37.71 A $1GW$ natural gas power plant has a heat rate of $7500\frac{Btu}{kWh}$. The higher heating value of natural gas is $21,000\frac{Btu}{lb}$. The specific carbon content of natural gas is $0.75\frac{lb_C}{lb_{fuel}}$. Assuming all the carbon produced becomes carbon dioxide, what is the mass of carbon dioxide generated by the plant annually?

A. $9.8 \times 10^5 lb$

B. $2.4 \times 10^7 lb$

C. $2.4 \times 10^9 lb$

D. $8.6 \times 10^9 lb$

Start by finding the amount of power produced by the plant annually. $1GW = 1 \times 10^6 KW$

$$Annual\ Production = \left(1 \times 10^6 KW\right)\left(24\frac{hr}{day}\right)(365 days) = 8.67 \times 10^9 kWh$$

Determine the mass of fuel required to produce this power by multiplying by the heat rate and dividing by the higher heating value. Take note of the units.

$$m_{fuel} = \frac{\left(8.67 \times 10^9 kWh\right)\left(7500\frac{Btu}{kWh}\right)}{21,000\frac{Btu}{lb}} = 3.13 \times 10^9 lb\ (fuel)$$

Multiply by the specific carbon content to determine the mass of carbon in the fuel.

$$m_C = \left(0.75\frac{lb_C}{lb_{fuel}}\right)\left(3.13 \times 10^9 lb\right) = 2.35 \times 10^9 lb\ (carbon)$$

Use the Periodic Table to determine the molar masses of carbon and carbon dioxide. Assuming all the carbon becomes carbon dioxide, the two will have a one-to-one correspondence in terms of moles, and the mass will scale according to the ratio of the molar masses.

$$M_C = 12$$

$$M_{CO_2} = 12 + (2)(16) = 44$$

$$m_{CO_2} = \left(\frac{44}{12}\right)\left(2.35 \times 10^9 lb\right) = 8.6 \times 10^9 lb\ (CO_2)$$

Answer D