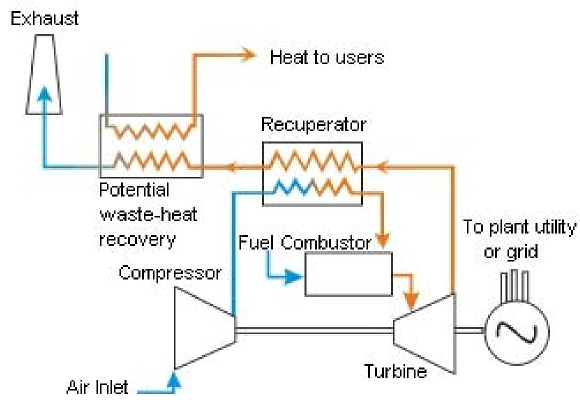
Microturbines

Technology Description



Microturbines are small combustion turbines of a size comparable to a refrigerator and with outputs of 30 kW to 400 kW. They are used for stationary energy generation applications at sites with space limitations for power production. They are fuel-flexible machines that can run on natural gas, biogas, propane, butane, diesel, and kerosene. Microturbines have few moving parts, high efficiency, low emissions, low electricity costs, and waste heat utilization opportunities; and are lightweight and compact in size. Waste heat recovery can be used in combined heat and power (CHP) systems to achieve energy efficiency levels greater than 80%.

System Concepts

- Microturbines consist of a compressor, combustor, turbine, alternator, recuperator, and generator.
- Microturbines are classified by the physical arrangement of the component parts: single shaft or two-shaft, simple cycle or recuperated, inter-cooled, and reheat. The machines generally operate at more than 40,000 rpm, while some machines operate at more than 100,000 rpm.
- A single shaft is the more common design, because it is simpler and less expensive to build. Conversely, the split shaft is necessary for machine-drive applications, which do not require an inverter to change the frequency of the AC power.
- Efficiency gains can be achieved with greater use of materials like ceramics, which perform well at higher engine-operating temperatures.

Representative Technologies

- Microturbines in a simple-cycle, or unrecuperated, turbine; heated, compressed air is mixed with fuel and burned under constant pressure conditions. The resulting hot gas is allowed to expand through a turbine to perform work. Simple-cycle microturbines have a lower cost, higher reliability, and more heat available for CHP applications than recuperated units.
- Recuperated units use a sheet-metal heat exchanger that recovers some of the heat from an exhaust stream and transfers it to the incoming air stream. The preheated air is then used in the combustion process. If the air is preheated, less fuel is necessary to raise its temperature to the required level at the turbine inlet. Recuperated units have a higher efficiency and thermal-to-electric ratio than unrecuperated units, and yield 30%-40% fuel savings from preheating.

Technology Applications

- Microturbines can be used in a wide range of applications in the commercial, industrial, and institutional sectors; microgrid power parks; remote off-grid locations; and premium power markets.
- Microturbines can be used for backup power, baseload power, premium power, remote power, grid support, peak shaving, cooling and heating power, mechanical drive, and use of wastes and biofuels.
- Microturbines can be paired with other distributed energy resources such as energy-storage devices and thermally activated technologies.

Current Status

- Microturbine systems have recently entered the market, and the manufacturers are targeting both traditional and nontraditional applications in the industrial and buildings sectors, including CHP, backup power, continuous power generation, and peak shaving.
- The most popular microturbine installed to date is the 30-kW system manufactured by Capstone. Microturbine efficiencies are 25-29% (LHV).

