Gas-Fired 200 kW Microturbine vs. Supercritical CO_2 Gas-Fired Brayton Turbine: What's Best for AI Data Center Prime Power

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https://www.infinityturbine.com/capstone-200kw-microturbine-vs-sco2-gas-fired-brayton-cycle-turbine-by-infinity-turbine.html

Compare a 200 kW Capstone C200 microturbine with a conceptual natural-gas-fired supercritical CO_2 (sCO_2) Brayton turbine (≈ 600 °C inlet, 45 °C cooling) — heat rates, fuel savings at $0.20/kWh grid power, and suitability for AI data centers.

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Overview of the Two Systems

200 kW Microturbine (Capstone C200)
The C200S (or similar) gas microturbine delivers ~200 kW (≈ 208 kVA) of electrical power.
Capstone Green Energy
Electrical (LHV) efficiency: ~33% → net heat rate ~10.9 MJ/kWh (≈ 10,300 BTU/kWh)

Exhaust temperature is ≈ 280 °C — enough for heat recovery in a CHP (combined heat and power) configuration.
Pure World Energy

With heat recovery (CHP), overall fuel-to-useful-energy efficiency (electric + thermal) can reach up to ~90%.
Capstone Green Energy

Supercritical CO_2 (sCO_2) Brayton Cycle Gas-Fired Turbine (Conceptual)
This is a closed-loop Brayton cycle using supercritical CO_2 (density like a liquid, behavior like a gas) as working fluid, instead of air (gas turbine) or water/steam (steam turbine).

When fueled by natural gas (combusted in a heat exchanger) with a turbine inlet temperature around 600 °C and cooled on the turbine back side to ~45 °C, the thermal-to-electric conversion efficiency can be significantly higher than steam or conventional gas turbine cycles.

Many sCO_2 Brayton cycles operate in the range of 40% to 50% net cycle efficiency (heat input → electricity) under realistic parameters.

Compact turbomachinery and smaller footprint compared with large steam plants or equivalent-size gas turbines.

Heat Rate & Fuel Cost Comparison (Electric-Only Mode)
Assume a data center uses either system purely for electricity (no heat recovery used) and that grid electricity costs $0.20 per kWh.
Microturbine (C200)
Heat rate: ~10.9 MJ/kWh → roughly ≈ 10,300 BTU/kWh

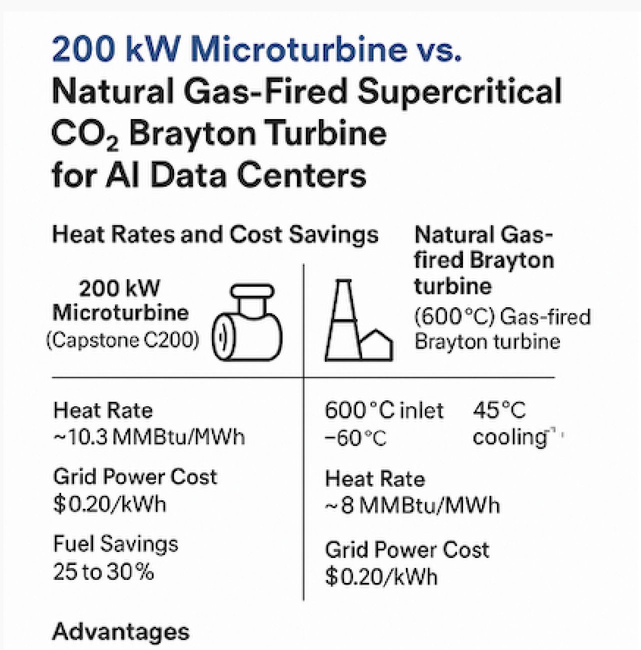
Electrical efficiency ~33%.
Fuel cost per delivered kWh depends on local natural gas price and its energy content. For illustration, if natural gas is cheap, but grid power is $0.20/kWh, onsite generation might pay off — especially with reliable output and potential for CHP.
sCO_2 Brayton Turbine (600 °C inlet, 45 °C cooling)
Net thermal-to-electric efficiency: likely in 40–50% range, depending on cycle design, recuperation, recuperator effectiveness, and real-world losses.

Heat rate (theoretical) = Lower than the microturbine: higher efficiency → less fuel per kWh. For example, a 45% efficient system has a theoretical heat rate of ~ (HHV: 3.6 MJ/kWh fuel per kWh electricity) ≈ 7.9 MJ/kWh. (This is a rough back-of-the-envelope, actual depends on real fuel HHV, parasitics, heat exchanger losses, etc.)
That corresponds to ~25–30% fuel savings per kWh compared to the microturbine (assuming ideal conditions).
Cost savings at $0.20/kWh grid rate:
If fuel and operating costs are low enough, every kWh produced by sCO_2 turbine rather than buying electricity avoids $0.20 cost.
With ~25–30% fuel savings vs microturbine, and higher efficiency, the sCO_2 route gives more net financial benefit — especially if gas is cheap and you have full load operation.
Advantages & Trade-offs
Microturbine (Capstone C200) — Strengths

Summary & Recommendation: Which to Use When

Use Case / Priority	Recommend	Why
Small / mid-size data center, modular growth, limited heat demand	Capstone 200 kW microturbine	Proven, modular, low-complexity, reliable, and scalable — fits distributed generation needs.
Large-scale AI data center, high continuous load, need maximum electrical efficiency, limited space	sCO_2 Brayton turbine (gas-fired)	Higher thermal-to-electric efficiency, lower fuel consumption and emissions, compact footprint, long-term operating cost savings.
Desire for cogeneration (heat + power), using waste heat, or maximizing fuel utilization	Either (microturbine CHP, or sCO_2 + heat recovery)	Microturbine CHP for simplicity; sCO_2 if waste heat is high-grade or system design allows efficient heat recovery.
Low capital cost, proven tech, minimal engineering risk	Microturbine	Mature technology, widespread field experience, easier to permit.

Max fuel efficiency, lower CO_2 footprint, future-proof power block	sCO_2 Brayton turbine	Higher cycle efficiency, smaller footprint, and strong theoretical advantages.



- Proven Technology
- Compact Size
- CHP Capability

- Higher Efficiency
- Compact Footprint
- Fuel Savings

Applications in AI Data Centers

- Distributed Generation
- Right-sizing Capacity
- Large-scale
- Continuous Load