TYCON® CUSTOMER EDUCATION SERIES

Off-Grid Power Fundamentals

A practical workbook for understanding solar, wind, batteries, PoE, and remote power systems

UNDERSTAND	PLAN	ASK
your load	for real conditions	better questions

Designed for customers planning reliable power for wireless, security, monitoring, communications, and other remote equipment.

This workbook explains the concepts that drive a good off-grid power design. It is educational and is not a substitute for a site-specific engineered design, local electrical code requirements, or manufacturer instructions.

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How to use this workbook

You do not need an electrical background to use this guide. Work through the sections in order, write directly into the worksheets, and use your equipment datasheets whenever possible. The goal is to help you describe your application accurately and understand the tradeoffs in an off-grid power system.

- Start with the load - what equipment needs power and how much energy it uses.
- Then consider the site - sunlight, wind, temperature, shading, and mounting conditions.
- Next define reliability - how long the system must operate through poor weather.
- Finally, combine those inputs into a complete power-system conversation.

The most important idea
A good remote-power system starts with the load, not with the solar panel or battery. If the load is wrong, everything downstream will be wrong.

Workbook roadmap

Section	What you will learn
1. The load	Volts, amps, watts, watt-hours, duty cycle
2. Batteries	Capacity, usable energy, autonomy, temperature
3. Solar	Peak sun hours, losses, shading, seasonal design
4. Wind	Why rated watts do not equal daily energy
5. System voltage	12V / 24V / 48V, current, cable considerations
6. PoE & remote devices	Power budgets, PSE, PD, AC vs. DC
7. Reliability	Autonomy, weather, redundancy, critical loads
8. Complete example	Walk through a realistic remote site
9. Project worksheet	Capture the information needed for a quote/design

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Start with the load

Understand what the equipment actually needs before choosing a power source.

The four basic electrical quantities

Quantity	Symbol	Unit	Plain-language meaning
Voltage	V	Volts	Electrical pressure
Current	I / A	Amps	Electrical flow
Resistance	R	Ohms (Ω)	Opposition to current
Power	P / W	Watts	How fast energy is being used

The relationship most customers will use is the power formula:

Watts = Volts × Amps

Example: A radio specified at 24VDC and 1.5A can use about 36W (24 × 1.5 = 36).

Why this matters

Manufacturers do not always list power in watts. If a datasheet gives voltage and current, you can estimate the power requirement.

Power versus energy

Watts tell you how much power equipment is using at a moment in time. Watt-hours tell you how much energy is used over time.

Watt-hours = Watts × Hours of operation

A 20W camera running 24 hours per day uses 480Wh per day. That daily energy number is one of the most important inputs for battery and generation sizing.

Practice

Equipment	Voltage	Current / Power	Hours/day	Calculate Wh/day
Camera	48V	12W	24	_____
Radio	24V	0.75A	24	_____
Sensor	12V	5W	12	_____
Your device	_____	_____	_____	_____

Quick self-check

1. What is the difference between watts and watt-hours?

Your answer: _____

2. If a device only runs 6 hours per day, why should you not multiply its watts by 24?

Your answer: _____

2 Batteries and backup time

Stored energy keeps the system operating when generation is low or unavailable.

Amp-hours and watt-hours

Battery capacity is often shown in amp-hours (Ah). To compare battery capacity with an electrical load, it is often helpful to convert to watt-hours:

Approximate battery energy (Wh) = Battery voltage × Amp-hours

Example: A nominal 12V, 100Ah battery contains roughly 1,200Wh of nameplate energy.

> **Nameplate energy is not the same as usable energy**
> Real battery systems must account for battery chemistry, permitted depth of discharge, efficiency, temperature, aging, and reserve margin.

Autonomy: how long should the system run without charging?

Autonomy is the amount of time the load can operate from stored energy without meaningful solar or wind charging. Critical applications often need more autonomy than non-critical installations.

Required usable energy ≈ Daily load energy × Days of autonomy

Example: A site that uses 900Wh/day and needs 3 days of usable backup requires about 2,700Wh of usable stored energy before additional design allowances are applied.

