

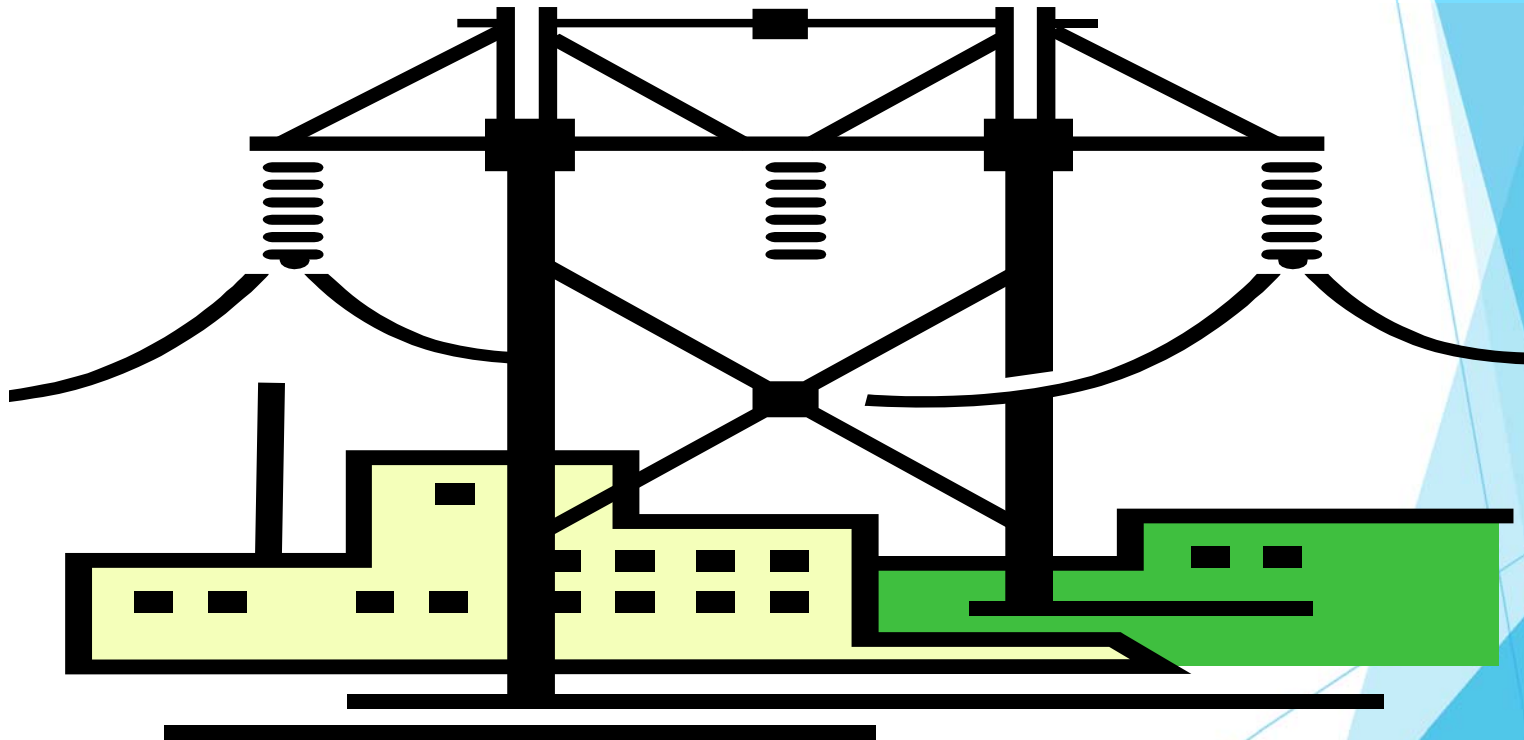


Micro-Turbine Combined Heat & Power Generators (CHP)

Cold Climate Applications
2014 Polar Technology Conference
Richard S. Armstrong, PE

