulation:

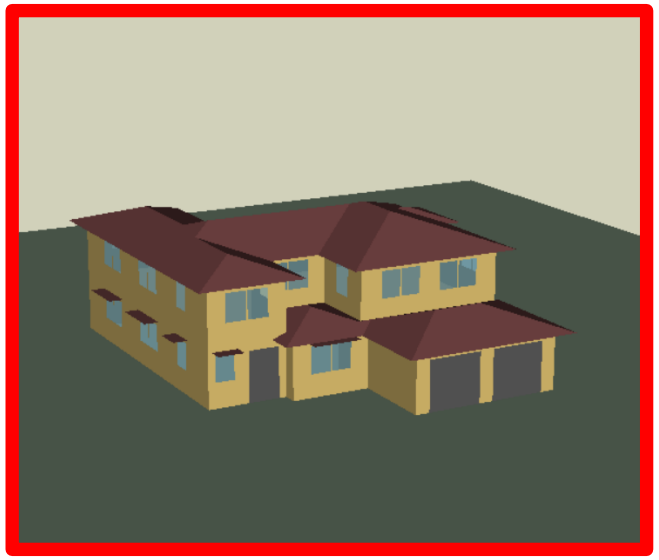
- Two sets of three residential units in California were modeled using BEOpt.
- A total of 4 unique layouts were used varying in size between 2 – 4 bedrooms.
- Four of the units were modeled with a conditioning schedule that has a setback from 9Am to 5PM during weekdays.
- Plug load schedules were modified to simulate reduced use during work hours.
- Half of the units were modeled with PV panels.



