Solar-Powered Sensor Node Deployment

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A well-designed solar sensor node can operate indefinitely without maintenance in most climates. The goal is to achieve an average current consumption below 1 mA so that even a small panel can replenish the battery daily, with comfortable margin through extended overcast periods.

Power Budget Design

Start with a current budget before selecting hardware. A 15-minute telemetry cycle on a RAK4631 + BME680 node breaks down as follows:

Event	Duration	Current	Charge (µAh)
Deep sleep	898 s	3 µA	748
Wake + sensor read	1.5 s	5 mA	2083
LoRa TX (1 packet)	0.5 s	40 mA	5556
Total per 15-min cycle	900 s	-	**8387 µAh ≈ 8.4 mAh/hr**
Average current	-	-	**0.56 mA**

At 0.56 mA average, daily consumption is ~13.4 mAh. A 0.5 W panel in typical mid-latitude conditions produces roughly 60 mAh/day after accounting for night and cloud cover - over 4× the node's daily consumption, leaving ample margin for battery recharge.

Sleep/Wake Cycle Design

The nRF52840 on the RAK4631 supports deep sleep with RAM retention at 2.5 µA. Choose the minimum useful reporting interval for your application:

- **Weather monitoring:** 15 - 30 minutes is sufficient. Temperature and humidity change slowly outdoors.

- **Air quality / smoke detection:** 5-minute maximum. VOC spikes and smoke events evolve faster than weather parameters.
- **Asset tracking with GPS:** 1 - 5 minutes when moving, 30 minutes when stationary (detected via onboard accelerometer). GPS adds ~18 mA active - budget accordingly.

Avoid waking more frequently than necessary. Each LoRa transmission occupies shared airtime. At a 15-minute interval a single node uses only ~0.5% duty cycle, well within LoRa regulatory limits in all regions.

Solar Panel Selection

Match panel output to your deployment's worst-case solar insolation. A conservative rule of thumb: the panel's short-circuit current (I_{sc}) should be at least 10× the node's average current draw.

- **0.5 W, 5 V panel** (~100 mA I_{sc}) - Sufficient for a basic BME680 node at 15-minute intervals. Physically small (~80×55 mm), suitable for fence-post or junction-box mounting.
- **1 W, 6 V panel** (~165 mA I_{sc}) - Comfortable margin for nodes with GPS enabled part-time, or deployments above 50° latitude where winter insolation is poor.
- **2 W, 6 V panel** - Required for nodes with MQ-2 gas sensor due to continuous heater draw (~150 mA). Also appropriate for any node needing frequent overnight operation.

Use a panel with a bypass diode to prevent reverse current at night. An MPPT charge controller (e.g., CN3791) improves harvest efficiency 15 - 30% over simple PWM controllers and is worthwhile for any deployment intended to last more than one year.

Battery Selection

- **LiPo (3.7 V, 2000 - 5000 mAh)** - Best energy density, wide availability, integrates directly with the RAK19007 PMIC. Avoid temperatures below −20°C; capacity drops sharply. Replace every 3 - 5 years.
- **18650 Li-ion** - More robust mechanically, better low-temperature performance. Requires a separate holder and protection circuit unless using pre-protected cells. Useful when cylindrical cells fit the enclosure better.
- **AA lithium primary (e.g., Energizer L91)** - For locations where charging is infeasible. Rated to −40°C. A 4×AA pack (~3000 mAh at 3.6 V) can run a 0.56 mA node for approximately 220 days without any solar input.

Size the backup battery for at least 7 days of autonomy without solar input. For a 0.56 mA node: 7 × 24 × 0.56 mA = 94 mAh minimum. A 2000 mAh LiPo provides over 100 days of pure battery reserve - enough to survive any realistic extended overcast period in temperate climates.

Mounting and Deployment Best Practices

- Orient solar panels within 30° of due south (Northern Hemisphere) or due north (Southern Hemisphere) at an angle matching the site's latitude for optimal year-round harvest.
- Mount the enclosure in shade where possible (under eaves, north-facing surface) while keeping the panel in direct sun. High ambient temperature degrades LiPo capacity over time.
- Use stainless steel hose clamps for pole mounting. UV-resistant zip ties degrade within 2 - 3 years outdoors and are not adequate for permanent installation.
- Route cables with a drip loop before entering the enclosure cable gland to prevent water wicking along the cable jacket into the enclosure.
- Record GPS coordinates, orientation, panel angle, and photos of each node at installation. This data is invaluable for remote troubleshooting and future maintenance visits.

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