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# Product Specification

## Model C200 – Capstone MicroTurbine™

## Summary

This Product Specification describes the Capstone Model C200 MicroTurbine power generating system (hereafter referred to by Capstone as a MicroTurbine). The MicroTurbine provides on-site electrical power for primary or standby applications, and for peak shaving, base loading, and/or capacity additions. MicroTurbine(s) may generate power in parallel with an electrical utility (Grid Connect mode), or isolated from the utility (Stand Alone mode). The system consists of a turbine engine, solid-state power electronics, a fuel system, and an indoor/outdoor-rated NEMA 3R enclosure.

Major turbine engine components include a compressor, a recuperator (exhaust gas heat exchanger), a combustor, a turbine, and a generator. The turbine engine is air-cooled and supported on air-lubricated compliant foil bearings. The compressor impeller, turbine rotor, and generator rotor are mounted on a single shaft, which comprises the only moving part in the engine. Power electronics are solid-state, double conversion type, producing three-phase alternating current output power from the high-frequency alternating current engine output.

## Available Model Types

Model C200 MicroTurbine systems are available in several versions, depending on fuel type, certifications, and other characteristics. Table 1 below summarizes the available construction types covered by this Product Specification.

**Table 1. C200 Model Designations**

| C200 Model Designations | External Heat Recovery Module | Certifications[1] | | Dual Mode Capable | Fuel Capability | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | CE | CARB [2] | | Natural Gas | Landfill Gas | Digester Gas | Propane Gas | Liquid Fuel |
| HP Natural Gas | Accessory | Option | | Option | X | | | | |
| LP Natural Gas | Accessory | Option | | Option | X | | | | |
| CARB Certified LP Natural Gas | Included | | X | Option | X | | | | |
| Landfill | Accessory | Option | Option | | | X[3] | | | |
| Digester | Accessory | Option | Option | | | | X[3] | | |
| Propane | Accessory | Option | | Option | | | | X | |
| Liquid Fuel | Accessory | Option | | Option | | | | | X |

**Notes:**

(1) All versions are planned to be UL Listed except the CE certified and liquid fuel models

(2) Systems are in process of being certified by the California Air Resources Board for exhaust emissions

(3) Operation on these fuels may be limited – see sections below

The tables and figures in the sections below may group the performance of these different construction types. Unless otherwise specified, the designation "C200" will cover all these construction types, and "All Other C200" will define all other constructions except any designations that are specifically called out in a given section.

# Definitions

- ISO conditions are defined as: 15 °C (59 °F), 60% relative humidity, and sea level pressure of 101.3 kPa (14.696 psia)
- HHV: Higher Heating Value
- LHV: Lower Heating Value
- HPNG: High Pressure Natural Gas
- LPNG: Low Pressure Natural Gas
- L/DG: Landfill/Digester Gas
- SG: Sour Gas
- $kW_{th}$: Kilowatt (thermal)
- $kW_e$ : Kilowatt (electric)
- Scf: Standard cubic feet (standard references ISO temperature and pressure)
- SCFM: Standard Cubic Feet per Minute (standard references ISO temperature and pressure)
- SLPM: Standard Liters per Minute (standard references ISO temperature and pressure)
- THD: Total Harmonic Distortion

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## Performance Ratings at Full Load Power

Table 2 summarizes performance ratings at full load power and ISO conditions.

**Table 2. Performance Ratings**

| Parameter | C200 Low Pressure NG | All Other C200[3] |
|---|---|---|
| **Net Power Output** | 190 (+0/- 4) kW net | 200 (+0/- 4) kW net |
| **Net Efficiency (LHV)** | 31 (± 2)% | 33 (± 2)% |
| **Nominal Net Heat Rate (LHV)** | 11,600 kJ/kWh (11,000 Btu/kWh) | 10,900 kJ/kWh (10,300 Btu/kWh) |
| **Nominal Generator Heat Rate (LHV)** | 10,700 kJ/kWh (10,200 Btu/kWh) | 10,200 kJ/kWh (9,700 Btu/kWh) |
| **Nominal Steady State Fuel Flow (HHV) [1] [2]** | 2,400,000 kJ/hr (2,280,000 BTU/hr) | 2,400,000 kJ/hr (2,280,000 BTU/hr) |

**Notes:**

(1) The ratio of Higher Heating Value (HHV) to Lower Heating Value (LHV) is assumed to be 1.1.

