

RULES OF THUMB

Prime Movers

❖ Reciprocating Engines

Capacity Range (<i>kW</i>)	100 – 500	500 – 2,000
Electric Generation Efficiency LHV of Fuel (%) Heat Rate (<i>BTU/kWh</i>)	24 – 28 14,000 – 12,000	28 – 38+ 12,000 – 9,000
Recoverable Useful Heat Hot Water (<i>BTU/h per kW</i>) Steam (<i>lbs/h per kW</i>)	4,000 – 5,000 4 - 5	4,000 – 5,000 4-5
Installed Cost (<i>\$/kW</i>) (with Heat Recovery)	1,800 – 1,400	1,400 – 1,000
O & M Costs (<i>\$/kWh</i>)	0.015 – 0.012	0.012 – 0.010
Emission Levels (<i>lbs/MWH</i>) NO _x (RB w/ 3-way catalyst) NO _x (LB w/o treatment)	≈0.5 2 - 6	2 - 6

❖ Gas Turbines

Capacity Range (<i>kW</i>)	1,000 – 10,000	10,000 – 50,000
Electric Generation Efficiency LHV of Fuel (%) Heat Rate (<i>BTU/kWh</i>)	24 – 28 14,000 – 12,000	31 – 36 11,000 – 9,500
Recoverable Useful Heat Hot Water (<i>BTU/h per kW</i>) Steam (<i>lbs/h per kW</i>)	5,000 – 6,000 5 - 6	5,000 – 6,000 5 - 6
Installed Cost (<i>\$/kW</i>) (with Heat Recovery)	1,500 – 1,000	1,000 – 800
O & M Costs (<i>\$/kWh</i>)	0.015 – 0.012	0.012 – 0.010
Emission Levels (<i>ppm</i>) NO _x (Dry Low NO _x Burner) NO _x (SCR)	< 25 < 10	< 25 < 10

❖ **Microturbines**

Capacity Range (<i>kW</i>)	100 – 500
Electric Generation Efficiency LHV of Fuel (%) Heat Rate (<i>BTU/kWh</i>)	25 – 30 13,700 – 11,400
Recoverable Useful Heat (<i>500° F</i>) Hot Water (<i>BTU/h per kW</i>) Steam (<i>lbs/h per kW</i>)	
Installed Cost (<i>\$/kW</i>) (<i>with Heat Recovery</i>)	2,000 – 1,000
O & M Costs (<i>\$/kWh</i>)	0.015 – 0.012
Emission Levels (<i>lbs/MWh</i>) NOx	< 0.49

❖ **Fuel Cells**

Fuel Cell Type	Availability	Efficiency	Operating Temperature	Heat Utilization
Phosphoric Acid (PAFC)	Commercial >\$3,500/kW	38 – 45%	480 °F	Hot Water
Solid Oxide (SOFC)	Demonstration	40 – 45%	1,800 °F	High Pressure Steam
Molten Carbonate (MCFC)	Demonstration	50 – 60%	1,200 °F	Medium to High Pressure Steam
Proton Exchange Membrane (PEM)	Demonstration	33 –45%	175°F	Hot Water

Absorption Chillers

❖ **Single Effect (Indirect Fired)**

- COP 0.6
- Recovered heat from reciprocating engine will produce approximately 0.22 to 0.28 RT/kW_e.
- Recovered heat from gas turbine will produce approximately 0.28 to 0.33 RT/kW_e.
- Steam Requirements: Approximately 18 lbs/h/RT @ 15 psig
- Hot Water Requirements: Approximately 18,000 BTU/h/RT @ 180°F

Size	<i>RT</i>	100	500	1,00	2,000
Cost	<i>\$/RT</i>	1,000	700	650	500
O & M	<i>\$/RT/year</i>	30	20	20	20

