Solar energy: electricity or heat?

Solar energy is renewable on human time scales. The important distinction is how sunlight is used: a photovoltaic cell makes electricity, while solar thermal systems provide heat.

1. PHOTOVOLTAIC (PV): LIGHT DIRECTLY TO ELECTRICITY

Light absorbed by a semiconductor enables electric current to flow through a circuit. PV cells are connected into panels and arrays. The cells produce direct current (DC); an inverter can convert this to alternating current (AC). No steam turbine is needed. A PV panel is a generator, not a battery: it does not store its own electricity.

2. ACTIVE SOLAR HEATING: COLLECT AND MOVE HEAT

A collector absorbs sunlight and warms a liquid or air. Pumps or fans circulate that fluid to a building or a heat-storage system. For example, a pump can move heated fluid from a roof collector to transfer heat into a water tank. This supplies useful heat; it does not mean the collector is a photovoltaic panel.

3. PASSIVE SOLAR DESIGN: USE THE BUILDING ITSELF

Window orientation, shading and building materials control solar heat gain without powered equipment to collect and move the heat. Sunlight can warm a floor that later releases heat into a room. Thermal mass can retain heat; passive does not mean heat storage is physically impossible. Insulation reduces heat loss, while shading limits unwanted summer heating.

EXTENSION: CONCENTRATING SOLAR-THERMAL POWER

Mirrors → receiver heats fluid → steam turbine → generator

Concentrating solar power uses heat to generate electricity, unlike PV. Some plants store heat in materials such as molten salt for later use. A domestic solar water heater need not generate electricity at all: identify the final useful output.

PV conversion and inverters: US EIA, Photovoltaics and Electricity.
Active heating: US EIA, Solar Thermal Collectors.
Passive design and thermal mass: US DOE, Guide to Passive Solar Home Design.
Concentrating systems: US EIA, Solar Thermal Power Plants.

Scope: College Board AP Environmental Science CED, Topic 6.8, p. 128.

Sunlight varies, so output varies

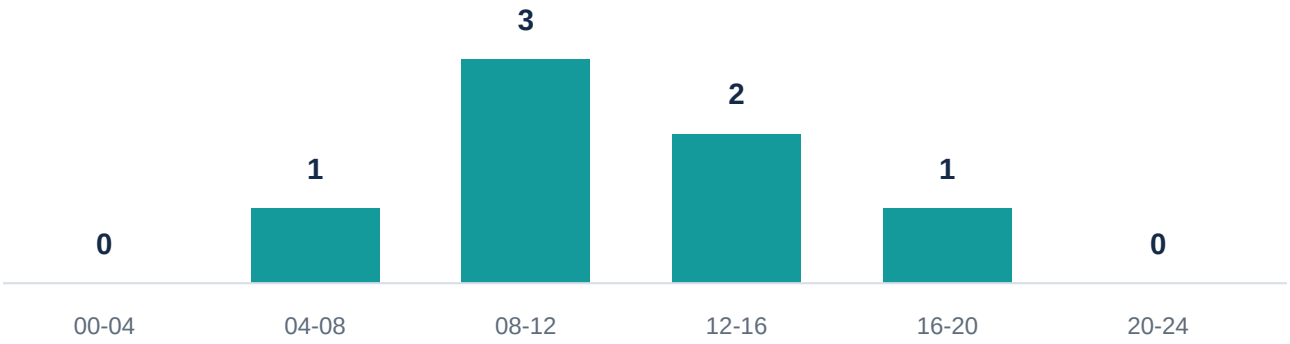
Latitude, season, weather and local shading affect incoming solar radiation. Panel orientation also matters. Solar energy is widely available, but the useful supply is not constant in time or place.

1. DISTINGUISH THE RESOURCE FROM THE OUTPUT

Insolation describes solar energy received per unit area over a period. More usable sunlight generally supports more generation, but conversion efficiency and system losses also matter. Clouds can reduce output; a PV array cannot generate solar electricity at night.

2. READ A DAY OF ILLUSTRATIVE PV OUTPUT

Average output during each 4-hour interval (kW)



Invented data, not a typical day for every site. Values are interval averages, not momentary peaks; each bar covers the same duration.

3. CONVERT POWER TO ENERGY

Energy = average power × time. Total = (0 + 1 + 3 + 2 + 1 + 0) kW × 4 h = 28 kWh. Power is a rate (kW); energy is an amount (kWh).

4. DO NOT EXTRAPOLATE ONE DAY TO A WHOLE YEAR

A rated capacity is not continuous output. Estimate annual generation using representative weather and seasonal data, not a single sunny day multiplied by 365.

Geography, weather and insolation: US EIA, Where Solar Is Found.
PV performance and output: US EIA, Photovoltaics and Electricity.
Data-analysis link: College Board, Topic 6.8; chart and calculation are illustrative.

Scope: College Board AP Environmental Science CED, Topic 6.8, p. 128.

Low operating emissions, real tradeoffs

Solar systems avoid fuel combustion during generation. Assess this benefit alongside installation costs, land use, materials and the need to match supply with demand.

1. BENEFITS AND COSTS OCCUR AT DIFFERENT STAGES

Sunlight has no fuel cost, and solar generation produces no direct combustion CO_2 or smoke. Replacing fossil-fuel generation can reduce emissions. However, panels, installation and related equipment require upfront spending. Mining materials, manufacturing and transport consume energy and resources, so low operating emissions do not mean a zero-impact life cycle.

2. A DESERT IS AN ECOSYSTEM, NOT EMPTY LAND

Large solar farms can clear vegetation, fragment habitats and disturb soils. Access roads and transmission connections add land impacts. Some solar-thermal plants need cooling water, which can be a concern in dry regions. Rooftops or suitable already-disturbed sites can reduce additional habitat conversion, but each site still needs assessment.

3. MATCH VARIABLE SUPPLY TO THE TIME OF USE

Batteries can store electricity generated earlier and discharge it later; they do not make the panels generate in darkness. Thermal storage stores heat rather than electricity directly. Storage has finite capacity, conversion losses and added costs. Shifting some demand to sunny hours, sharing power across a grid and using other generation sources can also help balance supply and demand.

4. PLAN FOR MATERIAL RECOVERY AND END OF LIFE

Panels contain useful materials such as glass, aluminum and semiconductor components. Recycling can recover materials, but separating bonded layers and recovering all components can be difficult or costly. Some panel types contain hazardous constituents that require appropriate handling. Plan collection and suitable recycling or disposal instead of assuming every retired panel is harmless or fully recyclable.

Emissions, materials, land and water: US EIA, Solar Energy and the Environment.
Storage and matching supply to demand: US DOE, Solar Energy and Storage Basics.
Material recovery and end-of-life limitations: US EPA, Solar Panel Recycling.

Scope: College Board AP Environmental Science CED, Topic 6.8, p. 128.