

HANDOUT 9-1

Case Study Number 9-1 Solution

Estimating PM₁₀ Emissions from Residential Wood Combustion

Question 1: What PM₁₀ emission factors are applicable to residential wood combustion?

Answer: The PM₁₀ emission factors used in the NEI for fireplaces without inserts are obtained from Houck, J.E. et al, *Review of Wood Heater and Fireplace Emission Factors*. The PM₁₀ emission factors for woodstoves and fireplaces with inserts are obtained from AP-42. The values are listed in the Notes section at the end of this case study.

Question 2: What is the methodology for estimating PM₁₀ emissions from residential wood combustion?

Answer: Although the emission factors and usage patterns are different for the various types of wood combustion units, the emission estimation methodology is basically the same.

The first step in estimating emissions from residential wood combustion is to determine the number of residential wood combustion units within the county. Data on the number of homes with wood combustion units are obtained from the results of the Residential Wood Combustion survey that was conducted in the study area. This data must be scaled up to reflect the entire county population as opposed to the surveyed population. In addition, these data need to be adjusted to account for the fact that some homes have more than one wood combustion unit (multiply by 1.17).

The next step is to use the survey data to estimate the amount of wood burned in each residential combustion unit. This is done by converting the wood consumption data from the survey to an annual basis. Specifically, the weekly wood consumption data is multiplied by the number of weeks in the winter heating season to obtain a winter heating consumption value and then apportioning based on the seasonal percentages applied to the climate zone (Table 9-7 of the Student Manual). The wood consumption values for each season are added together to obtain an annual consumption number.

Once the annual wood consumption for residential wood combustion units in the entire county is calculated, the next step is to apply emission factors to determine county emissions from residential wood combustion units. Because the emission factors and usage patterns are different for the various types of residential wood combustion units, it is necessary to perform these calculations separately for each.

Question 3: What is your estimate of the PM₁₀ emissions from residential wood combustion in the county within the past year without accounting for rule effectiveness or rule penetration?

Answer:

For Fireplaces without Inserts

Step 1 – Scale up the survey data to reflect the number of homes with fireplaces without inserts in the county.

$$110 \text{ homes}/500 \text{ homes} \times 380,000 \text{ homes in the county} = 83,600 \text{ homes}$$

Step 2 – Adjust the data to account for the fact that some homes have more than one wood combustion unit (multiply by 1.17).

$$83,600 \text{ homes} \times 1.17 \text{ fireplaces/home} = 97,812 \text{ fireplaces without inserts}$$

Step 3 – Estimate the amount of wood burned seasonally in all fireplaces without inserts.

$$\frac{1}{4} \text{ cord/fireplace without insert/week} \times 13 \text{ weeks/winter heating season} = 3.25 \text{ cords/} \\ \text{fireplace without insert/winter heating season}$$

Step 4 – Apportion the winter heating season wood consumption based on the seasonal percentages applied to the climate zone.

Because the county is located in Climate Zone 4 (from Table 9-7 in the Student Manual), 70 percent of the annual wood consumed is consumed in the winter season. Therefore, wood usage can be calculated on an annual basis as follows:

$$0.7 \times \text{annual wood usage} = 3.25 \text{ cords/winter heating season}$$

$$\text{Solving for annual wood usage} = 4.64 \text{ cords/year}$$

Step 5 – Estimate total wood consumption for the entire county.

The seasonally adjusted annual value for wood consumption can be multiplied by the number of fireplaces without inserts in the county to obtain a countywide, annual wood consumption estimate.

$$4.64 \text{ cords/ fireplace without insert/year} \times 97,812 \text{ fireplaces without inserts} = 453,848 \\ \text{cords/year}$$

Step 6 – Estimate emissions emitted from all fireplaces without inserts in the county.

