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Product Specification

Models C600, C800, and C1000

Capstone MicroTurbine™

Summary

This Product Specification describes the Capstone MicroTurbine Models C600, C800, and C1000 power generating systems. Capstone MicroTurbines provide on-site electrical power for primary or standby applications, for peak shaving, base loading, and/or capacity additions. MicroTurbines may generate power in parallel with an electrical utility (Grid Connect mode), or isolated from the utility (Stand Alone mode). MicroTurbine exhaust heat can be recovered for use in industrial processes or in building heating and cooling systems to decrease building energy demands and increase total system efficiency. The MicroTurbine consists of a turbine engine, solid-state power electronics, a fuel system, and an indoor/outdoor-rated NEMA 3R enclosure and is available in high humidity, high wind, high seismic and stackable configurations.

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.

The C600, C800, and C1000 packages are similar in size and dimensions to an ISO container with a length of 30 feet. The container has five separate internally isolated compartments with louvered access doors. Three 200 kW power modules are used in the C600, four in the C800, and five in the C1000. C600 and C800 units can be up-rated in increments of 200 kW with the addition of aftermarket 200 kW power module kits from Capstone. These upgrades can be used to meet future power demands or to add redundancy to an existing system.

The multiple power module configurations of the C600, C800, and C1000 makes the units inherently redundant, enabling the Capstone C1000 to provide better availability than other energy generation technologies in this size range. The unit controller provided with this product line includes modes that maximize system efficiency at lower power output levels and balances the running hours of the constituent power modules, better aligning system routine maintenance needs.

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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

Available Model Types

C600, C800, and C1000 MicroTurbine systems are available in several configurations, depending on fuel type, certifications, environmental and other characteristics. Table 1 below summarizes the differences in environmental capabilities for the two enclosure types that are currently offered. The High Humidity package includes more modifications than just those suitable for high humidity environments, more stringent seismic and higher wind ratings have also been included in this package.

Table 1. C600, C800, and C1000 Package Type Environmental Capabilities

Package Type	Wind Loading	Paint Spec	IBC Seismic	Condensation Protection	2 Units Can Be Stacked
Standard	110 mph	Standard	Cat A-E; Class A-D	None	Yes
High Humidity	156 mph	Marine	Cat A-F (no stack), Cat A-E (stacked); Class A-D	Greased, heated electronics	Yes (reduces wind rating)

Table 2 details the availability of emissions, certification and dual mode options with regard to MicroTurbine fuel type.

Table 2. C600, C800, and C1000 Fuel Type, Dual Mode Capability and Certifications

Fuel Type	External Heat Recovery Module	CE Certified (1)	CARB Emissions (2)	Dual Mode Capable	Fuel Capability				
					Natural Gas	Landfill Gas	Digester Gas	Propane Gas	Liquid Fuel
HP Natural Gas	Accessory	Option		Option	X				
LP Natural Gas	Accessory	Option		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) NG systems meet CARB (California Air Resources Board) 2007 emission levels when used with a heat recovery system producing at least 60% total system efficiency (HHV).

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

The tables and figures in following sections may group the performance of these different construction types. Unless otherwise specified, the designations C600, C800, and C1000 will cover all these construction types.

Performance Specification

Performance Ratings at Full Load Power

Table 3 summarizes performance ratings at full load power and ISO conditions.

Table 3. Performance Ratings

Parameter	C600		C800		C1000	
	Low Pressure NG	All Other (3)	Low Pressure NG	All Other (3)	Low Pressure NG	All Other (3)
Net Power Output	570 +0/-12 kW net	600 +0/-12 kW net	760 +0/-16 kW net	800 +0/-16 kW net	950 +0/-20 kW net	1000 +0/-20 kW net
Net Efficiency (LHV)	31 ±2%	33 ±2%	31 ±2%	33 ±2%	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)	11,600 kJ/kWh (11,000 Btu/kWh)	10,900 kJ/kWh (10,300 Btu/kWh)	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)	10,700 kJ/kWh (10,200 Btu/kWh)	10,200 kJ/kWh (9,700 Btu/kWh)	10,700 kJ/kWh (10,200 Btu/kWh)	10,200 kJ/kWh (9,700 Btu/kWh)
Nominal Steady State Fuel Flow (HHV)(1) (2)	7,200,000 kJ/hr (6,840,000 BTU/hr)		9,600,000 kJ/hr (9,120,000 BTU/hr)		12,000,000 kJ/hr (11,400,000 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 4 presents the electrical performance ratings for C1000 Series MicroTurbines operating in the Grid Connect mode at ISO conditions with zero back pressure.

