RULES OF THUMB

Prime Movers

❖ Reciprocating Engines

Capacity Rage *(kW)*	100 – 500	500 – 2,000
Electric Generation Efficiency LHV of Fuel *(%)* Heat Rate *(BTU/kWh)*	 24 – 28 14,000 – 12,000	 28 – 38+ 12,000 – 9,000
Recoverable Useful Heat Hot Water *(BTU/h per kW)* Steam *(lbs/h per kW)*	 4,000 – 5,000 4 - 5	 4,000 – 5,000 4-5
Installed Cost *($/kW)* *(with Heat Recovery)*	1,800 – 1,400	1,400 – 1,000
O & M Costs *($/kWh)*	0.015 – 0.012	0.012 – 0.010
Emission Levels *(lbs/MWH)* NO_x (RB w/ 3-way catalyst) NO_x (LB w/o treatment)	 ≈0.5 2 - 6	 2 - 6

❖ Gas Turbines

Capacity Rage *(kW)*	1,000 – 10,000	10,000 – 50,000
Electric Generation Efficiency LHV of Fuel *(%)* Heat Rate *(BTU/kWh)*	 24 – 28 14,000 – 12,000	 31 – 36 11,000 – 9,500
Recoverable Useful Heat Hot Water *(BTU/h per kW)* Steam *(lbs/h per kW)*	 5,000 – 6,000 5 - 6	 5,000 – 6,000 5 - 6
Installed Cost *($/kW)* *(with Heat Recovery)*	1,500 – 1,000	1,000 – 800
O & M Costs *($/kWh)*	0.015 – 0.012	0.012 – 0.010
Emission Levels *(ppm)* NO_x (Dry Low NO_x Burner) NO_x (SCR)	 < 25 < 10	 < 25 < 10

❖ **Microturbines**

Capacity Rage *(kW)*	100 – 500
Electric Generation Efficiency LHV of Fuel *(%)* Heat Rate *(BTU/kWh)*	 25 – 30 13,700 – 11,400
Recoverable Useful Heat *(500°F)* Hot Water *(BTU/h per kW)* Steam *(lbs/h per kW)*	
Installed Cost *($/kW)* *(with Heat Recovery)*	 2,000 – 1,000
O & M Costs *($/kWh)*	0.015 – 0.012
Emission Levels *(lbs/MWH)* 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	*RT*	100	500	1,00	2,000
Cost	*$/RT*	1,000	700	650	500
O & M	*$/RT/year*	30	20	20	20

- **Double Effect**
  - COP 0.9
  - Steam Requirements: Approximately 11 lbs/h/RT @ 125 psig
- **Average Electric Offset** ≈ 0.6 kW_e/RT

Desiccants

- **Solid** *(1)*

Parameter	Units	Industrial		Commercial	
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	
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.

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

Capacity Factors

- Based on equipment output vs. capacity

Electric *(> 70% Desirable)*	=	Avg. kW output (for period) System kW capacity
Thermal *(>80% Desirable)*	=	Avg. BTU output (for period) System capacity in BTUs
Steam *(>80% Desirable)*	=	Avg. lbs/h output (for period) System capacity in lbs/h

Load Factors

- Based on site load data

Electric	=	Avg. kW (for period) Peak kW (for period)
Thermal	=	Avg. BTUs (for period) Peak BTUs (for period)

PURPA Minimum Qualifying Facility (QF)

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

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

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	=	130000 BTUs
Fuel Oil #6	1 Gallon	=	143000 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!*