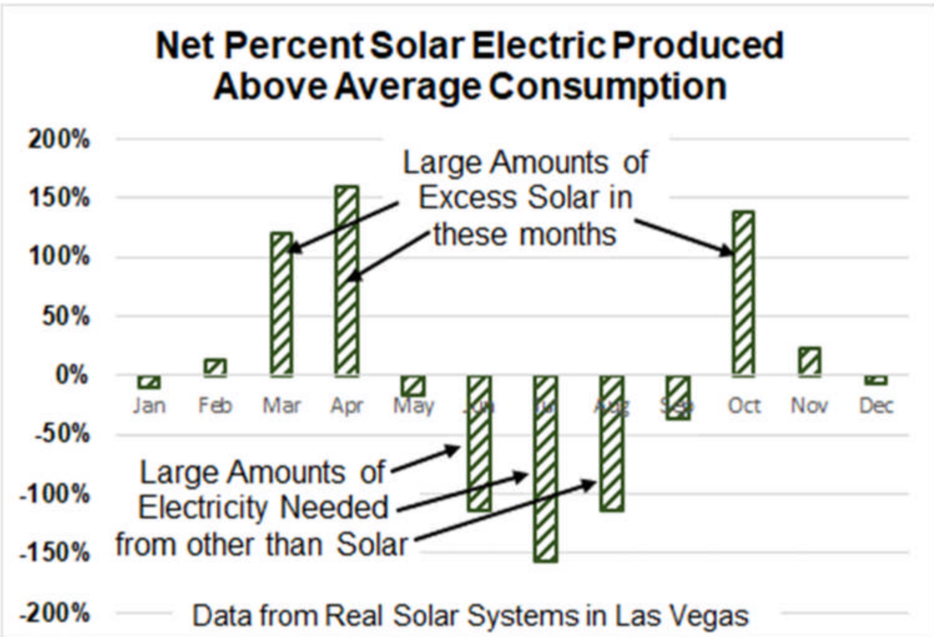
Practical Limitations of Rooftop Solar Electricity Supply

A common belief has become that solar can provide all of mankind's electricity. It sounds wonderful. Unfortunately, there are technological limits based on physics.

In the Las Vegas metro area where I live, the cumulative annual solar radiance is about as high as anywhere on planet earth. Cumulative radiance is higher in the Las Vegas metro compared to other locations due to three factors (1) an extreme low incidence of cloud cover (there is full sun on most days from sunrise to sunset); (2) extremely low humidity (humid air blocks solar radiation needed by solar panels); and (3) higher elevation above sea level (greater transmission of solar energy from the sun to solar panels that is reduced by more air at lower elevation).

There is historical data for annual electricity production for our house provided by the electric utility. The National Renewable Energy Laboratory (NREL) provides excellent solar system modeling tools to forecast production based on solar panel specifications, inverters, mounting angels, and geographic data. Those models include detailed factors such as temperature coefficient of current and voltage of particular solar panels and inverters. It becomes straightforward to design a solar system and calculate the total solar panel nameplate value required to produce 100% of annual electricity consumed by using all that data.

Unfortunately, no building uses the same amount of electricity every month, especially in hot or cold climates. In Las Vegas metro, almost half the annual electricity is consumed in June, July and August when most days have a temperature over 100F. Those are the same three months when monsoon overcasts occur. Those are among the lowest months for solar energy production, despite being the longest days of the year. A month-by-month solar excess or shortage is summarized in the chart below:



The sum of electricity from all months with excess is equal to the sum of electricity shortfalls in remaining months. That appears to be perfect for an off-grid solution since the solar system produces 100% of all electricity consumed over a 12-month period.

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LITHIUM-ION BATTERY STORAGE
The simple and ideal solution would be to store electricity from months with excess solar production and use it to provide power during months with solar electricity shortfalls. Kilowatt-Hours (KwHr). The electricity storage system would be charged during the months of October, March and April. That saved electricity would be consumed during June, July and August.

- Electricity stored in October provide the shortfall for June (8-months later).
- Electricity stored in March and April is consumed in July and August (4-months later).

The required electricity needed from storage to cover the summer shortfalls is about 4,200 KwHr. The time in storage would be 5.5 months on average. Unfortunately, LiIon batteries lose about 4% of their charge each month, even if there is no power consumed at all. Over 5.5 months, those batteries would lose 22%. LiIon batteries along with their charger and inverter functions lose about 18% of their energy to heating when charging and discharging. Then LiIon battery manufacturers strongly recommend that their batteries should not be discharged below 10% to prevent premature failure. The combination of those factors results in a need for nameplate battery capacity of 7,300 KwHr along with suitable high-efficiency DC-to-AC inverters and controllers to prevent overcharging. Companies that supply these batteries charge $860K or more for a system with that capacity after a quantity discount and require more than a single-car unattached garage for fire-safety code requirements. That price is more than 30 times the installed price for the solar electric system including inverter, wiring and permits.

OVERSIZE SOLAR PRODUCTION BY FOUR TIMES
Grossly oversizing the nameplate solar electric production would enable the solar system to produce needed power on all but an occasional day with monsoonal downpours. Most monsoon days are cloudy without rain so a system that produces 4 times as much power as needed on a sunny day will produce about the power needed on a cloudy day. Greater solar production minimizes both battery storage capacity needed and long-term storage of electricity. Increasing the solar generation capacity to produce 4 times the average annual production would avoid any storage longer than 40-hours based on weather data. That oversize solar generation reduces nameplate battery capacity needs to 54 KwHr allowing for losses. That capacity of storage system price is on the order of $60K installed with suitable inverters and cabinets.

The oversize solar production and smaller battery approach is 1/5 to 1/6 the total cost of minimum off-grid solar system size. High-quality single-crystal solar panels with lower temperature coefficients also tend to achieve longer useful life (25 years) before output drops below 86% of nameplate. LiIon batteries rarely achieve 10-year lifetimes before capacity falls below 75% with daily charge-discharge cycles. Lead-acid heavy-duty batteries that are never discharged below 50% have 8 to 9-year lifetimes at 1/8th the price of LiIon.

NOTE: Connecting to the grid shifts storage costs to the public electric utility that must charge higher electric rates to others, such as low-income homes without solar.

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