A GRID INDEPENDENT HOUSEHOLD WITH ENERGY STORAGE

FORT WORTH, TEXAS

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Introduction

Solar net-zero energy buildings (NZEBs) are energy-efficient structures that generate as much electricity on-site as they consume over one year. This project involves designing a net-zero solar home in Fort Worth, Texas, using well-insulated construction materials, optimized building orientation to maximize sunlight, and efficient heating and cooling equipment. The house's energy demand is met primarily by electricity produced from a photovoltaic (PV) system. Energy calculations and modeling are performed to estimate annual electricity consumption, and subsequent required PV system size. Results indicate that the house can reach net-zero energy performance under typical climate conditions in Fort Worth. This project shows that combining on-site solar generation with energy-efficient design strategies can significantly reduce residential energy use and lower environmental impact.

System Data and Analysis

Irradiance at every hour of the day: $$I_i = \frac{DHI \cdot (180 - \varphi)}{180} + \frac{GHI \cdot \alpha \cdot \varphi}{180} + DNI \cdot \cos\left[(SZA - \varphi) \cdot \frac{\pi}{180}\right]$$

Electric power generated by a PV system at any time: $$\dot{W}_i = \dot{I}_i A \eta_{PV}$$

Coefficient of Performance: $$COP = \frac{Cooling\ Output}{Electrical\ Energy\ Input}$$

Inputs such as solar irradiance, Fort Worth latitude, solar zenith angle, and surface albedo were used to calculate hourly PV energy generation. Household demand was divided into air-conditioning and other electrical loads, while storage performance was modeled using charging/discharging efficiencies and an initial stored energy value. An iterative method was then applied by assuming an initial storage level and trial PV area, calculating end-of-year storage, and adjusting the PV area until the starting and ending storage values were equal. The final required PV power was determined from the optimized panel area and maximum solar irradiance.

References

Michaelides, E.E., 2018, *Energy, the environment, and sustainability*, CRC Press.

Michaelides, E. E., April 11, 2025, *Energy Efficiency and Grid-Independent Buildings,* ASME. J. Sol. Energy Eng. October 2025; 147(5): 051001.

Results

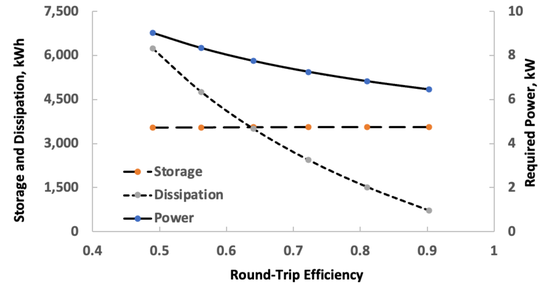

Figure 1: *Effect of storage round-trip efficiency in the baseline case without energy-efficiency measures*

As the round-trip efficiency increases, these values significantly decrease while the necessary storage capacity remains unchanged at approximately 3,550 kWh.

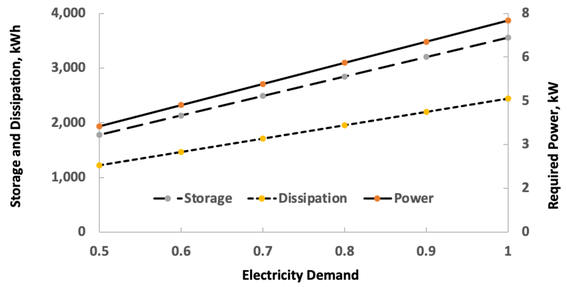

Figure 2: *Effect of energy-efficiency and conservation measures on building electricity demand*

Lowering electricity demand significantly reduces the storage capacity requirements, the energy storage dissipation, and the required PV power.

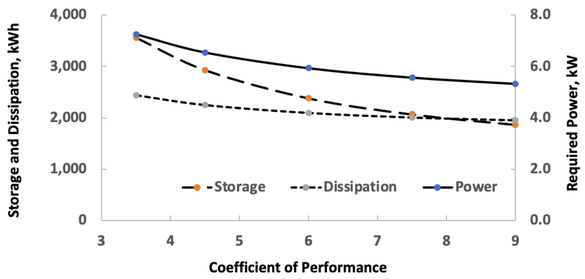

Figure 3: *Effect of improving the COP of the air-conditioning systems. The baseline case corresponds to COP= 3.5.*

The higher the COP, the more efficient the A/C system.

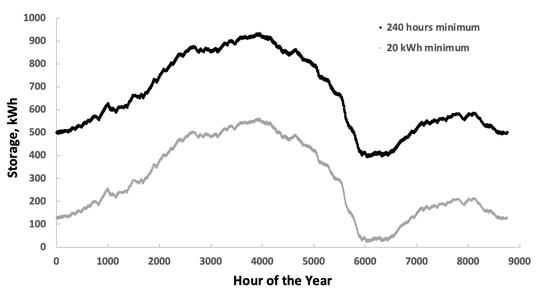

Figure 4: *Energy storage level throughout the year*

Storage level increases during the period when energy generation exceeds demand and decreases when stored energy is needed to cover the shortfall.

Conclusion

In Fort Worth, Texas, high temperatures make air conditioning a major contributor to household electricity use, making a grid-independent home both valuable and challenging to achieve. This study shows that better insulation, lower energy use, and more efficient air-conditioning can greatly reduce the solar panel area and storage capacity needed for year-round operation. Overall, the results suggest that improving energy efficiency is an essential step toward making grid-independent, solar-powered homes more practical in Fort Worth.