



Product Specification

Technical Specifications and Descriptions
for a Single Capstone[®] MicroTurbine[™] (Enclosed and Recuperated)

Summary

This Product Specification describes the Capstone 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 enclosure.

MicroTurbine systems are available in 30 kW or 60 kW versions, known as C30 or C60 models. The C60 has an option to include a top-mounted heat exchanger, marketed by Capstone as the Integrated Combined Heat and Power package (ICHP). The ICHP option includes an exhaust heat recovery unit and exhaust diverter to allow full or partial recovery of exhaust energy. This allows the user to realize high total system efficiency with respect to incoming fuel energy, while providing economical operation and operational flexibility.

Major MicroTurbine 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.

Definitions

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

Performance Ratings at Full Load Power

Table 1 summarizes performance ratings at full load power and ISO conditions.

Table 1. Performance Ratings

Product	Net Power Output	Net Efficiency (LHV)	Nominal Heat Rate (LHV)
Model C60 (HPNG) (without gas compression option)	60 (+0/-2) kW net 83 kVA max at 480 Volts AC 100 Amps per phase max continuous, 50/60 Hz	28 (± 2)%	12,900 kJ (12,200 Btu) /kWh
Model C30 (HPNG, SG, or LDG) (without gas compression option)	30 (+0/-1) kW net 38.2 kVA max at 480 Volts AC 46 Amps per phase max continuous, 50/60 Hz	26 (± 2)% (Efficiency values might be lower if fuel gas compression is required for L/DG)	13,800 kJ (13,100 Btu) /kWh
Model C30 (LPNG) (without gas compression option)	28 (+0/-1) kW net 38.2 kVA max at 480 Volts AC 46 Amps per phase max continuous, 50/60 Hz	25 (± 2)% (at 5 psig fuel inlet pressure)	14,400 kJ (13,700 Btu) /kWh
Model C30 (Liquid Fuel)	29 (+1/-1) kW net 38.2 kVA max at 480 Volts AC 46 Amps per phase max continuous, 50/60 Hz	25 (± 2)%	14,400 kJ (13,700 Btu) /kWh

Performance Derating

Performance is affected by ambient temperature and elevation. The performance ratings listed 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 (i.e. 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 parasitic losses and zero inlet and back pressure.

Electrical Performance Ratings at Full Load Power

Table 2 presents the electrical performance ratings for a C30 or C60 MicroTurbine operating in the Grid Connect mode at ISO conditions with zero back pressure (ICHP). The Grid Connect output current harmonic distortion is less than or equal to 5%, and complies with IEEE 519.

Table 2. Electrical Performance Ratings in Grid Connect Mode

Parameter	Model C60 & C60 ICHP (HPNG)	Model C30 (HPNG)
Net Power Output (without gas compression)	60 (+0/-2) kW net 83 kVA max at 480 VAC 100A per phase max continuous 50/60 Hz	30 (+0/-1) kW net 38.2 kVA max at 480 VAC 46A per phase max continuous 50/60 Hz
Net Electrical Efficiency (LHV)	28 (±2) %	26 (±2) %
Typical Heat Rate (LHV)	12,900 kJ (12,200 Btu /kWh)	13,800 kJ (13,100 Btu /kWh)
Voltage Operating Range	360 to 528 VAC	360 to 528 VAC
Frequency Operating Range	50/60 Hz	50/60 Hz
Output Voltage Connection	3-phase, 3 or 4 wire wye (The Grid must be neutral grounded)	3-phase, 3 or 4 wire wye (The Grid must be neutral grounded)
Output Current (maximum)	100 Amps RMS steady state	46 Amps RMS steady state
Out Current THD	IEEE 519 compliant, 5%	IEEE 519 compliant, 5%

Table 3 presents the electrical performance ratings for a MicroTurbine operating in the Stand Alone mode. The Stand Alone output voltage harmonic distortion with linear load is less than or equal to 5%, and complies with IEEE 519.

