Micro-Turbine Combined Heat & Power Generators (CHP)

Cold Climate Applications
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DISTRIBUTED CO-GENERATION DEFINED

Electricity and Heat production that is on-site or close to the load center and is interconnected to the utility distribution system.
WHY CHP?
COMBINED HEAT AND POWER

To create the same power output, traditional sources use more fuel and have much higher emissions.

**CAPSTONE MICROTURBINES**
- **FUEL**: 230kW of fuel
- **EMISSIONS**: 45kW waste heat, 0.15 lb/MWh NOx, 1,540 lb/MWh CO₂
- **OUTPUT**: 120kW hot water output, 65kW electricity output

**TRADITIONAL SOURCES**
- **FUEL**: 345kW of fuel
- **EMISSIONS**: 160kW waste heat, 3.4 lb/MWh NOx, 2,320 lb/MWh CO₂
- **OUTPUT**: 120kW hot water output, 65kW electricity output

**Comparison**:
- **FUEL** usage: Capstone MicroTurbine uses less fuel compared to traditional sources.
- **EMISSIONS**: The traditional sources emit more waste heat and NOx compared to the Capstone MicroTurbine.
- **OUTPUT**: Both systems produce similar outputs, but the Capstone MicroTurbine operates at a higher efficiency.
Advantages of Distributed Co-Generation

- Modular / Scalable / Phases
- Use of Existing Infrastructure
- Efficient Install / Minimal Operational Interruptions
- Reduced Environmental Impact / Carbon Footprint
- Reduced Noise, Vibrations & Emissions over recip
- No Utilidors, Steam-plants or Controls
WHAT IS A MICRO TURBINE?

In layman’s terms, “A miniature jet engine that runs at speeds up to 96,000 rpm and generates electricity and heat.

- **Electrical Power Output**
  - 30 kW to 100 MW range
- **Highly Reliable**
- **Ultra Low Emissions**
- **Multiple Fuels**
  - natural gas, propane diesel, biodiesel, methane/biomass/liquid fuels
- **Simple/Cost Effective Design**
- **Very Low Maintenance**
C65 Microturbine

Simple System: only one moving part
Reasons to Use Micro-Turbines with Distributed Generation

- Maintenance: 6 hours per year
- Noise: Very quiet
- Reliability: 99.99% reliable - One moving part
- Back-up to grid
- Good turn-down ratio for load following
- Base load, peak follow, time of day follow
- Can eliminate utilidor piping for waste heat at remote locations
- Can size for all heat requirements, or just minimum heat requirements
- Can use with smart grid to optimize power plant loading
- Extremely low emissions: Meets Tier 4 requirements out of the box
- Works using NG, Methane, diesel, AN-8, or Jet Fuels
- Cold WX yields higher efficiency down to -10 degrees F
Efficiency

- Micro-Turbines make power at 25-32% of the input energy
- Waste heat provides 50% of the input energy
- No heat loss from the utilidor piping
- No pumping loss from the power plant to the building
- Turndowns allow unit to match loads
- Smart Grid could allow single generator operation with load sharing for small grids
C30 Liquid Fuel Net Power & Efficiency
FUEL FLEXIBILITY

- C30, C65, C200
  - Natural gas
  - Low BTU gas down to 325 BTU/Cu. Ft
  - LPG
  - Liquid fuels
    - Diesel
    - Kerosene
    - Bio Diesel
    - Jet fuel
Ultra Low Emissions

Liquid Fuel Micro-Turbines meet Tier IV Emission requirements as shipped

**CARB Natural Gas Emission Standard**

<table>
<thead>
<tr>
<th>Units</th>
<th>2003</th>
<th>2007</th>
<th>Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOx</td>
<td>lb/MWh</td>
<td>0.5</td>
<td>0.07</td>
</tr>
<tr>
<td>CO</td>
<td>lb/MWh</td>
<td>6.0</td>
<td>0.10</td>
</tr>
<tr>
<td>VOC</td>
<td>lb/MWh</td>
<td>1.0</td>
<td>0.02</td>
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Power Electronics

UL 1741, UL 2200
• Makes grid interconnect easy, safe
• Includes protective relays and sync gear – easily integrates with other technologies
• Meets California Rule 21 utility interconnect requirements
• Provides UPS quality power
Normal (Base) Mode

[kW]

Utility

MicroTurbine

Time of Day (24 hours)
Load Following

Time of Day (24 hours)

Utility

MicroTurbine

kW
Time-of-Use Mode

MicroTurbine

Utility

Time of Day (24 hours)
# Microturbines vs Piston Engines

<table>
<thead>
<tr>
<th>Capstone Microturbines</th>
<th>Traditional Piston Engines</th>
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<tbody>
<tr>
<td><strong>Ultra low emissions</strong></td>
<td>Local air permits and exhaust cleanup required</td>
</tr>
<tr>
<td><strong>Low maintenance – Six hours per year</strong></td>
<td>High maintenance – Oil, Coolant, Injectors-160 scheduled maintenance periods in 5 years</td>
</tr>
<tr>
<td><strong>On board digital electronics</strong></td>
<td>External controls without power electronics</td>
</tr>
<tr>
<td><strong>Integrated utility protection &amp; synchronizing</strong></td>
<td>Requires external relays &amp; control equipment</td>
</tr>
<tr>
<td><strong>Lightweight &amp; small footprint</strong></td>
<td>More than twice the weight &amp; footprint</td>
</tr>
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Low Maintenance

Capstone MicroTurbine

- 6 hrs planned maintenance per year
- Scheduled/unscheduled maintenance $0.015 / kW-hr
- Average uptime 99%

Operating Hours | Item | Action
--- | --- | ---
8,000 | Air/fuel filters, Igniter | Inspect, replace
20,000 | Injectors, batteries | Replace
40,000 | Engine/generator, injectors, batteries | Overhaul

Internal Combustion Engine

- 120 hrs planned maintenance per year
- Scheduled/unscheduled maintenance $0.018 to $0.022 / kW-hr
- Average uptime 82%

Operating Hours | Item | Action
--- | --- | ---
1,000 – 2,000 | Air & oil filters, oil, spark plugs | Inspect, replace
1,500 | Top end | Inspect
20,000 | Top end | Overhaul
40,000 | Bottom end | Overhaul

Significantly lower total cost of ownership: Maintenance costs are 25% lower on average.
C-200 Cost of Ownership

Operating Cost-Turbines Vs. Recip

Initial Year 1 Year 2 Year 3 Year 4 Year 5 Year 6 Year 7 Year 8 Year 9 Year 10

$0

($200,000)

($400,000)

($600,000)

($800,000)

($1,000,000)

($1,200,000)

$200,000

$400,000

$600,000

$1,000,000

$1,200,000

$1,400,000

$1,600,000

$1,800,000

$2,000,000

$2,200,000

$2,400,000

$2,600,000

$2,800,000

$3,000,000

$3,200,000

$3,400,000

$3,600,000

$3,800,000

$4,000,000

$4,200,000

$4,400,000

$4,600,000

$4,800,000

$5,000,000

$5,200,000

$5,400,000

$5,600,000

$5,800,000

$6,000,000

4/23/201
PRODUCTS

- Capstone Product Line
  - C30 = 30KW
  - C65 = 65KW
  - C200 = 200KW

- Capstone Has Pre-engineered Packages to 1MW
  - C600 = 600KW
  - C800 = 800KW
  - C1000 = 1000KW
  - Controls