



Solar-PV-Driven sCO₂ + Concentrated Solar Thermal: Can It Beat Plain PV?

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<https://salgenx.com/can-solar-hybrid-beat-plain-solar-pv-by-salgenx.html>

Assessment of a hybrid system that uses solar PV to power a supercritical CO₂ compressor and concentrated solar heat at 500 C+ for the turbine inlet, compared with 22 percent-efficient standalone PV. Includes realistic efficiency ranges, energy flows, and economics.



This webpage QR code

PDF Version of the webpage (maximum 10 pages)

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Concept Recap (Hybrid PV-sCO₂-CSP)

- Use solar PV electricity to drive the compressor in a closed-loop supercritical CO₂ (sCO₂) Brayton cycle.
- Use concentrated solar thermal (CSP) to heat the recuperated, compressed sCO₂ to ≥ 500 C before expansion through a turbine-generator.
- Aim: offset the high compressor work with PV electricity and exploit the high cycle efficiency of recuperated sCO₂ at moderate-to-high turbine inlet temperatures.

Thermodynamic Plausibility

- sCO₂ Brayton cycles are well-matched to 500–700 C heat sources and shine with recuperation and tight temperature glide near the CO₂ critical point.
- At ~500–550 C TIT with good recuperation and reasonable pressure ratios, net thermal-to-electric efficiency is typically 35–45 percent; pushing closer to ~50 percent needs hotter receivers (~600–700 C), excellent recuperators, and optimized turbomachinery.
- Compressor work in sCO₂ is non-trivial (often 30–45 percent of turbine work), but because it occurs near the critical region the specific work is low; supplying that from PV can reduce the “parasitic” internal load on the cycle’s net output.

Energy Flow Comparison (High-Level)

- Standalone PV (assume 22 percent module, ~20 percent DC-to-AC net):
- Every 1,000 W/m² of insolation yields ~200 W/m² AC at noon conditions; land-average depends on capacity factor and tracking.
- Hybrid PV + CSP sCO₂ at 500 C:
- Thermal path: DNI → receiver → sCO₂ turbine → ~35–45 percent conversion to AC.
- Electrical assist path: PV → compressor; this does not multiply energy, it reduces internal cycle load and can slightly raise net electrical output per unit thermal input.
- With adequate storage (thermal and possibly electrical buffering), the hybrid can shift generation and smooth output, something PV alone cannot do without batteries.

Where the Efficiency Advantage Can Come From

- Receiver and cycle integration:
- Good recuperation effectiveness (≥ 90 percent) and low pressure drops are vital to reach the upper 30s to low 40s percent net thermal efficiency at ~500–550 C.
- PV-to-compressor coupling:
- If PV covers most compressor work, gross turbine output minus a smaller compressor draw yields a higher net for the same thermal input. The effective solar-to-wire efficiency (considering both optical-thermal and PV inputs) depends on how you account for the PV energy.
- Thermal storage:
- CSP with hot-tank storage (molten salt or advanced media) lets you run the turbine at near-optimal load longer, raising capacity factor and grid value compared to PV-only.

Practical Efficiency Ranges (Realistic, Not Marketing Best-Case)

- Optical & thermal losses (heliostats/collector + receiver): typically 55–70 percent from DNI to receiver outlet heat at operating temperature.
- Cycle (receiver heat to AC): 35–45 percent net at ~500–550 C; 40–50 percent net becomes more realistic above ~600 C with excellent recuperation and components.
- Effective solar-to-wire for the thermal branch: multiply the two:
- Example: 0.63 (optical/thermal) $\times$ 0.40 (cycle) $\approx$ 25 percent from DNI to AC for the thermal branch under solid but not exotic assumptions.
- Add PV branch for compressor: the PV electricity is additional solar input; it improves net cycle output but doesn’t change first-law totals. When you combine both solar inputs (DNI + PV), the aggregate solar-to-wire efficiency typically ends up similar to or modestly better than the thermal branch alone, while delivering dispatchability that PV lacks without batteries.

Economics (Order-of-Magnitude 2025 Landscape)

- PV alone:

Current commercial PV and CSP LCOE values are highly dependent on technology and location.
