P492-7.1:

a. 
\[ P = \eta \cdot \frac{1}{2} \rho A v^3 = \eta \cdot \frac{1}{2} \rho \cdot \frac{\pi d^2}{4} \cdot v^3 = 30\% \cdot \frac{1}{2} \cdot 1.225 \cdot \frac{\pi 20^2}{4} \cdot 10^3 = 57.7 \text{ kW} \]

b. use equation 7.17

\[ \rho_{2500m, 10^6 \text{C}} = \frac{353.1}{T} \exp\left(-0.0342 \frac{z}{T}\right) = \frac{353.1}{273.15 + 10} \exp\left(-0.0342 \frac{2500}{273.15 + 10}\right) = 0.922 \text{ kg/m}^3 \]

c. 
\[ P_{2500m, 10^6 \text{C}} = \eta \cdot \frac{1}{2} \rho_{2500m, 10^6 \text{C}} A v^3 = \frac{\rho_{2500m, 10^6 \text{C}}}{\rho} \eta \cdot \frac{1}{2} \rho \cdot \frac{\pi d^2}{4} \cdot v^3 = \frac{\rho_{2500m, 10^6 \text{C}}}{\rho} P = \frac{0.922}{1.225} \cdot 57.7 = 43.43 \text{ kW} \]

P492-7.2:

a. Here \( \alpha = 0.2 \), based on equation 7.18:

\[ \frac{v_{120}}{v_{10}} = \left(\frac{H_{120}}{H_{10}}\right)^{\alpha} \]

\[ v_{120} = v_{10} \cdot \left(\frac{H_{120}}{H_{10}}\right)^{\alpha} = 5 \cdot \left(\frac{120}{10}\right)^{0.2} = 8.218 \text{ m/s} \]

\[ p_{120} = \frac{1}{2} \rho v_{120}^3 = \frac{1}{2} \cdot 1.225 \cdot 8.218^3 = 339.9 \text{ W/m}^2 \]

b. 

\[ v_{40} = v_{10} \cdot \left(\frac{H_{40}}{H_{10}}\right)^{\alpha} = 5 \cdot \left(\frac{40}{10}\right)^{0.2} = 6.598 \text{ m/s} \]

\[ p_{40} = \frac{1}{2} \rho v_{40}^3 = \frac{1}{2} \cdot 1.225 \cdot 6.598^3 = 175.9 \text{ W/m}^2 \]

c. 
\[ \frac{p_{120}}{p_{40}} = \frac{339.9}{175.9} = 1.93 \]
based on equation 7.20

\[ \frac{p_{120}}{p_{40}} = \left( \frac{H_{120}}{H_{40}} \right)^3 \approx 1.93 \]

d.

\[ \rho_{120m,15^\circ C} = \frac{353.1}{T} \exp(-0.0342 \frac{z}{T}) = 1.225 \exp(-0.0342 \frac{120}{273.15 + 15}) = 1.208 \text{ kg/m}^3 \]

\[ p_{120m,15^\circ C} = \frac{1}{2} \rho_{120m,15^\circ C} v_{120}^3 = \frac{1}{2} 1.208 \cdot 8.218^3 = 335.2 \text{ W/m}^2 \]

Because

\[ \frac{p_{120m,15^\circ C}}{p_{120m}} = \frac{335.2}{339.9} = 0.986 \]

there is no need to consider the density difference in this problem

Problem a. Compare the total wind energy at 0 \(^\circ\)C, 1 atm of pressure, contained in 1-m\(^2\) surface area under the following wind patterns:

\[ \rho = \frac{353.1}{T} \exp(-0.0342 \frac{z}{T}) = \frac{353.1}{273.15} = 1.293 \text{ kg/m}^3 \]

(i) 100 hours of 10 m/s winds

\[ \text{energy}_1 = \frac{1}{2} \rho Av_{10}^3 \cdot t_{10} = \frac{1}{2} 1.293 \cdot 1 \cdot 10^3 \cdot 100 = 64.65 \text{ kWh} \]

(ii) 50 hours of 8 m/s winds plus 50 hours of 12 m/s winds

\[ \text{energy}_2 = \frac{1}{2} \rho Av_8^3 \cdot t_8 + \frac{1}{2} \rho Av_{12}^3 \cdot t_{12} = \frac{1}{2} 1.293 \cdot 1 \cdot 8^3 \cdot 50 + \frac{1}{2} 1.293 \cdot 1 \cdot 12^3 \cdot 50 = 72.41 \text{ kWh} \]

Although the average wind speeds of two cases above are the same, the total energy produced in the second case is higher than that of the first one. It tells us the average wind
speed is not an appropriate index for us to judge which wind pattern is better because the wind power is proportional to the \( v_{\text{wind}}^3 \).

Problem b.
Correct answer \((iv)\). See 7.5.1

Problem c.
(i) Natural gas consumption for a) electricity generation: 8.37 quads b) residential: 5.20 quads c) commercial: 3.55 quads d) industrial 9.46 quads e) transportation: 0.942 quads

(ii) Coal consumption in 2014 for a) electricity generation: 16.4 quads b) residential: 0 quads c) commercial: 0.0470 quads d) industrial 1.51 quads e) transportation: 0 quads

Petroleum consumption in 2014 for a) electricity generation: 0.294 quads b) residential 0.945 quads c) commercial: 0.561 quads d) industrial: 8.16 quads e) transportation: 24.8 quads

(iii) Electricity generation inputs (in quads): solar 0.170, nuclear 8.33, hydro 2.44, wind 1.73, geothermal 0.159, natural gas 8.37, coal 16.4, biomass 0.507 and petroleum 0.294.

Total inputs: 38.4 quads

Total output: 12.4 (useful electricity) + 25.8 (rejected energy) = 38.2 quads

\[
\text{efficiency of electricity generation} = \frac{\text{output}}{\text{input}} = \frac{12.4}{38.4} = 32.3\%
\]

(iv) Total energy inputs: 98.303 quads, total consumption by energy services: 38.9 quads, total rejected energy: 59.4 quads

\[
\text{overall efficiency of energy usage} = \frac{38.9}{98.3} = 39.6\%
\]