Table 3. Electrical Performance Ratings in Stand Alone Mode

Parameter	Model C60 (HPNG)	Model C30 (HPNG)
Voltage Operating Range	360 to 480 VAC	360 to 480 VAC
Frequency Operating Range	10 to 60 Hz	10 to 60 Hz
Output Voltage Connection	3-phase, 4 wire wye (Neutral must be solidly grounded)	3-phase, 4 wire wye (Neutral must be solidly grounded)
Output Current	100 Amps RMS maximum steady state	46 Amps RMS maximum steady state

Electrical Performance/Temperature Derating

The electrical performance parameters are listed at full load power and ISO conditions, using natural gas..

Figure 1 presents the nominal rating and minimum/maximum net power output versus ambient temperature for the Model C30 MicroTurbine (HP Natural Gas, landfill/digester gas, or sour gas only).

Minimum and maximum values refer to factory production test limits.

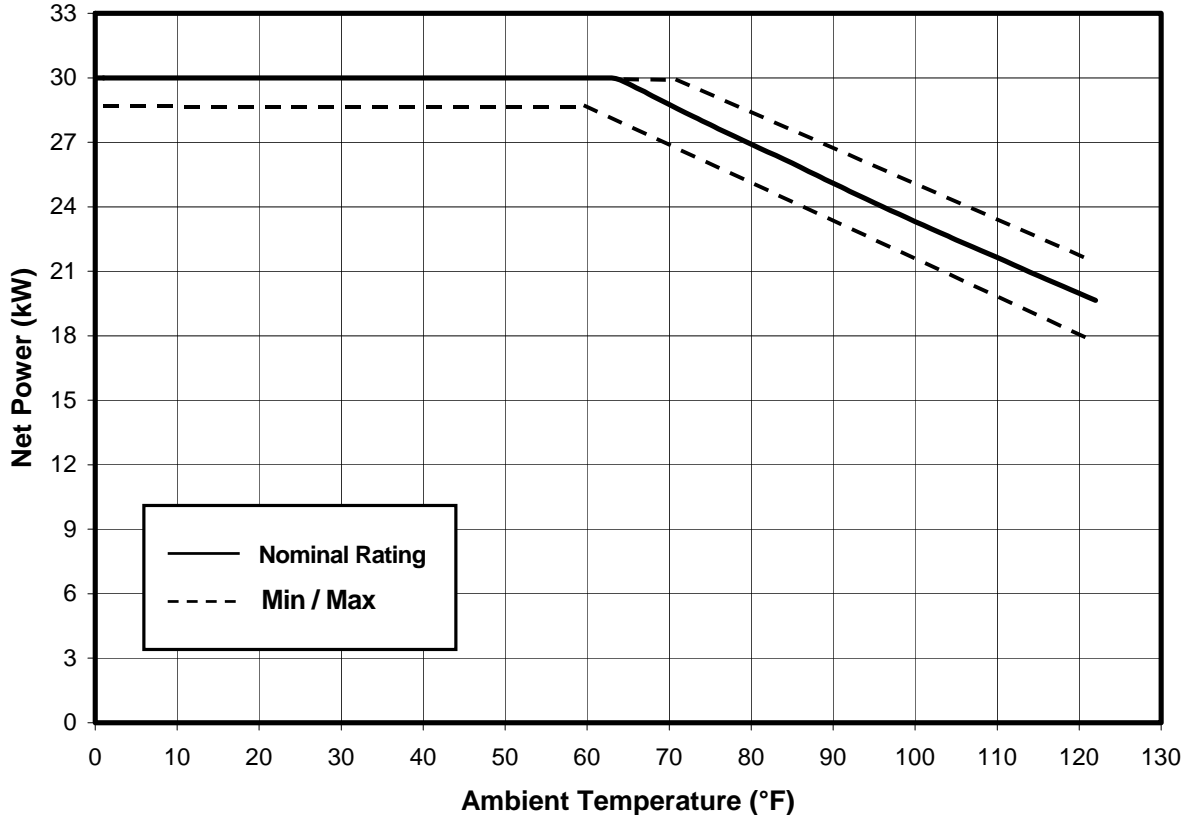


Figure 1.
Nominal Rating and Min/Max Net Power Output vs. Ambient Temperature at Sea Level with Zero Back Pressure for the Model C30 MicroTurbine, Operating on HPNG, L/DG, or SG Only (without Gas Compression)

Figure 2 presents the nominal rating and minimum/maximum net efficiency versus ambient temperature for the Model C30 MicroTurbine (HP Natural Gas, landfill/digester gas, or sour gas only).

