Capstone Turbine Corporation • 21211 Nordhoff Street • Chatsworth • CA 91311 • USA
Telephone: (818) 734-5300 • Facsimile: (818) 734-5320 • Website: www.microturbine.com

Product Specification

Model C65 – Capstone MicroTurbine™

Summary

This Product Specification describes the Capstone Model C65 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 C65 MicroTurbine systems are available in several versions, depending on fuel type, ICHP integrated heat recovery, certifications, and other characteristics. Table 1 below summarizes the available construction types covered by this Product Specification.

Table 1. C65 Model Designations

C65 Model Designations	ICHP Core Material		Certifications (1)		Dual Mode Capable	Fuel Capability			
	Copper	SS	CE	CARB (2)		Natural Gas	Landfill Gas	Digester Gas	Propane (HD-5)
Standard	Option	Option	Option		Option	X			X (4)
CARB	X			X	Option	X			
Low NOx	Option				Option	X			
NYC (3)	Option				Option	X			X (4)
Landfill			Option	Option			X (4)		
Digester		Option	Option	Option				X (4)	

Notes:

(1) All versions are UL Listed except the CE Certified models

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

(3) The New York City versions include a fuel regulator inside the MicroTurbine enclosure

(4) 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 "C65" will cover all these construction types, and "All Other C65" 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, without fuel gas compression or other external parasitic loads.

Table 2. Performance Ratings

Parameter	C65 CARB & Low NOx	All Other C65
Net Power Output	65 (+0/-3) kW net	65 (+0/-2) kW net
Net Efficiency (LHV)	28 (± 2)%	29 (± 2)%
Nominal Net Heat Rate (LHV)	12,900 kJ /kWh (12,200 Btu /kWh)	12,400 kJ /kWh (11,800 Btu /kWh)
Nominal Generator Heat Rate (LHV)	12,100 kJ /kWh (11,400 Btu /kWh)	11,600 kJ /kWh (11,000 Btu /kWh)
Nominal Steady State Fuel Flow (HHV) Notes (1) and (2)	919,000 kJ/hr (871,000 Btu/hr)	888,000 kJ/hr (842,000 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.

Electrical Performance Ratings at Full Load Power

Table 3 presents the electrical performance ratings for Model C65 MicroTurbines operating in the Grid Connect mode at ISO conditions with zero back pressure, and without fuel gas compression or other external parasitic loads.

Table 3. Electrical Performance Ratings in Grid Connect Mode

Parameter	C65 CARB & Low NOx	All Other C65
Net Power Output	65 (+0/-3) kW	65 (+0/-2) kW
Max Apparent Power Output (1)	65 kVA at 480 VAC	65 kVA at 480 VAC
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	100 Amps RMS steady state	100 Amps RMS steady state
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 must be neutral grounded.

Table 4 presents the electrical performance ratings for C65 MicroTurbines operating in the Stand Alone mode at ISO conditions, without fuel gas compression or other external parasitic loads.

Table 4. Electrical Performance Ratings in Stand Alone Mode

Parameter	C65 CARB & Low NOx	All Other C65 Types
Net Power Output	65 (+0/-3) kW	65 (+0/-2) kW
Max Apparent Power Output (1)	83 kVA at 480 VAC	83 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)	127 Amps RMS steady state	127 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

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 parasitic losses and zero inlet and exhaust back pressure.

Figure 1 presents the nominal rating and minimum/maximum net power output versus ambient temperature (at sea level) for the standard C65 MicroTurbine, without fuel gas compression. For C65 ICHP versions, this plot assumes the heat recovery module is in full bypass mode.

