SOURCE REDUCTION

This chapter describes the development of material-specific emission factors for source reduction in EPA's Waste Reduction Model (WARM). Source reduction, or waste prevention, refers to practices that reduce the amount of materials entering the waste stream, including changes in the design, manufacture, purchase or use of materials. This document provides examples of source reduction and a summary of how EPA estimates the GHG benefits from source reduction of materials.

1 TYPES OF SOURCE REDUCTION

Source reduction can result from any activity that reduces the amount of a material needed and therefore used to make products. Some specific examples of source reduction practices are:

- Redesigning products to use fewer materials (e.g., lightweighting, material substitution).
- Reusing products and materials (e.g., a refillable water bottle).
- Extending the useful lifespan of products.
- Avoiding using materials in the first place (e.g., reducing junk mail).

In addition to the activities above, there are limited circumstances where the emission factors can be used to estimate GHG benefits of substituting one material or product for another material or product. Section 3.2 presents considerations for estimating the GHG effects of material substitution.

2 A SUMMARY OF THE GHG IMPLICATIONS OF SOURCE REDUCTION

When a material is source reduced, GHG emissions associated with producing the material and/or manufacturing the product and managing the post-consumer waste are avoided. Consequently, source reduction provides GHG emission benefits by: (1) avoiding the "upstream" GHGs emitted in the raw material acquisition, manufacture and transport of the source-reduced material; (2) increasing the amount of carbon stored in forests (when wood and paper products are source reduced); and (3) avoiding the downstream GHG emissions from waste management.

Because many materials are manufactured from a mix of virgin and recycled inputs, the quantity of virgin material production that is avoided is not always equal to the quantity of material source reduced. Therefore, to estimate GHG emissions associated with source reduction, WARM uses a mix of virgin and recycled inputs, based on the national average for each material. However, WARM also allows users to evaluate the benefits of source reducing materials manufactured from 100-percent virgin inputs, instead of a mix of virgin and recycled inputs.

WARM assumes that source reduction of paper and wood products increases the amount of carbon stored in forests by reducing the amount of wood harvested. For more information on the calculations that went into creating the forest carbon storage offset, see the Forest Carbon Storage chapter.

In order to measure the full GHG impact of source reduction, the user must compare the GHG emissions from source reduction to the GHG emissions of another materials management option. For example, a user could compare the benefits from source reducing one short ton of office paper instead of sending the paper to the landfill. This approach enables policy-makers to evaluate, on a per-ton basis, the overall difference in GHG emissions between (1) source reducing one short ton of material, and (2) manufacturing and then managing (post-consumer) one short ton of the same material. For most materials, source reduction has lower GHG emissions than the other materials management options.[1]

3 APPLYING EMISSION FACTORS TO SPECIFIC SOURCE REDUCTION STRATEGIES

3.1 CALCULATING THE ENERGY AND GHG EMISSIONS BENEFITS OF REUSE

The GHG and energy benefits of reusing materials or products multiple times before they are sent for end-of-life management can be modeled using the source reduction pathway in WARM. The process for calculating the GHG and energy benefits of reuse is as follows:

1. Using the downloadable (i.e., Excel-based) version of WARM, run the model using a baseline scenario of landfilling, recycling, combustion or composting (depending on the likely fate of the material or product if it is not reused), and an alternate scenario of source reduction. For example, if the item was originally destined for a landfill and now will be reused, the baseline scenario is landfilling.
2. Select whether the reused material is manufactured from 100-percent virgin inputs or the current mix of virgin and recycled inputs. (The assumption that the material is manufactured from 100-percent virgin inputs indicates an upper bound estimate of the benefits from reuse.)
3. Multiply the GHG emissions reduction result (i.e. "total change in GHG emissions" from WARM) by the number of times the material is reused. The reuse number should equal one less than the number of total uses to account for the production of the initial material.

This methodology for calculating the GHG benefits from reuse is summarized in the following formula. Energy use can be similarly calculated by replacing the GHG emission factors with energy use factors.

$$\textit{GHG Benefits of Reuse} = (N - 1) \times (A)$$

Where,

N = Number of total uses
A = GHG benefits of the source reduction (alternate) pathway minus the baseline pathway (i.e., "total change in GHG emissions" from WARM)

For example, consider reusable HDPE plastic crates, weighing 1,000 short tons total, used for transporting bread to a grocery store. Assume that the crates are typically recycled after each use, but could be reused up to 20 times before they are recycled. In order to calculate the GHG benefits of reusing the crates, the user can run WARM using a baseline of recycling 1,000 short tons HDPE and an alternate scenario of source reducing 1,000 short tons HDPE. Assuming that reusing the crates offsets the production of HDPE crates that would otherwise have been manufactured from 100-percent virgin

[1] The most notable exceptions are for aluminum cans and carpet, where recycling benefits are higher. For aluminum cans, source reduction benefits (for the current mix of inputs) are smaller than recycling benefits. This is because of two factors: (1) the large difference in GHG emissions between virgin and recycled manufacture of aluminum cans and (2) the relatively high recycled content (51 percent) in aluminum cans. In this instance, source reduction is relatively less beneficial because of the high recycled content of a "virgin" can. The discrepancy in the carpet emission factors is due to the open-loop recycling process modeled for carpets (see the Carpet chapter for more details). This issue is discussed further on the WARM FAQ page, available at: http://www.epa.gov/climatechange/wycd/waste/calculators/WARM_faq.html.

inputs, WARM's results indicate that source reduction of 1,000 short tons of HDPE crates results in a net emissions reduction of 583 $MTCO_2E$ relative to the baseline recycling scenario.[2]