(2) Onload fuel flows can be up to two times higher than the steady state values.

(3) Liquid fuel systems will experience a minimal parasitic load due to fuel pump power requirements. This will have a minimal impact on net efficiency.

## Electrical Performance Ratings at Full Load Power

Table 3 presents the electrical performance ratings for Model C200 MicroTurbines operating in the Grid Connect mode at ISO conditions with zero back pressure.

**Table 3. Electrical Performance Ratings in Grid Connect Mode**

| Parameter | C200 Low Pressure NG | All Other C200[3] |
|---|---|---|
| **Net Power Output** | 190 (+0/- 4) kW | 200 (+0/- 4) kW |
| **Max Apparent Power Output** [1] | 190 kVA | 200 kVA |
| **Nominal Voltage Operating Range** | 400 to 480 VAC | 400 to 480 VAC |
| **Nominal Frequency Operating Range** | 50/60 Hz | 50/60 Hz |
| **Output Voltage Connection** [2] | 3-phase, 3 or 4 wire wye | 3-phase, 3 or 4 wire wye |
| **Max Output Current Steady State** | 275 Amps RMS @ 400V<br>230 Amps RMS @ 480V | 290 Amps RMS @ 400V<br>240 Amps RMS @ 480V |
| **Current THD** | IEEE 519 compliant, 5% | IEEE 519 compliant, 5% |

**Notes:**

(1) The microturbine system operates at unity power factor in Grid Connect mode.

(2) The grid connection to the microturbine must be neutral grounded.

(3) Liquid fuel systems will have a minimal power derating due to liquid fuel pump parasitic loads

Table 4 presents the electrical performance ratings for C200 MicroTurbines operating in the Stand Alone mode at ISO conditions.

**Table 4. Electrical Performance Ratings in Stand Alone Mode**

| Parameter | C200 Low Pressure NG | All Other C200 (4) |
|---|---|---|
| **Net Power Output** | 190 (+0/- 4) kW | 200 (+0/- 4) kW |
| **Max Apparent Power Output** (1) | 258 kVA at 480 VAC | 258 kVA at 480 VAC |
| **Nominal Voltage Operating Range** | 400 to 480 VAC | 400 to 480 VAC |
| **Frequency Operating Range** | 10 to 60 Hz | 10 to 60 Hz |
| **Output Voltage Connection** (2) | 3-phase, 4 wire wye | 3-phase, 4 wire wye |
| **Max Output Current** (3) | 310 Amps RMS steady state | 310 Amps RMS steady state |
| **Voltage THD** | IEEE 519 Compliant, 5% | IEEE 519 Compliant, 5% |

**Notes:**

(1) System power factor is limited by maximum current in Stand Alone mode
(2) Neutral must be solidly grounded
(3) Values assume linear load
(4) Liquid fuel systems will have a minimal power derating due to liquid fuel pump parasitic loads

## Performance Derating

Performance is affected by ambient temperature and elevation. The performance ratings listed above are at full load power at ISO conditions. Performance derating occurs at ambient temperatures and elevations above ISO conditions and is also affected by air inlet pressure, back pressure, and system parasitic loads (e.g. fuel gas compressor, battery charging).

Typical derating curves for power output and efficiency based on ambient temperature are shown in the curves on the following pages. These curves assume no external parasitic loads no inlet air restrictions, and no exhaust back pressure.