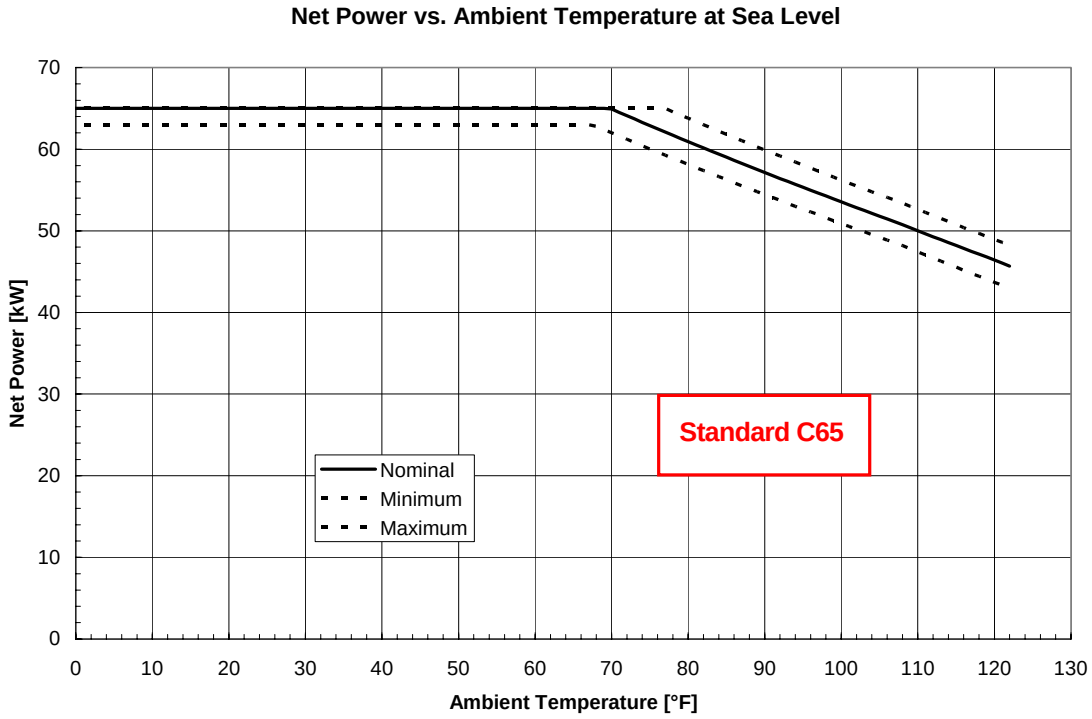

Figure 1. C65 Net Power Output vs. Ambient Temperature

Notes:

(1) Nominal Rating and Min/Max Net Power vs. Ambient Temperature at Sea Level with Zero Back Pressure for the Standard C65 MicroTurbine (without Gas Compression).

(2) All other C65 versions behave according to Figure 1, except the CARB and Low NOx versions.

Figure 2 presents the nominal rating and minimum/maximum net efficiency versus ambient temperature (at sea level) for the standard C65 MicroTurbine, without gas compression. For C65 ICHP versions, this plot assumes the heat recovery module is in full bypass mode.

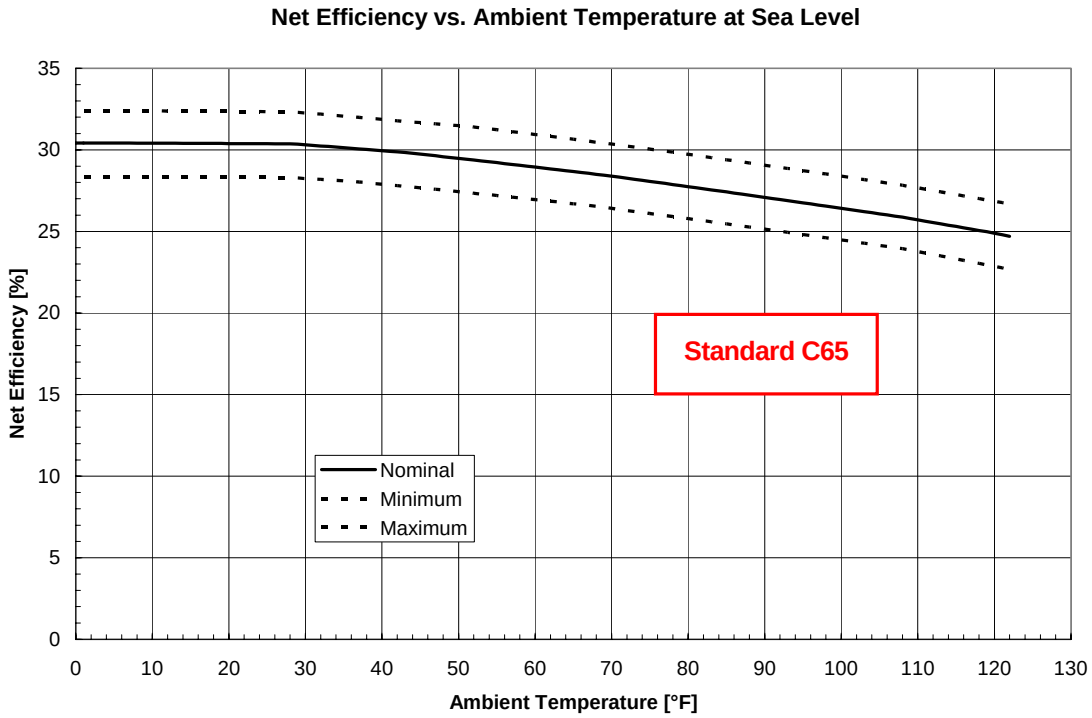

Figure 2. C65 Net Efficiency vs. Ambient Temperature

Notes:

(1) Nominal Rating and Min/Max Net Efficiency vs. Ambient Temperature at Sea Level with Zero Back Pressure for the Standard C65 MicroTurbine (without Gas Compression).

