8. ENERGY AND EMISSION BENEFITS

Earlier chapters of this report examined the energy implications and GHG emissions from each of five waste management options. This chapter summarizes the GHG emission factors for each option, explains the analytic framework for applying emission factors, reviews tools that can be used to evaluate GHG emissions from waste management practices, and describes opportunities for GHG emission reductions. The full discussion of the energy implications of waste management options, and tables showing the associated energy savings, are presented in Chapter 7. Readers are referred to Chapter 7 for complete explanation of energy impacts, or for help applying energy factors to a particular waste management option.

In the discussion that follows, the focus is on national average conditions. For example, landfills are represented as having the national average landfill gas recovery systems, and combustors are represented based on mass burn units with the national average system efficiency for collection of ferrous metal. As shown in the previous chapters, GHG emissions are sensitive to site-specific variables; emissions can and do differ from the national average scenario presented here. To allow customization of emission factors that better reflect site-specific conditions, EPA has developed three accounting tools: the WAste Reduction Model (WARM), which enables users to input several key variables (e.g., information on landfill gas collection systems, transportation distances) to assess the GHG and energy implications of waste management options; the Recycled Content (ReCon) Tool, which enables consumers and producers to assess the energy and GHG impacts of buying or producing goods with varying percentages of recycled content; and the Durable Goods Calculator, which assesses the energy and GHG impacts of recycling goods such as refrigerators and washing machines. EPA encourages readers to take advantage of these models when assessing their waste management options. The tools are described in further detail in Section 8.3 below.

8.1 NET GHG EMISSIONS FOR EACH WASTE MANAGEMENT OPTION

The net life-cycle GHG emissions for each waste management option for each material considered are shown in 8 exhibits that summarize the GHG emissions and sinks in MTCE/ton, which are described in detail in earlier chapters. In these exhibits, emission factors are shown for mixed plastics, mixed recyclables, and mixed organics. EPA developed the emission factor for mixed recyclables by calculating the average (weighted by tons recycled in 2003) of emission factors for aluminum cans, steel cans, glass, HDPE, LDPE, PET, corrugated cardboard, magazines/third-class mail, newspaper, office paper, phonebooks, textbooks, medium-density fiberboard, and dimensional lumber. The emission factor for mixed plastics is the average (weighted by tons recycled in 2003) of emission factors for HDPE, LDPE, and PET. The mixed organics emission factor is the average (weighted by tons composted in 2003) of emission factors for yard trimmings and food discards.[1]

As mentioned in Chapter 1, EPA used a waste generation reference point for measuring GHG emissions (i.e., GHG emissions were accounted for at the point of waste generation). All subsequent emissions and sinks from waste management practices are counted. Changes in emissions and sinks from raw material acquisition and manufacturing processes are captured to the extent that source reduction and recycling affect these processes.[2] Negative emission factors indicate that, from a waste generation

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[1] All data on recycling and compost rates are from EPA's OSW. 2005. *Municipal Solid Waste in the United States: 2003 Facts and Figures*, EPA 430-R-05-003.

[2] For reference, GHG emissions from raw materials acquisition and manufacturing are shown in column "a" of several exhibits in this chapter.

reference point, a given management practice for a particular material type results in emission reductions. However, it is important to note that none of the management-specific emission factors are to be used alone; it is the *difference* between two competing management practices that matters.

This report provides emissions and savings from several of the most common materials in MSW. For materials not explicitly covered in the previous chapters, Exhibit 8-1 presents the recommended proxy materials that readers of this report can use to calculate emissions of common materials not covered in the body of the report, including mixed metals, PVC, rubber, and textiles.