2 Bedroom, 2 Bathroom

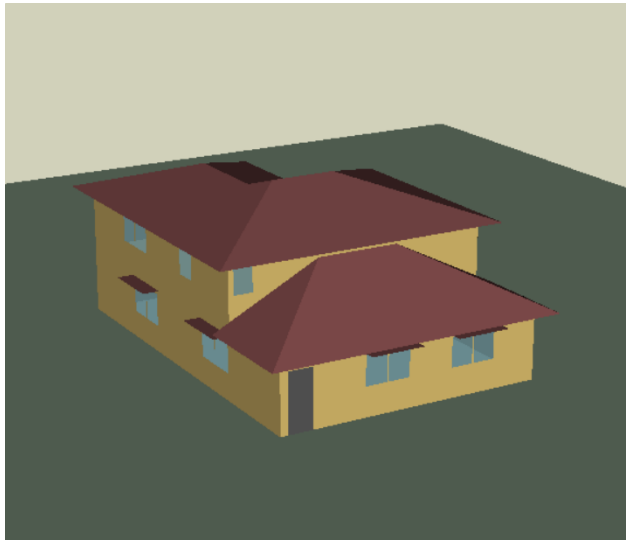


3 Bedroom, 2 Bathroom

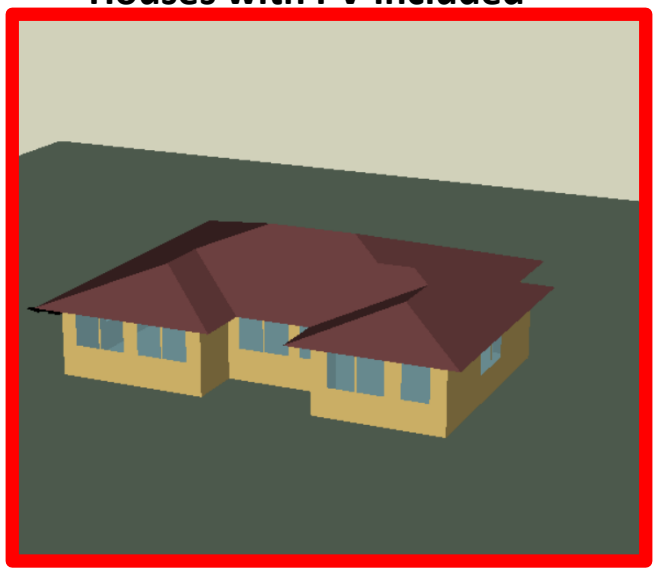


4 Bedroom, 2.5 Bathroom

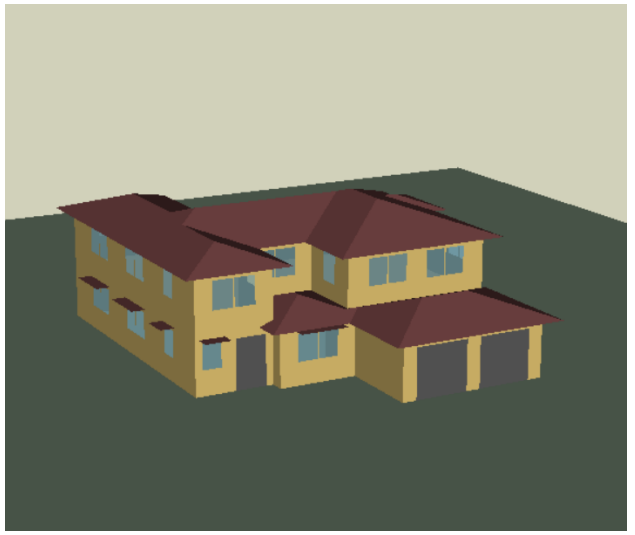
Houses with PV Included



2 Bedroom, 1.5 Bathroom



3 Bedroom, 2 Bathroom

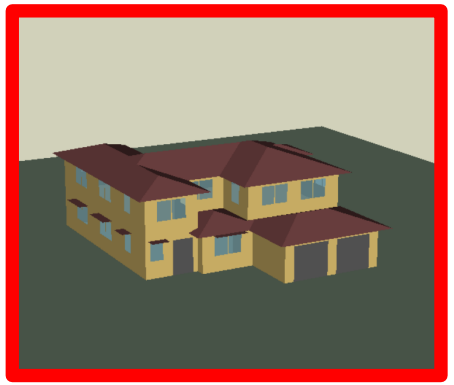


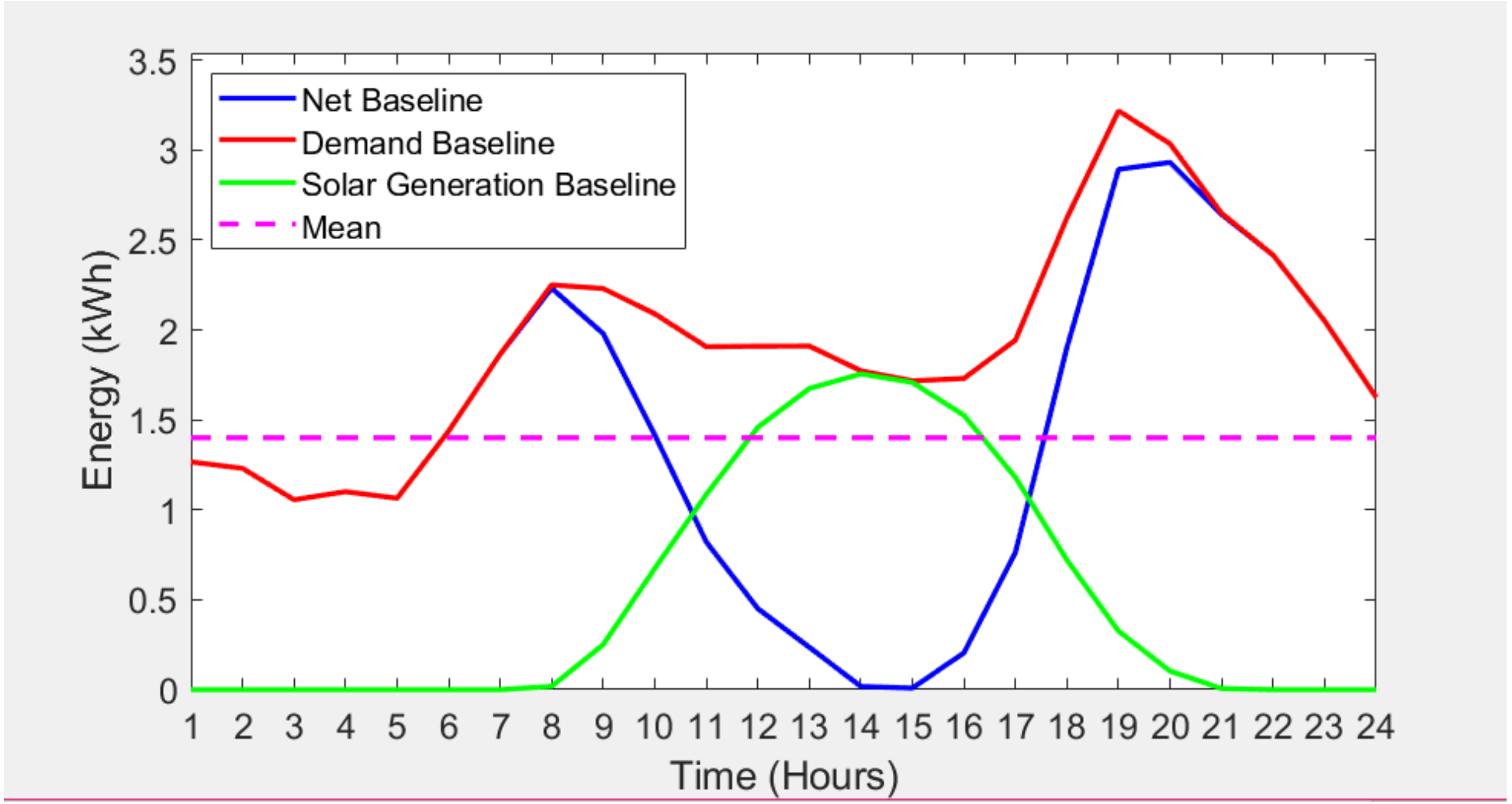
4 Bedroom, 2.5 Bathroom

Houses without PV