Table 4. Electrical Performance Ratings in Grid Connect Mode

Parameter	C600		C800		C1000	
	Low Pressure NG	All Other (3)	Low Pressure NG	All Other (3)	Low Pressure NG	All Other (3)
Net Power Output	570 +0/-12 kW	600 +0/-12 kW	760 +0/-16 kW	800 +0/-16 kW	950 +0/-20 kW	1000 +0/- 20 kW
Max Apparent Power Output (1)	570 kVA	600 kVA	760 kVA	800 kVA	950 kVA	1000 kVA
Nominal Voltage Operating Range	400 to 480 VAC					
Nominal Frequency Operating Range	50/60 Hz					
Output Voltage Connection (2)	3-phase, 3 or 4 wire wye					
Max Output Current Steady State	825 Amps RMS @ 400V 690 Amps RMS @ 480V	870 Amps RMS @ 400V 720 Amps RMS @ 480V	1100 Amps RMS @ 400V 920 Amps RMS @ 480V	1160 Amps RMS @ 400V 960 Amps RMS @ 480V	1375 Amps RMS @ 400V 1150 Amps RMS @ 480V	1450 Amps RMS @ 400V 1200 Amps RMS @ 480V
Current THD	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 5 presents the electrical performance ratings for C1000 Series MicroTurbines operating in the Stand Alone mode at ISO conditions.

Table 5. Electrical Performance Ratings in Stand Alone Mode

Parameter	C600		C800		C1000	
	Low Pressure NG	All Other (4)	Low Pressure NG	All Other (4)	Low Pressure NG	All Other (4)
Net Power Output	570 +0/-12 kW	600 +0/-12 kW	760 +0/-16 kW	800 +0/-16 kW	950 +0/-20 kW	1000 +0/- 20 kW
Max Apparent Power Output (1)	774 kVA at 480 VAC	774 kVA at 480 VAC	1032 kVA at 480 VAC	1032 kVA at 480 VAC	1290 kVA at 480 VAC	1290 kVA at 480 VAC
Nominal Voltage Operating Range	400 to 480 VAC					
Frequency Operating Range	10 to 60 Hz					
Output Voltage Connection (2)	3-phase, 4 wire wye					
Max Output Current (3)	930 Amps RMS steady state	930 Amps RMS steady state	1240 Amps RMS steady state	1240 Amps RMS steady state	1550 Amps RMS steady state	1550 Amps RMS steady state
Voltage THD	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 C600, C800, and C1000 MicroTurbines, without fuel gas compression. For C600, C800, or C1000 installations with external heat recovery module, this plot assumes the heat recovery module is in full bypass mode.

