PV and Heat Pump vs. Concentrated Solar: Which Provides More Heat per Square Meter at Midday

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At noon in full sunshine, one square meter of sunlight provides about 1 kilowatt-hour of energy. This article compares how much usable heat can be produced when that sunlight powers a solar photovoltaic panel and heat pump versus when it is concentrated directly as thermal energy.

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Solar PV vs. CSP

Overview
Both solar photovoltaics (PV) and concentrated solar power (CSP) capture energy from sunlight, but they do it differently. PV converts light into electricity, which can then run a heat pump. CSP concentrates sunlight with mirrors to produce heat directly.
This analysis compares the amount of heat each method can deliver from one square meter of sunlight over one hour at midday under clear skies.

Assumptions Used for Comparison
• Incoming solar radiation at noon: about 1 kilowatt-hour per square meter per hour (equal to about 3,412 BTU).
• PV efficiency: 22 percent (common for high-quality modern panels).
• Heat pump coefficient of performance (COP): 5. This means for every unit of electricity, the heat pump moves 5 units of heat.
• CSP efficiency: between 50 and 70 percent under real conditions; 100 percent represents the theoretical upper limit if all sunlight were captured as heat.

Results for Solar PV and Heat Pump
A PV panel with 22 percent efficiency produces about 0.22 kilowatt-hours of electricity per square meter per hour. When that electricity is used to run a heat pump with a COP of 5, it delivers about 1.10 kilowatt-hours of heat.
• Heat from PV and heat pump = 1.10 kilowatt-hours per square meter per hour
• Converted to BTU: approximately 3,755 BTU
If the PV panel efficiency is slightly lower, around 20 percent, the heat produced would be about 1.00 kilowatt-hour, or roughly 3,412 BTU.

Results for Concentrated Solar
Each square meter of sunlight contains 1 kilowatt-hour of energy (3,412 BTU). Even in ideal conditions, CSP cannot exceed this value because that is the total available solar input.
In practice, CSP systems typically capture only 50 to 70 percent of that sunlight as usable heat due to mirror reflection losses, tracking errors, and receiver heat losses. That means realistic CSP heat output ranges from 0.50 to 0.70 kilowatt-hours per square meter per hour, or between 1,706 and 2,388 BTU.

Comparison Table
System	Typical Conditions	Heat Output (kWh)	Heat Output (BTU)
PV + Heat Pump	22% PV, COP 5	1.10	3,755
PV + Heat Pump	20% PV, COP 5	1.00	3,412
Concentrated Solar (Ideal)	100% capture	1.00	3,412
Concentrated Solar (Realistic)	50–70% capture	0.50–0.70	1,706–2,388

Interpretation
• When PV efficiency is above 20 percent and the heat pump COP is 5, the PV-plus-heat-pump system produces the same or more heat per square meter than an ideal CSP system.
• Under realistic conditions, where CSP operates between 50 and 70 percent efficiency, the PV-plus-heat-pump approach clearly delivers more usable heat.
• PV systems also generate electricity, making them more flexible and easier to install on rooftops or small lots.

When CSP Can Still Be Useful
CSP is advantageous in certain specialized cases:
• When high-temperature heat (above 150 to 200 degrees Celsius) is needed for industrial or chemical processes.
• When thermal energy storage (molten salt or similar systems) is required for nighttime operation.