Figure 1 presents the nominal rating and minimum/maximum net power output versus ambient temperature (at sea level) for the standard high pressure natural gas C200 MicroTurbine, without fuel gas compression. For C200 installations with external heat recovery module, this plot assumes the heat recovery module is in full bypass mode.

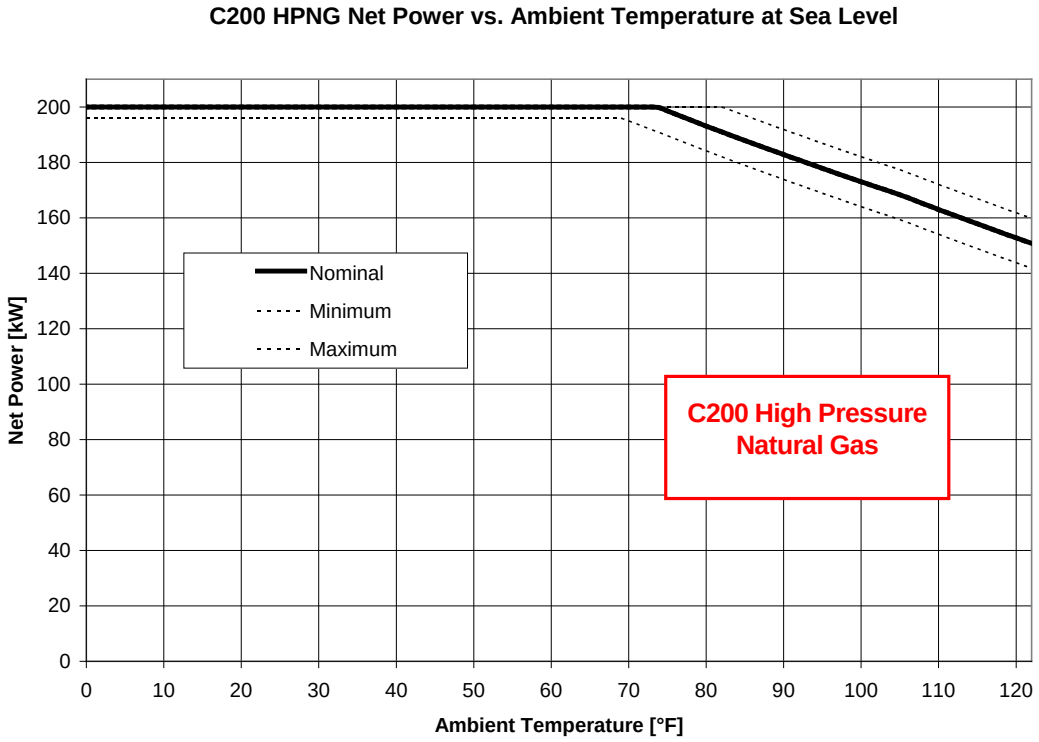


**Figure 1. C200 Net Power Output vs. Ambient Temperature**

**Notes:**

(1) Nominal Rating and Min/Max Net Power vs. Ambient Temperature at Sea Level with Zero Back Pressure for the high pressure natural gas C200 MicroTurbine (without gas compression or liquid fuel pump).

(2) All other C200 versions behave according to Figure 1, except the low pressure natural gas versions.

Figure 2 presents the nominal rating and minimum/maximum net efficiency versus ambient temperature (at sea level) for the high pressure natural gas C200 MicroTurbine, without gas compression. For C200 installations with external heat recovery module, this plot assumes the heat recovery module is in full bypass mode.

