Understanding the Economics of Solar + Storage

[1] Peter Lilienthal, [2] Henri E. Francois, [2] Perfect Mfashijwenimana, [2] Musodiq Ogunlowo.

[1] CEO, HOMER Energy, [2] University of Notre Dame.

What are HOMER Pro and Grid

The **HOMER** software is a microgrid design tool that chronologically simulates the operation of a hybrid microgrid in time steps from one minute to one hour and for a single year or an entire project life. It has multiple optimization algorithms that rank possible configurations and automatizes sensitivity analyses.

HOMER Pro models a wide variety of technologies and applications. **HOMER Grid** is specifically designed for behind-the-meter, solar-plus-storage, CHP, and hybrid distributed generation systems, especially when demand charges and energy arbitrage matter.

Since its release, HOMER has been downloaded by over 200,000 people in 193 countries. This is a global community of pioneering practitioners in renewable and distributed power.

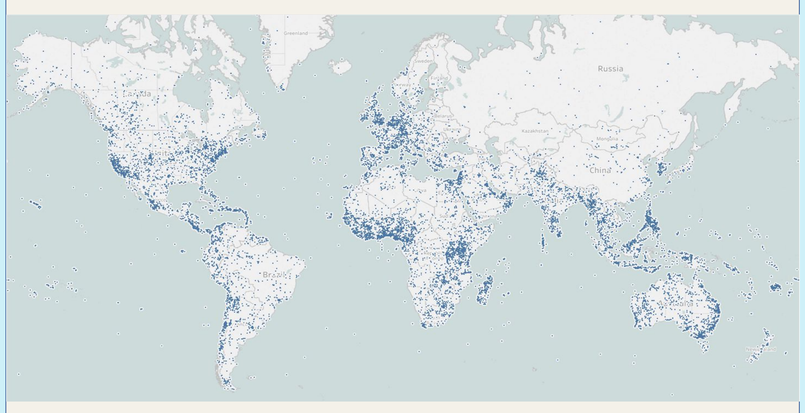


Figure 1 - 70,000 projects modeled by HOMER

Solar + Storage Solutions

While the cost of solar PV and electric storage have plummeted in recent years, their value depends on many factors, ranging from the solar resource, load profiles and reliability requirement, and the cost and performance of individual system components.

The following charts show the impact of battery costs on system design for an off-grid system with solar + storage + backup diesel and a similar but grid-tied system.

Off-Grid System (Solar + Storage)

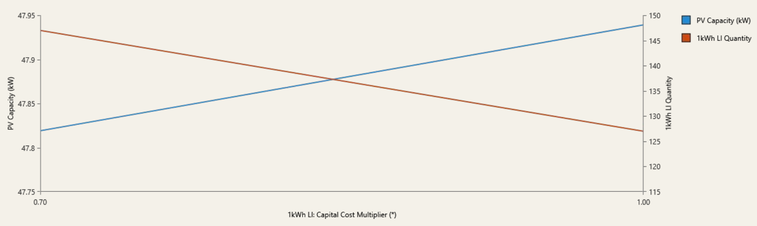


Figure 2 - Line Graph for tradeoff between PV and Battery

In the system modeled above we can see the impact that a cost reduction of batteries has on the system. If the batteries cost 30% less, the least cost system would use more batteries and less PV. In effect, the batteries are replacing some of the PV. This would not be obvious without these modeling results. This tradeoff is one of many to consider when designing an optimal least cost system.

Off-grid Diesel + Solar + Storage

Backup generators can increase the reliability of a solar + storage system. Sensitivity analysis in HOMER Pro shows the tradeoffs between the use of a generator and standard solar + storage solutions.

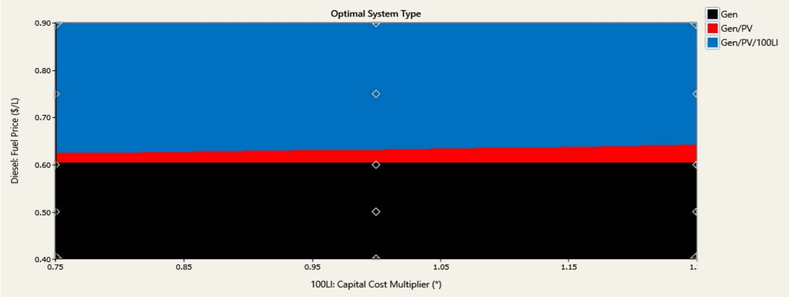


Figure 3 - Optimal System Type graph of battery price vs fuel cost

The graph above shows the impact of an increase in diesel price on the optimal system type. PV is cost-effective at any fuel price above $0.60/liter. The impact of the price of batteries is much smaller. The red band shows a possibly small role for a simple PV-Generator system which requires a controller that curtails the PV output when it would otherwise result in the generator running below its minimum load.

