Cold Weather Operation

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Solar power systems in cold climates face challenges that warm-climate systems do not. This page consolidates solar-specific cold weather guidance. See also the DIY Build Guide > Cold Weather & Winter Operation page for enclosure and battery chemistry details.

Solar Panel Performance in Cold

Cold temperatures actually improve solar panel efficiency slightly. A standard silicon solar panel produces about 0.4% more power per degree Celsius below 25°C. At - 20°C (45° below the standard test condition), if the cell temperature actually reached - 20°C a 6W panel could produce roughly 7W (about +18%). In practice the gain is smaller because cell temperature under sunlight runs above ambient. Either way, this efficiency bump is minor compared with the real cold-weather problem below: far less light reaches the panel in winter, so net winter harvest is dramatically lower, not higher.

The main cold-weather solar challenge is **reduced daylight hours and lower sun angle**, not panel efficiency. A December day in North Dakota (~47°N) has only about 8.5 hours of daylight with the sun reaching a maximum elevation of only ~20° above the horizon, far less than the ~66° of midsummer. (Daylight length and solar elevation can be confirmed from a solar-position calculator for your latitude.)

Snow Accumulation on Panels

Snow covering the panel can reduce output to zero. Mitigation strategies:

- **Steep mounting angle:** A steep tilt helps most wet snow slide off. As a general guideline use roughly 45 - 60° from horizontal, or about latitude + 15°. Dry powder snow may still accumulate.
- **Dark-coloured back-sheet:** Panels with a black or dark back sheet absorb more heat and melt snow faster.
- **Panel heating:** Some high-end installations use resistive heating elements on the panel back, powered by the battery during overnight cold snaps. Rarely justified for community mesh nodes due to the added power consumption.

- **Size for zero-solar periods:** The most practical approach - size the battery for 5 - 7 no-sun days in an ordinary northern winter, and 7 - 14 days where snow burial or polar darkness can persist for weeks. When the panel can be buried for an extended period, the battery is your only reserve - size it for the worst burial you expect.

Battery Temperature Management

Batteries lose usable capacity in cold, and charging is governed by a hard lower limit that is separate from how much capacity is available. The two columns below address these separately: discharge capacity falls gradually with temperature, while charging is simply prohibited below 0°C. The discharge figures are approximate and depend on cell and discharge rate; treat them as illustrative.

Temperature	Approx. discharge capacity (illustrative)	Charging permitted?
+25°C (77°F)	~100% (baseline)	Yes
0°C (32°F)	Reduced	0°C is the practical lower charge limit - many BMS modules cut off charging at or just above 0°C. Charge only at a reduced rate; do not charge any colder.
- 10°C (14°F)	Reduced	Do not charge - charging here causes lithium plating, permanent capacity loss, and an internal-short / fire hazard (not merely capacity loss)
- 20°C (- 4°F)	Substantially reduced	Do not charge
- 40°C (- 40°F)	Heavily reduced	Do not charge. LiFePO4 is preferred for cold DISCHARGE and survival/storage only - it still must NOT be charged below 0°C without a heater.

A charge controller that monitors battery temperature and reduces or stops charging below 0°C is ideal. **The CN3791 has NO low-temperature cutoff and no battery-temperature sensing** (per its datasheet feature list) - on its own it will happily charge a frozen battery below 0°C, causing lithium plating and a hidden internal-short fire risk. The CN3791 is recommended elsewhere in this book as a default solar charger, so for any cold-climate or winter build you MUST add low-temperature charge protection: use a temperature-sensing charge controller, or a battery/BMS with built-in low-temperature charge cutoff, or a thermostat that disconnects charging below ~0 - 5°C.

Enclosure Thermal Behaviour

An enclosed node generates a small amount of heat (roughly 75 - 150 mW from the node and charge controller - for example ~25 mA at 3.7V is about 93 mW on the node side, plus charge-

controller losses). In a sealed IP67 enclosure, this self-heating can keep the interior several degrees above ambient, which helps battery performance marginally. A black enclosure absorbs more solar heat during daylight, which can add a few more degrees of warmth. A white enclosure stays cooler in summer (preventing overheating) but provides less passive warming in winter.

For very cold deployments, a small Nichrome heating resistor (1 - 2W) inside the enclosure, powered from the battery via a thermostat relay, can keep the battery warm enough to charge. If the goal is to permit charging, set the thermostat to keep the cells **above 0°C** (target roughly +2 to +5°C) - NOT - 10°C, because charging is prohibited below 0°C and a battery sitting at - 8°C must not be charged. Note that a 1 - 2W heater may be too weak to warm a battery from deep-cold ambient to above freezing in a small outdoor enclosure, so verify the wattage against the enclosure's thermal mass and heat loss. Critically, the heater runs in winter - exactly when solar harvest is lowest - and its draw must be added to the power budget (a 1 - 2W heater can exceed the node's own consumption and flatten the battery it is protecting). Add a low-voltage cutoff so the heater cannot deep-discharge the pack. This adds complexity and power consumption but can be worthwhile for nodes at critical infrastructure sites.

Annual Maintenance Schedule

Cold-climate solar nodes require more frequent inspection than warm-climate nodes:

- **Pre-winter (October):** Inspect gaskets, cable glands, replace desiccant; verify battery capacity is adequate; clean solar panel; verify mounting is secure
- **Mid-winter (January):** Remote check - verify node is online and battery voltage is healthy. The healthy threshold depends on your battery: for a single Li-ion/LiPo cell aim for above ~3.5V; for a single LiFePO4 cell aim for above ~3.0 - 3.2V resting; for a multi-cell pack (for example a 4S 12.8V LiFePO4 pack) scale the threshold to the pack (a 4S LiFePO4 pack should stay well above ~12V resting). Tie the threshold to your deployed battery type and cell count. Investigate any offline nodes promptly.
- **Post-winter (April):** Inspect for frost/condensation damage inside enclosure; replace desiccant; clean solar panel; verify all connections

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