Results: Unmodified unit Average Annual Hour to Hour Demand

- **4 Bedroom house**
- **PV installed**
- **No EV charging**
- **No Vehicle to grid.**





Results: Unmodified unit Average Annual Hour to Hour Demand

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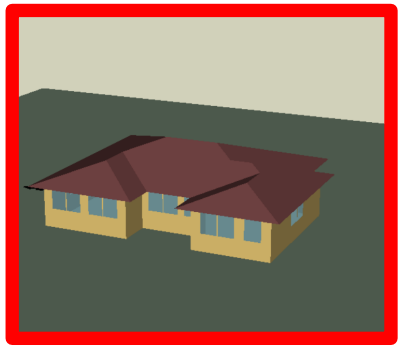
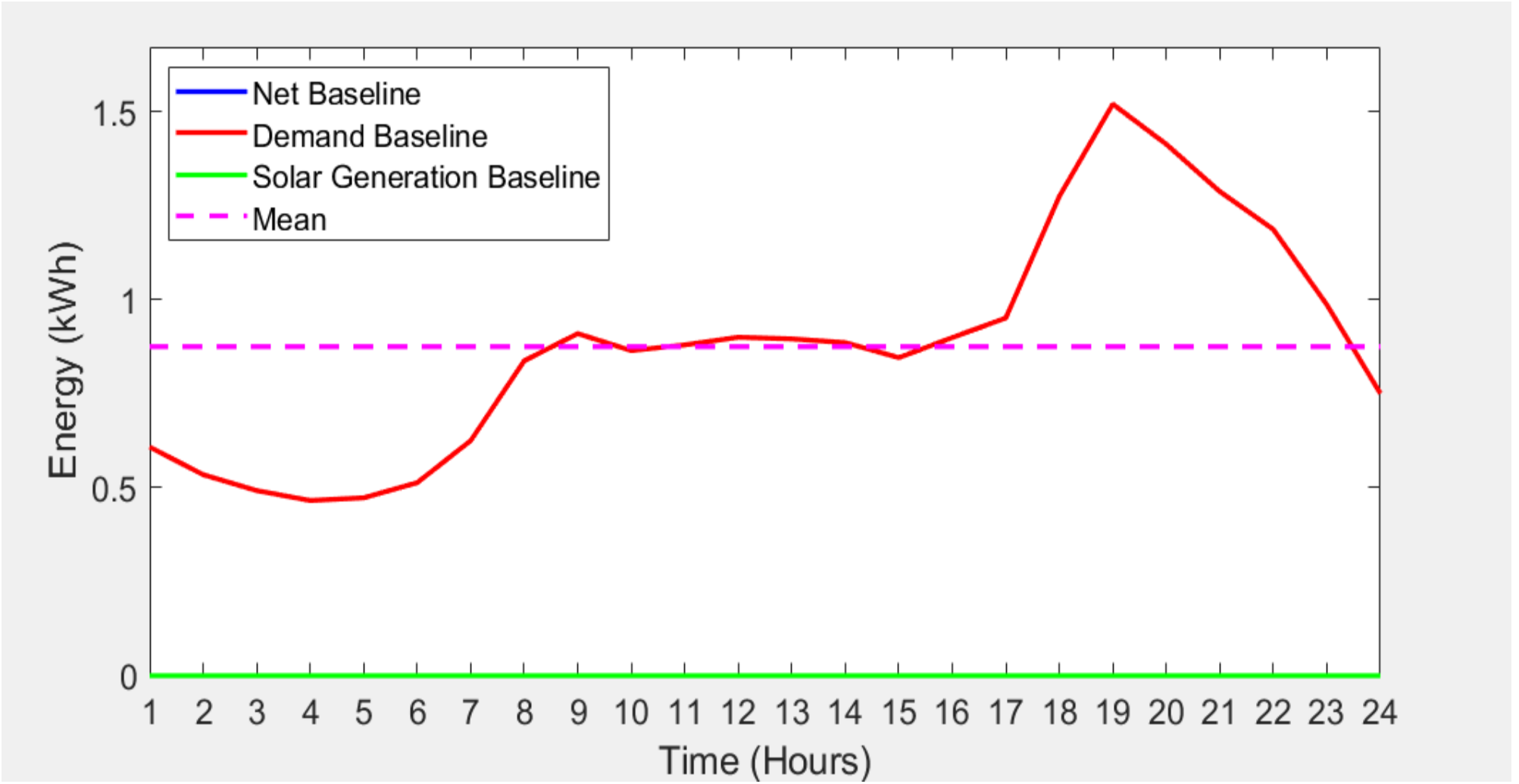
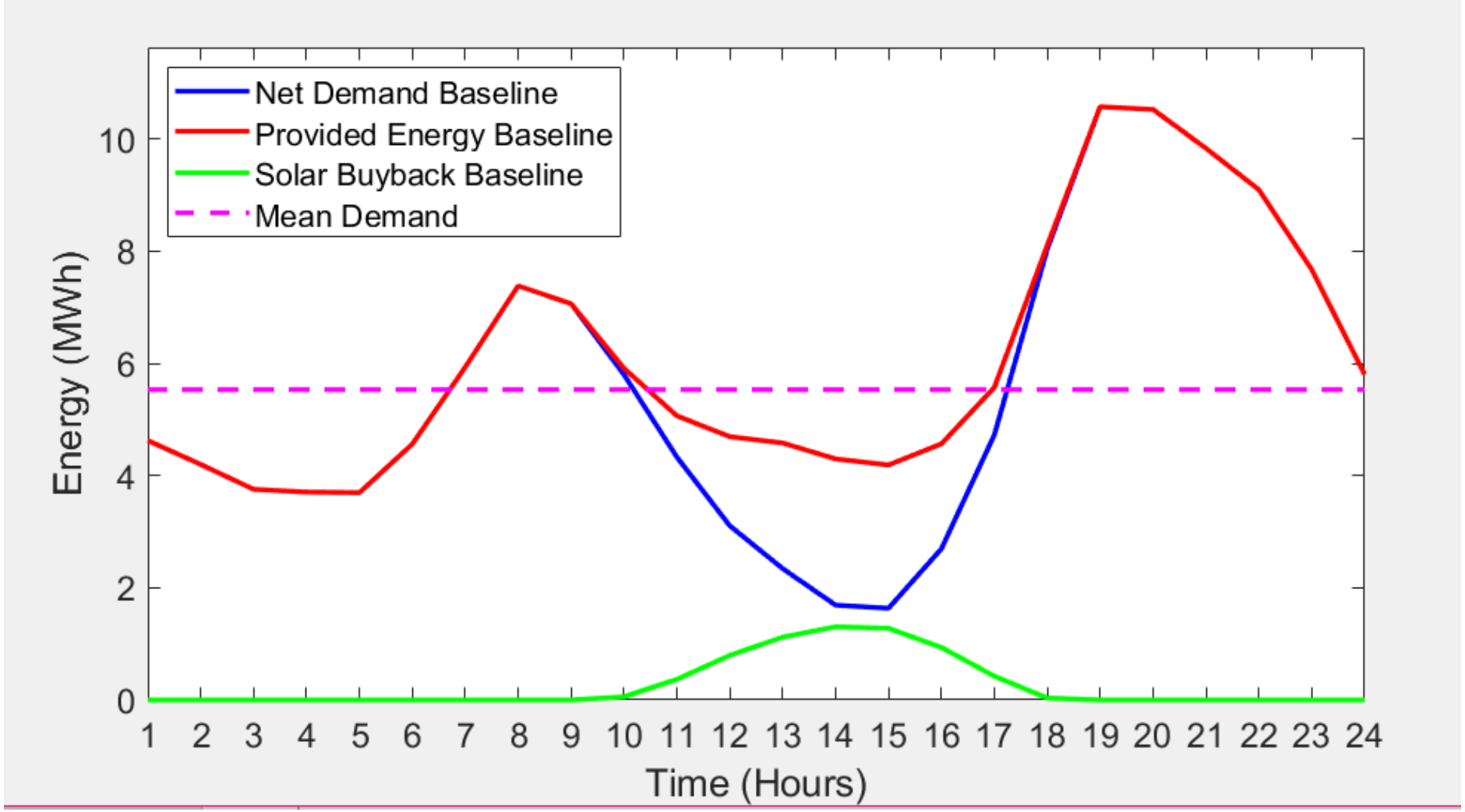




