

INTRODUCTION TO SOLAR POWER SYSTEM DESIGN

ECE 514E – RADAR & SATELLITE ENGINEERING

Monday, January 5, 2026

BASIC SOLAR SYSTEM COMPONENTS

Every solar power system consists of three primary components:

1. Solar Panels (PV Modules)

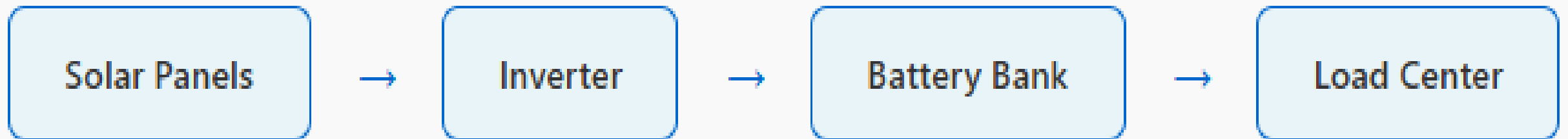
Converts sunlight into direct current (DC) electricity through the photovoltaic effect.

2. Inverter

Converts DC electricity from panels/batteries into alternating current (AC).

3. Battery Bank (Optional)

Stores excess energy for use when the sun isn't shining or during grid outages.



SOLAR SYSTEM TYPES

SYSTEM TYPE	COMPONENTS	BEST FOR
Grid-Tied	Panels + Grid-tie Inverter	Reducing electricity bills with utility backup
Hybrid	Panels + Hybrid Inverter + Batteries	Backup power + energy independence
Off-Grid	Panels + Charge Controller + Batteries + Inverter	Remote locations without grid access (includes Satellites)

The choice of system type will determine which components you need and how they should be sized.

PHOTOVOLTAIC MODULE: PANEL TECHNOLOGY /01

PANEL TYPE	EFFICIENCY	COST	SPACE EFFICIENCY	LIFESPAN
Monocrystalline	18-22%	High	Excellent	25+ years
Polycrystalline	15-17%	Medium	Good	25+ years
Thin-Film	10-13%	Low	Poor	10-15 years

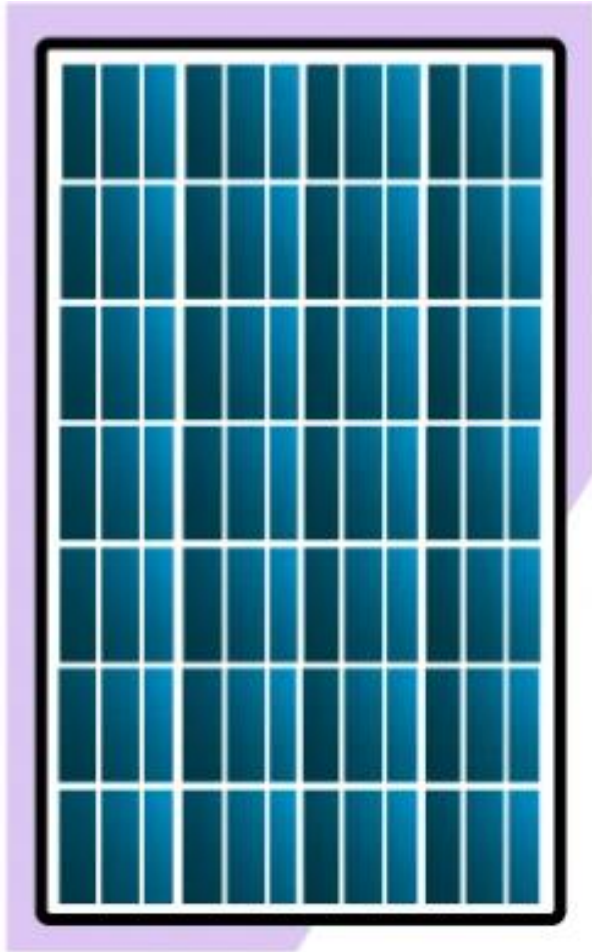
Selection Guidance:

Monocrystalline: Best when space is limited or maximum efficiency is needed

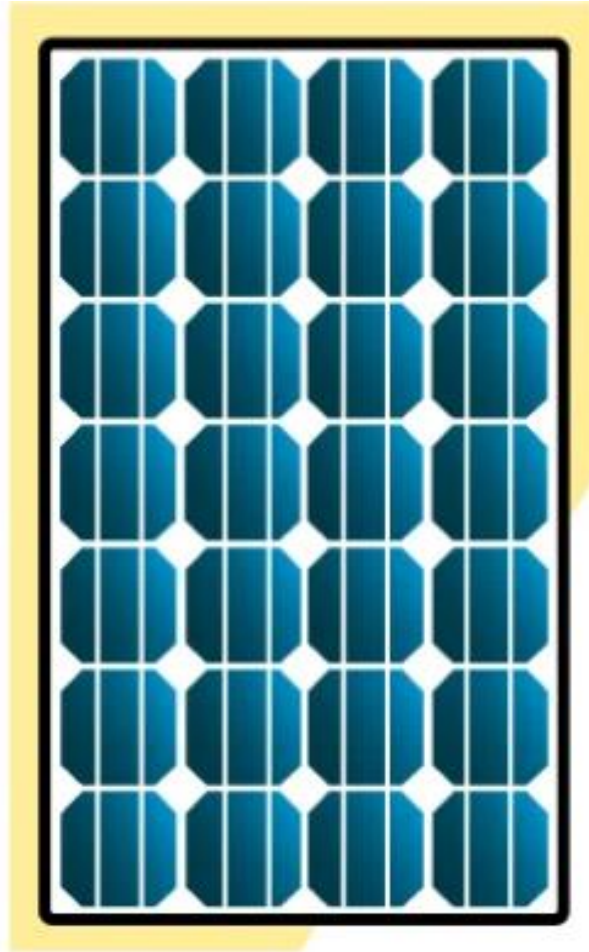
Polycrystalline: Good balance of cost and performance for residential use

Thin-Film: Suitable for large commercial roofs with weight constraints

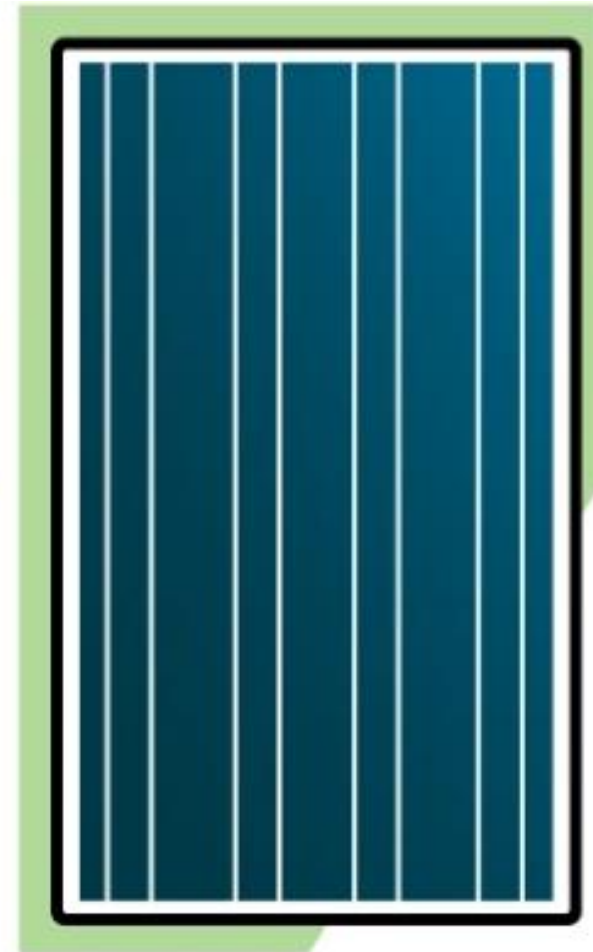
PHOTOVOLTAIC MODULE: PANEL TECHNOLOGY /02



POLYCRYSTALLINE



MONOCRYSTALLINE



THIN FILM

[What is the difference between monocrystalline, polycrystalline and thin-film solar panels? - Solar Technology - My Solar Quotes Blog](#)

PHOTOVOLTAIC MODULE: KEY PANEL SPECIFICATIONS

Power Rating (Wattage)

- Today's panels range from 300W to 450W. Higher wattage means fewer panels for the same system size.

Temperature Coefficient

- How efficiency drops with heat. Look for coefficients closer to zero (e.g., $-0.3\%/^{\circ}\text{C}$ vs $-0.5\%/^{\circ}\text{C}$).

Warranty Terms

- Product warranty (10-12 years) and performance warranty (25+ years at 80-85% output).

PHOTOVOLTAIC MODULE: PANEL CALCULATIONS

1. Number of Panels = $\frac{\text{System Size (kW)} \times 1000}{\text{Panel Wattage}}$

2. **Example:**

6kW system with 400W panels = $6000\text{W} \div 400\text{W} = 15$ panels

PHOTOVOLTAIC MODULE: PERFORMANCE IN REAL CONDITIONS

1. Low-Light Performance:

Some panels perform better in cloudy conditions or early/late hours. Check specifications for low-light efficiency.