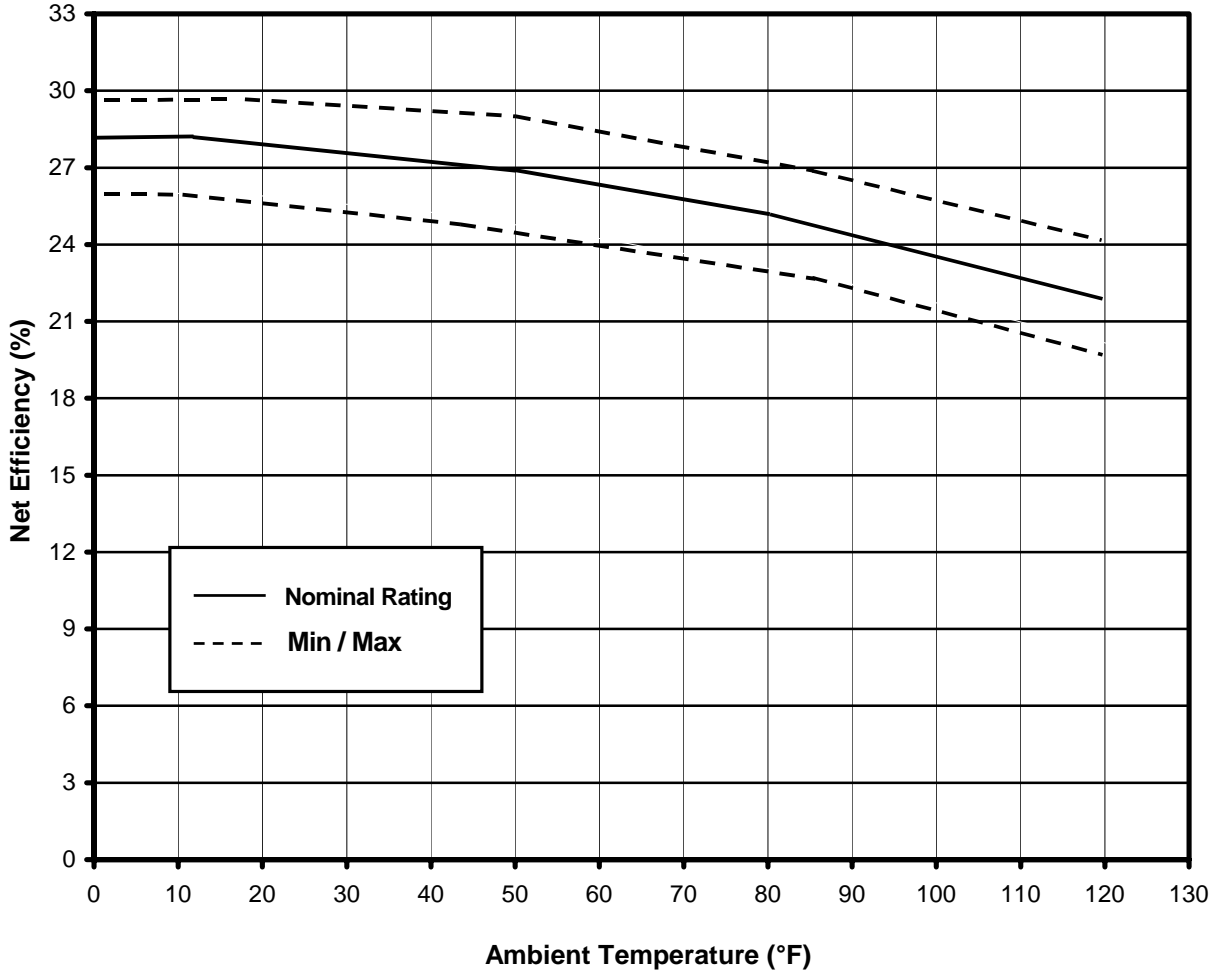


Figure 2.
Nominal Rating and Min/Max Net Efficiency vs. Ambient Temperature at Sea Level with Zero Back Pressure for the Model C30 MicroTurbine, Operating on HPNG, L/DG, or SG Only (without Gas Compression)

Figure 3 presents the nominal rating and minimum/maximum net power output versus ambient temperature (at sea level) for the Model C60 MicroTurbine (without gas compression). For the C60 ICHP, this plot assumes heat exchanger is in full bypass mode.