Temperature matters

- Cold temperatures can reduce available battery capacity.
- Very high temperatures can shorten battery life.
- Some battery chemistries have charging restrictions at low temperature.
- Outdoor enclosures, insulation, heaters, and battery selection may all affect the final design.

Your project

Question	Your answer
Estimated daily energy use	_____ Wh/day
Desired autonomy	_____ days
Lowest expected temperature	_____ °F / °C
Highest expected temperature	_____ °F / °C
Is the load mission-critical?	Yes / No / Somewhat

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Solar power fundamentals

Solar array size is driven by daily energy, available sunlight, losses, and season.

Why a 50W load does not mean a 50W solar panel

A continuous load operates 24 hours per day. A solar array produces useful energy only when sunlight is available. This is why the array wattage usually needs to be several times larger than the continuous load wattage.

Peak sun hours

Peak sun hours are a simplified way to express the daily solar resource. They are not the same as daylight hours. A location may have 10 hours of daylight but only 4 equivalent peak sun hours.

Theoretical solar watts = Daily load Wh ÷ Peak sun hours

Example: 1,200Wh/day ÷ 4 peak sun hours = 300W theoretical minimum before losses and design margin.

Real systems need margin

Controller losses, battery charging losses, cable losses, panel temperature, dirt, snow, clouds, seasonal variation, and system availability all reduce real-world performance.

Solar site checklist

- Location (city/state/country or coordinates)
- South-facing exposure in the Northern Hemisphere when practical
- Trees, buildings, towers, mountains, or other shading
- Panel tilt and mounting constraints
- Snow, dust, salt air, or severe weather
- Worst-season solar resource, not just annual average

Think through your site

What can shade the array between 9 AM and 3 PM?

_____

Is winter operation more important than summer operation?

_____

Will the panels be accessible for cleaning or snow removal?

_____

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Wind and hybrid systems

Wind can complement solar, but turbine nameplate wattage is not enough to predict energy production.

Rated watts are not average watts

A wind turbine rated at 400W does not produce 400W whenever it is spinning. Output depends strongly on wind speed and the turbine power curve. The site must be evaluated for usable wind resource.

Three wind concepts to recognize

Term	Meaning
Cut-in speed	Wind speed where useful generation begins
Rated speed	Wind speed where rated output is reached
Turbulence	Unsteady airflow caused by obstacles or terrain; generally undesirable

Good wind questions

- What is the average wind speed at the intended hub height?
- Are there nearby trees, buildings, ridges, towers, or other obstructions?
- How high can the turbine be mounted?
- Is wind seasonal?
- Is the goal wind-only power or a solar/wind hybrid?

Hybrid advantage

Solar and wind can sometimes complement each other. A hybrid system may improve charging opportunity when one resource is weak, but both resources still need to be evaluated realistically.

Quick self-check

1. Why is turbine rated wattage alone insufficient for system sizing?

Your answer: _____

2. What site condition often makes low-mounted wind turbines perform poorly?

Your answer: _____

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12V, 24V, and 48V systems

Higher voltage can reduce current for the same amount of power.

For the same power level, increasing voltage reduces current:

Amps = Watts ÷ Volts

Load power	At 12V	At 24V	At 48V
120W	10A	5A	2.5A
240W	20A	10A	5A
480W	40A	20A	10A

Why current matters

- Higher current generally requires larger wire.
- Higher current can increase voltage drop and power loss.
- Connectors, fuses, breakers, controllers, and wiring must all be rated appropriately.
- System voltage must be compatible with the equipment or proper conversion must be used.

Voltage drop

All wire has resistance. As current travels through wire, some voltage is lost. Voltage drop becomes more important with longer cable runs, higher current, and smaller conductors.

Customer takeaway

When asking for a remote-power design, include cable distances. A long cable run can change the recommended system architecture even when the load itself stays the same.

Your cable distances

Connection	Approx. one-way distance
Solar array to controller	_____
Battery/system to load	_____
PoE switch/injector to powered device	_____
Other	_____

6 PoE, wireless, security, and remote equipment

Translate device specifications into a realistic site load.