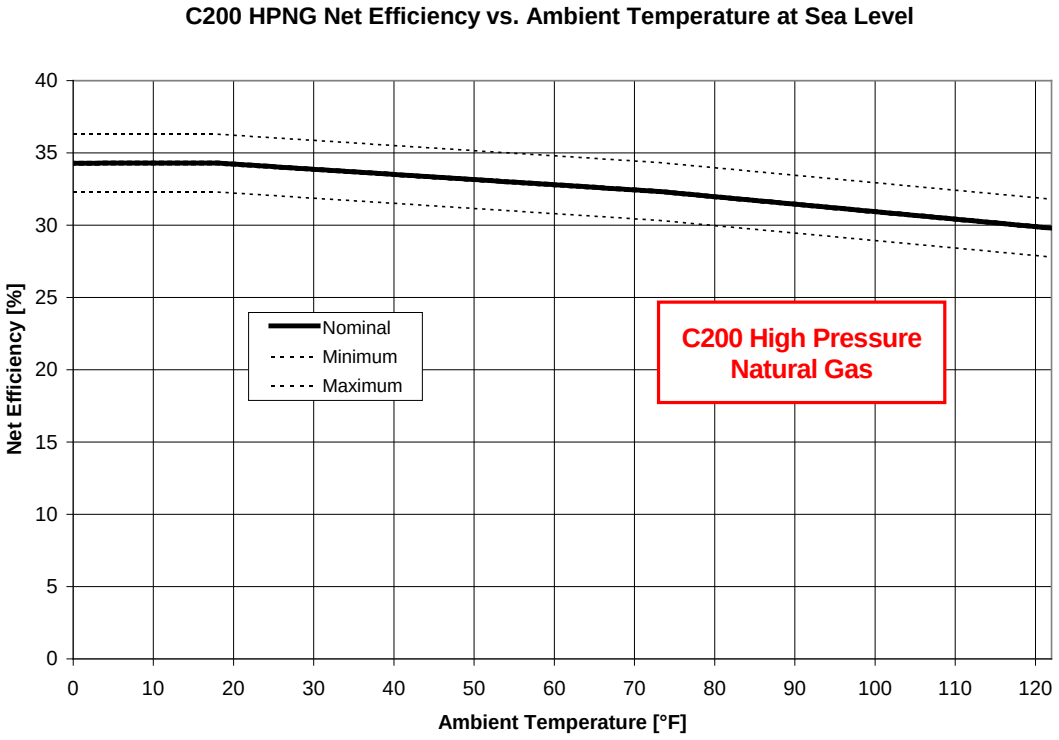


**Figure 2. C200 Net Efficiency vs. Ambient Temperature**

**Notes:**

(1) Nominal Rating and Min/Max Net Efficiency vs. Ambient Temperature at Sea Level with Zero Back Pressure for the high pressure natural gas C200 MicroTurbine (without gas compression or liquid fuel pump).

(2) All other C200 versions behave according to Figure 2, except the low pressure natural gas versions.

Figure 3 presents the nominal rating and minimum/maximum net power output versus ambient temperature (at sea level) for the C200 low pressure natural gas versions, with the external heat recovery module in full bypass mode and inlet fuel pressure of .25 psig (1.7 kPag).