HPNG Net Power vs. Ambient Temperature at Sea Level

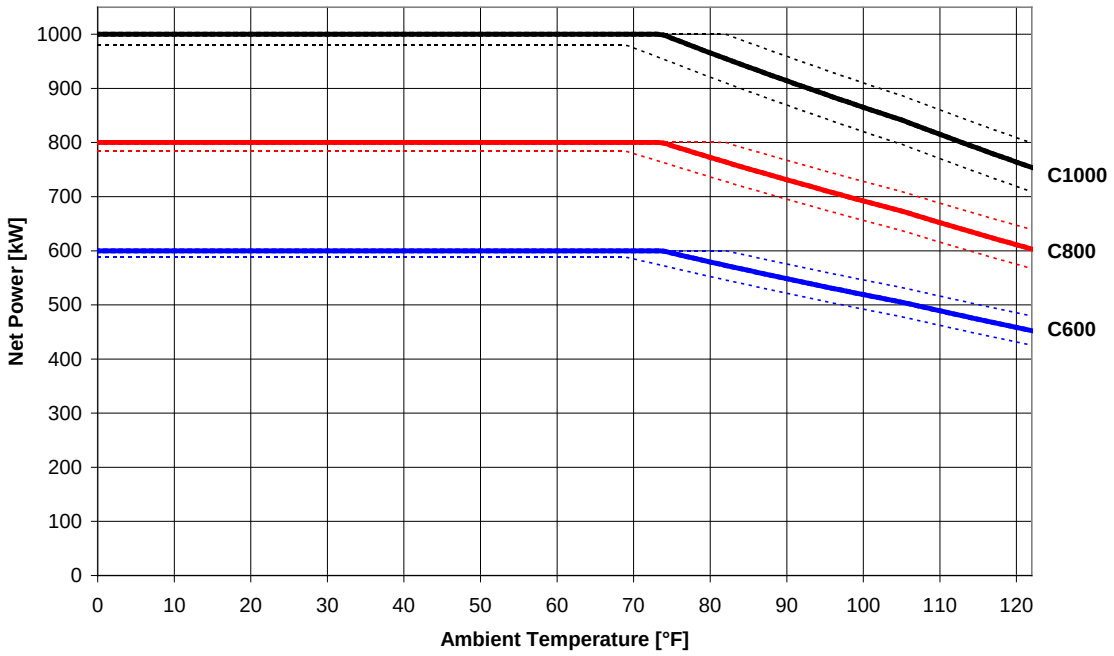

Figure 1. C600, C800, and C1000 Net Power Output vs. Ambient Temperature

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 C600, C800, and C1000 MicroTurbines (without gas compression or liquid fuel pump).

(2) All other C600, C800, and C1000 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 C600, C800, and C1000 MicroTurbines, without gas compression. For C600, C800, and C1000 installations with external heat recovery module, this plot assumes the heat recovery module is in full bypass mode.

