



## MEMORANDUM

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**To:** Elizabeth Scheehle, EPA/ OAP, Henry Ferland, EPA/OSW  
**From:** Randy Freed  
**Date:** July 27, 2005  
**Re:** Revised Landfill Carbon Storage Factor and Net Emission Factor for Leaves based on New Experimental Results  
**CC:** Dr. Mort Barlaz (NCSU), Diana Pape, Anne Choate, Jeremy Scharfenberg, Amanda Vemuri

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### Introduction and Summary

This memorandum provides updated landfilling emission factors for leaves, based on (1) recent experimental results developed by Dr. Mort Barlaz and (2) the revised methodology for achieving a perfect (inputs = outputs) carbon balance for these material types, as discussed in our memo of May 6, 2005 (*Revised Landfilling Emission Factors based on New WOODCARB Inputs*).

Our May 6 memo describes the background and potential approaches available to perfect the carbon mass balance from Dr. Barlaz's experimental results, and outlines two situations: (1) cases where carbon outputs (gas plus residual stored carbon) exceed inputs (total carbon in original material) and (2) cases where carbon inputs exceed outputs. Previously, the results for leaves were in the first category. Based on the re-analysis for leaves (funded by Elizabeth Scheehle), the new results fall into the second category, and thus this memo uses the assumptions on "missing" carbon that pertain to that situation, as outlined in our earlier memo.

The effect of the revisions is to change the landfill carbon storage factor for leaves, used in the US GHG inventory, from 0.32 gm C/wet gm leaves, to 0.21 gm C/wet gm leaves. In terms of the Climate and Waste Program, the net GHG emission factor for leaves (for a national average landfill) increases (becomes less negative) from -0.29 MTCE/ton (Exhibit 7-6 of the report *Solid Waste Management and GHGs*) to -0.17 MTCE/ton. The changes are driven by a reduction in the carbon storage factor, and an increase in the proportion of carbon released as methane. These changes in the emission factor for leaves affect the values for yard trimmings; the original value was -0.09 MTCE/ton, and the updated value is -0.07 MTCE/ton (the revised value reflects revisions to grass and branches as well).

The updated calculations are provided below. Attachment 1 is the letter report from Mort Barlaz describing the experimental results for leaves.

### Calculation and Adjustment Methodology

To summarize the key features of the adjustment approach, there are several elements in the mass balance for carbon in landfills:

- Initial carbon content (measured),
- Carbon output as methane,
- Carbon output as carbon dioxide, and
- Residual carbon (i.e., landfill carbon storage factor).

In a simple system where the only carbon fates are CH<sub>4</sub>, CO<sub>2</sub>, and carbon storage, you would expect

$$\text{CH}_4\text{-C} + \text{CO}_2\text{-C} + \text{LF C} = \text{Initial C.}$$

If the only decomposition is anaerobic, then CH<sub>4</sub>-C = CO<sub>2</sub>-C.<sup>1</sup> Mort Barlaz and his colleagues did not measure CO<sub>2</sub> outputs in their experiments. So, you would expect the system to be defined by

$$2 * \text{CH}_4\text{-C} + \text{LF C} = \text{Initial C.}$$

The original leaves values and the new results are shown in Exhibit 1 below. For the new experimental results, the outputs (2 \* CH<sub>4</sub>-C + LF C) were less than the initial carbon (i.e., we were missing about 10% of the initial carbon; see Exhibit 1). Thus, consistent with the adjustments we made to other materials in our May 6 memo, we increased the CH<sub>4</sub>-C (with respect to the measured values) as follows:

$$(\text{Initial C} - \text{LF C})/2 = \text{CH}_4\text{-C}$$

This has the effect of increasing methane emissions (using the new results) from 9% (measured) to 14% (adjusted) of total carbon.

**Exhibit 1. Experimental and Adjusted Results** (blue highlighting indicates adjusted values).<sup>2</sup>

Carbon Source	Methane released (gm CH <sub>4</sub> /dry gm)	Fraction of dry matter that is C	Fraction carbon released as CH <sub>4</sub>	Fraction carbon released as CO <sub>2</sub> (est.)	Total fraction released as landfill gas (est.)	Fraction of carbon stored (calculated)	Fraction of dry matter stored (measured)
Leaves (based on measured 1995 values)	0.020	49%	3%	3%	6%	NC	54%
Leaves (based on measured 2005 values)	0.037	42%	7%	7%	13%	72%	30%
Leaves (based on adjusted 2005 values)	0.077	42%	14%	14%	28%	72%	30%

Although the 1995 experimental results had found a methane yield of 0.020 gm CH<sub>4</sub>/gm, there was fairly low (75%) methane recovery in that experiment, and we had made an adjustment to account for the low recovery; the value used in our *Solid Waste Management and GHGs* report was 0.037 gm CH<sub>4</sub>/gm (coincidentally, exactly matching the measured value in the 2005 results). The newly adjusted value (0.077 gm CH<sub>4</sub>/gm) is quite a bit higher.

The overall carbon content of leaves (42%) is lower in the new results than the earlier value (49%); this has the effect of reducing both the carbon storage and methane emissions components of the GHG balance compared to the earlier value.

So, with respect to the value in our original report, there are three significant changes:

- Landfill carbon storage declines from 54% to 30% (expressed on a dry matter basis)

<sup>1</sup> The molar ratio of CH<sub>4</sub> to CO<sub>2</sub> is 1:1 for carbohydrates (e.g., cellulose, hemicellulose). For proteins, the molar ratio is 1.65 CH<sub>4</sub> per 1.55 CO<sub>2</sub>, for protein as C<sub>3.2</sub>H<sub>5</sub>ON<sub>0.86</sub> (Barlaz et al. 1989). Given the predominance of carbohydrates, for all practical purposes, the overall ratio is 1:1.

<sup>2</sup> Note that the US Inventory has used an adjusted value of 46% as the fraction of dry matter stored as carbon, rather than the measured value of 54% shown in this table.

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- Methane emissions increase from 0.0372 gm CH<sub>4</sub>/dry gm (the original measured value) to 0.077 gm CH<sub>4</sub>/ dry gm.
- Overall carbon content declines from 49% to 42%.

### **Landfill Carbon Storage and Net Landfill Emission Factors**

Based on the new data and adjustments above, the landfill carbon storage factor for leaves will change in the US GHG inventory from 0.32 gm C/wet gm leaves, to 0.21 gm C/wet gm leaves. for net landfill emission factors (for national average gas recovery) are shown below for both leaves and yard trimmings.

	Solid Waste Mgmt & GHG Report Value (MTCE/ton)	Revised Value (MTCE/ton)
Leaves	-0.29	-0.17
Yard Trimmings (inc revisions to grass & branches)	-0.09	-0.07

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We welcome your thoughts on these new emission factors. Please feel free to contact us if you would like more information or would like to discuss this.

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**Attachment 1. Leaves Report, from Dr. Barlaz.**