



TES SYSTEMS AND CHP SYSTEMS CEM REFRESHER TRAINING

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FOR ENERGY MANAGEMENT AND EFFICIENCY PROFESSIONALS





COMBINED HEAT AND POWER + ADDITIONAL FOR ENERGY PROFESSIONALS

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WHAT SHOULD YOU LEARN



- Distributed Generation
- DG Technologies
- Comparing CHP Fuel and Operating Costs vs. Utilities
- Comparing types of Renewable Energy and Storage Technologies



OTHER ITEMS

- ✓ CHP is (typically) a type of DG
- ✓ CHP can work well with
 - District heating systems
 - Thermal energy storage systems
 - Gas cooling systems
- ✓ Energy security and surety issues are giving CHP and DG more justification

DISTRIBUTED GENERATION

- ✓ Also known as:
 - Fuel can include natural gas, diesel, biogas, gasoline, propane, and more
 - Available in sizes typically from 30 kW to 3,000 kW. Some systems are available as low as 1 kW for home energy systems, including CHP.
 - Efficiencies up to 40% (LHV) electric; over 80% when heat recovery is added
 - Basic equipment costs around \$300 to \$600/kW, without CHP
- ✓ Definition: (and there are several)
 - Any small-scale power generation that provides electric power at a site closer to the end user than central generation, and is usually interconnected to the distribution system or directly to the end user's facility [Reference 2]
 - Any method of producing power that will be used on or near the site at which it is generated [Reference 5]

DG TECHNOLOGIES

- ✓ Internal combustion engines
 - Fuel can include natural gas, diesel, biogas, gasoline, propane, and more
 - Available in sizes typically from 30 kW to 3,000 kW. Some systems are available as low as 1 kW for home energy systems, including CHP.
 - Efficiencies up to 40% (LHV) electric; over 80% when heat recovery is added
 - Basic equipment costs around \$300 to \$600/kW, without CHP
- ✓ Combustion turbines
 - Fuels are typically gas (natural gas, biogas, etc.) but liquid systems are available
 - Most efficient systems are greater than 40 MW but systems as low as 500 kW are available

DG TECHNOLOGIES +

✓ Wind-Powered Generators

- Large systems (600 kW and above) are becoming cost effective in select locations
- Smaller systems (2 kW to 500 kW) are commercially available but more expensive
- Wind is an intermittent source, so another power source is frequently required for a stable supply

✓ Photovoltaics (PV)

- Still very expensive but the cost continues to come down. Equipment around \$6,000 - \$10,000/kW today
- PV is an intermediate source, so another power source (i.e., battery) is frequently required for a stable supply Can be cost effective in remote locations

DG TECHNOLOGIES +

✓ Microturbines

- Fuels are typically gas but liquid systems are being developed
- Size range is limited because technology is still being developed. 30 kW, 60 kW, 70 kW and 250 kW systems are available
- Electrical efficiency is low but emission levels are attractive

✓ Fuel Cells

- Fuel cells use a chemical reaction rather than a combustion process. They require hydrogen as a fuel source.
- Fuel processors extract hydrogen from other fuels
- Emission levels are excellent because of non combustion reaction
- Technology is still developmental and very (very) expensive
- Fuel processor, maintenance costs, and fuel cell stack life are current concerns for a stable supply Can be cost effective in remote locations

PERFORMANCE COMPARISONS

Technology	Size Range (kW)	Installed Cost (\$/kW) (2)	Heat Rate (kJ/kWh)	Approx. Efficiency (%)	Variable O&M (\$/kW/yr)	Emissions (1) kg/kWh @ 2.2		
						NO _x	CO ₂	
Diesel Engine	1-10,000	350-800	7,800	45	0.025	0.017	1.7	
Natural Gas Engine	1-5,000	450-1,100	9,700	35	0.025	0.0099	0.97	
Natural Gas Engine w/CHP (3)	1-5,000	575-1,225	9,700	35	0.027	0.0099	0.97	
Dual-Fuel Engine	1-10,000	625-1,000	9,200	37	0.023	0.01	1.2	
Microturbine	15-40	950-1,700	12,200	28	0.014	0.00049	1.19	
Microturbine w/CHP (3)	15-40	1,100-1,850	12,200	28	0.014	0.00049	1.19	
Combustion Turbine	300-10,000	550-1,700	11,000	31	0.024	0.0012	1.15	
Combustion Turbine w/CHP (3)	300-10,000	700-2,100	11,000	31	0.024	0.0012	1.15	
Fuel Cell	100-250	\$,000++	6,650	50	0.01-0.05	0.000015	0.85	
Photovoltaic	0.01-8	8,000-13,000	--	N/A	0.002	0.0	0.0	
Wind Turbine	0.25-2,000	1,000-3,000	--	N/A	0.010	0.0	0.0	
Battery	1-1,000	1,100-1,300	--	70	0.010	(4)	(6)	
Flywheel	2-1,000	400	--	70	0.004	(4)	(6)	
SMES	750-5,000	600	--	70	0.02	(4)	(6)	
Hybrid System	1-10,000	(5)	(5)	(5)	(5)	(5)	(5)	

(1) Nationwide utility averages for emissions from generating plants are 0.00178 kg/kWh of NO_x and 0.8 kg/kWh of CO₂.
 (2) The high end of the range indicates costs with NO_x controls for the most severe emissions limits (internal combustion technologies only).
 (3) Although the electric conversion efficiency of the prime mover does not change much, CHP significantly improves the fuel utilization efficiency of a DER system.
 (4) Storage devices have virtually no emissions at the point of use. However, the emissions associated with the production of the stored energy will be those from the generation source.
 (5) Same as generation technology selected.
 (6) Add cost of component technologies.

PERFORMANCE COMPARISONS

Comparison Factor	Diesel Engine	Gas Engine	Simple Cycle Gas Turbine	Microturbine	Fuel Cell	Photovoltaic
Product Availability	Commercial	Commercial	Commercial	2000	1996-2010	Commercial
Size Range (kW/unit)	20 to 10,000+	50 to 5,000+	1,000 to 30,000	20 to 200	50 to 1000+	1+
Typical DG Range (kW/unit)	200 to 2,000	300 to 3,000	1,000 to 10,000	20 to 100	50 to 200	1 to 5
Efficiency (HHV)	36 to 43%	28 to 42%	21 to 40%	25 to 30%	35 to 54%	n.a.
General Package Cost (\$/kW)	125 to 300	250 to 600	300 to 600	300 to 600	1,500 to 3,000	n.a.
Turnkey Cost- With no heat recovery (\$/kW)	350 to 500	600 to 1,000	650 to 900	650 to 900	1,900 to 3,500	5,000 to 10,000
Heat Recovery Added Cost (\$/kW)	100 to 200	75 to 150	100 to 200	75 to 350	Included	n.a.
O&M Cost (\$/kW-hr)	0.010 to 0.010	0.007 to 0.015	0.003 to 0.008	0.005 to 0.010	0.005 to 0.010	0.001 to 0.004

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O&M Cost (\$/kW-hr)	0.015 to 0.010	0.007 to 0.015	0.003 to 0.008	0.005 to 0.010	0.005 to 0.010	0.001 to 0.004

REFERENCES

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