Exhibit 8-1 Recommended Surrogates for Voluntary Reporting

Material Source Reduced	Surrogate Material
Iron	Steel Cans
Other Ferrous Metals	Steel Cans
Other Nonferrous Metals	Average of Copper and Aluminum
Steel	Steel Cans
Metal (type unknown)	Average of Aluminum, Steel, and Copper
Mixed Metals (ferrous and nonferrous)	Appropriate Weighted Average
Copper	Copper Wire
Plastic (resin unknown)	Average of PET, HDPE, and LDPE
PVC/Vinyl	Average of PET, HDPE, and LDPE
Polypropylene	Average of PET, HDPE, and LDPE
Polystyrene	Average of PET, HDPE, and LDPE
Other plastic (resin known, but not 41-46)	Average of PET, HDPE, and LDPE
Rubber	Average of PET, HDPE, and LDPE
Boxboard	Corrugated Cardboard
Kraft Paper	Corrugated Cardboard
Coated Paper	Magazines/Third-class Mail
High-grade Paper	Office Paper
Paper (type unknown)	Mixed Paper – Broad Definition
Wood	Dimensional Lumber
Food	Food Discards
Organics (type unknown)	Yard Trimmings
Other Yard Waste	Yard Trimmings
Textiles	Carpet

Exhibit 8-2 shows the life-cycle GHG impacts of source reduction, presented in MTCE/ton.[3] In brief, the exhibit shows that, for all of the manufactured materials evaluated, source reduction results in GHG emission reductions. On a per-ton basis, PCs, aluminum cans, and copper wire have the greatest potential for emission reduction, due primarily to reductions in energy use in the raw material acquisition and manufacturing step.

Exhibit 8-3 shows the life-cycle GHG emissions associated with recycling. Columns (c), (d), and (e) show the GHG impacts of using recycled inputs in place of virgin inputs when the material is remanufactured. As the final column indicates, recycling results in negative emissions (measured from the point of waste generation) for all the materials considered in this analysis. GHG emission reductions associated with recycling are due to several factors, including avoided waste management emissions and reduced process energy emissions.[4] In addition, emission reductions from recycling paper products

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[3] All data in these tables are presented in metric tons of carbon equivalent per short ton of waste discarded (MTCE/ton). To see these tables in $MTCO_2E$/ton, please refer to Appendix B.

[4] Process energy emissions for recycled corrugated cardboard, office paper, wood products (i.e., dimensional lumber and medium-density fiberboard), and mixed paper (broad and residential definitions) are actually higher than those for virgin production because production with recycled inputs tends to use fossil fuel-derived energy, while production with virgin inputs uses higher proportions of biomass fuel (CO_2 from such fuel is not counted in GHG

(when measured at the point of waste generation) are due in part to the forest carbon sequestration benefits of recycling paper. The materials with the greatest potential for emission reduction through recycling are aluminum cans, carpet, copper wire, and several paper grades. In addition, though the emission reductions per ton for concrete are relatively small (0.002), the enormous quantities of this material disposed of make it particularly promising as a mitigation strategy—200 million tons of waste concrete are disposed of annually in the United States.

Exhibit 8-4 presents the life-cycle GHG emissions from composting food discards, yard trimmings, and mixed organics. The exhibits show that composting these materials results in net emissions of -0.05 MTCE/ton, based on the difference between the emissions associated with transporting the materials to the composting facility and the soil carbon sequestration benefits.

Exhibit 8-5 presents the life-cycle GHG emissions from combusting each of the materials considered. This exhibit shows emissions for mass burn facilities and assumes the national average rate of ferrous recovery. Results for RDF facilities are similar. As the exhibit shows, mixed MSW combustion has net emissions of -0.03 MTCE/ton. Net GHG emissions are positive for plastics, aluminum, and glass, and negative for the other materials.

GHG emissions from landfilling each of the materials in MTCE/ton are shown in Exhibit 8-6. The values in the final column indicate that net GHG emissions from landfilling mixed MSW, under national average conditions in 2003, are positive. Among individual materials, emissions are lowest for newspaper, phonebooks, magazines/third-class mail, wood products, and yard trimmings, and highest for office paper, textbooks, and food discards.