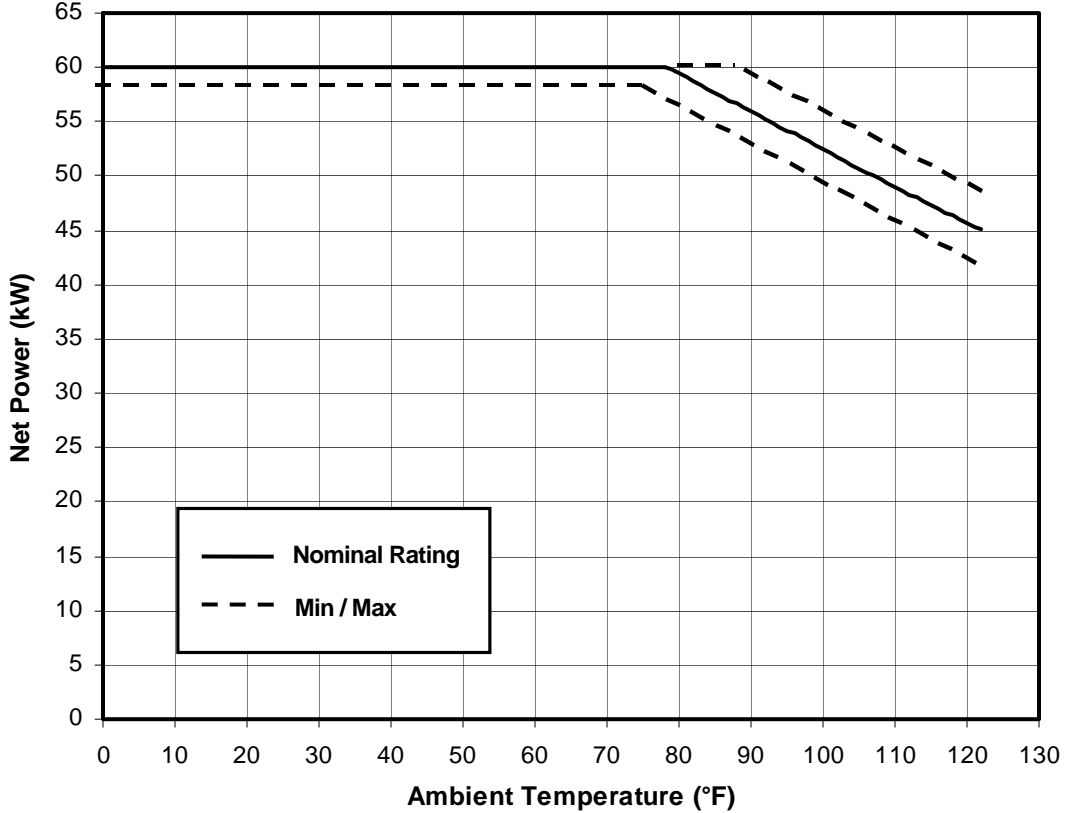


Figure 3.
Nominal Rating and Min/Max Net Power Output vs. Ambient Temperature at Sea Level with Zero Back Pressure for the Model C60 MicroTurbine (without Gas Compression)

Figure 4 presents the nominal rating and minimum/maximum net efficiency versus ambient temperature (at sea level) for the Model C60 MicroTurbine (without gas compression). For the C60 ICHP, this plot assumes heat exchanger is in full bypass mode.