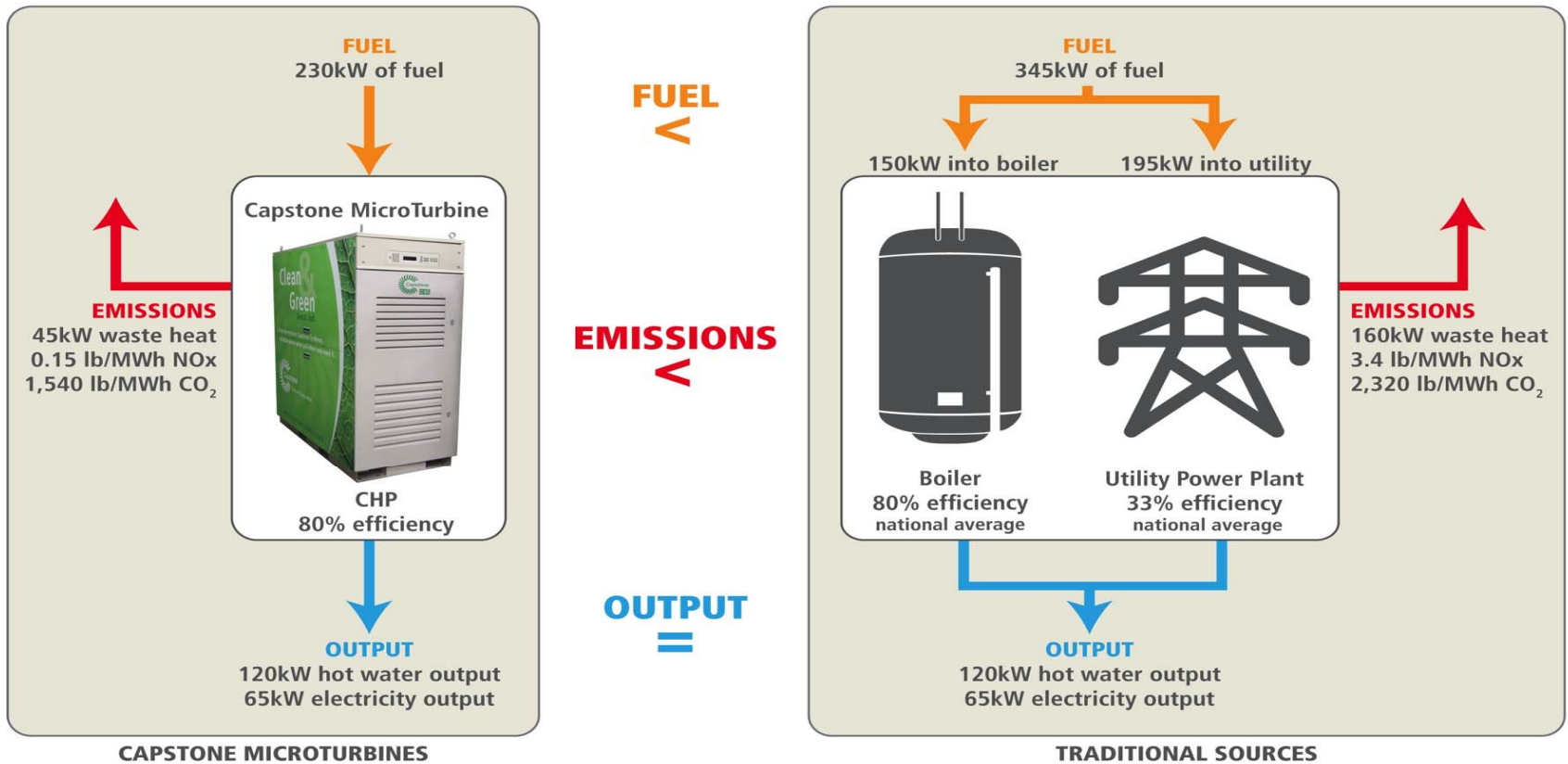
DISTRIBUTED CO-GENERATION DEFINED

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



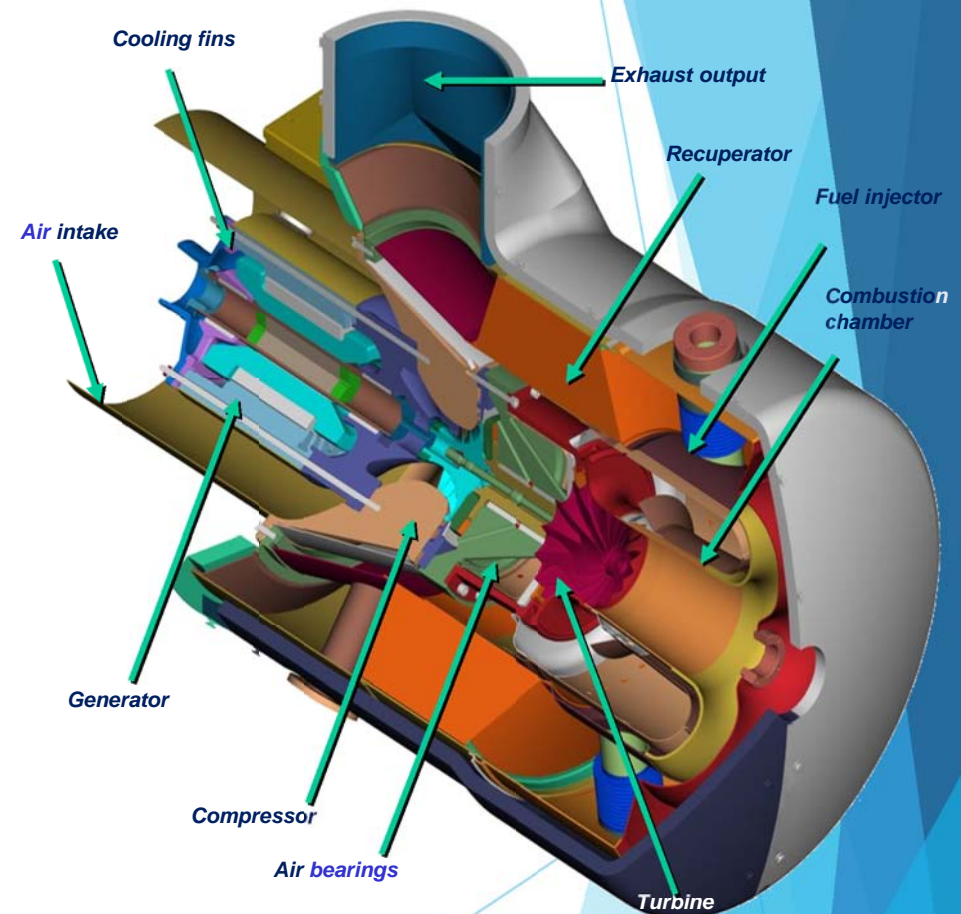