Once the annual wood consumption for residential wood combustion units in the entire county is calculated, the next step is to apply emission factors to determine county emissions from residential wood combustion units. However, since the

emission factors are in the units of pounds of particulate per ton of wood burned, it is necessary to convert the annual wood consumption value from cords per year to tons per year.

$$453,848 \text{ cords/year} \times 128 \text{ ft}^3/\text{cord} = 58.1 \text{ million ft}^3/\text{year}$$

$$58.1 \text{ million ft}^3/\text{year} \times 23.9 \text{ pounds/ft}^3 \times 1 \text{ ton}/2000 \text{ pounds} = 694,295 \text{ tons/year}$$

$$694,295 \text{ tons/year} \times 23.2 \text{ lbs. PM}_{10}/\text{ton wood burned} = 16.1 \text{ million pounds PM}_{10}/\text{year}$$

$$16.1 \text{ million pounds PM}_{10}/\text{year} \times 1 \text{ ton}/2000 \text{ pounds} = 8,050 \text{ tons PM}_{10}/\text{year}$$

For Fireplaces with Inserts

Step 1 – Scale up the survey data to reflect the number of homes with fireplaces with inserts in the county.

$$30 \text{ homes}/500 \text{ homes} \times 380,000 \text{ homes in the county} = 22,800 \text{ homes}$$

Step 2 – Adjust the data to account for the fact that some homes have more than one wood combustion unit (multiply by 1.17).

$$22,800 \text{ homes} \times 1.17 \text{ fireplaces/home} = 26,676 \text{ fireplaces with inserts}$$

Step 3 – Estimate the amount of wood burned seasonally in all fireplaces with inserts.

$$\frac{1}{4} \text{ cord/fireplace with insert/week} \times 13 \text{ weeks/winter heating season} = 3.25 \text{ cords/} \\ \text{fireplace with insert/winter heating season}$$

Step 4 – Apportion the winter heating season wood consumption based on the seasonal percentages applied to the climate zone.

Because the county is located in Climate Zone 4 (from Table 9-7 in the Student Manual), 70 percent of the annual wood consumed is consumed in the winter season. Therefore, wood usage can be calculated on an annual basis as follows:

$$0.7 \times \text{annual wood usage} = 3.25 \text{ cords/winter heating season}$$

$$\text{Solving for annual wood usage} = 4.64 \text{ cords/year}$$

Step 5 – Estimate total wood consumption for the entire county.

The seasonally adjusted annual value for wood consumption can be multiplied by the number of fireplaces with inserts in the county to obtain a countywide, annual wood consumption estimate.

$$4.64 \text{ cords/ fireplace with insert/year} \times 26,676 \text{ fireplaces with inserts} = 123,777 \text{ cords/year}$$

Step 6 – Estimate emissions emitted from all fireplaces with inserts in the county.

Once the annual wood consumption for residential wood combustion units in the entire county is calculated, the next step is to apply emission factors to determine county emissions from residential wood combustion units. However, since the emission factors are in the units of pounds of particulate per ton of wood burned, it is necessary to convert the annual wood consumption value from cords per year to tons per year.

$$123,777 \text{ cords/year} \times 128 \text{ ft}^3/\text{cord} = 15.8 \text{ million ft}^3/\text{year}$$

$$15.8 \text{ million ft}^3/\text{year} \times 23.9 \text{ pounds/ ft}^3 \times 1 \text{ ton}/2000 \text{ pounds} = 189,329 \text{ tons/year}$$

$$189,329 \text{ tons/year} \times 30.6 \text{ lbs. PM}_{10}/\text{ton wood burned} = 5.8 \text{ million pounds PM}_{10}/\text{year}$$

$$5.8 \text{ million pounds PM}_{10}/\text{year} \times 1 \text{ ton}/2000 \text{ pounds} = 2,897 \text{ tons PM}_{10}/\text{year}$$

For Woodstoves

Step 1 – Scale up the survey data to reflect the number of homes with woodstoves in the county.

$$40 \text{ homes}/500 \text{ homes} \times 380,000 \text{ homes in the county} = 30,400 \text{ homes}$$

Step 2 – Adjust the data to account for the fact that some homes have more than one wood combustion unit (multiply by 1.17).

$$30,400 \text{ homes} \times 1.17 \text{ woodstove/home} = 35,568 \text{ woodstoves}$$

Step 3 – Estimate the amount of wood burned seasonally in all woodstoves.

$$1/8 \text{ cord/woodstove/week} \times 13 \text{ weeks/winter heating season} = 1.625 \text{ cords/woodstove/winter heating season}$$

Step 4 – Apportion the winter heating season wood consumption based on the seasonal percentages applied to the climate zone.