Results: Unmodified Grid Average Annual Hour to Hour Demand

- **The demand on the grid.**
- **No EV charging**
- **No Vehicle to grid.**



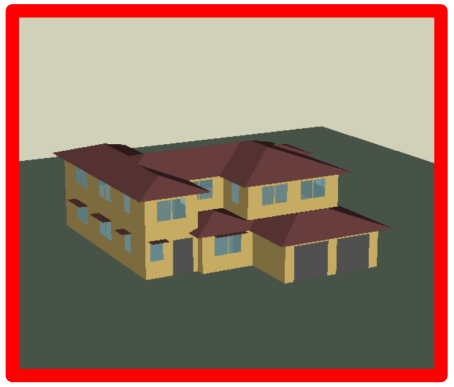
Approach: MATLAB Data Processing of Demand with an Unoptimized EV Charging

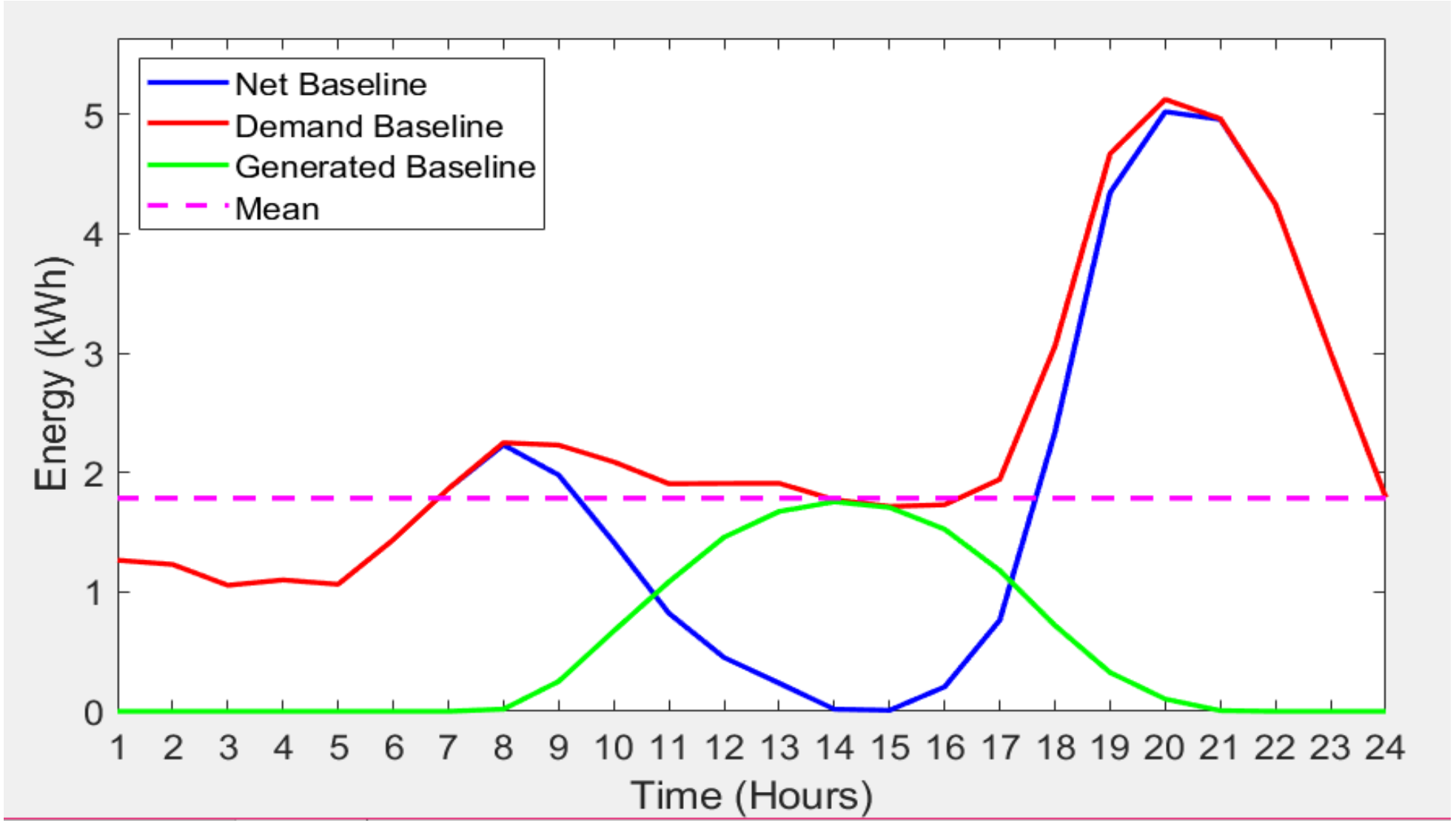
Assumptions to calculate the effect of unoptimized charging:

