CO2 Power Cycles Compared: Rankine/ORC vs. sCO_2 Brayton Across 45 °C to 700 °C

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https://infinityturbine.com/infinity-turbine-sco2-cycle-guide-best-choice-for-temperature.html

When CO_2 is the working fluid, should you stay gas-phase with a Brayton cycle (compressor–turbine) or condense and pump like a Rankine/ORC. This guide compares expected efficiencies and best-fit choices at 45 °C, 100 °C, 300 °C, 500 °C, and 700 °C with references.

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Brayton Cycle: a gas-phase cycle (often supercritical CO_2 Brayton, sCO_2) using a compressor → heater → turbine → cooler → compressor loop, typically with recuperation (and often recompression) to lift efficiency. It stays single-phase; no condenser. ([OSTI][1])
Rankine / ORC: a phase-change cycle that pumps liquid, boils/evaporates in a heater, expands through a turbine, then condenses. With CO_2 specifically, true subcritical Rankine needs a sink below the 31 °C critical temperature; otherwise CO_2 cycles are transcritical. ORC usually means non-CO_2 organic fluids at low temperatures. ([ScienceDirect][2])

sCO_2 Brayton shows very high thermal efficiency once turbine-inlet temperature (TIT) reaches ~450–600 °C, with ~40% at ~500 °C reported for optimized layouts, and ~50% near ~710–720 °C (recompression variants). ([ScienceDirect][3])
At low-to-moderate heat-source temperatures, ORC and transcritical CO_2 cycles are favored; reviews report single-digit to low-teens percent at ~100 °C for ORC and transcritical CO_2, and ≤~20–24% for high-temperature ORC around a few hundred °C. ([MDPI][4])
Multiple DOE/Sandia/NETL sources position sCO_2 Brayton as compact and efficient above ~300–450 °C, with recompression cycles excelling as TIT climbs. ([OSTI][5])

What to pair with the turbine: compressor (Brayton) vs. condenser+pump (Rankine/ORC)?

Rule of thumb:

Below ~200–300 °C heat sources → condense & pump (ORC or transcritical CO_2) generally beats gas-only Brayton because compressor work dominates at low TIT and recuperation cannot recover enough. ([MDPI][4])
≥~450–600 °C heat sources → sCO_2 Brayton (with recompression/recuperation) surpasses ORC/Rankine on efficiency and power density. ([ScienceDirect][3])

Temperature-by-temperature recommendations

45 °C heat source (very low grade)

Best fit: ORC with a very low-boiling organic fluid, or transcritical CO_2 in niche WHR layouts.
Typical efficiency band: ~3–8% depending on temperature lift and pinch constraints; 45 °C is on the edge of practicality for power. ([MDPI][4])
Brayton? Not advisable. Gas compression losses overwhelm at such low TIT.
Verdict: Condense & pump (ORC/transcritical) wins on net output at this temperature.

100 °C heat source

Best fit: ORC or transcritical CO_2 power cycle; literature reports single-digit to low-teens thermal efficiencies at ~100 °C when well optimized. ([MDPI][4])
Brayton? Still poor; insufficient TIT for competitive Brayton efficiency.
Verdict: Condense & pump (ORC/transcritical) is more efficient and uses less input work than gas-only Brayton.

300 °C heat source

Borderline region.
ORC: High-temperature ORC can approach ~20–24% in the best commercial/academic reports. ([ScienceDirect][2])
sCO_2 Brayton: With recuperation (possibly recompression), sCO_2 at 300 °C can be competitive to superior depending on pressure ratio and heat exchanger effectiveness; Sandia/DOE work positions sCO_2 as "high efficiency ~300 °C" but not yet at its sweet spot. ([OSTI][5])