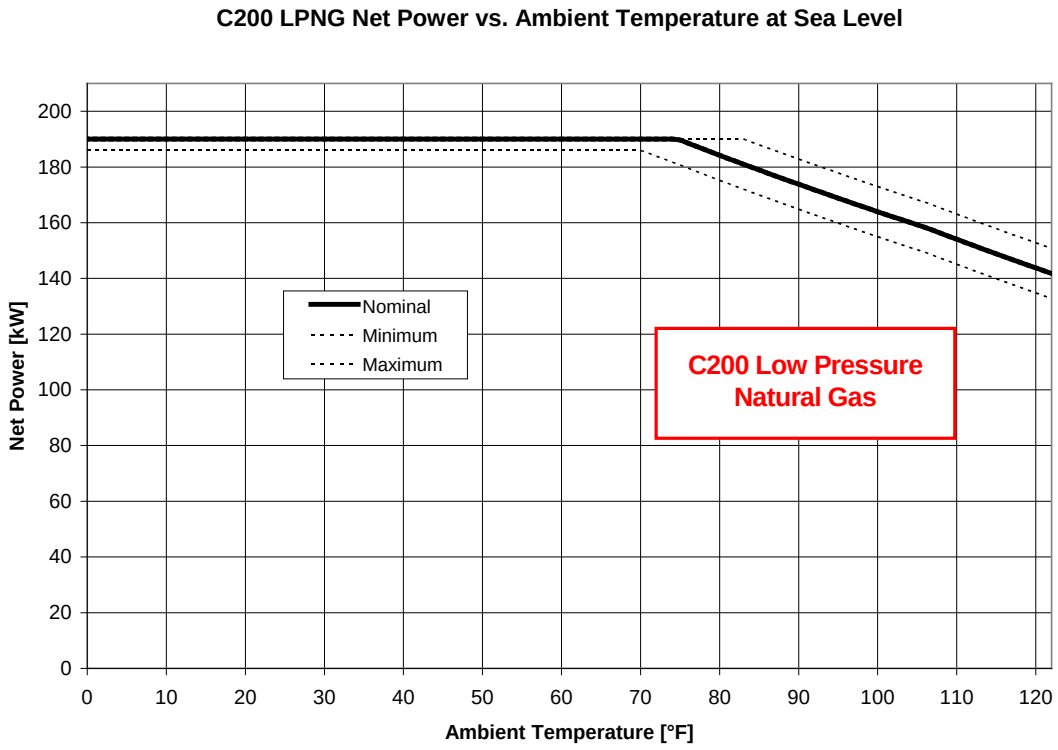


**Figure 3. C200 Low Pressure Natural Gas Net Power vs. Ambient Temperature**

**Note:**

(1) Nominal Rating and Min/Max Net Power vs. Ambient Temperature at Sea Level with Zero Back Pressure for the C200 low pressure natural gas versions and inlet fuel pressure of .25 psig (1.7 kPag).

Figure 4 presents the nominal rating and minimum/maximum net efficiency versus ambient temperature (at sea level) for the C200 low pressure natural gas versions, including the external heat recovery module in full bypass mode and inlet fuel pressure at .25 psig (1.7 kPag).