As discussed in Chapter 6 and shown in Exhibit 6-6, the results for landfills are very sensitive to site-specific factors. Landfill gas collection practices significantly influence the net GHG emissions from landfilling the organic materials. For mixed MSW, net emissions are 0.37 MTCE/ton in landfills without landfill gas collection, and -0.09 MTCE/ton in landfills with landfill gas collection and energy recovery (see Exhibit 6-8), a difference of 0.46 MTCE to be gained by recovering and using landfill gas for electricity generation. The largest such differences attributable to landfill gas recovery are for office paper and textbooks (approximately 0.8 MTCE/ton), corrugated cardboard and mixed paper. The CH_4 oxidation rate and gas collection system efficiency also have a strong influence on the estimated net emissions for mixed waste and the organic materials. The values in Exhibit 8-6 reflect national average CH_4 recovery practices, thus the value for mixed MSW is 0.12 MTCE/ton.

Exhibit 8-7 displays the national average emissions for each management option and each material in MTCE/ton. When reviewing the emission factors, it is important to recall caveats that appear throughout this report. In particular, these estimates do not reflect site-specific variability, and they are not intended to compare one material to another from a use-phase perspective. Rather, these estimates are designed to support accounting for GHG emissions and sinks from waste management practices. A brief recap of how to apply the emission factors appears in the following section.

8.2 APPLYING GHG EMISSION FACTORS

The net GHG emission estimates presented in Exhibit 8-2 through Exhibit 8-7 (and the more detailed estimates in the preceding chapters) provide emission factors that may be used by organizations interested in quantifying and voluntarily reporting emissions reductions associated with waste management practices. In conjunction with DOE, EPA has used these estimates as the basis for developing guidance for voluntary reporting of GHG reductions, as authorized by Congress in Section 1605(b) of the Energy Policy Act of 1992. However, under the new, more rigorous 1605(b) reporting guidelines, emissions reductions from solid waste management practices must be reported separately

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inventories). In the case of dimensional lumber, production with recycled inputs requires more energy than virgin production.

Applying Emission Factors: Nonlinear Relationship between Recycling and Emission Reductions and Forest Carbon Leakage

Two caveats should be considered when applying emission factors to analyze large-scale shifts in waste management. First, increased recycling and GHG emission reductions may have a nonlinear relationship, such that emission reductions increase at a *declining rate* as recycling increases. This decline may be due to three factors: (1) energy use in manufacturing processes may be nonlinear with respect to recycled content; (2) manufacturing capacity for recycled materials may be limited in the short term, so that large-scale increases in recycling would require additional capital investment in capacity; and (3) market penetration of recyclables may have limits (e.g., due to performance characteristics), such that recyclables cannot completely replace virgin inputs in the short term.

In terms of the second caveat, the forest carbon sequestration benefits of paper and wood source reduction and recycling are based on the assumption that reduced demand for a given paper or wood product translates directly into reduced tree harvesting. Given that pulpwood and roundwood can be used for many products, some of the forest carbon sequestration benefits may be lost by an increase in harvests for these other products. This phenomenon is a form of what is sometimes termed "leakage" in the context of GHG mitigation projects.

Although both of these issues are important considerations in applying the emission factors in this report, EPA notes that the emission factors are primarily designed for use by local waste managers. The factors are intended to assess the GHG impacts of waste management decisions at a small-to-moderate scale. Readers should be cautious when applying the emission factors at a larger scale, however, since the nonlinear nature of the factors and the issue of leakage become most relevant in the larger context.

tons of office paper).[5] The emission factors developed in this report then can be used to calculate emissions under both the baseline and the alternative management practices. Once emissions for the two scenarios have been determined, the next step is to calculate the difference between the alternative scenario and the baseline scenario. The result represents the GHG emission reductions or increases attributable to the alternative waste management practice.