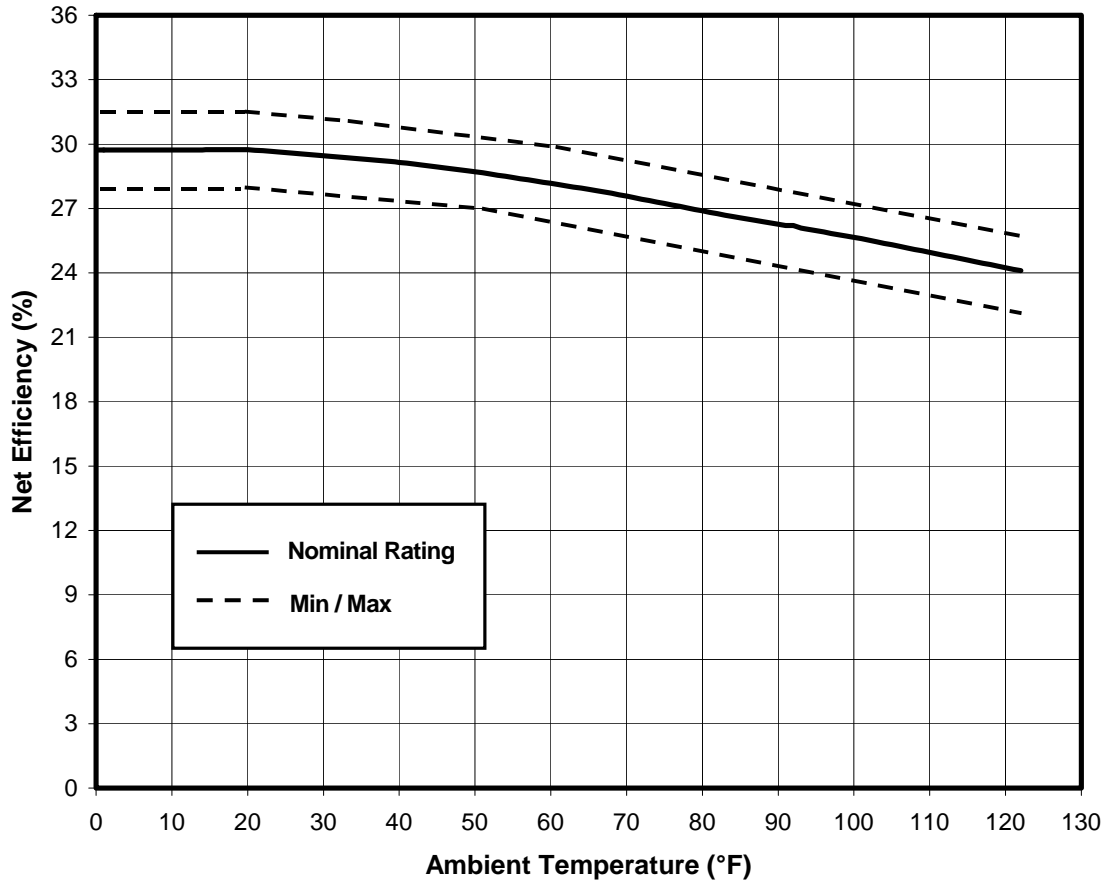


Figure 4.
Nominal Rating and Min/Max Net Efficiency vs. Ambient Temperature at Sea Level with Zero Back Pressure for the Model C60 MicroTurbine (without Gas Compression)

Fuel Input Requirements at Full Load Power

Table 4 presents fuel input requirements at full load power and ISO conditions.

Table 4. Fuel Input Requirements

Product	Fuel Type	Fuel Heat Content Range (HHV)	Nominal Full Power Steady State Fuel Flow (HHV) (Notes 1 and 2)
Model C60	NG	30,700 – 47,500 kJ/m ³ (825 to 1275 BTU/scf)	849,000 kJ/hr (804,000 Btu/hr)
	High Btu	46,600 – 79,400 kJ/m ³ (1252 to 2131 BTU/scf)	
	LPG	93,700 – 110,000 kJ/m ³ (2516 to 2962 BTU/scf)	
Model C60 (IChP)	NG	30,700 – 47,500 kJ/m ³ (825 to 1275 BTU/scf)	849,000 kJ/hr (804,000 Btu/hr)
Model C30 (HPNG, SG)	NG	30,700 – 47,500 kJ/m ³ (825 to 1275 BTU/scf)	457,000 kJ/hr (433,000 Btu/hr)
	High Btu	46,600 – 79,400 kJ/m ³ (1252 to 2131 BTU/scf)	
Model C30 (LPNG)	NG	30,700 – 47,500 kJ/m ³ (825 to 1275 BTU/scf)	457,000 kJ/hr (433,000 Btu/hr)
Model C30 (L/DG)	Low Btu	12,100 – 32,100 kJ/m ³ (325 to 861 BTU/scf)	457,000 kJ/hr (433,000 Btu/hr)
	Sour Low Btu	12,100 – 32,100 kJ/m ³ (325 to 861 BTU/scf)	
Model C30 (Liquid Fuel)	-	ASTM D975 Diesel Fuel No. 2-D ASTM D3699 Kerosene No. 1-K ASTM D1655 (Jet-A) MIL-DTL-83133E (JP-8) MIL-DTL-5624U (JP-5)	459,000 kJ/hr (435,000 Btu/hr)

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

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

Exhaust Output Ratings at Full Load Power

Table 5 presents exhaust output ratings at full load power and ISO conditions, using natural gas.