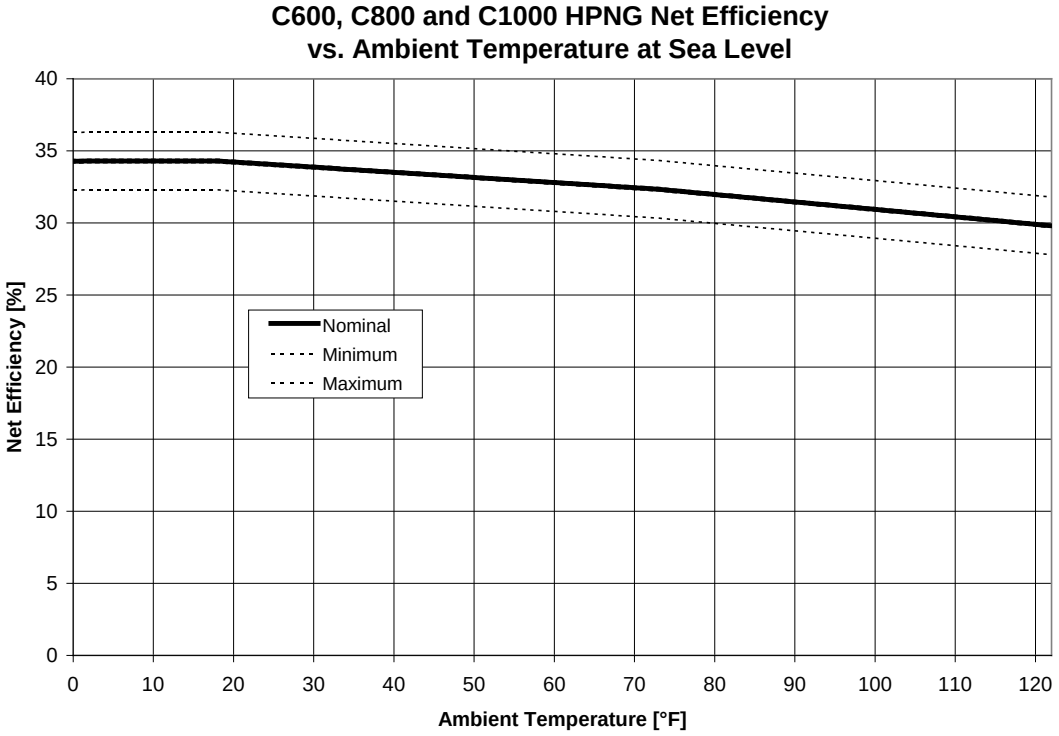

Figure 2. C600, C800, and C1000 Net Efficiency vs. Ambient Temperature

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 C600, C800, and C1000 MicroTurbines (without gas compression or liquid fuel pump).

(2) All other C600, C800, and C1000 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 C600, C800, and C1000 low pressure natural gas versions, with the external heat recovery module in full bypass mode and inlet fuel pressure of 0.25 psig (1.7 kPag).

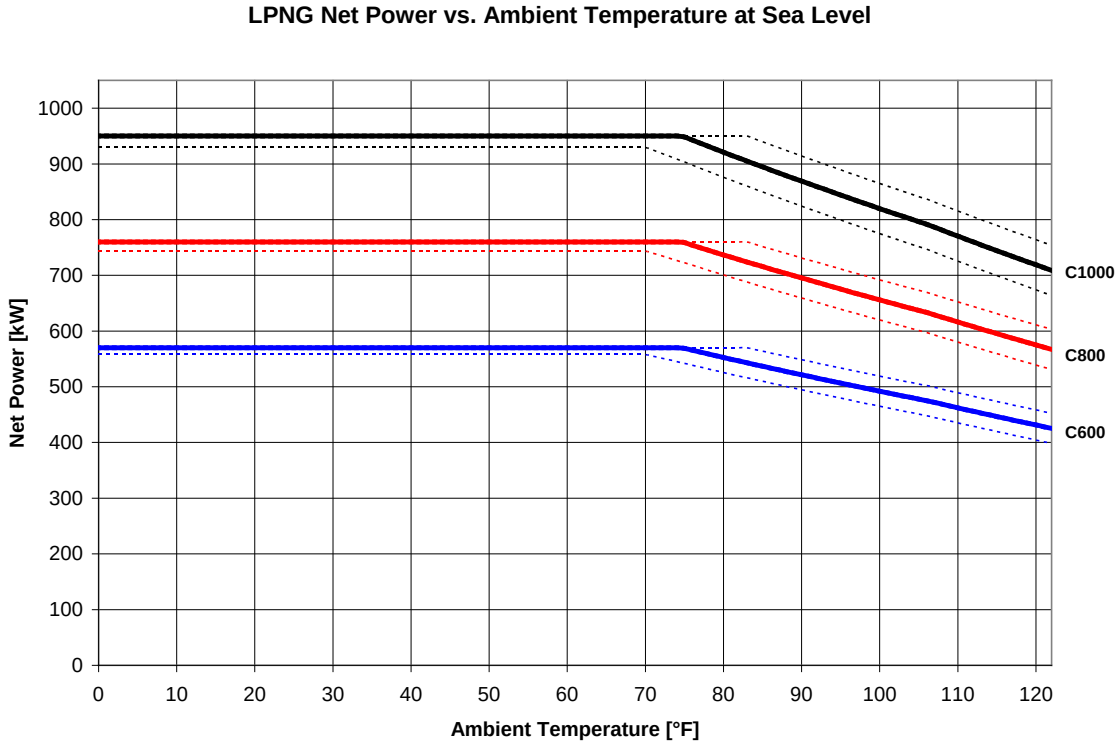

Figure 3. C600, C800, and C100 Low Pressure Natural Gas Net Power vs. Ambient Temperature

Note:

(1) Nominal Rating and Min/Max Net Power vs. Ambient Temperature at Sea Level with Zero Back Pressure for the C600, C800, and C1000 low pressure natural gas versions and inlet fuel pressure of 0.25 psig (1.7 kPag).