Exhibit 8-8 illustrates the results of this procedure in a scenario where the baseline management scenario is disposal in a landfill with national average conditions (i.e., the weighted average in terms of landfill gas recovery practice). Alternative scenarios involve source reduction, recycling, composting, or combustion. The values in the cells of the matrix are expressed in MTCE/ton and represent the *incremental change* in GHG emissions. For example, recycling 1 ton of office paper, rather than landfilling it, reduces GHG emissions by 1.31 MTCE, (see the "Recycling" columns of the exhibit). Continuing the example from the previous paragraph, if a business implements an office paper recycling program and annually diverts 10 tons of office paper (that would otherwise be landfilled) to recycling, the GHG emission reductions are:

$$10 \text{ tons/yr} \times -1.31 \text{ MTCE/ton} = -13.1 \text{ MTCE/yr}$$

Under the sign convention used in this report, the negative value indicates that emissions are reduced.

In 2003, the most recent year for which data was available, the United States recycled 30.6 percent of the MSW it produced. As part of its effort to encourage recycling, waste reduction, and GHG reduction, the EPA has set national recycling goal of 35 percent by 2008 and has proposed a goal of 40 percent by 2011. Using WARM, EPA calculated the projected incremental benefits of these goals. The current rate of 30.6 percent gave GHG benefits in 2003 of 49 MMTCE and energy benefits of 1.5

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[5] The emission factors are expressed in terms of GHG emissions per ton of material managed. In the case of recycling, EPA defines 1 ton of material managed as 1 ton *collected* for recycling. As discussed in Chapter 4, the emission factors can be adjusted to calculate GHG emissions in terms of tons of recycled materials *as marketed* (reflecting losses in collection and sorting processes), or changes in the *recycled content* of products.

quadrillion Btu saved compared to a baseline of no recycling. These calculations assume landfilling 80 percent and combusting 20 percent of MSW not recycled (the national average rates). Increasing the rate to 35 percent would give GHG benefits in 2008 of 57 MMTCE and energy benefits of 1.7 quadrillion Btu saved. The benefits in 2011 of a 40 percent recycling rate would be 65 MMTCE and 1.9 quadrillion Btu.

Due to resource and data limitations, emission factors have not been developed for all material types reported by WasteWise partners, the Voluntary Reporting of GHG Program—or 1605(b) as it is commonly called—and other parties interested in reporting voluntary emission reductions. However, existing emission factors will continue to be updated and improved and new emission factors will be developed as more data become available. The latest emission factors, reflecting these ongoing revisions, can be found in WARM, EPA's waste emissions spreadsheet tool.[6]

In cases where parties have been using source reduction or recycling techniques for materials not specifically analyzed in this report, it is possible to estimate the GHG emission reductions by assigning surrogate materials. A list of materials not specifically analyzed, and their corresponding surrogates, is presented earlier in this chapter (see Exhibit 8-1). Surrogates are assigned based on consideration of similarities in characteristics likely to drive life-cycle GHG emissions, such as similarities in energy consumption during the raw material acquisition and manufacturing life-cycle stages. Note that the use of these surrogates involves considerable uncertainty.

8.3 TOOLS AND OTHER LIFE-CYCLE GHG ANALYSES

Life-cycle analysis is increasingly being used to quantify the GHG impacts of private and public sector decisions. In addition to the life-cycle analyses that underpin the emission factors in this report, Environmental Defense,[7] ICLEI, Ecobilan, and others have analyzed the life-cycle environmental impacts of various industry processes (e.g., manufacturing) and private and public sector practices (e.g., waste management). In many cases, the results of life-cycle analyses are packaged into life-cycle software tools that distill the information according to a specific user's needs.

ICF International worked with EPA to create the WARM, ReCon, and DGC tools, in addition to researching and writing this report, and creating the emission factors used here and in the tools. As mentioned earlier, the WAste Reduction Model (WARM) was designed as a tool for waste managers to weigh the GHG and energy impacts of their waste management practices. As a result, the model focuses exclusively on waste sector GHG emissions, and the methodology used to estimate emissions is consistent with international and domestic GHG accounting guidelines. Life-cycle tools designed for broader audiences necessarily include other sectors and/or other environmental impacts, and are not necessarily tied to the IPCC guidelines for GHG accounting or the methods used in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks*.