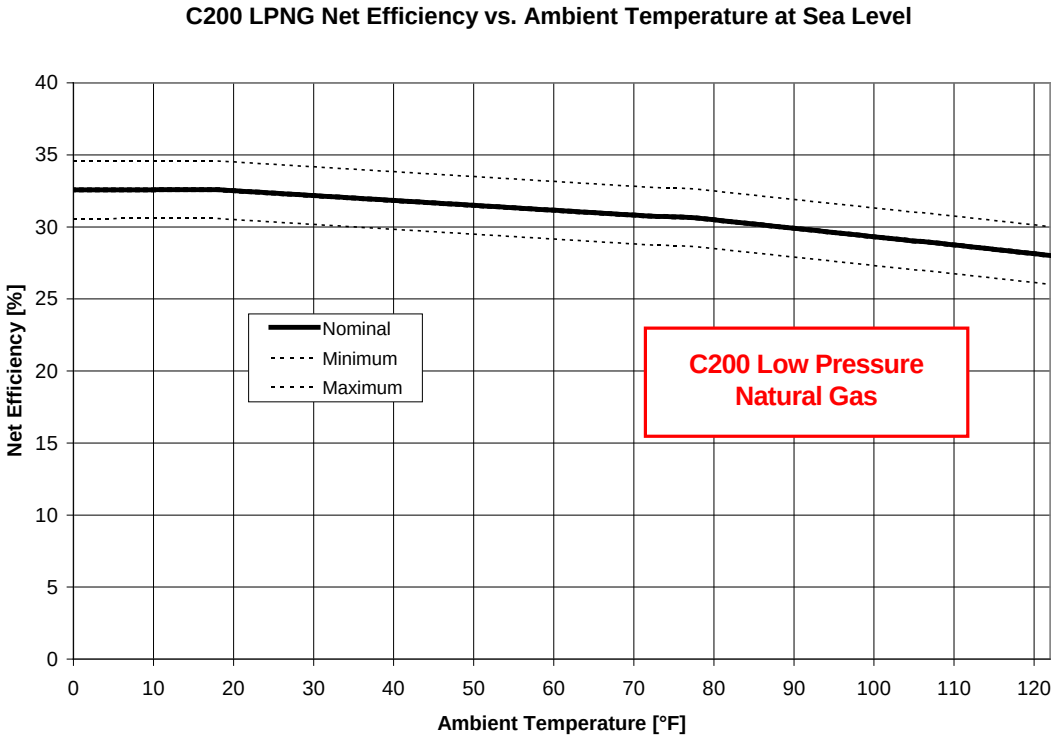


**Figure 4. C200 Low Pressure Natural Gas Net Efficiency vs. Ambient Temperature**

**Note:**

(1) Nominal Rating and Min/Max Net Efficiency vs. Ambient Temperature at Sea Level with Zero Back Pressure for the C200 low pressure natural gas versions with inlet fuel pressure at .25 psig (1.7 kPag).

## Fuel Input Requirements at Full Load Power

Table 5 presents fuel input requirements at full load power and ISO conditions.

**Table 5. Fuel Input Requirements**

| C200 Version | Inlet Pressure Range | Fuel Type | Fuel Energy Content Range [HHV] |
|---|---|---|---|
| High Pressure NG | 75 - 80 psig (517 – 552 kPaG) | Natural Gas | 30,700 – 47,500 kJ/m$^3$ (825 – 1,275 Btu/scf) |
| Low Pressure NG | 0.25 – 5 psig (1.8 – 103 kPaG) | | |
| Landfill | 75 – 80 psig (517 – 552 kPaG) | Landfill Gas | 13,000 – 22,300 kJ/m$^3$ (350 – 600 Btu/scf) |
| Digester | 75 – 80 psig (517 – 552 kPaG) | Digester Gas | 20,500 – 32,600 kJ/m$^3$ (550 – 875 Btu/scf) |
| Propane | 75 – 80 psig (517 – 552 kPaG) | Propane Gas | (2,450 – 2,550 Btu/scf) |
| Liquid Fuel | Note (2) | Liquid Fuel | Note (2) |

**Notes:**

(1) Minimum power output is 100kW for these fuels. Additional fuel gas conditioning will be required. Consult Capstone for specific application guidance.

(2) Refer to MicroTurbine Fuel Requirements Technical Reference (410002) for liquid fuel specifications.

## Exhaust Output Ratings at Full Load Power

Table 6 presents nominal exhaust output ratings at full load power and ISO conditions.

**Table 6. Exhaust Output Ratings**

| Parameter | C200 CARB Natural Gas | All Other C200 |
|---|---|---|
| **Nominal Exhaust Gas Temp** (1) | 280 °C (535 °F) | 280 °C (535 °F) |
| **Nominal Total Exhaust Energy** (1) | 1,420,000 kJ/hr (1,350,000 Btu/hr) | 1,420,000 kJ/hr (1,350,000 Btu/hr) |
| **NOx Emissions** (2) | <4 ppm V @ 15% $O_2$ | <9 ppm V @ 15% $O_2$ |
| **Exhaust Mass Flow** | 1.33 kg/s (2.93 lbm/s) | 1.33 kg/s (2.93 lbm/s) |

**Notes:**

(1) These are the final exhaust temperature and exhaust energy if the external heat recovery module is bypassing exhaust heat. Temperature and exhaust energy will be lower while recovering heat.

(2) Emissions for standard natural gas at 1,000 BTU/scf (HHV).

## Air Flow Requirements at Full Load Power

Table 7 summarizes the nominal air flow requirements of the C200 MicroTurbine systems.