Figure 4 presents the nominal rating and minimum/maximum net efficiency versus ambient temperature (at sea level) for C600, C800, and C1000 low pressure natural gas versions, including the external heat recovery module in full bypass mode and inlet fuel pressure at 0.25 psig (1.7 kPag).

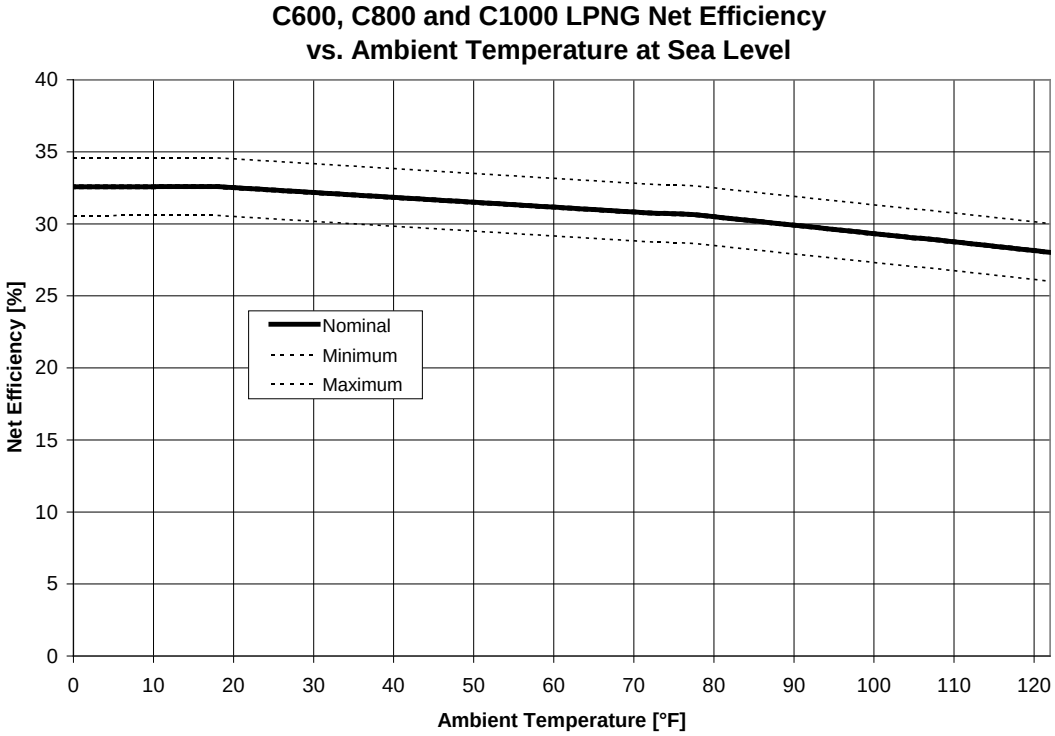

Figure 4. C600, C800, and C1000 Low Pressure Natural Gas Net Efficiency vs. Ambient Temperature

Note:

(1) Nominal Rating and Min/Max Net Efficiency vs. Ambient Temperature at Sea Level with Zero Back Pressure for C600, C800, and C1000 low pressure natural gas versions with inlet fuel pressure at 0.25 psig (1.7 kPag).

Fuel Input Requirements at Full Load Power

Table 6 presents fuel input requirements at full load power and ISO conditions for C600, C800, and C1000 models.

Table 6. Fuel Input Requirements

Fuel Type	Fuel Heat Content Range (HHV)
All Natural Gas	30,700 – 47,500 kJ/m^3 (825 to 1,275 Btu/scf)
Landfill(1)	13,000 - 22,300 kJ/m^3 (350 to 600 Btu/scf)
Digester(1)	20,500 - 32,600 kJ/m^3 (550 to 875 Btu/scf)
Propane	91,300 – 95,000 kJ/m^3 (2,450 to 2,550 Btu/scf)
Liquid Fuel	Note (2)

Note:

(1) Minimum power output for Landfill and Digester fuels is 300kW (C600), 400kW (C800) and 500kW (C1000). 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 7 presents nominal exhaust output ratings at full load power and ISO conditions.