Advantages of Distributed Co-Generation

- ▶ 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

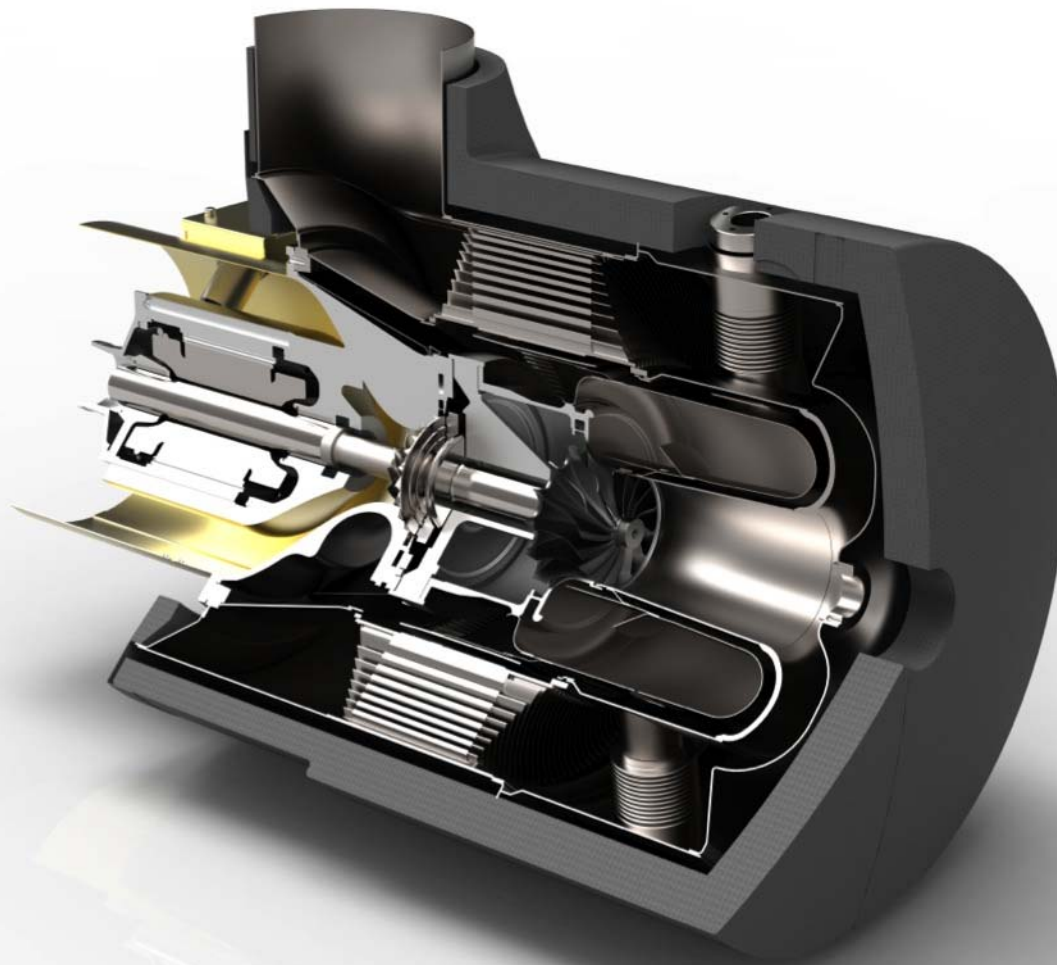
WHAT IS A MICRO TURBINE?