Power over Ethernet (PoE)

PoE carries data and electrical power over Ethernet cabling. It is commonly used for IP cameras, wireless radios, access points, sensors, and other network devices.

Term	Meaning
PSE	Power Sourcing Equipment, such as a PoE switch or injector
PD	Powered Device, such as a camera or radio
PoE budget	Maximum power the source can make available to connected devices
Passive PoE	Power delivered without IEEE negotiation; voltage and polarity compatibility are critical

Do not confuse PoE budget with actual load

A switch with a 240W PoE budget does not necessarily consume 240W all the time. If four connected cameras each use 15W, the connected camera load is about 60W, plus the switch electronics and conversion losses.

AC loads and inverters

If equipment requires AC power, an inverter converts DC battery power to AC. Inverters introduce efficiency losses and may consume standby power. Some loads also have startup surge requirements.

Efficiency opportunity
When practical, powering compatible DC equipment directly can avoid unnecessary conversion steps. The correct approach depends on equipment requirements and system architecture.

Device data worksheet

Device	Qty	Input	Watts each	Hours/day
_____	___	_____	_____	_____
_____	___	_____	_____	_____
_____	___	_____	_____	_____

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Design for reliability, not just average conditions

A system that works on a perfect day is not necessarily a reliable remote-power system.

Define the consequence of downtime

Reliability requirements should reflect what happens when the system loses power. A temporary outage at a non-critical sensor may be acceptable; a security, communications, or public-safety application may require much more margin and redundancy.

Consideration	Questions to ask
Autonomy	How many low-generation days should the system ride through?
Season	What is the worst operating season?
Temperature	What are the true minimum and maximum temperatures?
Criticality	What happens if power is lost?
Access	Can someone service the site quickly?
Redundancy	Is backup generation or another power source available?

Average versus worst case

Good design pays attention to worst-season solar, actual wind conditions, temperature extremes, peak equipment demand, and required autonomy - not just annual averages.

A useful rule of thumb

The more remote, difficult to access, or mission-critical the site is, the more important design margin, environmental protection, and realistic site data become.

Reliability profile

If this site loses power, what happens?

_____

How quickly could someone reach the site?

_____

What is the longest poor-weather period you want the system to survive?

_____

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Worked example: remote camera and radio site

Follow the logic from equipment load through battery and generation considerations.

Scenario

A customer needs to power two IP cameras, one wireless radio, and a small controller at a remote location. Everything operates continuously.

Equipment	Qty	Power each	Total watts	Daily Wh
IP camera	2	12W	24W	576Wh
Wireless radio	1	18W	18W	432Wh
Controller	1	6W	6W	144Wh
TOTAL			48W	1,152Wh/day

Step 1 - Daily load

The site uses about 1,152Wh of energy each day before system losses.

Step 2 - Autonomy target

If the desired usable autonomy is 3 days: 1,152 × 3 = 3,456Wh of usable stored energy. The actual nameplate battery bank would need to be larger after battery limits, temperature, reserve, and efficiency are considered.

Step 3 - Solar starting point

If the design resource is 4 peak sun hours, a simple theoretical starting point is 1,152 ÷ 4 = 288W of solar. A real design would add capacity for system losses, weather, seasonal variation, battery charging, and required reliability.

Step 4 - Site realities

- Check winter solar resource, not only annual average.
- Confirm panel shading and mounting orientation.
- Verify minimum temperature for the battery system.
- Confirm cable distances and PoE requirements.
- Decide whether wind or another backup source is justified.

Notice the sequence

The calculation begins with the equipment load, then moves to daily energy, autonomy, generation, and site conditions. This sequence is far more reliable than choosing a panel or battery first.

Try it yourself

A site has a 25W camera, a 15W radio, and a 10W sensor. All run 24 hours per day.

1. Calculate the total continuous watts.
2. Calculate the daily watt-hours.
3. Calculate three days of usable load energy.
4. If the site has 5 peak sun hours, calculate the theoretical solar starting point before losses.

Show your work

_____

_____

_____

_____

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Your remote-power project worksheet

Complete this page before requesting a system recommendation or quote.