- The 6 home owners were assumed to have an EV car each, and that each one drives it for an average of 12,000 miles a year.
- The annual miles were divided between a morning and an evening commute. Both with uncertainties in duration, distance, and speed.
- The chargers were assumed to be single phase 3.7KW chargers. Charge time is set to be between 5 and 9 PM with uncertainty about start and end time added.

Results : Average Annual Unit Demand with an Unoptimized EV Charging

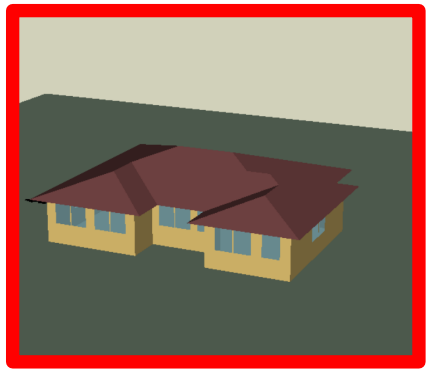
- **4 Bedroom house**
- **PV installed**
- **EV charging**
- **No Vehicle to grid.**

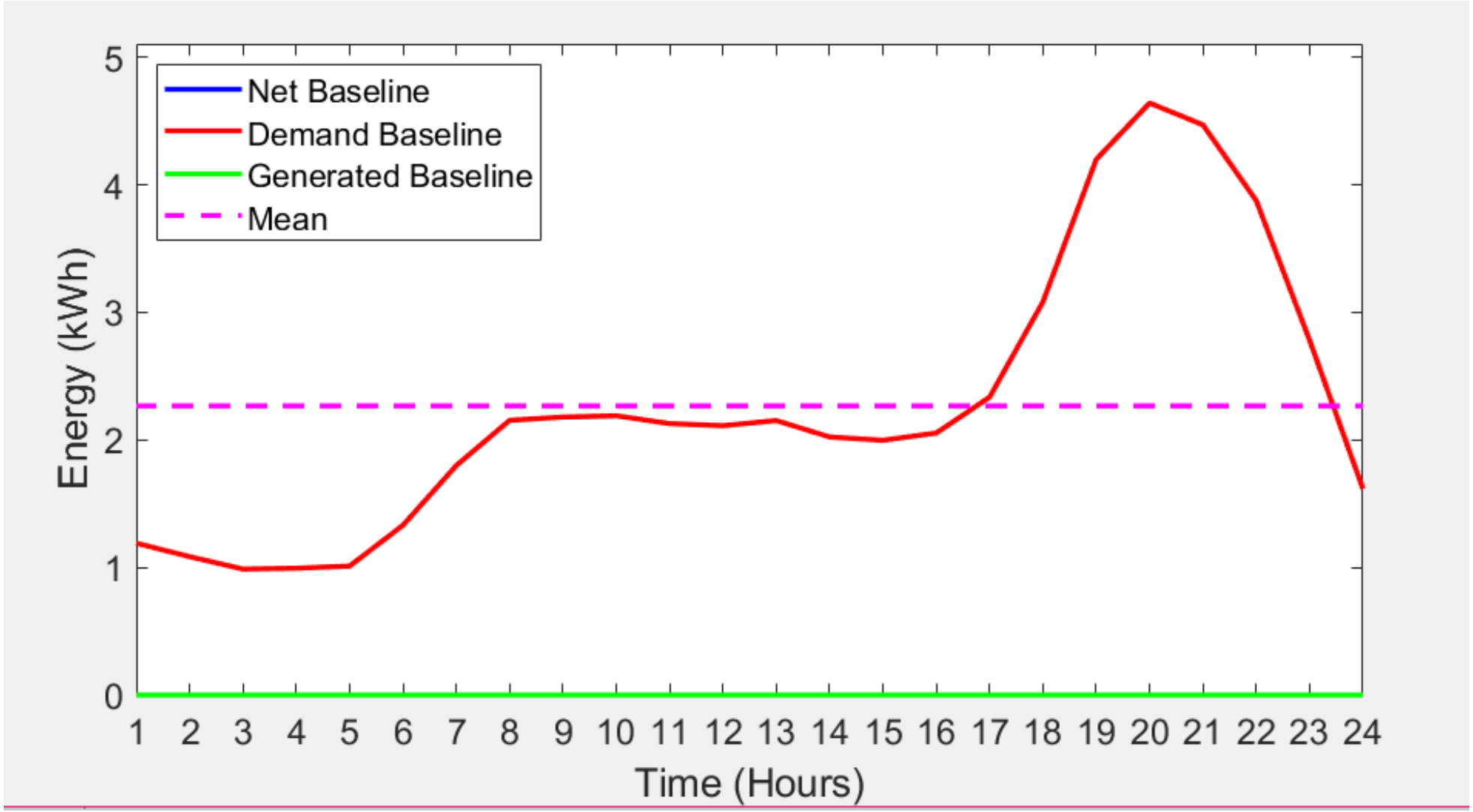




Results : Average Annual Unit Demand with an Unoptimized EV Charging

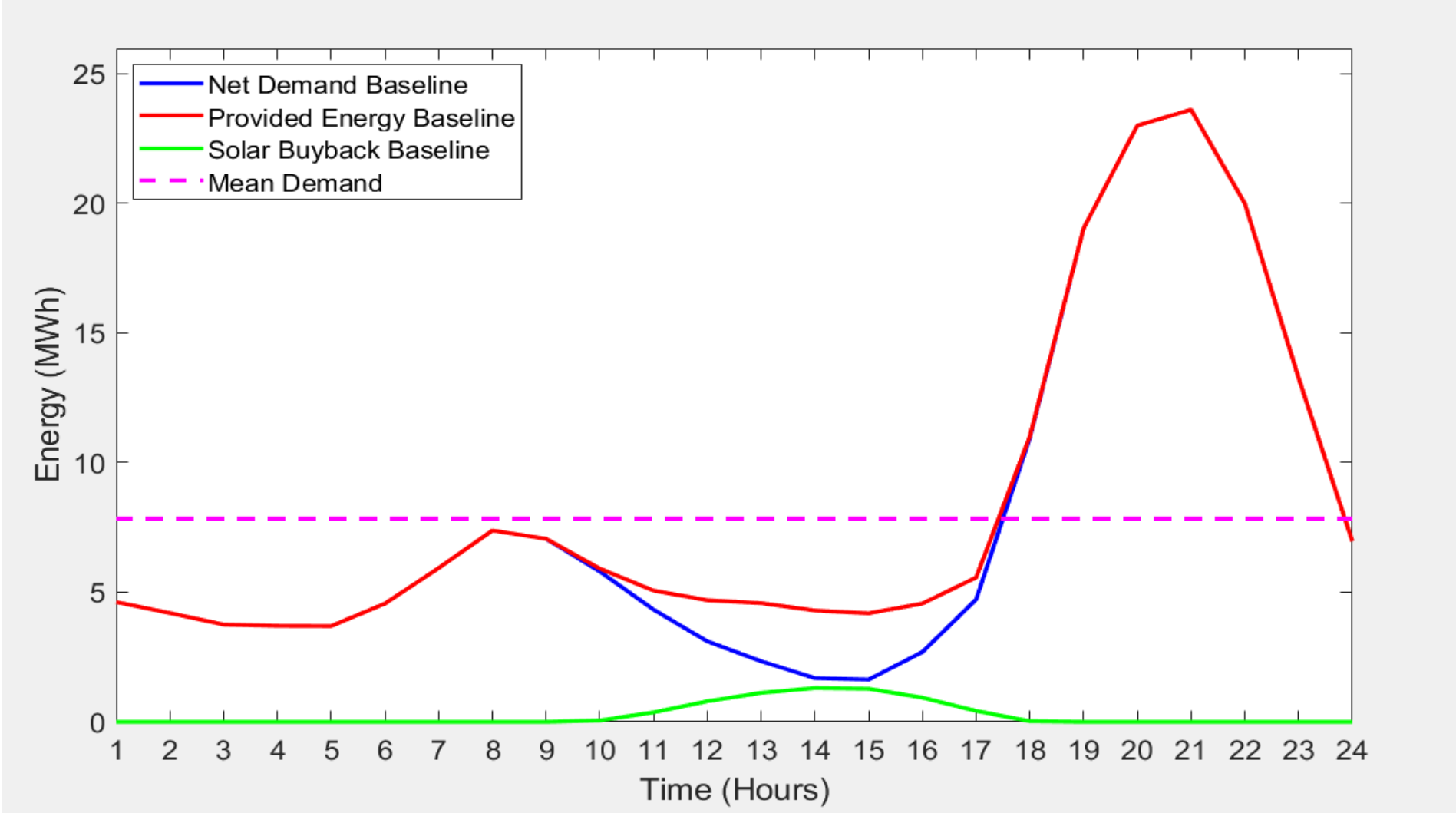
- **3 Bedroom house**
- **No PV installed**
- **EV charging**
- **No Vehicle to grid.**





Results : Average Annual Grid Demand with an Unoptimized EV Charging

- **The demand on the grid.**
- **EV charging**
- **No Vehicle to grid.**



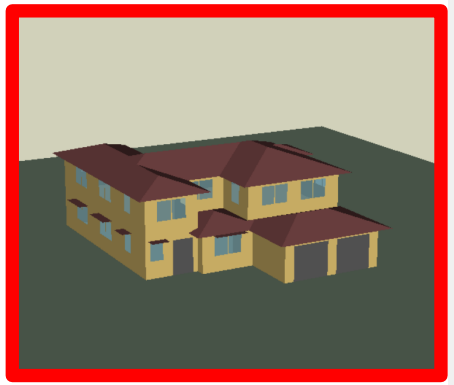
Approach: MATLAB Data Processing of Demand with Optimized EV Charging

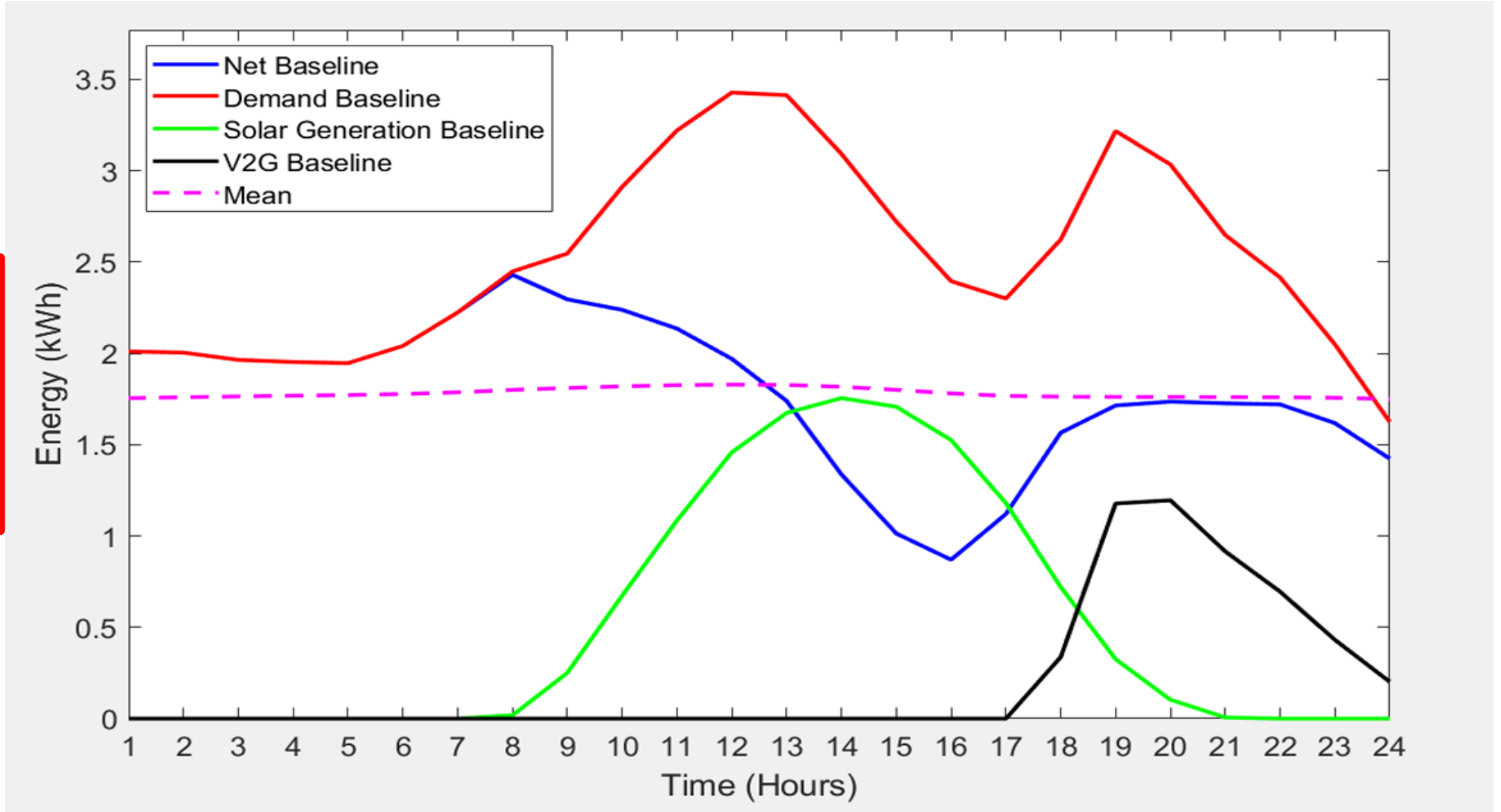
Assumptions to calculate the effect of Optimized charging:

- Cars are charged in off peak times at rates that reduce the difference between mean and current demand
- Cars are discharged and used to reduce demand at peak times.
- The rate of charge is set as the difference between the current demand and the current average demand.
- With optimized charging, the daily average baseline is calculated.