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

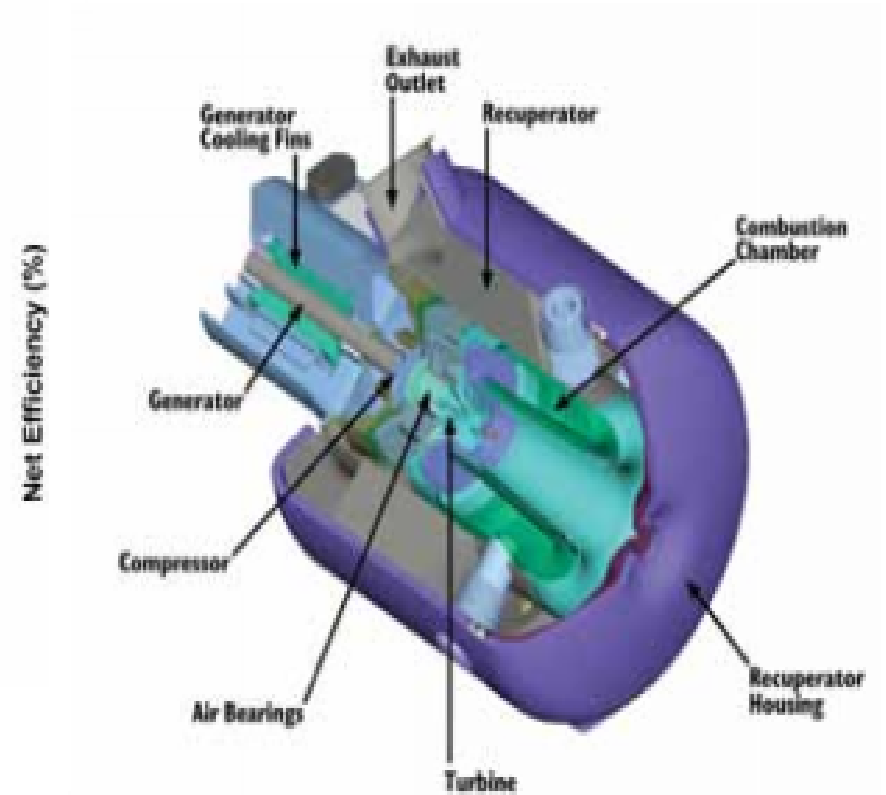
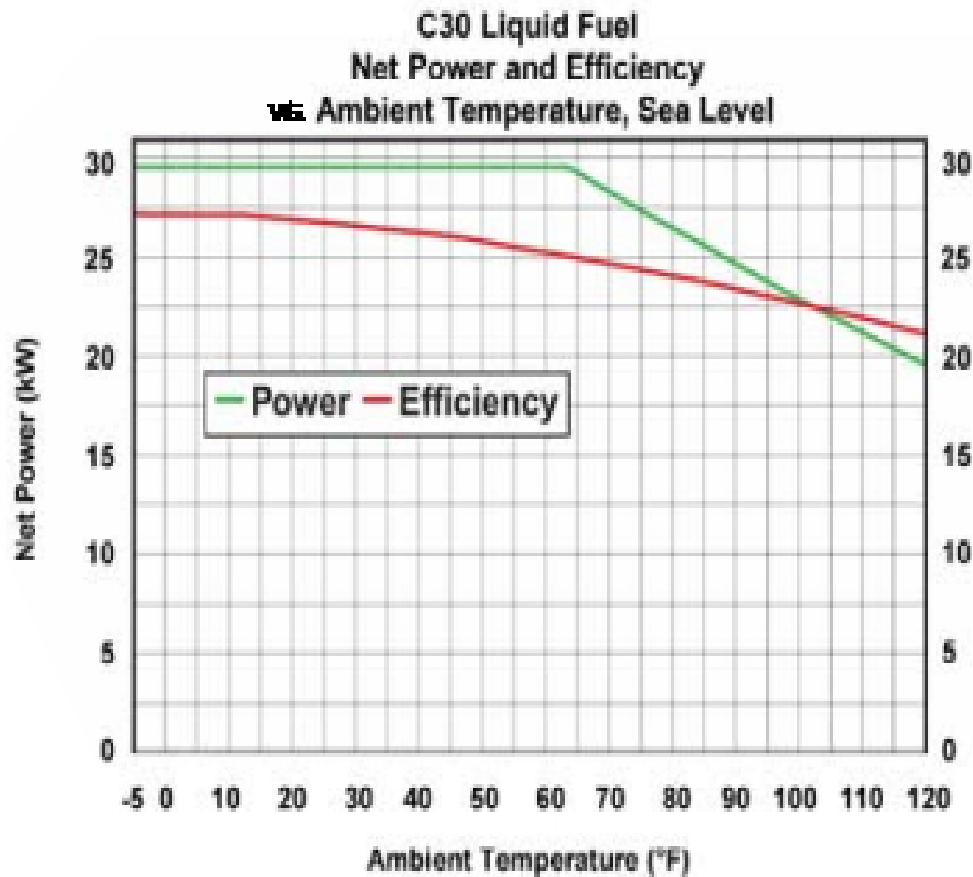
Reasons to Use Micro-Turbines with Distributed Generation