A. Project and site

Field	Your information
Project / application	_____
Site location	_____
Mounting type	Pole / tower / building / ground / trailer / other
Minimum temperature	_____
Maximum temperature	_____
Shading or obstructions	_____
Wind information available?	Yes / No / Unsure

B. Equipment load

Device	Qty	Voltage	Watts / Amps	Hours/day	Daily Wh
_____	___	_____	_____	_____	_____
_____	___	_____	_____	_____	_____
_____	___	_____	_____	_____	_____
_____	___	_____	_____	_____	_____
_____	___	_____	_____	_____	_____

C. Reliability and installation

Question	Your answer
Required autonomy / backup time	_____
What happens if power is lost?	_____
Power-source-to-load distance	_____

Solar-array-to-controller distance	_____
Existing utility or generator backup?	_____
Special enclosure / environmental needs	_____

Project notes and questions

Use this space for items you want to discuss with a remote-power specialist:

_____

_____

_____

_____

_____

_____

_____

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Common customer questions

Short answers to the issues that most often cause confusion.

Why is the solar array much larger than my load wattage?

Because your load may operate 24 hours per day while meaningful solar production occurs for only part of the day. The array must collect enough daily energy to run the load, recharge batteries, and overcome losses.

Can I size a system from the battery amp-hour rating alone?

Not reliably. Battery voltage, chemistry, usable depth of discharge, temperature, load energy, and autonomy all matter.

Is a 400W wind turbine the same as 400W of continuous power?

No. Turbine output depends on wind speed and the turbine power curve. Daily energy production is determined by the site wind resource.

Why do you need my exact equipment model numbers?

Different versions of cameras, radios, switches, and routers can have very different voltage, PoE, surge, and power requirements.

Why does cable length matter?

Longer cables can increase voltage drop and power loss. Distance can affect wire size, voltage choice, converter selection, and system architecture.

Should I use 12V, 24V, or 48V?

There is no universal best voltage. The correct choice depends on load power, equipment compatibility, wiring distances, battery configuration, controllers, converters, and system size.

How much backup time do I need?

That depends on site weather, accessibility, application criticality, and acceptable downtime. The right autonomy target is a design decision, not a fixed number for every site.

11 Remote-power glossary

Useful terms for discussing your application.

Term	Definition
Amp (A)	Unit of electrical current.
Amp-hour (Ah)	A common battery-capacity unit.
Autonomy	How long a system can operate from stored energy without meaningful charging.
Charge controller	Device that manages charging from a solar array into a battery system.
DC	Direct current; commonly used by batteries, solar systems, radios, cameras, and electronics.
Inverter	Converts DC power to AC power.
MPPT	Maximum Power Point Tracking; a solar-controller technology used to optimize energy harvest.
Peak sun hours	Equivalent daily hours of full-intensity solar energy used for simplified solar calculations.
PoE	Power over Ethernet.
PSE	Power Sourcing Equipment in a PoE system.
PD	Powered Device in a PoE system.
Voltage drop	Reduction in voltage caused by resistance in wiring and connections.
Watt (W)	Unit of electrical power.
Watt-hour (Wh)	Unit of electrical energy over time.
Wind power curve	Shows turbine output at different wind speeds.

Ready to plan your remote-power system?

The best next step is to gather your equipment specifications and complete the project worksheet in this workbook. With accurate load, site, and reliability information, a remote-power system can be designed around the conditions it will actually face.

Bring these five things to the conversation

1) Equipment model numbers and quantities
2) Voltage / watt / amp specifications
3) Site location and environmental conditions
4) Cable distances and mounting details
5) Required backup time and application criticality

Before you request a design or quote

- Attach equipment datasheets when possible.
- Include photos of the intended installation area if shading or mounting is uncertain.
- Provide the most accurate site location available.
- Call out any unusual temperature, wind, snow, dust, salt-air, or access conditions.
- Tell us what failure would mean for the application so reliability can be considered appropriately.

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Educational use notice: This workbook presents general concepts and simplified examples. Final system design should consider product specifications, electrical safety, applicable codes, installation practices, site conditions, and required reliability.