Results : Average Annual Unit Demand with V2G

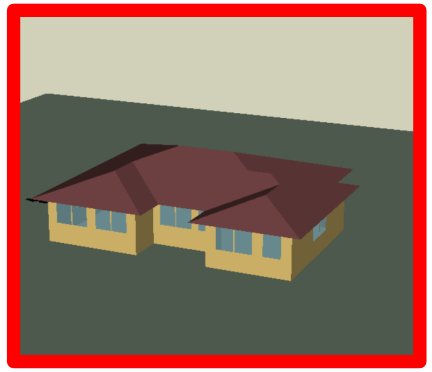
- **4 Bedroom house**
- **PV installed**
- **EV charging**
- **Vehicle to grid.**

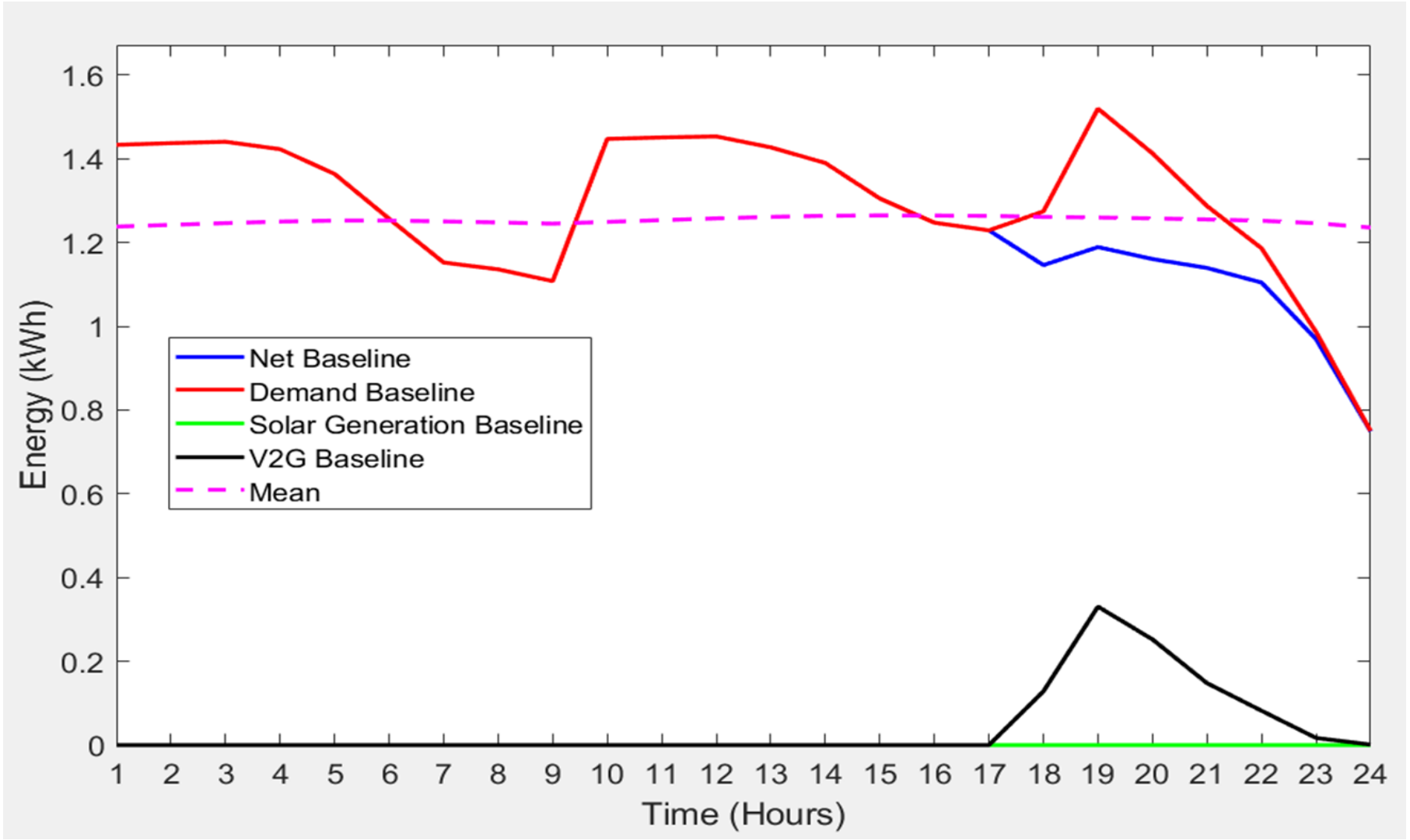




Results : Average Annual Unit Demand with V2G