- ▶ 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

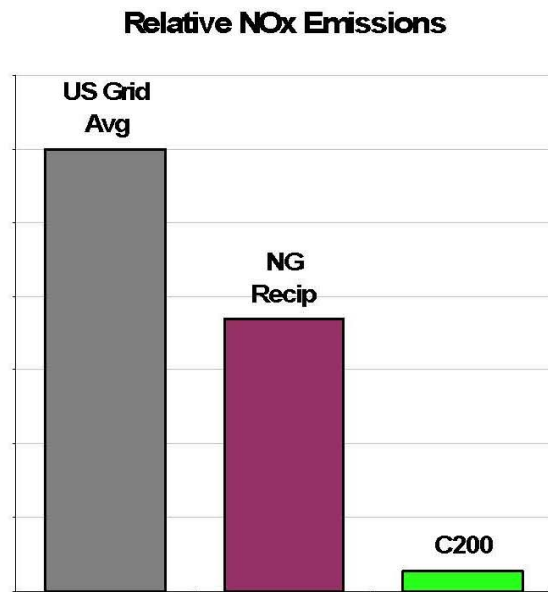


FUEL FLEXIBILITY

- 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

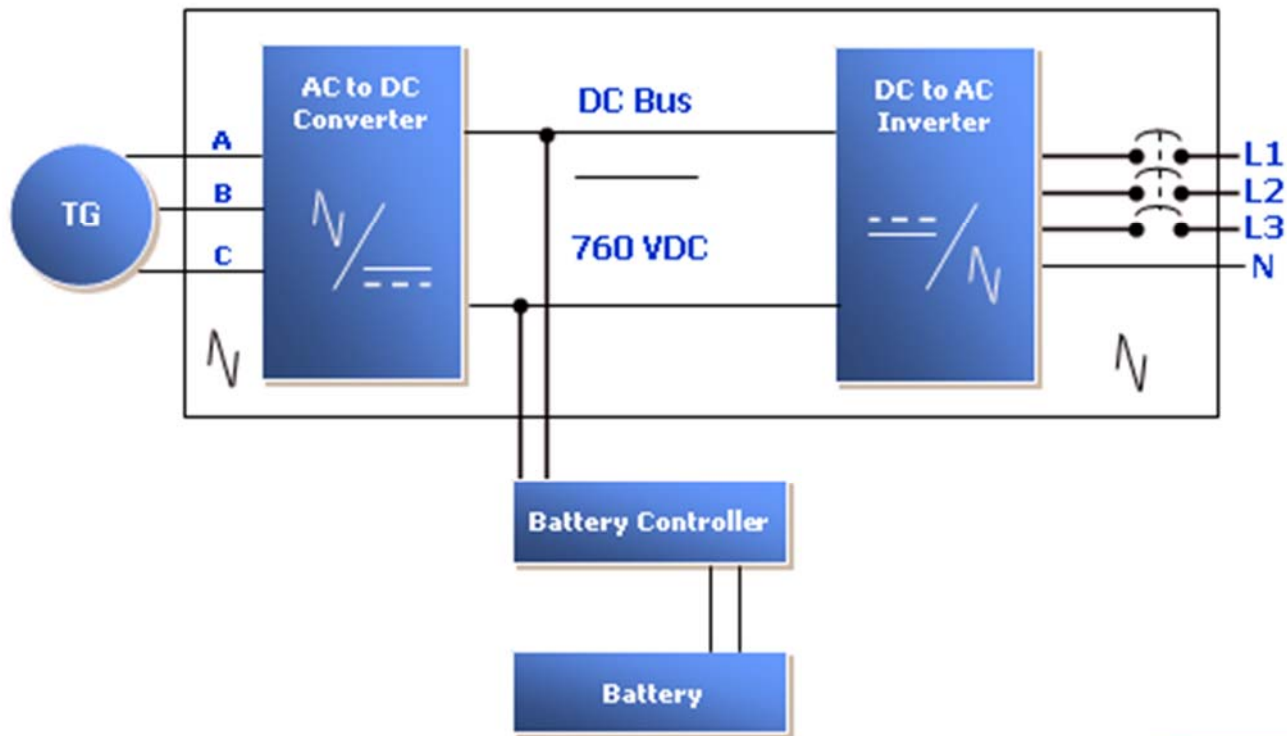


CARB Natural Gas Emission Standard				
	Units	2003	2007	Reduction
NOx	lb/MWh	0.5	0.07	86%
CO	lb/MWh	6.0	0.10	98%
VOC	lb/MWh	1.0	0.02	98%