(2) All other C65 versions behave according to Figure 2, except the CARB and Low NOx versions.

Figure 3 presents the nominal rating and minimum/maximum net power output versus ambient temperature (at sea level) for the C65 CARB & Low NOx versions, including the ICHP module in full heat recovery mode but without fuel gas compression.

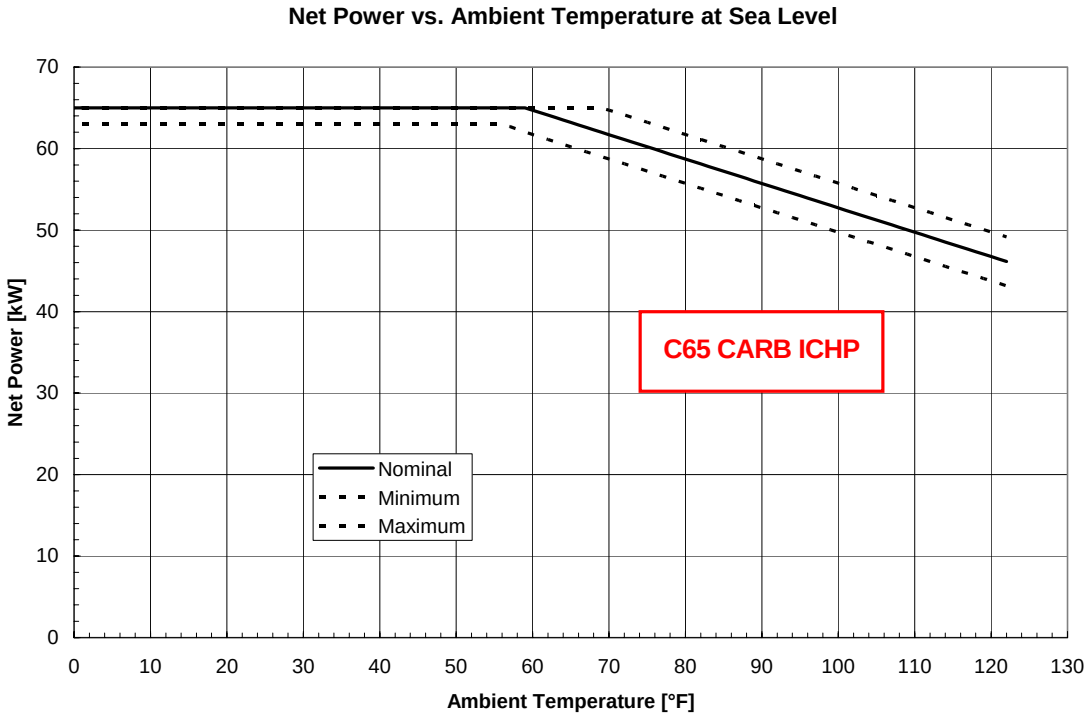

Figure 3. C65 CARB & Low NOx Net Power vs. Ambient Temperature

Note:

(1) Nominal Rating and Min/Max Net Power vs. Ambient Temperature at Sea Level with Zero Back Pressure for the C65 CARB and Low NOx versions (without Gas Compression).

Figure 4 presents the nominal rating and minimum/maximum net efficiency versus ambient temperature (at sea level) for the C65 CARB and Low NOx versions, including the ICHP module in full heat recovery mode but without fuel gas compression.