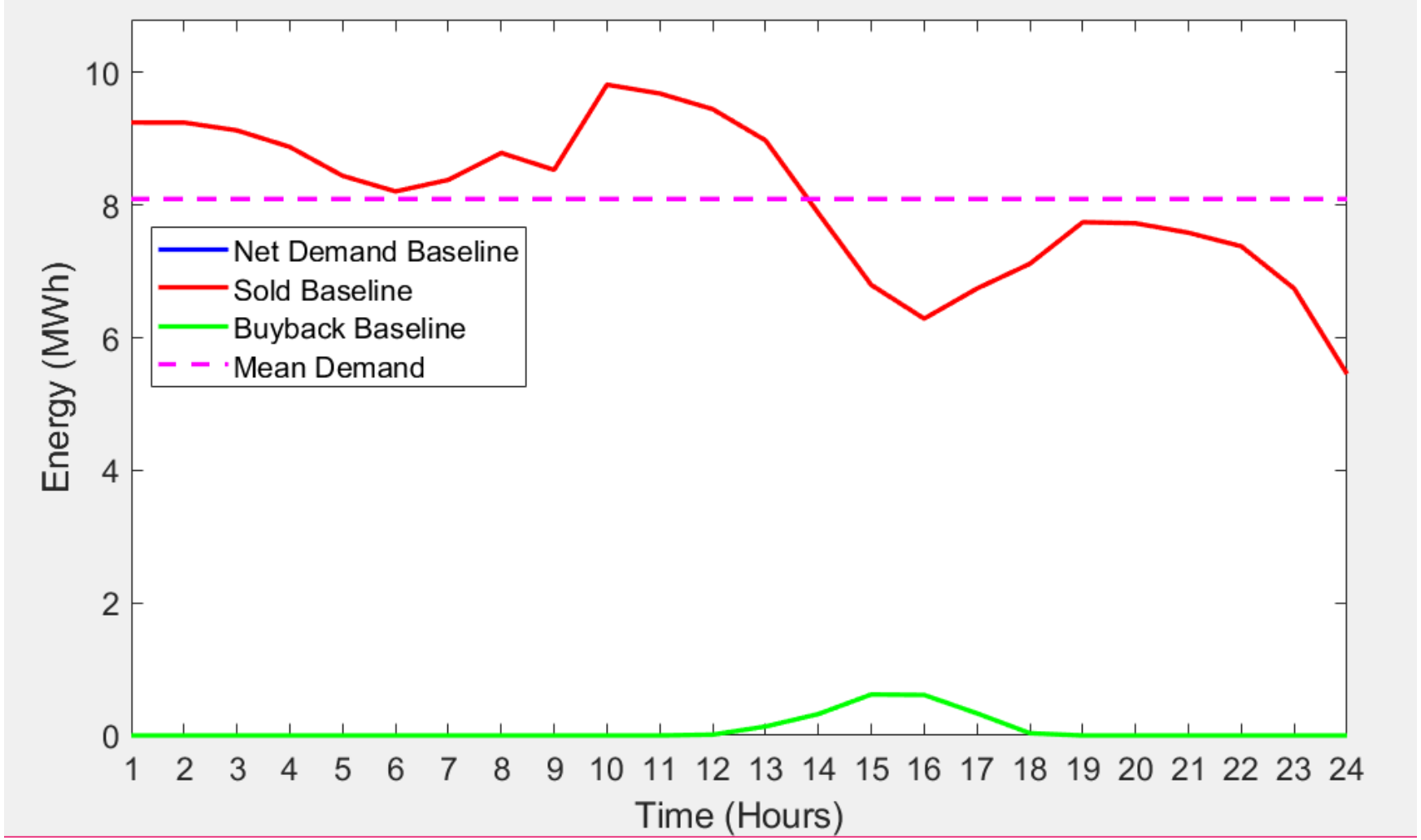
- **3 Bedroom house**
- **No PV installed**
- **EV charging**
- **Vehicle to grid.**



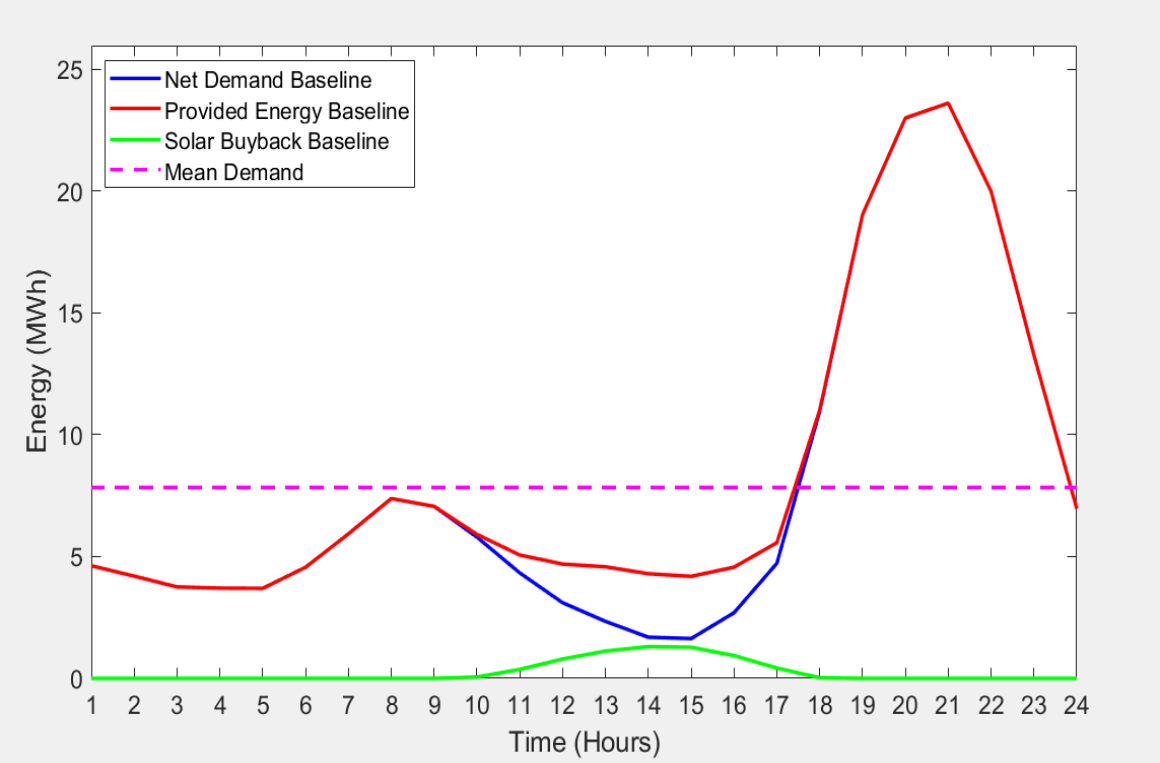


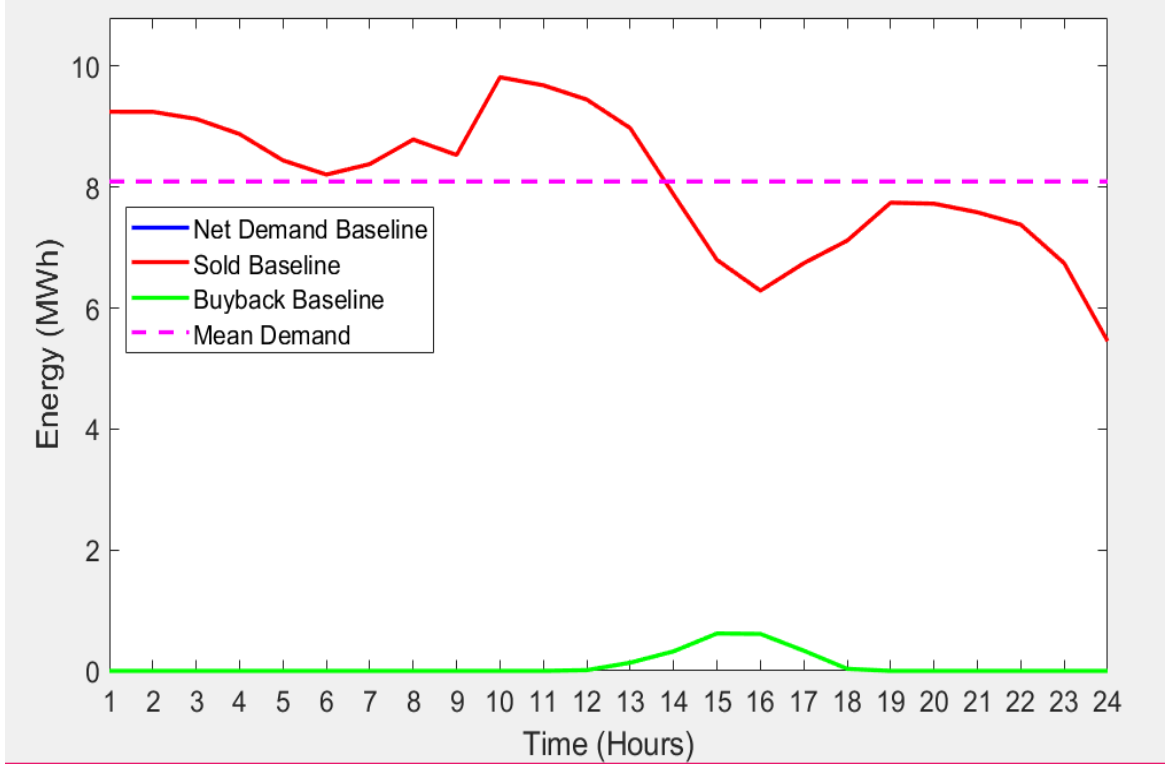
Results : Average Annual Grid Demand with V2G