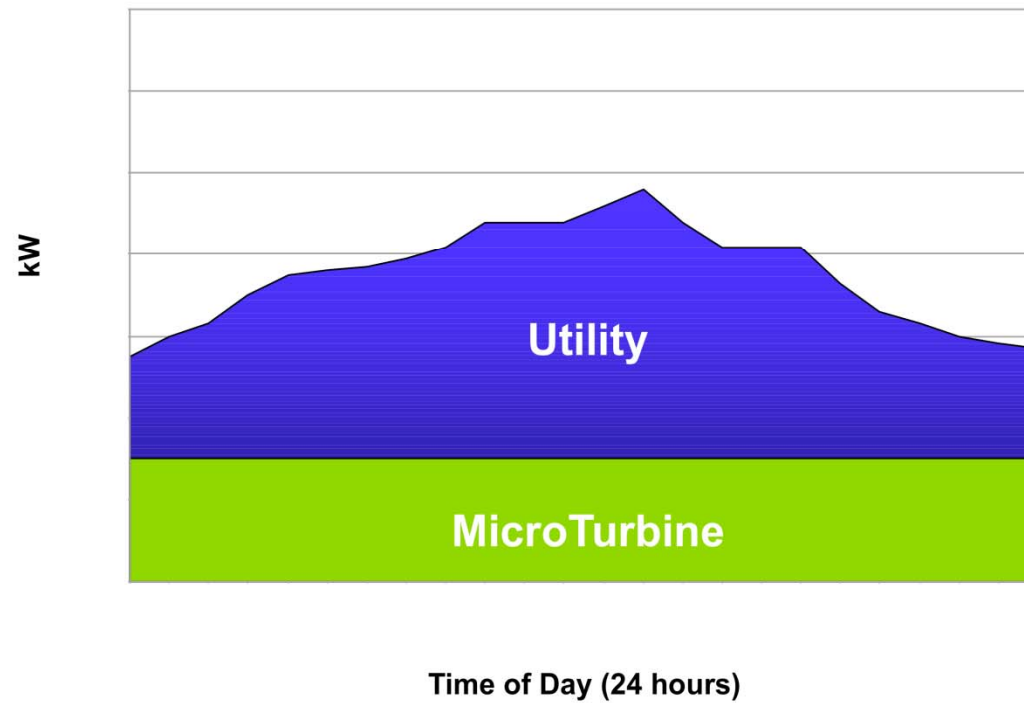
Power Electronics

UL 1741, UL 2200

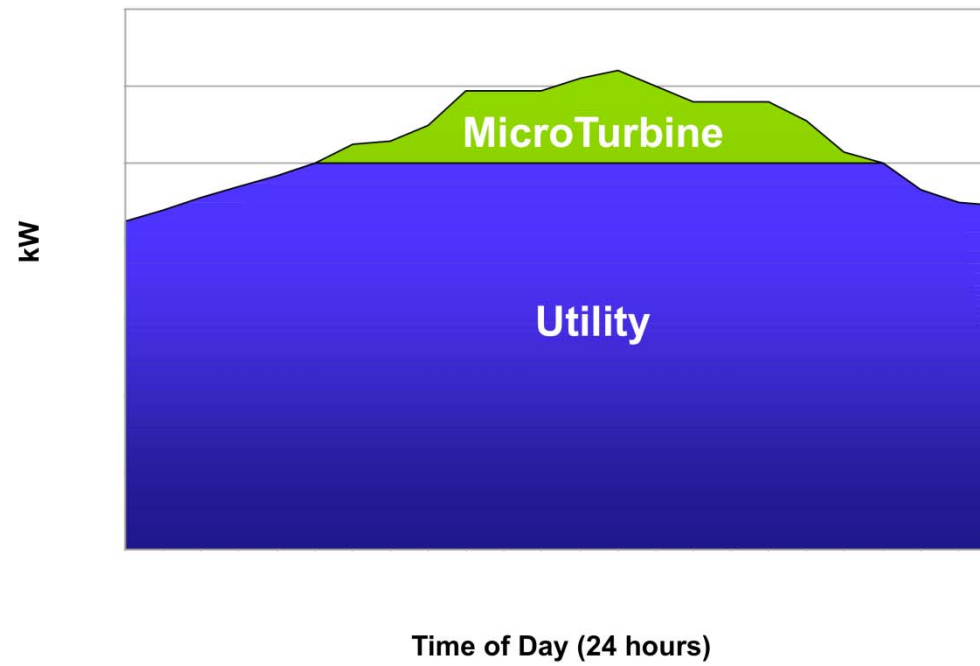
- *Makes grid interconnect easy, safe*
- *Includes protective relays and sync gear – easily integrates with other technologies*
- *Meets California Rule 21 utility interconnect requirements*
- *Provides UPS quality power*