The GHG benefits should then be multiplied by 19 reuses (i.e., 20 total uses – 1 original use). Energy use can be similarly calculated by replacing the GHG emission factors with energy use factors. In equation form:

GHG Benefits of Reuse = 19 × (source reduction of 1,000 short tons HDPE – recycling of 1,000 short tons HDPE)

100% virgin inputs (upper bound for reductions):
GHG Benefits of Reuse = 19 × (583 $MTCO_2E$) = 11,077 $MTCO_2E$

3.2 CALCULATING THE ENERGY AND GHG EMISSIONS BENEFITS OF MATERIAL SUBSTITUTION

The analysis of source reduction is based on an assumption that source reduction is achieved by practices such as lightweighting, double-sided copying and material reuse. However, it is also possible to source reduce one type of material by substituting another material. The GHG impact of this type of source reduction is the net GHG benefits from source reduction of the original material and manufacturing and disposing of the substitute material.

Where both the original material and the substitute material are available in WARM, the GHG impacts of source reduction with material substitution may be estimated as long as users verify that the material production and end-of-life pathways in WARM are representative of the materials involved in the substitution. However, for cases where one of the materials in the substitution pair is not in WARM, a quantitative analysis of source reduction with material substitution is beyond the scope of the emission factors described in this documentation. The large number of materials that could be substituted for the materials available in WARM, and the need for specific information on application of material substitution, make such an analysis prohibitive and highly uncertain.

In the case where both the material being replaced and its substitute are in WARM, the GHG benefits can be estimated as described below. Note that this calculation cannot be run in WARM, because WARM requires the user to have the same material in the baseline and alternate scenarios:

1. Calculate the GHG emissions from manufacturing and end-of-life management of the original material that will be replaced by the substitute material (i.e., the baseline scenario; see equations below for an explanation of this calculation).
2. Calculate the GHG emissions from manufacturing and end-of-life management of the substitute material (i.e., the alternate scenario; see equations below for an explanation of this calculation).
3. Calculate the mass substitution rate. The mass substitution rate is the number of tons of substitute material used per ton of original material. In calculating the mass substitution rate, users should also account for any difference in the number of times that a product made from the original material is used prior to waste management, compared to the number of times a product made from the substitute material will be used prior to waste management.

[2] If reusing the crates offsets crates that would otherwise have been manufactured from the current mix of virgin and recycled inputs, source reduction of 1,000 short tons HDPE would result in a net emissions reduction of 403 $MTCO_2E$ relative to the baseline recycling scenario.

4. Calculate the net GHG benefits by subtracting the GHG emissions that would have been generated to produce the baseline material from the GHG emissions generated by producing an equivalent amount of the substitute materials.

This basic methodology for calculating the GHG benefits of material substitution is summarized in the following formula. Energy use can be similarly calculated by replacing the GHG emission factors with energy use factors.

$$\textit{GHG Benefits of Material Substitution} = (EF_{alternate\ material} * MS - EF_{baseline\ material})$$

Where,

$EF_{alternate\ material}$ = GHG emissions from production and end-of-life management of the substitute material per unit of substitute material

$EF_{baseline\ material}$ = GHG emissions from production and end-of-life management of the original material per unit of original material

MS = Material substitution rate = Amount of substitute material required to replace a unit of the original material

Because source reduction GHG emission factors represent the benefits of avoided production of materials, the GHG emissions generated by the production of materials can be calculated by taking the absolute value of WARM's source reduction factors. The energy or GHG emissions from end-of-life management can be calculated using the various end-of-life materials management factors in WARM (e.g., recycling, composting, combustion or landfilling). Consequently, the $EF_{alternative\ material}$ and $EF_{baseline\ material}$ terms are equal to:

$$EF_{alternate\ material} = -EF_{source\ reduction,\ alternate\ material} + EF_{end\text{-}of\text{-}life\ management,\ alternate\ material}$$

$$EF_{baseline\ material} = -EF_{source\ reduction,\ baseline\ material} + EF_{end\text{-}of\text{-}life\ management,\ baseline\ material}$$

Where,

$EF_{source\ reduction}$ = WARM emission factor for source reduction of the baseline and alternative materials

$EF_{end\text{-}of\text{-}life\ management}$ = WARM emission factor for the end-of-life management practice (recycling, composting, combustion or landfilling) used to manage the baseline and alternative materials

4 LIMITATIONS

Because the data presented in this chapter were developed using data presented in the raw materials and acquisition section of the Overview chapter (and the Forest Carbon Storage chapter), the limitations discussed there also apply to the values presented here. Other limitations include:

- There may be additional GHG impacts from disposal of industrial wastes, particularly paper sludge at paper mills. Because of the complexity of analyzing these second-order effects and the lack of data, EPA did not include them. A screening analysis for paper sludge was performed based on (1) data on sludge generation rates and sludge composition (i.e., percentage of cellulose, hemicellulose, lignin, etc. in sludge) (ICF, 1996), and (2) professional judgment on the CH_4 generation rates for cellulose, etc. The screening analysis indicated that net GHG emissions

(CH_4 emissions minus carbon storage) from paper sludge are probably on the order of 0.00 $MTCO_2E$ per short ton of paper made from virgin inputs to 0.04 $MTCO_2E$ per short ton for recycled inputs. The worst-case bounding assumptions indicated maximum possible net GHG emissions ranging from 0.11 to 0.40 $MTCO_2E$ per short ton of paper (depending on the type of paper and whether virgin or recycled inputs were used).

5 REFERENCES

ICF. (1996). Memorandum to EPA Office of Solid Waste: "Methane Generation from Paper Sludge," December.