2. Degradation Rate:

Panels lose efficiency over time. Premium panels degrade slower (0.3-0.5%/year vs 0.7-1.0%/year).

3. PID Resistance:

Potential Induced Degradation (PID) can reduce output in high humidity. Quality panels include PID-resistant cells.

INVERTERS: TYPES & COMPARISON

INVERTER TYPE	HOW IT WORKS	EFFICIENCY	BEST APPLICATION
String Inverter	Multiple panels in series to single inverter	96-98%	Simple roofs, no shading
Microinverter	One inverter per panel	94-96%	Complex roofs, partial shading
Power Optimizer + String Inverter	Optimizers per panel + string inverter	97-98%	Mixed orientations, moderate shading
Hybrid Inverter	Manages solar + batteries + grid	94-97%	Systems with battery storage

INVERTERS: SELECTION FACTORS

1. Efficiency Rating

Look for peak and weighted efficiency (CEC efficiency). Difference between 95% and 98% equals 3% more energy production.

2. Input Voltage Range

Must match your panel string configuration. Wider MPPT range handles temperature variations better.

3. Monitoring Capabilities

Built-in WiFi/ethernet for performance tracking. Some offer per-panel monitoring with optimizers/microinverters.

INVERTERS: GRID-INTERACTIVE FEATURES

1. Voltage & Frequency Ride-Through:

Advanced inverters can remain connected during minor grid disturbances (per IEEE 1547).

2. Reactive Power Support:

Some inverters can provide voltage support to the grid, potentially required by utilities.

3. Rapid Shutdown Compliance:

NEC 690.12 requires rapid shutdown capability. Most modern inverters include this feature.

4. Smart Inverters:

Advanced inverters can communicate with the grid and adjust output based on signals from utilities. Consider for future-proofing.

BATTERY: BATTERY CHEMISTRY COMPARISON

BATTERY TYPE	ENERGY DENSITY	CYCLE LIFE	DEPTH OF DISCHARGE	MAINTENANCE
Lithium Iron Phosphate (LFP)	High	3000-6000+ cycles	80-100%	None
Lithium NMC	Very High	2000-4000 cycles	80-90%	None
Lead-Acid (Flooded)	Low	500-1500 cycles	50%	Regular
Lead-Acid (AGM)	Medium	500-1000 cycles	70%	Minimal

BATTERY: KEY SPECIFICATIONS

1. Usable Capacity (kWh)

Amount of energy you can actually use based on Depth of Discharge (DoD).

A 10kWh battery with 90% DoD = 9kWh usable.

2. Power Rating (kW)

How much power the battery can deliver at once.

Critical for starting motors or running multiple appliances.

3. Round-Trip Efficiency

Round-trip efficiency = $\frac{\text{Energy out}}{\text{Energy in}}$

Lithium: 90-97%, Lead-acid: 70-85%.

Higher efficiency means less energy loss.

BATTERY SIZING FORMULA

1. Battery Capacity (kWh) =
$$\frac{\text{Daily Usage (kWh)} \times \text{Days Autonomy}}{\text{Depth of Discharge (DoD)}}$$

2. Example:

- A solar system is rated at 10kWh daily and has 2 days backup with 90% Depth of Discharge (DoD). Calculate the capacity of battery storage.
- Battery capacity = $10 \times 2 \div 0.9 = 22.2\text{kWh}$ battery needed

BATTERY: SYSTEM INTEGRATION APPROACHES

1. AC-Coupled Systems

Battery connects on AC side. Easier to retrofit to existing solar. Compatible with most inverters.

2. DC-Coupled Systems

Battery connects on DC side between panels and inverter. Higher efficiency but less flexible.

3. All-in-One Systems

Integrated inverter + battery units (Tesla Powerwall, LG RESU). Simplified design and installation

4. Modular vs. Integrated

Modular batteries allow capacity expansion later. Integrated systems offer cleaner installation but limited expansion.

SOLAR SYSTEM SIZING

1. Analyze Energy Consumption

Review 12 months of utility bills to understand seasonal variations. Calculate average daily kWh usage.

2. Determine Solar Potential

Use tools like PVWatts to estimate production based on location, roof orientation, and shading.

3. Set System Goals

Define objectives: bill reduction, backup power, energy independence, or environmental impact.

4. Calculate Component Sizes

Size panels, inverter, and batteries based on goals, budget, and physical constraints.