Table 5. Exhaust Output Ratings

Parameter	Model C60 (HPNG)	Model C30 (HPNG)	Model C30 (LPNG)	Model C30 (L/DG)	Model C30 (Liquid Fuel)
Nominal Exhaust Gas Temp	305 °C (580 °F)	275 °C (530 °F)	275 °C (530 °F)	275 °C (530 °F)	275 °C (530 °F)
Nominal Total Exhaust Energy	571,000 kJ/hr (541,000 Btu/hr)	327,000 kJ/hr (310,000 Btu/hr)	327,000 kJ/hr (310,000 Btu/hr)	327,000 kJ/hr (310,000 Btu/hr)	327,000 kJ/hr (310,000 Btu/hr)
NOx Emissions	<9 ppm V @ 15% O ₂	<9 ppm V @ 15% O ₂	<9 ppm V @ 15% O ₂	<9 ppm V @ 15% O ₂	<35 ppm V @ 15% O ₂
Exhaust Mass Flow	0.48 kg/s (1.06 lbm/s)	0.31 kg/s (0.69 lbm/s)	0.31 kg/s (0.69 lbm/s)	0.31 kg/s (0.69 lbm/s)	0.31 kg/s (0.69 lbm/s)

Note: These are the final exhaust temperature and exhaust energy if the heat exchanger is bypassing exhaust heat. Temperature and exhaust energy will be lower while recovering heat.

Air Flow Requirements at Full Load Power

Table 6 summarizes the nominal air flow requirements of the MicroTurbine systems.

Table 6. Air Flow Requirements at ISO Conditions with Zero Back Pressure

Parameter	Model C60 (HPNG)	Model C30 (HPNG)	Model C30 (LPNG)	Model C30 (Liquid Fuel)
Engine Inlet Air Flow	900 scfm (25,500 slpm)	540 scfm (15,291 lpm)	540 scfm (15,291 lpm)	540 scfm (15,291 lpm)
Engine Inlet Air Temp(Note 3)	-20 to 50 °C (-4 to 122 °F)	-20 to 50 °C (-4 to 122 °F)	-20 to 50 °C (-4 to 122 °F)	-20 to 50 °C (-4 to 122 °F)
Electronics Controller Inlet Air Flow	500 scfm (Notes 1,4) (14,500 slpm)	460 scfm (13,025 slpm)	460 scfm (13,025 slpm)	460 scfm (13,025 slpm)
Electronics Controller Inlet Air Temp (Note 2)	-20 to 50 °C (-4 to 122 °F)	-20 to 50 °C (-4 to 122 °F)	-20 to 50 °C (-4 to 122 °F)	-20 to 50 °C (-4 to 122 °F)
Rotary Flow Compressor Inlet Air Flow	Not Applicable	Not Applicable	260 scfm (Note 5)	260 scfm (Note 5)
Battery and Battery Controller Inlet Air Flow (Note 3)	370 scfm (Note 3) (10,500 slpm)	250 scfm (7,080 slpm)	250 scfm (7,080 slpm)	250 scfm (7,080 slpm)
Battery Inlet Air Temp (Note 3)	-20 to 50 °C (-4 to 122 °F)	-20 to 50 °C (-4 to 122 °F)	-20 to 50 °C (-4 to 122 °F)	-20 to 50 °C (-4 to 122 °F)

Note 1. The Electronics Controller inlet air temperature must be within 2° C (3.6° F) of the Engine inlet air temperature.

Note 2. These values for the Model C60 Grid Connect version, are comprised of 250 scfm for the Load Control Module and 250 scfm for the Engine Control Module.