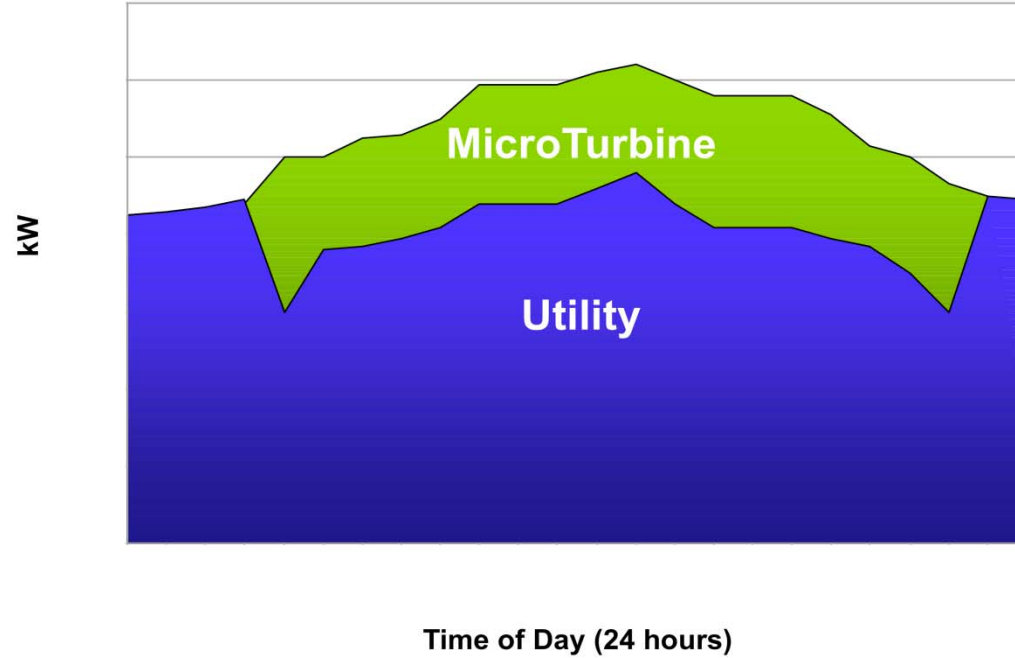
Normal (Base) Mode



Load Following



Time-of-Use Mode

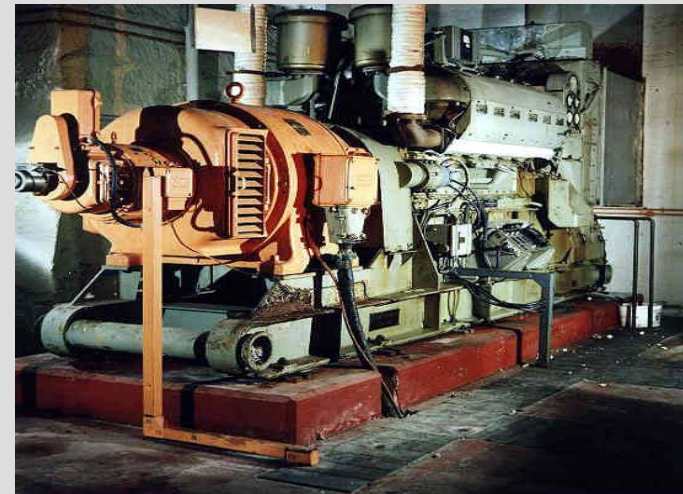


MICROTURBINES VS PISTON ENGINES

Capstone Microturbines



Traditional Piston Engines



Ultra low emissions

Low maintenance – Six hours per year

On board digital electronics

Integrated utility protection & synchronizing

Lightweight & small footprint

Local air permits and exhaust cleanup required

High maintenance – Oil, Coolant, Injectors-160 scheduled maintenance periods in 5 years

