SKILL GUIDE · ENERGY & HEAT

# Sizing a Solar Array & Battery System

The Energy & Heat chapter's Solar Generator and Off-Grid Solar Array items both say to size against real load, not marketed capacity. This guide is the actual method: four load tiers, the formulas behind each, and the one Utah-specific number that undersizes most first attempts at this. See Sizing a Fuel-Powered Generator for the same load tiers applied to a generator instead, and an honest comparison between the two.

## Four load tiers, not one number

"How much solar do I need" doesn't have one answer, because a household typically wants several different levels of backup, and they don't scale the same way.

| Tier | What it covers | What actually scales it |
|---|---|---|
| Whole house | Everything: full HVAC, all kitchen appliances, laundry, water heater, every outlet | The house itself: square footage, insulation, climate zone. Headcount matters far less than the building does. |
| House essentials (critical loads) | Fridge/freezer, a well or sump pump, a furnace blower, key lighting, internet | Also the house: a fridge or a well pump draws the same wattage whether one person lives there or five. A bigger household adds only a smaller secondary load from more hot water, laundry, and cooking. |
| Non-house essentials | A portable power station running medical equipment, radios, laptops, and charging | Headcount, closely. This is literally each person's own devices and needs. |
| Bare essentials (recharging only) | Phones, headlamps, handheld radios kept topped off, nothing else | Headcount, almost linearly. A family of five's bare-minimum tier is genuinely close to five times a single person's. |

### Why this distinction matters for sizing, not just planning

A single formula that scales every tier by household size will oversize your portable power station if you live alone, and undersize your critical-loads panel if you have a big family in a small, efficient house. Size the top two tiers against your actual appliances and square footage; size the bottom two against your actual headcount.

## Sizing the panels

```
Panel wattage = daily Wh needed ÷ (peak sun hours × 0.75) × 1.1–1.2
```

The 0.75 factor covers real-world losses: wiring resistance, charge controller conversion, panel angle, dust, and heat all take a bite out of a panel's rated output. The 1.1–1.2 is a margin for degradation and bad-weather days.

> WARNING
>
> **Size against your worst month, not the annual average**
>
> Salt Lake City averages 5.1 peak sun hours per day annually, but that swings from roughly 8.3 hours in June down to about 1.8 hours in December, more than a 4x difference. A system sized off the annual average works great in summer and does almost nothing in the exact winter storm outage this manual is built around. Always size the panel array against your local worst-month figure, not the yearly average.

## Sizing the charge controller

The charge controller sits between the panels and the battery, regulating how the panels' power actually charges the bank, and it comes in two types worth knowing apart. A **PWM controller** is essentially a fast switch: its output amps equal the array's current regardless of what the panels are rated at in watts, and it only makes sense for small systems under about 300W where the panel voltage closely matches the battery voltage. An **MPPT controller** is a DC-DC converter that trades surplus panel voltage for extra current, harvesting roughly 10-30% more usable energy from the same array; use MPPT for any system over 500W or where the panel voltage runs meaningfully higher than the battery's.

```
Controller amps (minimum) = (total array watts ÷ battery charging voltage) × 1.25
```

Use the battery's actual charging voltage, not its nominal voltage, a 12V-nominal battery often charges closer to 14.4V; using 12V in the formula undersizes the controller by roughly 20%. A 1,600W array on a 24V bank, for example, needs 1,600 ÷ 24 = 66.7A, × 1.25 = 83.3A, so you'd buy a controller rated at least 100A. Also check the controller's maximum input voltage rating against your panels' actual open-circuit voltage in series: cold weather raises a panel's voltage output, sometimes 20% or more above its rated figure on a freezing morning, and exceeding the controller's input rating can damage it.

