

Introduction to Solar PV Systems

Introduction to Solar Photovoltaic (PV) Systems

Designed as a quick-reference guide for students, technicians, and anyone new to solar power.

1. What Is a Solar PV System?

Component	Function
Solar modules (panels)	Convert sunlight into direct current (DC) electricity via the photovoltaic effect.
Inverter	Changes DC to alternating current (AC) for home appliances or grid connection.
Mounting structure	Secures panels on roofs, ground, or tracking systems; provides proper tilt and orientation.
Balance-of-System (BOS)	Wiring, combiner boxes, disconnects, fuses, and monitoring equipment.
Energy storage (optional)	Batteries store excess energy for use when solar production is low.
Grid-interface equipment	Metering, anti-islanding protection, and utility interconnection hardware.

2. Basic Principles

1. **Photovoltaic Effect** – Photons hitting a semiconductor (usually silicon) free electrons, creating a flow of DC electricity.

2. **Power Equation**

$$[P = V \times I]$$

- P : Power (W)
- V : Voltage (V)
- I : Current (A)

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3. Key Performance Metrics

- **Module efficiency** – % of solar energy turned into electricity (typical 15–22%).
- **Temperature coefficient** – Power loss per °C rise above 25°C (−0.3%/°C for silicon).
- **Maximum Power Point (MPP)** – The voltage–current combination where the module delivers its highest power.

3. System Configurations

Configuration	Description	Typical Use
Grid-tied (on-grid)	PV feeds the utility grid; no batteries needed. Excess energy is exported (net metering).	Residential & commercial rooftops.
Off-grid	Isolated from the utility; requires batteries and charge controllers.	Remote cabins, islands, telecom sites.
Hybrid (grid-plus-storage)	Combines grid connection with battery backup for resilience and peak-shaving.	Commercial buildings, microgrids.
Floating PV	Panels mounted on water bodies (reservoirs, ponds).	Land-scarce regions; reduces water evaporation.

4. Sizing a Residential PV System (Step-by-Step)

1. Determine annual energy consumption

- Obtain utility bills – total kWh/year.

2. Estimate usable solar production

$$[\text{Production (kWh)}] = \text{Solar Irradiance (kWh/m}^2\cdot\text{day)} \times \text{System Size (kW)} \times \text{Derate Factor}]$$

- Derate factor accounts for losses (inverter, wiring, shading) – usually 0.75–0.85.

3. Calculate required system size

$$[\text{System Size (kW)}] = \frac{\text{Annual Consumption (kWh)}}{\text{Annual Solar Yield}}$$

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(kWh/kW)} }]

4. Select modules & inverter

- Match inverter's DC input rating to $1.0\text{--}1.2 \times$ the array's DC rating.
- Choose module wattage to fit roof area and desired layout.

5.