(3) Given 120 MBtu output   60% eff = 0.60

eff = out/in

input = out/eff

a) input = $\frac{120 \text{ MBtu}}{0.6}$ = 200 MBtu

$200 \text{ MBtu} \times \frac{1 \times 10^6 \text{ Btu}}{1 \text{ MBtu}} \times \frac{1 \text{ cf}}{1030 \text{ Btu}} \times \frac{1 \text{ ccf}}{100 \text{ cf}} =$ (1940 ccf)

b) 1940 ccf × \$.90/ccf = \$ (1746)

c) New furnace = 80% eff

input = out/eff = $\frac{120 \text{ MBtu}}{.80}$ = 150 MBtu

$150 \text{ MBtu} \times \frac{1 \times 10^6 \text{ Btu}}{1 \text{ MBtu}} \times \frac{1 \text{ cf}}{1030 \text{ Btu}} \times \frac{1 \text{ ccf}}{100 \text{ cf}} =$ 1456 ccf

1456 ccf × \$.90/ccf = \$1310

  \$1746 (old furnace)
− \$1310 (new furnace)
  \$436 savings

$\frac{\$4000}{\$436/\text{yr}}$ = (9.1 yrs)

(5) a $\frac{250\,W}{m^2} \times 10\,m^2 = 2500\,W$

(solar flux) (area of panels)

$2500\,W \times .10 = 250\,W$

(efficiency)

$250\,W \times \frac{1\,KW}{1000\,W} = .25\,KW$

$.25\,KW \times 8760\,hr = 2190\,\frac{KWh}{yr}$

(# hrs in yr)

b $\frac{2190\,KWh}{10,000\,KWh} = 21.9\%$

c) $\frac{10\,m^2}{2190\,KWh} = \frac{X}{10,000\,KWh} = 45.7\,m^2$

(7) Wind = 250 KW
NP = 1000 MW ⟩ get both in Watts

$$\frac{250,000 \text{ W}}{1,000,000,000 \text{ W}} = 4000 \text{ Windmills}$$

(8) Battery = 4.5 Wh = 4.5×10^{-3} KWh

cost/KWh = \$1.00 / 4.5×10^{-3} KWh = \$222/KWh

Comparison: \$222 / .10 = 2220x as much

(9)

natural gas

$$\frac{\$1.14}{ccf} \times \frac{1\,ccf}{100\,cf} \times \frac{1\,cf}{1030\,Btu} \times \frac{1\times10^{6}\,Btu}{1\,MBtu} = \$11.06/MBtu$$

$$120\,MBtu / .8 = 150\,MBtu \times \frac{\$11.06}{MBtu} = \$1660$$

propane

$$\frac{\$1.69}{gallon} \times \frac{1\,gall}{92\,KBtu} \times \frac{1\,KBtu}{1000\,Btu} \times \frac{1\times10^{6}\,Btu}{1\,MBtu} = \$18.37/MBtu$$

$$120\,MBtu / .8 = 150\,MBtu \times \frac{\$18.37}{MBtu} = \$2755$$

fuel oil

$$\frac{\$1.93}{gall} \times \frac{1\,gall}{133\,KBtu} \times \frac{1\,KBtu}{1000\,Btu} \times \frac{1\times10^{6}\,Btu}{1\,MBtu} = \$14.51/MBtu$$

$$120\,MBtu / .8 = 150\,MBtu \times \$14.51 = \$2177$$

electric

$$\frac{\$.10}{KWh} \times \frac{1\,KWh}{3412\,Btu} \times \frac{1\times10^{6}\,Btu}{1\,MBtu} \times \$29.31$$

$$120\,MBtu \times \frac{\$29.31}{MBtu} = \$3517$$

Name: Key

How much coal does it take to run a
100 watt light bulb 24 hours a day for one year????

Useful Info:

1000 watts = 1 kW

2000 pounds = 1 ton

Thermal energy content of coal = 6,150 kWh/ton
(…so every ton of coal produces 6,150 kWh of energy)

Coal-fired power are ~40% efficient

Show work below:

$\frac{24 \text{ hr}}{1 \text{ day}} \times \frac{365 \text{ day}}{1 \text{ year}} = 8760 \text{ hr/yr}$

$100 \text{ W} \times \frac{1 \text{ KW}}{1000 \text{ W}} = .1 \text{ KW}$

$8760 \text{ hr/yr} \times .1 \text{ KW} = 876 \text{ KWh/yr}$

$6150 \frac{\text{KWh}}{\text{ton}} \times .40 = 2460 \text{ KWh/ton of coal}$ efficiency

$\frac{876 \text{ KWh/yr}}{2460 \text{ KWh/ton}} = .356 \text{ tons of coal/yr} \times \frac{2000 \text{ lbs}}{1 \text{ ton}} = 712 \text{ pounds/yr}$

FYI:

Key to Exercise 3: Photovoltaic Power

(Answers appear in bold.)

1. The PV system is operating in a location where the annual average daily incident solar energy (the insolation) on the array equals 5.0 kWh/m²/day. Calculate the average amount of solar energy incident on the PV array each day.
   50 m^2 × 5.0 kWh/m^2/day = 250 kWh/day

2. The efficiency of the PV system equals 10 percent (that is, 10 percent of the solar energy incident on the array is transformed into useful electric power). Calculate the daily average electric energy produced by this system.
   0.10 × 250 kWh/day = 25 kWh/day

3. Calculate the average amount of electric energy produced by this system each year.
   365 days/year × 25 kWh/day = 9,125 kWh/year

4. Over the next 20 years, U.S. annual electric energy consumption is projected to increase by 1.5 trillion kWh/year. How many rooftop PV systems would be needed to supply 10 percent of this additional energy?
   0.10 × 1.5 trillion kWh/year / 9,125 kWh/year = 16 million

5. Calculate the cost of installing these residential PV systems.
   16 million × $50,000 = $800 billion

6. Assuming the electric energy produced by these PV systems is worth 10 cents per kWh, these residential systems would generate electric energy worth produce $15 billion/year. Calculate the simple payback period for these PV systems. (Payback period is the time it takes for a system's net benefits to equal its cost.)
   $800 billion / $15 billion/year = 50 years

Key to Exercise 2: Windpower

(Answers appear in bold.)

1. If this turbine runs at its rated power 100 percent of the time for a full year, how much energy would it produce in a year?
   1,500 kW × 8,760 h/year = 13 million kWh/year

2. This wind turbine has a capacity factor equal to 0.38. This means that over a year, it will produce only 38 percent of its theoretical maximum energy production. How much energy does this turbine actually produce in a year?
   0.38 × 13 million kWh/year = 5.0 million kWh/year

3. Over the next 20 years, U.S. annual electric energy consumption is projected to increase by 1.5 trillion kWh/year. How many 1.5 MW wind turbines would be needed to supply 10 percent of this additional energy?
   0.10 × 1.5 trillion kWh/year / 5.0 million kWh/year/turbine = 30,000 turbines

4. Calculate the cost of installing these wind turbines.
   30,000 turbines × $1.5 million/turbine = $45 billion

5. Assuming the electric energy produced by these turbines is worth 5 cents per kilowatt-hour, these turbines would generate electric energy worth $7.5 billion per year. Calculate the simple payback period for these turbines. (Payback period is the time it takes for a system's net benefits to equal its cost.)
   $45 billion / $7.5 billion/year = 6 years