## Sizing the battery

```
Battery Wh = daily load × days of autonomy ÷ usable depth of discharge
```

Depth of discharge changes this a lot by battery chemistry: LiFePO4 (lithium iron phosphate) can safely use about 85% of its rated capacity, while lead-acid or AGM batteries should only be drawn down to about 50%, meaning a lead-acid bank needs nearly double the rated capacity for the same usable power. Most home systems target 2-5 days of autonomy; lean toward the higher end in a cloudy winter climate. Cold temperatures also reduce a lithium battery's usable capacity, so an unheated garage or shed installation needs extra margin beyond the autonomy math alone.

## Sizing the inverter

Size the inverter's continuous rating to the sum of everything you'd realistically run at once, and its surge rating to your single largest motor-driven load. A fridge compressor or a well pump can spike 3-7x its running wattage for a second or two at startup; an inverter that looks fine on paper for continuous load can still fail to start a well pump if its surge rating is too low.

## Calculate your own numbers

Plug in your own figures below to run the two formulas above directly. This doesn't replace understanding the method, it just does the arithmetic; the exact formula used is shown with your numbers filled in.

**Daily energy needed (Wh)**

e.g. 3600

List each device you'd run, multiply its watts by hours used per day, and add them up. Find watts on the appliance's nameplate/label; if it only lists amps, multiply amps × 120V (or 240V for large appliances) to get watts.

**Worst-month peak sun hours**

e.g. 1.8

Look up your own address at NREL's PVWatts Calculator (a free, real government tool), then use the lowest "Solar Radiation" value shown across all 12 months, not the annual average, same reasoning as the Salt Lake City example above.

**Days of battery autonomy**

3

**Battery chemistry**

Lithium (LiFePO4), 85% usable

Calculate

**Want an exact reading instead of an estimate?**

A plug-in power meter (a "Kill A Watt" or equivalent, roughly $20-30) gives you a real number for anything that plugs into a standard outlet: plug the meter into the wall, the appliance into the meter, and leave it connected a full 24 hours to read the accumulated kilowatt-hours, this captures a cycling load like a fridge far better than a nameplate figure or a guess at hours-used. Most of these meters cap out around 1875W, check that against the appliance first. For a hardwired 240V load that can't plug into anything, a well pump, electric dryer, or central AC, a clamp meter at the breaker (a one-time reading, or worth having an electrician do if you're not comfortable near an open panel) or a whole-home monitor like Emporia Vue or Sense, installed at the panel, gives the same kind of real, continuous number per circuit.

## Real anchor numbers by tier

| Tier | Typical figure |
|---|---|
| Bare essentials | Roughly 150-300Wh/day per person for phone charging, a headlamp, and a handheld radio; a household's absolute floor is often cited around 500-1,000Wh/day total |
| Non-house essentials | Roughly 2-5kWh/day for a household's first 72 hours running a power station for medical equipment, communication, and charging; higher if a CPAP or oxygen concentrator is in that mix |
| House essentials (critical loads) | Roughly 1-2kW continuous for a typical critical-loads panel, spiking to 3-4kW when a well or sump pump cycles |
| Whole house | Roughly 10-20kWh/day for an energy-conscious off-grid household, versus about 29kWh/day for a typical grid-connected U.S. household; a 5kWh/day site needs roughly 1.5kW of panels, a 20kWh/day site roughly 6kW |

## Sources


- Panel and battery sizing formulas, depth of discharge by chemistry: How to Go Solar; AltE Store
- Salt Lake City peak sun hours by month: TurbineGenerator.org
- Critical-loads panel tiers and typical draw: Palmetto; SunWatts
- Emergency/portable power station daily targets: Entropy Survival
- Whole-house off-grid daily energy figures: The Act of Thriving, Physical Foundation chapter (this site)

- Plug-in power meter accuracy and use: Wikipedia, Kill A Watt; P3 International
- Clamp meters and whole-home circuit-level monitoring: Energy Vanguard
- Charge controller sizing formula, MPPT vs. PWM, and cold-weather voltage rise: Renogy; PowMr Academy