- WARM covers 34 types of materials and five waste management options: source reduction, recycling, combustion, composting, and landfilling. WARM accounts for upstream energy and nonenergy emissions, transportation distances to disposal and recycling facilities, carbon sequestration, and utility offsets that result from landfill gas collection and combustion. The tool provides participants in DOE's 1605(b) program with the option to report results by year, by gas, and by year and by gas (although under 1605(b)'s revised guidelines, avoided emissions from recycling must be reported separately under "other indirect emissions" and not included in the

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[6] Available at EPA's Global Warming—Waste, "Waste Reduction Model" website. Available at: http://www.epa.gov/mswclimate, then follow the link to Tools.

[7] Blum, L., Denison, R.A., and Ruston, V.F. 1997. "A Life-Cycle Approach to Purchasing and Using Environmentally Preferable Paper: A Summary of the Paper Task Force Report," *Journal of Industrial Ecology*; Volume 1; No. 3; pp, 15-46. Denison, R.A. 1996. "Environmental Life-Cycle Comparison of Recycling, Landfilling, and Incineration: A Review of Recent Studies;" *Annual Review of Energy and the Environment;* Volume 21, Chapter 6, pp.191–237.

main corporate inventory). WARM software is available free of charge in both a Web-based calculator format and a Microsoft® Excel spreadsheet. The tool is ideal for waste planners interested in tracking and reporting voluntary GHG emission reductions from waste management practices and comparing the climate change impacts of different approaches. To access the tool, visit: http://www.epa.gov/mswclimate, and follow the link to Tools. The latest version of WARM can also calculate energy savings resulting from waste management decisions.

- Recycled Content (ReCon) Tool was created by EPA to help companies and individuals estimate life-cycle GHG emissions and energy impacts from purchasing and/or manufacturing materials with varying degrees of postconsumer recycled content. The tool covers 17 material types and an analysis of baseline and alternative recycled-content scenarios. ReCon accounts for total "upstream" GHG emissions based on manufacturing processes, carbon sequestration, and avoided disposal that are related to the manufacture of the materials with recycled content. ReCon also accounts for the total energy (based on manufacturing processes and avoided disposal) related to the manufacture of materials with recycled content. The tool is ideal for companies and individuals who want to calculate GHG emissions and energy consumption associated with purchasing and manufacturing, using baseline and alternate recycled-content scenarios. To access the tool, visit: http://www.epa.gov/mswclimate, and follow the link to Tools.
- The Durable Goods Calculator (DGC) is an EPA model that enables users to calculate the GHG emission and energy implications for various disposal methods of durable goods. The model covers 14 types of durable goods and three waste management options: recycling, landfilling, and combustion. This tool functions by producing an aggregate GHG emission profile by creating a weighted average of the raw material content. The Durable Goods Calculator was developed for individuals and companies who want to make an informed decision on the GHG and energy impact they will have by disposing of durable household goods. Emission and energy estimates provided by the Durable Goods Calculator are intended to provide information regarding the GHG emission implications of waste management decisions. To access the tool, visit: http://www.epa.gov/mswclimate, and follow the link to Tools.
- The Cities for Climate Protection (CCP) campaign's GHG Emission Software was developed by Torrie Smith Associates for ICLEI (Local Governments for Sustainability). This Windows™-based tool, targeted for use by local governments, can analyze emissions and emission reductions on a community-wide basis and for municipal operations alone. The community-wide module looks at residential, commercial, and industrial buildings, transportation activity, and community-generated waste. The municipal operations module considers municipal buildings, municipal fleets, and waste from municipal in-house operations. In addition to computing GHG emissions, the CCP software estimates reductions in criteria air pollutants, changes in energy consumption, and financial costs and savings associated with energy use and other emission reduction initiatives. A version of the software program was made available for use by private businesses and institutions during the summer of 2001. CCP software subscriptions, including technical support, are available to governments participating in ICLEI. For more information, visit: www.iclei.org or contact the U.S. ICLEI office at 510–844–0699, iclei_usa@iclei.org.
- The Decision Support Tool (DST) and life-cycle inventory database for North America have been developed through funding by EPA's ORD through a cooperative agreement with the Research Triangle Institute (CR823052). The methodology is based on a multimedia, multipollutant approach and includes analysis of GHG emissions as well as a broader set of emissions (air, water, and waste) associated with MSW operations. The MSW-DST is available for site-specific applications and has been used to conduct analyses in several states and 15 communities, including use by the U.S. Navy in the Pacific Northwest. The tool is intended for use by solid waste planners at state and local levels to analyze and compare alternative MSW management