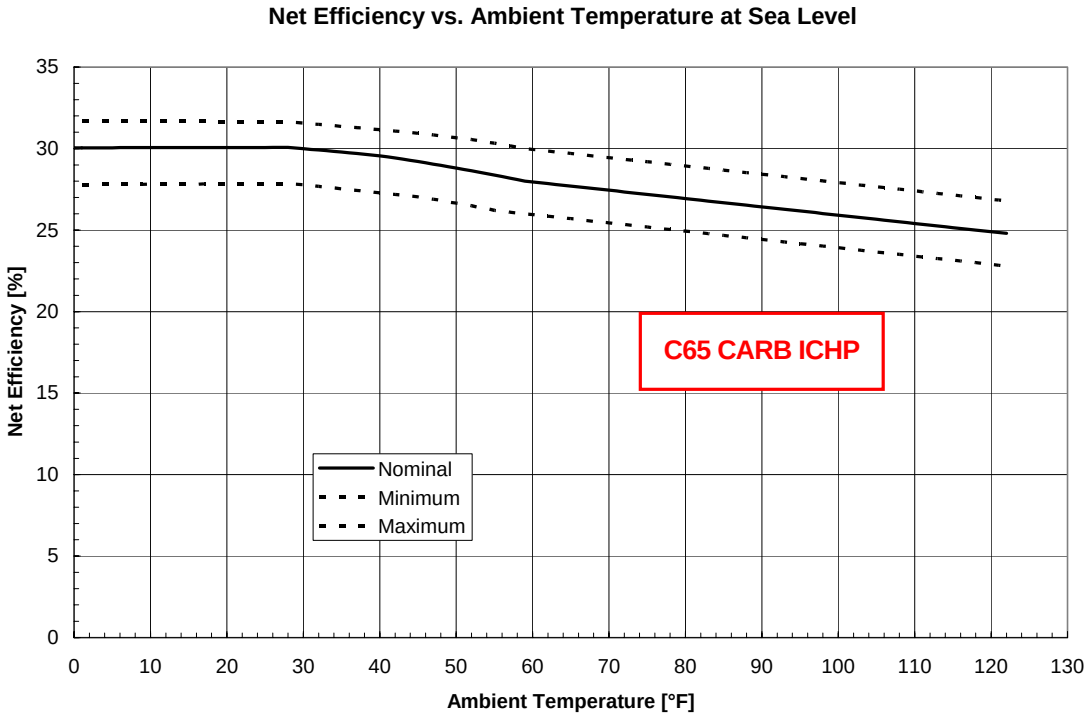

Figure 4. C65 CARB & Low NOx Net Efficiency vs. Ambient Temperature

Note:

(1) Nominal Rating and Min/Max Net Efficiency vs. Ambient Temperature at Sea Level with Zero Back Pressure for the C65 CARB and Low NOx versions (without Gas Compression).

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

C65 Version	Fuel Type	Fuel Heat Content Range (HHV)
Standard CARB Low NOx NYC	Natural Gas	30,700 – 47,500 kJ/m^3 (825 to 1,275 Btu/scf)
Standard NYC	Propane (HD-5) (1)	91,300 - 95,000 kJ/m^3 (2,450 to 2,550 Btu/scf)
Landfill	Landfill Gas (2)	13,000 - 22,300 kJ/m^3 (350 to 600 Btu/scf)
Digester	Digester Gas (2)	20,500 - 32,600 kJ/m^3 (550 to 875 Btu/scf)

Notes:

(1) Propane (HD-5) will limit the ambient temperatures, elevation, and minimum power conditions where the microturbine systems can operate. Full operation is possible above 65°F and below 4,000 ft elevation; however, the fuel must always remain in the gaseous state. Contact Capstone for specific application guidance.

(2) Minimum power output is 35kW for these fuels. Additional fuel gas conditioning will be required. Consult Capstone for specific application guidance.

Exhaust Output Ratings at Full Load Power

Table 6 presents nominal exhaust output ratings at full load power and ISO conditions, using natural gas.

Table 6. Exhaust Output Ratings

Parameter	C65 CARB & Low NOx	All Other C65
Nominal Exhaust Gas Temp (1)	311 °C (592 °F)	309 °C (588 °F)
Nominal Total Exhaust Energy (1)	623,000 kJ/hr (591,000 Btu/hr)	591,000 kJ/hr (561,000 Btu/hr)
NOx Emissions (2)	<4 ppm V @ 15% O_2	<9 ppm V @ 15% O_2
Exhaust Mass Flow	0.51 kg/s (1.13 lbm/s)	0.49 kg/s (1.08 lbm/s)

Notes:

(1) These are the final exhaust temperature and exhaust energy if the ICHP versions' 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 C65 MicroTurbine systems.

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

Parameter	All C65
Engine Inlet Air Flow	965 scfm (27,300 slpm)
Engine Inlet Air Temp (1) (2)	-20 to 50 °C (-4 to 122 °F)
Electronics Controller Inlet Air Flow (3)	500 scfm (14,200 slpm)
Electronics Controller Inlet Air Temp (2)	-20 to 50 °C (-4 to 122 °F)
Battery and Battery Controller Inlet Air Flow (4)	370 scfm (10,500 slpm)
Battery Inlet Air Temp	-20 to 50 °C (-4 to 122 °F)

Notes:

(1) For C65 versions that include the ICHP integral 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 for the C65 Grid Connect versions are comprised of 250 scfm for the Load Control Module and 250 scfm for the Engine Control Module.