- **The demand on the grid.**
- **EV charging.**
- **Vehicle to grid.**



Results : Comparing unoptimized charging with optimized charging (V2G)



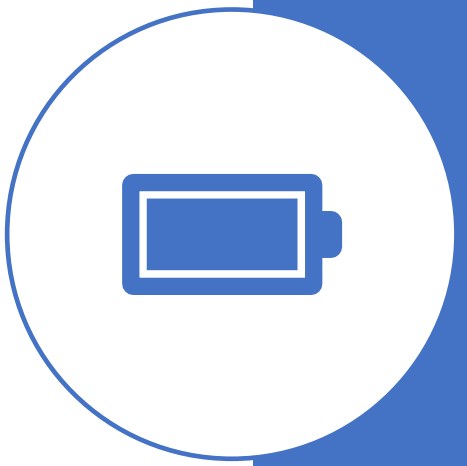


- **The demand on the grid.**
- **EV charging**
- **No Vehicle to grid.**

- **The demand on the grid.**
- **EV charging.**
- **Vehicle to grid.**

Approach: Battery degradation

- QLoss=B x $e^{\left(\frac{-31500+370\ x\ CRate}{R\ x\ T}\right)}$ x $Ah^{0.552}$



- *Q loss : T*he percentage of capacity loss
- *B : T*he pre-exponential factor (which depends on the C-rate)
- C-rate: measure of the rate at which a battery is discharged relative to its maximum capacity.
- *R : T*he gas constant
- *T : T*he absolute temperature
- *Ah : T*he total charge throughput of the cell

Discussion: Cost analysis

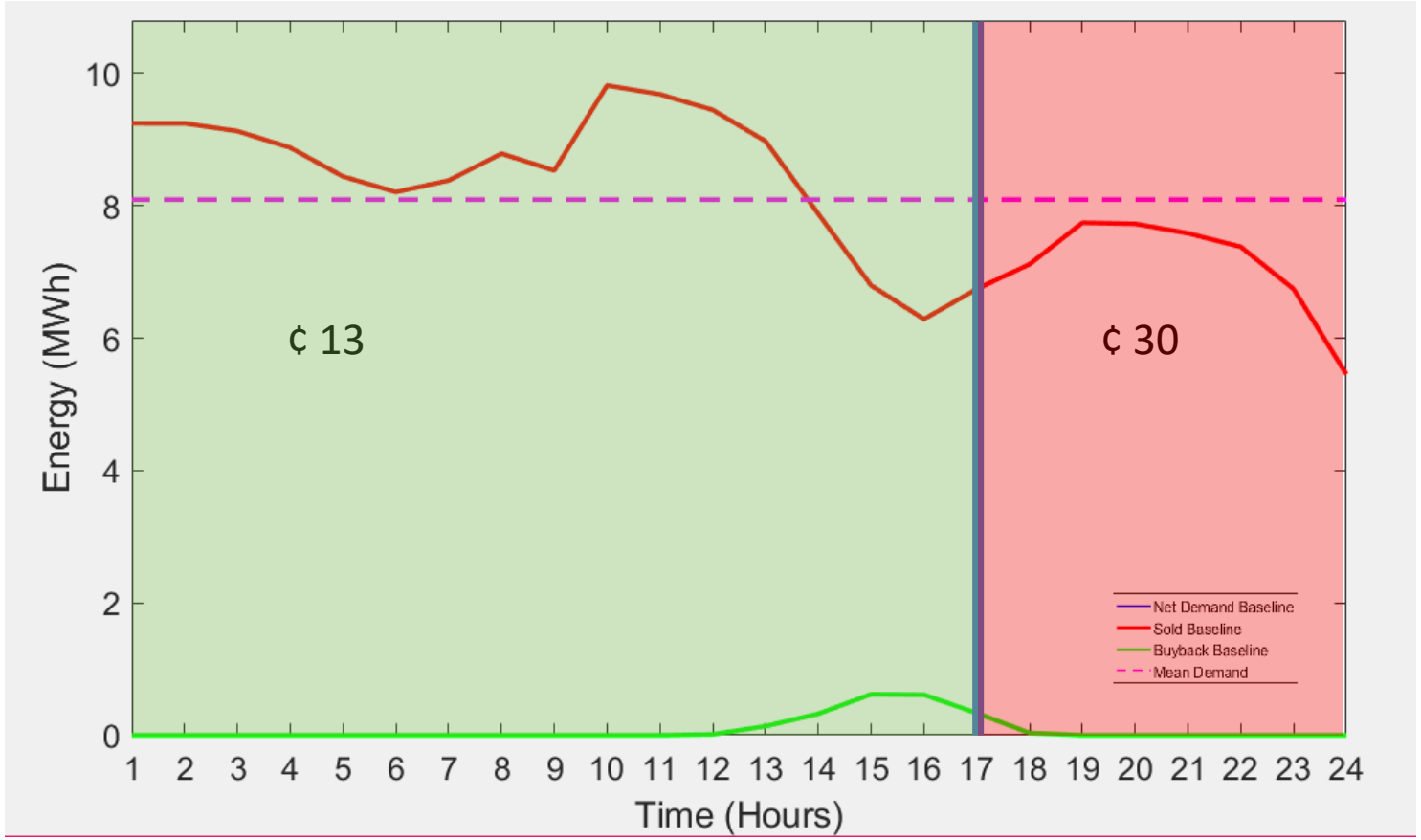
- Ten-year return on investment is targeted here.
- Price for battery replacement and inverter were assumed.
- Difference in battery life (with vs without V2G) is calculated.
- The total KWh discharged to the house used in the 10 years is calculated for each house.
- Total cost divided by the total KWh used to get utility rate difference needed.
- Electricy price should be: base + 17/24*Difference in on peak hours
- Electricy price should be: base + 7/24*Difference in off peak hours
- This will encourage V2G adoption.

Discussion

- The proposed usage case for EV owners is to charge their cars from the grid during peak solar production, and to discharge the battery to provide energy during the peak demand period to the house.
- Cost of a separate inverter for people with PV cell inverters may not be needed, which would make this approach more feasible.
- Regions with inexpensive electricity prices cannot easily modify their price by such a significant amount.

Conclusion

- Grid balancing can get harder in the future when electric vehicles become more common.
- V2G is a valid solution that can balance the grid.
- Time of use pricing can encourage V2G adoption.



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