External controls without power electronics

Requires external relays & control equipment

More than twice the weight & footprint

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



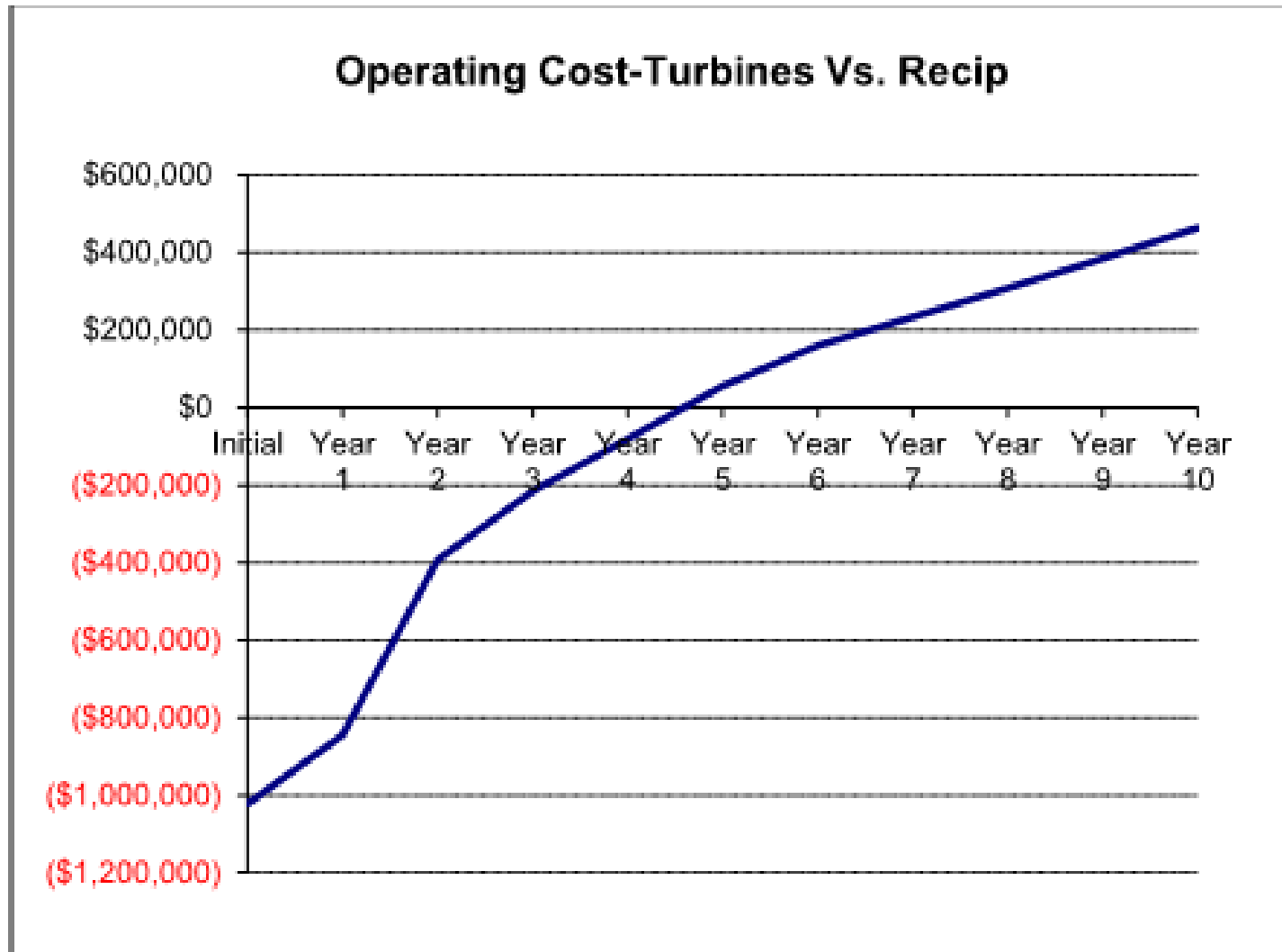
Internal Combustion Engine

- **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



4/25/201

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PRODUCTS

- Capstone Product Line

- ▶ C30 = 30KW
- ▶ C65 = 65KW
- ▶ C200 = 200KW

- Capstone Has Pre-engineered Packages to 1MW

- ▶ C600 = 600KW
- ▶ C800 = 800KW
- ▶ C1000 = 1000KW
- ▶ Controls