• The typical 30 kW unit package cost averages \$1,100/kW. For gas-fired microturbines, the present installation cost (site preparation and natural gas hookup) for a typical 30 kW commercial unit averages \$2,263/kW for power only systems and \$2,636 for CHP systems. Service contracts are available at 1 to 2 cents/kWh
Technology History
• Microturbines represent a relatively new technology, which entered the commercial market in 1999-2000. The technology used in microturbines is derived from aircraft auxiliary power systems, diesel-engine turbochargers, and automotive designs. • In 1988, Capstone Turbine Corporation began developing the microturbine concept; and, in 1998, Capstone was the first manufacturer to offer commercial power products using microturbine technology.
Technology Future
• The acceptable cost target for microturbine energy is \$0.05/kWh, which would present a cost advantage over most nonbaseload utility power. • "Ultra-clean, high-efficiency" microturbine product designs focus on the following DOE performance targets: – High Efficiency — Fuel-to-electricity conversion efficiency of at least 40%. – Environment — NOx < 7 ppm (natural gas). – Durability — 1,000 hours of reliable operations between major overhauls and a service life of at least 45,000 hours. – Cost of Power — System costs < \$500/kW, costs of electricity that are competitive with alternatives (including grid) for market applications by 2005 (for units in the 30-60 kW range) – Fuel Flexibility — Options for using multiple fuels including diesel, ethanol, landfill gas, and biofuels.

Source: National Renewable Energy Laboratory. *Gas-Fired Distributed Energy Resource Technology Characterizations.* NREL/TP-620-34783. November 2003.

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Market Data

Microturbine Shipments	Source: Debbie Haught, communications 2/26/02. Capstone sales reported in Quarterly SEC filings, others estimated.				
No. of units		**1998**	**1999**	**2000**	**2001**
Capstone		2	211	790	1,033
Other Manufacturers					120
MW					
Capstone			6	23.7	38.1
Other Manufacturers					10.2

Technology Performance

Source: Manufacturer Surveys, Arthur D. Little (ADL) estimates.

Current System Efficiency (%)	LHV: 17-20% unrecuperated, 25-30%+ recuperated	
Lifetime (years)	5-10 years, depending on duty cycle	
Emissions (natural gas fuel)	Current	Future (2010
CO_2	670 - 1,180 g/kWh (17-30% efficiency)	
SO_2	Negligible (natural gas)	Negligible
NO_x	9-25 ppm	<9 ppm
CO	25-50 ppm	<9 ppm
PM	Negligible	Negligible
Typical System Size	Current Products: 25-100 kW Units can be bundled or "ganged" to produce power in larger increments	Future Products: up to 1 MW
Maintenance Requirements (Expected)	10,000-12,000 hr before major overhaul (rotor replacement)	
Footprint [ft^2/kW]	0.2-0.4	

Technology Performance

Sources: Debbie Haught, DOE, communication 2/26/02 and Energetics Inc. *Distributed Energy Technology Simulator: Microturbine Validation*, July 12 2001.

	Capstone Turbine Corporation		Elliot Energy Systems	Ingersoll-Rand Energy Services	Turbec	DTE Energy Technologies
Model Name	Model 330	Capstone 60	TA-80	PowerWorks		ENT 400 recuperated
Size	30 kW	60 kW	80 kW	70 kW	100 kW	300 kW
Voltage	400-480 VAC				400 VAC	480/277 VAC
Fuel Flexibility	natural gas, medium Btu gas, diesel, kerosene		natural gas	natural gas	natural gas, biogas, ethanol, diesel	natural gas (diesel, propane future)
Fuel Efficiency (cf/kWh)	13.73	14.23			11.2	
Efficiency	26% (+/-2%)	28% (+/- 2%)	28%	30-33%	30%	28% (+/- 2%)
	70-90% CHP	70-90% CHP	80% CHP		80% CHP	74% CHP
Emissions	NO_x <9ppmV @15% O_2		NO_x diesel <60ppm, NO_x NG <25ppm, CO diesel <400ppm, CO NG <85ppm	NO_x <9ppmV @15% O_2, CO <9ppmV @15% O_2	NO_x <15ppmV @15% O_2, CO <15ppm, UHC <10ppm	NOx <9ppmV @15% O_2
Units Sold	1999: 211 units			2000: 2 precommercial units, expected commercial in 2001	2000: 20 units in the European market	Available late 2001
	2000: 790 units					
	2001: 1,033 units		2001: 100 units			
Unit Cost	$1000/kW				$75,000	
Cold Start-Up Time	3 min					3 min emergency, 7 min normal
Web site	www.capstone.com		www.elliott-turbo.com/new/products_microtubines.html	www.irco.com/energysystems/powerworks.html	www.turbec.com	www.dtetech.com/energynow/portfolio/2_1_4.asp