Sizing Your Solar System

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Proper solar sizing means the system reliably recharges within your worst-case season and holds enough battery reserve to survive your design number of consecutive no-sun days. No solar system runs unattended forever: cells fade with cycling, panels degrade, and a long overcast stretch can outlast any fixed reserve. Plan for battery replacement every few years and use remote monitoring (see Monitoring Battery State) so you catch a failing node before it dies.

Step-by-Step Sizing Process

Step 1: Determine Daily Energy Consumption

Daily energy depends heavily on platform, firmware, TX duty cycle, and whether the screen/Bluetooth/Wi-Fi are on, so always use your own measured value where possible. As representative planning figures (measure your own): an **nRF52840 repeater (RAK4631, T-Echo) averages ~10–15 mA**, while an **always-on ESP32 board (Heltec V3) averages ~40–80 mA** (higher with Wi-Fi/MQTT). Compute daily energy as: **Daily energy (Wh/day) = average current (mA) × 24 h × system voltage (V) ÷ 1000**. The worked example below uses a Heltec V3 (ESP32) repeater drawing a conservative ~25 mA average at 3.7 V: 25 × 24 × 3.7 ÷ 1000 = **2.22 Wh/day**. A higher-duty ESP32 node can easily draw 2–3× this, so re-run the calculation with your measured current.

Step 2: Find Worst-Case Peak Sun Hours

Peak sun hours (PSH) vary by location and season. Size the panel against your **worst month** (December for the northern hemisphere). Do **not** assume a flat "4 PSH year-round" — northern-US winter PSH is often only ~1–2.5 h/day. Look up your exact site on the NREL PVWatts calculator (which uses the NREL NSRDB dataset) rather than relying on a single state-wide number, because PSH varies sharply by city and dataset. The values below are rough orientation only — replace them with a PVWatts result for your coordinates:

Location (approx.)	December PSH (approx.)	Annual Average PSH (approx.)
North Dakota / Fargo (~47°N)	~2.5 h/day	~4.5 h/day
Minnesota (~45°N)	~2.8 h/day	~4.6 h/day

Location (approx.)	December PSH (approx.)	Annual Average PSH (approx.)
Texas (~30°N) — varies widely by region; central/eastern TX (e.g. Austin) can be ~2.7 h in December	~2.7–4.1 h/day	~5.5 h/day
Pacific Northwest / Seattle, Portland (~47°N)	~1.5 h/day	~4.2 h/day
Florida (~28°N)	~4.8 h/day	~5.5 h/day

Note: winter PSH can run anywhere from ~7% to ~42% below the 12-month average depending on latitude and climate, and a single state (especially Texas) is too large to treat as one number. Always confirm your site in PVWatts. (Figures as of 2026-06-08.)

Step 3: Calculate Required Panel Size

Panel size (W) = Daily energy (Wh) ÷ (PSH × system derate factor)

Use a **system derate factor of 0.75** — this single planning factor covers charge-controller, wiring, temperature, and soiling losses. (We use 0.75 consistently across all Mesh America sizing pages; size your panel against this and confirm production in PVWatts.)

Example (North Dakota repeater):
Panel = 2.22 Wh ÷ (2.5 h × 0.75) = 2.22 ÷ 1.875 = **~1.18 W minimum**

A 6 W panel is roughly **5× the nameplate minimum** — but treat this as a *nameplate* ratio, not real surplus. In deep winter at high latitude (low sun angle, cold, dirt, snow, and a cheap controller running off its maximum-power point), a panel rarely delivers anything close to its nameplate wattage, and a snow-covered panel produces essentially zero regardless of its rating. The large nominal oversize is therefore **needed, not luxury**: it buys back winter harvest losses and helps recover after a cloudy or snowy stretch. The real protection against multi-day storms and snow cover is **battery reserve** (Step 4), not panel margin.

Step 4: Calculate Battery Reserve

Battery capacity (Wh) = Daily energy × Reserve days ÷ Usable fraction

- Reserve days: 3–5 days for most locations; **5–7+ days for high-latitude winter or emergency-comms nodes** (panels do not help during a multi-day overcast, so reserve is your only protection).
- Usable fraction: **0.80 for LiFePO4** (plan to 80% depth of discharge for longevity; this is the single value used across all Mesh America sizing pages so you get the same battery size on every page). Lithium-ion (LiPo/NMC) cells are also commonly planned at ~0.80. Do not apply a second derate on top of this unless you explicitly state and justify it.

Example (3-day reserve, LiFePO4 at 0.80):
Battery = 2.22 × 3 ÷ 0.80 = **8.33 Wh minimum (nameplate)**

A single 3500 mAh 18650 cell (e.g. Samsung INR18650-35E, 3500 mAh nominal, ~3.6–3.7 V nominal) = 3.5 Ah × 3.7 V = 12.95 Wh nameplate, or ~10.4 Wh usable at the 0.80 fraction. That comfortably satisfies the **3-day** requirement (8.33 Wh) with margin. It does **not** satisfy the 5-day example below.

For a 5-day reserve (LiFePO4 at 0.80):
Battery = 2.22 × 5 ÷ 0.80 = **13.9 Wh minimum (nameplate)**
→ Two 3500 mAh 18650 cells in parallel = 25.9 Wh nameplate (~20.7 Wh usable at 0.80) — comfortably covers the 13.9 Wh requirement with real positive margin. A single 12.95 Wh cell (~10.4 Wh usable) is **not** enough for 5 days.

Cold-climate charging warning: For any winter/cold-climate build, **never charge lithium (including LiFePO4) below 0 °C (32 °F)** — sub-freezing charging causes lithium plating, permanent capacity loss, and a hidden internal-short fire risk (discharging in the cold is fine). The CN3791 used in the example build has **no low-temperature charge cutoff**, so a cold-climate node built around it must add a BMS with low-temp protection or a charge controller with a battery temperature sensor. See the Cold-Weather Operation page.

Complete Sizing Example: North Dakota Year-Round Repeater

Parameter	Value
Node	Heltec V3 (ESP32), MeshCore Repeater
Average current draw (representative — measure your own)	~25 mA (conservative for an ESP32 board; higher-duty configs draw more)
Daily energy	2.22 Wh/day
Location	Fargo, ND (~47°N) — confirm PSH in PVWatts
December PSH (approx.)	~2.5 h/day
System derate factor	0.75 (controller + wiring + temperature + soiling)
Panel required (minimum)	~1.18 W
Panel selected	6 W 6 V monocrystalline
Panel margin	~5× nameplate (effective winter margin far lower — this is the reason for the large nominal oversize, not surplus)
Battery usable fraction (LiFePO4)	0.80
Battery reserve target	5 days
Battery required (nameplate)	13.9 Wh
Battery selected	2× Samsung 35E 18650 in parallel = 25.9 Wh nameplate (~20.7 Wh usable at 0.80) — comfortable positive margin over the 13.9 Wh requirement

Parameter	Value
Charge controller	CN3791 (PWM switch-mode MPPT solar Li-ion charger). Has no low-temp cutoff — add a BMS with low-temperature charge protection for this cold-climate build.
Total build cost (rough, as of 2026-06-08)	~$85–$100 (re-price the bill of materials from current store listings before ordering)

Revision #3
Created 2026-05-03 03:13:10 UTC by Mesh America Admin
Updated 2026-06-08 22:45:07 UTC by Mesh America Admin