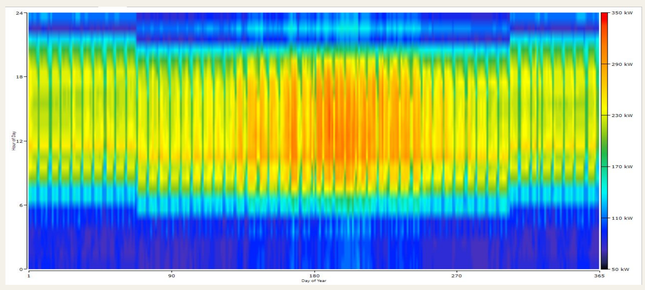


Figure 4 - Load profile for a supermarket in Fort Collins, Colorado showing a wide variation between Summer midday loads and nighttime loads.

Grid+PV+Diesel+Solar+Storage

HOMER Grid analyzes solar + storage & CHP systems tied to the grid with or without a backup generator. Figure 5 shows that a backup generator is only needed if there is a concern about outages. Otherwise, the least cost system either uses PV or batteries, but surprisingly doesn't use both.

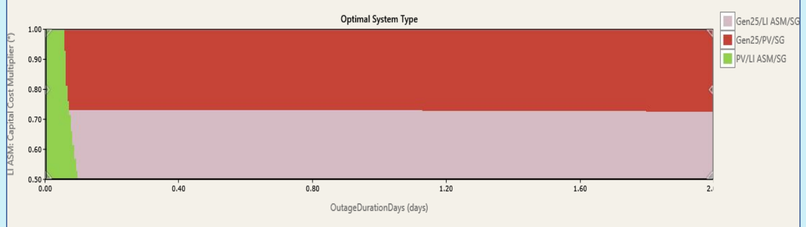


Figure 5 - Optimum System Type for Grid+PV+Diesel+Solar+Storage System

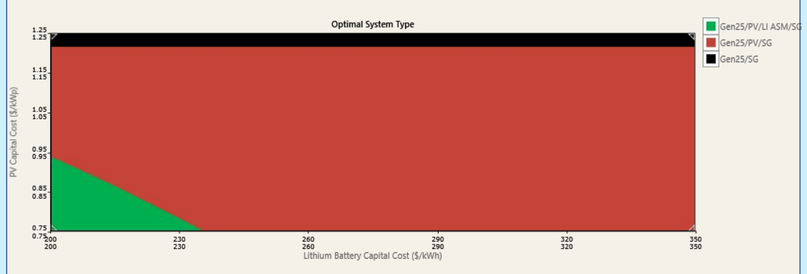
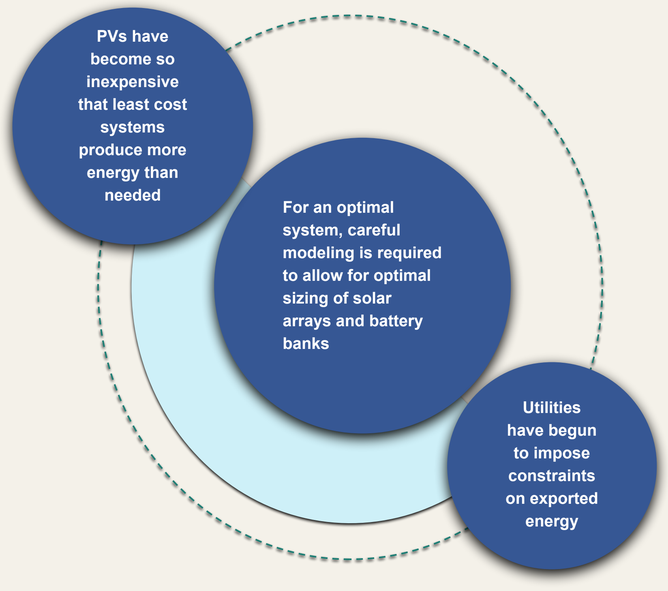


Figure 6 - Optimum System Type for Grid+PV+Diesel+Solar+Storage System

Figure 6 shows that backup generators are always part of the least cost system configuration for a site that needs to provide its own power during a 2-day outage that is expected on an annual basis. For this application in Ft. Collins, Colorado where grid power is relatively inexpensive, the installed cost of PV after any incentives would have to be less than $1.25 /kWp to be cost-effective. Likewise, lithium batteries would have to be less than about $240/kWh.

Design Trade-Offs

1. **Backup generation**
   - Reduces solar + storage cost that can economically support facility during outage
2. **Battery Size trade-off**
   - Battery bank size for microgrid resilience vs. amount of fuel consumption and deliveries
3. **Solar Array Sizing**
   - Photovoltaic price vs grid exports or curtailments
   - Interaction of facility load and solar resources



4. **Load Management**
   - Determining high and low priority loads for curtailment
   - Curtailing of a load eliminates the need for a backup serving as a spinning reserve

Conclusion

Hybrid distributed power systems can provide increased resilience to the host site. Properly designed they can also be very cost-effective while reducing emissions, but their complexity requires design optimization that most facilities and solar installers are not familiar with. Our analysis shows some of the tradeoffs that occur when sizing and operating the different components. Some of these interactions are intuitive, but many are not. We recommend rigorous modeling of alternative designs to understand these tradeoffs.