(4) Values for the C65 Dual Mode versions are comprised of 250 scfm for the Battery Control Module and 120 scfm for the Battery, and are in addition to the Electronics Controller air flow for the grid connect version.

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	C65 ICHP Versions	All Other C65
Acoustic Emissions (1)	65 dBA	70 dBA

Note:

(1) The optional acoustic inlet hood kit can reduce acoustic emissions at the front of the microturbine by up to 5 dBA.

MicroTurbine Dimensions and Weights

Table 9 summarizes approximate dimensions and weights of the C65 MicroTurbine systems.

Table 9. MicroTurbine Dimensions and Weights

Parameter	C65 CARB ICHP	All Other C65 ICHP	All Other C65
Height (1)	2,620 mm (103 inches)	2,390 mm (94 inches)	2110 mm (83 inches)
Width	762 mm (30 inches)	762 mm (30 inches)	762 mm (30 inches)
Depth (2)	2,200 mm (87 inches)	2,200 mm (87 inches)	1956 mm (77 inches)
Weight	1090 kg (2,400 lb) (Grid Connect) 1,450 kg (3,200 lb) (Dual Mode)	1000 kg (2,200 lb) (Grid Connect) 1,364 kg (3,000 lb) (Dual Mode)	758 kg (1671 lb) (Grid Connect) 1121 kg (2471 lb) (Dual Mode)

Notes:

(1) Height dimensions are to the roof line. Exhaust outlet extends at least 7 inches above the roof line.

(2) Depth includes 10 inch extension for the heat recovery module rain hood on ICHP versions.

MicroTurbine Temperature Ratings

Table 10 summarizes the temperature ratings of MicroTurbine systems. The C65 and C65 ICHP systems must be stored dry. C65 ICHP system minimum operating temperature depends on heat recovery fluid characteristics.

Table 10. MicroTurbine Temperature Ratings

Parameter	C65
Operating Temperature	-20 to 50 °C (-4 to 122 °F)
Storage Temperature	-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.

ICHP Version Heat Recovery

The C65 ICHP versions, in heat recovery mode, recover the exhaust energy of the C65 MicroTurbine. Tables 11 through 13 show the 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 11. C65 CARB ICHP with Copper Heat Recovery Module

Water Temperature		Heat Recovery
Inlet	Outlet	
30 °C (85 °F)	42 °C (108 °F)	132 kW_{th} (450 MBtu/hr)
60 °C (140 °F)	71 °C (160 °F)	118 kW_{th} (400 MBtu/hr)
85 °C (185 °F)	95 °C (203 °F)	106 kW_{th} (360 MBtu/hr)

Table 12. All Other C65 ICHP with Copper Core Heat Recovery Module

Water Temperature		Heat Recovery
Inlet	Outlet	
30 °C (85 °F)	41 °C (106 °F)	126 kW_{th} (430 MBtu/hr)
60 °C (140 °F)	70 °C (159 °F)	112 kW_{th} (380 MBtu/hr)
85 °C (185 °F)	94 °C (202 °F)	100 kW_{th} (345 MBtu/hr)

Table 13. All Other C65 ICHP with Stainless Steel Heat Recovery Module

Water Temperature		Heat Recovery
Inlet	Outlet	
30 °C (85 °F)	37 °C (98 °F)	78 kW_{th} (265 MBtu/hr)
60 °C (140 °F)	67 °C (152 °F)	70 kW_{th} (240 MBtu/hr)
85 °C (185 °F)	91 °C (196 °F)	63 kW_{th} (215 MBtu/hr)

Conditions for Tables 11-13:

- ±10% performance range
- 2.5 l/s (40 gal/min) water flow
- Full power output @ 65 kW_e
- ISO Conditions

Certification Information

Please contact Capstone for the latest certification information.

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Capstone Contact Information

If questions arise regarding Model C65 Product Specification, please contact Capstone Turbine Corporation for assistance and information:

Capstone Applications

Toll Free Telephone: (866) 4-CAPSTONE or (866) 422-7786

Fax: (818) 734-5385

E-mail: applications@capstoneturbine.com

Capstone Service

Capstone Technical Support

Toll Free Telephone: (877) 282-8966

Service Telephone: (818) 407-3600 • Fax: (818) 734-1080

E-mail: service@capstoneturbine.com

Capstone Technical Support (Japan)

Service Telephone: (818) 407-3700 • Fax: (818) 734-1080

E-mail: servicejapan@capstoneturbine.com