Note 3. These values for the Model C60 are comprised of 250 scfm for the Battery Control Module and 120 scfm for the Battery.

Note 4: Minimum operating ambient temperature depends on heat recovery fluid characteristics and the heat recovery system. For water, minimum ambient temperature is 1.7 C (35 °F). The heat recovery system minimum operating ambient temperature is -20 °C (-4 °F).

Note 5. The Rotary Flow Compressor (RFC) cooling air temperature must be within 2° C (3.6° F) of the Engine inlet air temperature, and the RFC Heat Exchanger must be in the air outflow. Additionally, the RFC provides air assist functionality in the Liquid Fuel system only.

Acoustic Emissions Ratings at Full Load Power

Table 7 presents nominal acoustic emissions ratings, captured at full rated output power at a distance of 10 meters (33 feet).

Table 7. Acoustic Emissions Ratings

	Model C60 (Industrial Package)	Model C30 (Industrial Package)
Acoustic Emissions	70 dBA	65 dBA

MicroTurbine Dimensions and Weights

Table 8 summarizes dimensions and weights of the MicroTurbine systems.

Table 8. MicroTurbine Dimensions and Weights

Parameter	Model C60	Model C60 ICHP	Model C30 (Industrial Package)
Height	2110 mm (83 inches)	2,390 mm (94 inches)	1943 mm (76.5 inches)
Width	762 mm (30 inches)	762 mm (30 inches)	762 mm (30 inches)
Depth	1956 mm (77 inches)	1956 mm (77 inches)	1516 mm (59.7 inches)
Weight	758 kg (1671 pounds) (Add 363 kg or 800 pounds for the Stand Alone option)	1000 kg (2,200 lb) (Grid Connect) 1,364 kg (3,000 lb) DM (Dual Mode)	405 kg (891 pounds) (Add 173 kg or 380 pounds for the Stand Alone option)

MicroTurbine Temperature Ratings

Table 9 summarizes the temperature ratings of MicroTurbine systems. The C60 ICHP system may be stored dry within a temperature range of -40 to 65 °C (-40 to 149 °F). System is not to be stored wet.

Table 9. MicroTurbine Temperature Ratings

Parameter	Model C60 and C60 ICHP	Model C30
Operating Temperature	-20 to 50°C (-4 to 122°F)	-20 to 50°C (-4 to 122°F)
Storage Temperature	-40 to 65 °C (-40 to 149 °F)	-40 to 65 °C (-40 to 149 °F)

Engine Cycling Life

Consult Capstone for specific guidance if application requires more than 10,000 onload operations from idle to full power, or repeated cycling of more than 50% of engine power range within five minute intervals.

Integral Heat Exchanger

The ICHP heat exchanger, in heat recovery mode, recovers the exhaust energy of the C60 MicroTurbine. Table 10 below shows the C60 ICHP system heat recovery in full heat recovery mode for water at various inlet water temperatures. The minimum heat recovery is 3 kW_{th}(10 MBtu/hr) in full bypass mode.

Table 10.
Heat Recovery Performance of ICHP System for Water at Varying Inlet Temperatures

Water Temperature		Heat Recovery
Inlet	Outlet	
30°C (85°F)	41°C (106°F)	123 kW _{th} (420 MBtu/hr)
60°C (140°F)	70°C (159°F)	110 kW _{th} (375 MBtu/hr)
85°C (185°F)	94°C (202°F)	98 kW _{th} (335 MBtu/hr)

Conditions:

- ±10% performance range
- 2.5 l/s (40 gal/min) water flow
- Full power output @ 60 kW_e
- ISO Conditions

Certification Information

Please contact Capstone for the latest certification information.

Disclaimer Statement

All information contained in this document is subject to change without notice. The products described in this document are NOT intended for use in applications where malfunction may result in injury or death to persons. The information contained in this document does not affect or change Capstone's warranties. Nothing in this document shall operate as an express or implied license or indemnity under the intellectual property rights of Capstone or third parties. All information contained in this document was obtained in specific environments and is presented as an illustration. The results obtained in other environments may vary.

THE INFORMATION CONTAINED IN THIS DOCUMENT IS PROVIDED ON AS "AS IS" BASIS. In no event will Capstone be liable for damages arising directly or indirectly from any use of the information contained in this document.