Because the county is located in Climate Zone 4 (from Table 9-7 in the Student Manual), 70 percent of the annual wood consumed is consumed in the winter season. Therefore, wood usage can be calculated on an annual basis as follows:

$$0.7 \times \text{annual wood usage} = 1.625 \text{ cords/winter heating season}$$

Solving for annual wood usage = 2.32 cords/year

Step 5 – Estimate total wood consumption for the entire county.

The seasonally adjusted annual value for wood consumption can be multiplied by the number of woodstoves in the county to obtain a countywide, annual wood consumption estimate.

$$2.32 \text{ cords/ woodstove/year} \times 35,568 \text{ woodstoves} = 82,518 \text{ cords/year}$$

Step 6 – Estimate emissions emitted from all woodstoves in the county.

Once the annual wood consumption for residential wood combustion units in the entire county is calculated, the next step is to apply emission factors to determine county emissions from residential wood combustion units. However, since the emission factors are in the units of pounds of particulate per ton of wood burned, it is necessary to convert the annual wood consumption value from cords per year to tons per year.

$$82,518 \text{ cords/year} \times 128 \text{ ft}^3/\text{cord} = 10.5 \text{ million ft}^3/\text{year}$$

$$10.5 \text{ million ft}^3/\text{year} \times 23.9 \text{ pounds/ ft}^3 \times 1 \text{ ton}/2000 \text{ pounds} = 126,220 \text{ tons/year}$$

$$126,220 \text{ tons/year} \times 34.6 \text{ lbs. PM}_{10}/\text{ton wood burned} = 4.4 \text{ million pounds PM}_{10}/\text{year}$$

$$4.4 \text{ million pounds PM}_{10}/\text{year} \times 1 \text{ ton}/2000 \text{ pounds} = 2,184 \text{ tons PM}_{10}/\text{year}$$

Total

Total emissions for residential wood combustion in the county are obtained by adding the estimates for fireplaces without inserts, fireplaces with inserts, and woodstoves.

$$8,050 \text{ tons PM}_{10}/\text{yr} + 2,897 \text{ tons PM}_{10}/\text{yr} + 2,184 \text{ tons PM}_{10}/\text{yr} = 13,131 \text{ tons PM}_{10}/\text{yr}$$

Question 4: What is your estimate of the PM₁₀ emissions from residential wood combustion in the county within the past year accounting for rule effectiveness and rule penetration?

Answer: Adjustments for rule effectiveness and rule penetration can be made by multiplying the total countywide emissions by (1-(RE/100)(RP/100)) as shown below.

$$13,131 \text{ tons PM}_{10}/\text{yr} \times (1-((100/100)(75/100))) = 3,283 \text{ tons PM}_{10}/\text{yr}$$

Question 5: If the residential wood combustion survey failed to collect data on the amount of wood burned, how could emissions from fireplaces without inserts be calculated?

Answer: If the survey failed to collect data on the amount of wood consumed in the various residential wood combustion units, data from the US Department of Census (DOC) would need to be used to estimate wood consumption rates for the county. However, because the DOC data separates fireplaces without inserts into 2 categories, those used for heating and those used for aesthetics, it is necessary to separate the number of homes that use fireplaces without inserts for heating and those that use them for aesthetic purposes. In order to do this, the survey would need to have collected data on what the fireplaces is used for (heating or aesthetics). The amount of wood burned in each device is determined by assuming wood consumption rates of 0.656 cords burned /unit/year for fireplaces used for heating and 0.069 cords/unit/year for fireplaces used for aesthetics.

Question 6: How would you propose to estimate PM_{2.5} emissions from residential wood combustion in the county?

Answer: The PM_{2.5} emission factor is assumed to be the same as the PM₁₀ primary emission factor.