❖ **Double Effect**

- COP 0.9
- Steam Requirements: Approximately 11 lbs/h/RT @ 125 psig

❖ **Average Electric Offset \approx 0.6 kW_e/RT**

Desiccants

❖ **Solid ⁽¹⁾**

Parameter	Units	Industrial		Commercial	
		600	40,000	2,000	12,000
Flow Rate	SCFM	600	40,000	2,000	12,000
Installed Cost	\$/SCFM	\$20	\$5	\$8	\$4.50
O&M Costs	\$/SCFM/yr	0.26	0.06	0.09	0.06
Regeneration (200°F)	BTU/hr per SCFM	55	55	45	45
Latent Heat Removal	lbs/hr per 1000 SCFM	35	35	30	30
Parasitic Electric Use	KWh per 1000 SCFM	1.1	1.1	0.8	0.8

❖ **Liquid ⁽¹⁾**

Parameter	Units	Industrial		Commercial	
		3,000	84,000	10,000	84,000
Flow Rate	SCFM	3,000	84,000	10,000	84,000
Installed Cost	\$/SCFM	\$18	\$5	\$7	\$5
O&M Costs	\$/SCFM/yr	0.38	0.11	0.15	0.11
Regeneration (200°F)	BTU/hr per SCFM	45	45	35	35
Latent Heat Removal	lbs/hr per 1000 SCFM	30	30	30	30
Parasitic Electric Use	KWh per 1000 SCFM	1.3	1.3	1.3	1.3

(1) Based on 200°F regeneration (jacket water). Thermal inputs and latent Heat removal both are higher with higher temperature hot water/steam. Latent Heat Removal based on 55°F saturated inlet for the industrial desiccants and 80°F/50% Relative humidity (RH) for the inlet of the commercial desiccants.

Other Information

Heating Value of Fuels

- ❖ Higher Heating Value (HHV): Total energy from combustion process
- ❖ Lower Heating Value (LHV): Assumes heat of condensation cannot be recovered
- ❖ LHV is used for majority of calculations.

	<u>Units</u>	<u>LHV</u>	<u>HHV</u>	<u>LHV/HHV</u>
Natural Gas	<i>BTU/CF</i>	950	1,050	0.905
#2 Fuel Oil	<i>BTU/Gallon</i>	130,000	138,300	0.940
#6 Fuel Oil	<i>BTU/Gallon</i>	143,000	150,500	0.950
Propane	<i>BTU/Gallon</i>	84,650	92,000	0.920
Sewage/Landfill	<i>BTU/CF</i>	350	380	0.921
Coal - Bituminous	<i>BTU/lbs</i>	13,600	14,100	0.965

Capacity Factors

- ❖ Based on equipment output vs. capacity

Electric (<i>> 70% Desirable</i>)	=	$\frac{\text{Avg. kW output (for period)}}{\text{System kW capacity}}$
Thermal (<i>>80% Desirable</i>)	=	$\frac{\text{Avg. BTU output (for period)}}{\text{System capacity in BTUs}}$
Steam (<i>>80% Desirable</i>)	=	$\frac{\text{Avg. lbs/h output (for period)}}{\text{System capacity in lbs/h}}$

Load Factors

- ❖ Based on site load data

Electric	=	$\frac{\text{Avg. kW (for period)}}{\text{Peak kW (for period)}}$
Thermal	=	$\frac{\text{Avg. BTUs (for period)}}{\text{Peak BTUs (for period)}}$

PURPA Minimum Qualifying Facility (QF)

- ❖ *>42.5% (or >45% if < 15% Thermal Recovery)*

$\text{QF Efficiency} = \frac{(\text{kWe} \times 3412.8) + 1/2(\text{Useful Thermal Energy})}{\text{Fuel Input (BTU/h in LHV)}}$
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CONVERSIONS

Electrical to Thermal

Energy 1 kWh = 3,412.8 BTUs
1 BTU = 778 ft-lbs

Rate of Energy = Power 1 kW = 3,412.8 BTU/h
1 hp = 2,545 BTU/h

Fuel Oil #2 1 Gallon = 130,000 BTUs

Fuel Oil #6 1 Gallon = 143,000 BTUs

Natural Gas 1 therm = 100,000 BTU

Refrigeration Tons 1 RT = 12,000 BTUs/h

1 RT-h = 12,000 BTUs

Steam to Thermal

Energy 1 lbs steam* = 1,000 BTUs

Rate of Energy = Power 1 lbs stm/h* = 1,000 BTU/h

** Use actual enthalpy values from steam tables at given pressure and temperature for more accuracy!*