Table 7. Exhaust Output Ratings

Parameter	C600		C800		C1000	
	CARB(3) Emissions Low Pressure NG	**All Other C600**	**CARB(3) Emissions Low Pressure NG**	**All Other C800**	**CARB(3) Emissions Low Pressure NG**	**All Other C1000**
Nominal Exhaust Gas Temp (1)	280 °C (535 °F)					
Nominal Total Exhaust Energy (1)	4,260,000 kJ/hr (4,050,000 Btu/hr)		5,680,000 kJ/hr (5,400,000 Btu/hr)		7,100,000 kJ/hr (6,750,000 Btu/hr)	
NOx Emissions (2)	<4 ppm V @ 15% O_2	<9 ppm V @ 15% O_2	<4 ppm V @ 15% O_2	<9 ppm V @ 15% O_2	<4 ppm V @ 15% O_2	<9 ppm V @ 15% O_2
Exhaust Mass Flow	3.99 kg/s (8.79 lbm/s)		5.32 kg/s (11.72 lbm/s)		6.65 kg/s (14.65 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).

(3) Emissions meet CARB requirements. Unit is not CARB certified.

Air Flow Requirements at Full Load Power

Table 8 summarizes the nominal air flow requirements of C600, C800, and C1000 MicroTurbine systems.

Table 8. Air Flow Requirements at ISO Conditions with Zero Back Pressure

Parameter	C600	C800	C1000
Engine Inlet Air Flow	7,800 scfm (220,800 slpm)	10,400 scfm (294,400 slpm)	13,000 scfm (368,000 slpm)
Engine Inlet Air Temp (1) (2)	-20 to 50 °C (-4 to 122 °F)		
Electronics Controller Inlet Air Flow (3)	10,800 scfm (306,000 slpm)	14,400 scfm (408,000 slpm)	18,000 scfm (510,000 slpm)
Electronics Controller Inlet Air Temp (2)	-20 to 50 °C (-4 to 122 °F)		

Notes:

(1) For C600, C800 and C1000 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 C600, C800, and C1000 configurations, including low pressure and dual mode versions with batteries.

Acoustic Emissions Ratings at Full Load Power

Table 9 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 9. Acoustic Emissions Ratings

Parameter	C600, C800, C1000
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 10 summarizes approximate dimensions and weights of the C600, C800, and C1000 MicroTurbine systems.

Table 10. MicroTurbine Dimensions and Weights

Parameter	C600		C800		C1000	
	Low Pressure Natural Gas	All Other	Low Pressure Natural Gas	All Other	Low Pressure Natural Gas	All Other
Height	2,900 mm (114 inches)					
Width	2,400 mm (94.5 inches)					
Depth	9,100 mm (358 inches)					
Weight[(1)] Grid Connect:	12,292 kg (27,100 lb)	11,475 kg (25,300 lb)	13,879 kg (30,600 lb)	12,791 kg (28,200 lb)	15,467 kg (34,100 lb)	14,106 kg (31,100 lb)
Dual Mode:	14,143 kg (31,180 lb)	13,326 kg (29,380 lb)	16,347 kg (36,040 lb)	15,258 kg (33,640 lb)	18,551 kg (40,900 lb)	17,191 kg (37,900 lb)

Note:

(1) Weight shown is design maximum for High Humidity configuration with 155 mph wind rating, Standard configurations and as-built will not exceed these limits.

MicroTurbine Temperature Ratings

Table 11 summarizes the temperature ratings of MicroTurbine systems. The MicroTurbine must be stored dry. For MicroTurbine systems with external heat recovery, minimum operating temperature depends on heat recovery fluid characteristics.

Table 11. MicroTurbine Temperature Ratings

Parameter	C600, C800, and C1000
Operating Temperature	-20 to 50 °C (-4 to 122 °F)
Storage Temperature	-40 to 65 °C (-40 to 149 °F)

Certification Information

Please contact Capstone for the latest certification information.

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