**Table 7. Air Flow Requirements at ISO Conditions with Zero Back Pressure**

| Parameter | All C200 |
|---|---|
| **Engine Inlet Air Flow** | 2,600 scfm<br>(73,600 slpm) |
| **Engine Inlet Air Temp** (1) (2) | -20 to 50 °C<br>(-4 to 122 °F) |
| **Electronics Controller Inlet Air Flow** (3) | 3,600 scfm<br>(102,000 slpm) |
| **Electronics Controller Inlet Air Temp** (2) | -20 to 50 °C<br>(-4 to 122 °F) |

**Notes:**

(1) For C200 versions that include the external heat recovery module, minimum operating ambient temperature may be higher, depending on heat recovery fluid characteristics. For water, minimum ambient temperature is 1.7 °C (35 °F).

(2) The Electronics Controller inlet air temperature must be within 2 °C (3.6 °F) of the Engine inlet air temperature.

(3) Values are the same for all C200 configurations, including low pressure and dual mode versions with batteries.

## Acoustic Emissions Ratings at Full Load Power

Table 8 presents nominal acoustic emissions ratings, captured at full rated output power at a distance of 10 meters (33 feet). Actual sound levels for a given installation depend on many site factors, so the numbers provided here should only be used as general guidance.

**Table 8. Acoustic Emissions Ratings**

| Parameter | All C200 |
|---|---|
| **Acoustic Emissions** (1) | 65 dBA |

**Note:**

(1) Average of acoustic emissions measurements taken 10 meters from all sides at a height of 1.4 meters.

## MicroTurbine Dimensions and Weights

Table 9 summarizes approximate dimensions and weights of the C200 MicroTurbine systems.

**Table 9. MicroTurbine Dimensions and Weights**

| Parameter | C200 Low Pressure Natural Gas | All Other C200 |
|---|---|---|
| **Height** (1) | 2,490 mm (98 inches) | 2,490 mm (98 inches) |
| **Width** | 1,700 mm (67 inches) | 1,700 mm (67 inches) |
| **Depth** | 3,660 mm (144 inches) | 3,660 mm (144 inches) |
| **Weight** | 2,730 kg (6,000 lb) (Grid Connect)<br><br>3,640 kg (8,000 lb) (Dual Mode) | 2,270 kg (5,000 lb) (Grid Connect)<br><br>3,180 kg (7,000 lb) (Dual Mode) |

**Notes:**

(1) Height dimensions are to the roof line. Exhaust outlet extends at least 8 inches above the roof line. Rear roof extension and exhaust outlet can be removed to provide 88 inch height for shipment, if needed.

## MicroTurbine Temperature Ratings

Table 10 summarizes the temperature ratings of MicroTurbine systems. The C200 must be stored dry. For C200 systems with external heat recovery, minimum operating temperature depends on heat recovery fluid characteristics.

**Table 10. MicroTurbine Temperature Ratings**

| Parameter | C200 |
|---|---|
| **Operating Temperature** | -20 to 50 °C (-4 to 122 °F) |
| **Storage Temperature** | -40 to 65 °C (-40 to 149 °F) |

# External Heat Recovery Module

A Capstone external heat recovery module is available as an accessory for all C200 systems. Tables 11 shows the heat recovered in full heat recovery mode for water at various inlet water temperatures. The minimum heat recovery is 5 $kW_{th}$ (17 MBtu/hr) in full bypass mode.

**Table 11. C200 with External Capstone Heat Recovery Module Accessory**

| Water Temperature | | Heat Recovery |
|---|---|---|
| **Inlet** | **Outlet** | |
| 30 °C (85 °F) | 37 °C (98 °F) | 284 $kW_{th}$ (970 MBtu/hr) |
| 60 °C (140 °F) | 66 °C (151 °F) | 245 $kW_{th}$ (835 MBtu/hr) |
| 85 °C (185 °F) | 90 °C (195 °F) | 212 $kW_{th}$ (724 MBtu/hr) |

Conditions for Table 11:

- ±10% performance range
- 9.5 l/s (150 gal/min) water flow
- Full power output @ 200 $kW_e$
- ISO Conditions

# Certification Information

Please contact Capstone for the latest certification information.

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