strategies with respect to cost, energy consumption, and environmental releases to the air, land, and water. The costs are based on full-cost accounting principles and account for capital and operating costs using an engineering economics analysis. The MSW-DST calculates not only projected emissions of GHGs and criteria air pollutants, but also emissions of more than 30 air- and water-borne pollutants. The DST models emissions associated with all MSW management activities, including waste collection and transportation, transfer stations, materials recovery facilities, compost facilities, landfills, combustion and refuse-derived fuel facilities, utility offsets, material offsets, and source reduction. The differences in residential, multifamily, and commercial sectors can be evaluated individually. The software has optimization capabilities that enable one to identify options that evaluate minimum costs as well as solutions that can maximize environmental benefits, including energy conservation and GHG reductions.

As of the publication of this report, RTI expects to release the database in the summer of 2006, and will be available in a Web-based version. The MSW-DST provides extensive default data for the full range of MSW process models and requires minimum input data. The defaults can be tailored to the specific communities using site-specific information. The MSW-DST also includes a calculator for source reduction and carbon sequestration using a methodology that is consistent with the IPCC in terms of the treatment of biogenic CO_2 emissions. For further information, visit RTI's website at http://www.rti.org/, and search the term "DST."

- The Tool for Environmental Analysis and Management (TEAM), developed by Ecobilan, simulates operations associated with product design, processes, and activities associated with several industrial sectors. The model considers energy consumption, material consumption, transportation, waste management, and other factors in its evaluation of environmental impacts. Many firms and some government agencies have used the model. http://www.ecobalance.com/uk_team.php.

8.4 OPPORTUNITIES FOR GHG REDUCTIONS

Although this report has focused on the five most common waste management practices—source reduction, recycling, composting, combustion, and landfilling—for select materials, future GHG quantification efforts may include a number of emerging practices:

- Co-firing waste biomass. For utilities and power generating companies with coal-fired capacity, co-firing with waste biomass may represent one of the least-cost renewable energy options. Co-firing involves replacing a portion of the coal with biomass at an existing power plant boiler. This replacement can be achieved by either mixing biomass with coal before fuel is introduced into the boiler or by using separate fuel feeds for coal and biomass. Specific biomass feedstocks include agricultural and wood waste, MSW, and industrial wastes. Given the increasing use of co-firing technology as an energy source, understanding its GHG benefits will likely be an important future EPA effort.

- Biomass pyrolysis/gasification. Pyrolysis and gasification are similar technologies in which waste is thermally decomposed in an oxygen-poor environment. In pyrolysis, organic matter is vaporized, and the vapor is condensed and collected as "bio-oil," which can then be burned for energy.[8] The advantage of pyrolysis over normal waste-to-energy incineration is that pyrolysis produces a liquid fuel that can be stored and used in a number of applications (similar to biodiesel), whereas WTE produces only electricity for immediate consumption. Biomass gasification is similar except that a gas rather than a liquid is produced.

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[8] The Biomass Technology Group, "Flash Pyrolysis." Available online at: www.btgworld.com/technologies/pyrolysis.html.

- Compost as landfill cover. Using compost as landfill cover on closed landfills provides an excellent environment for the bacteria that oxidize CH_4. Under optimal conditions, compost covers can practically eliminate CH_4 emissions. Furthermore, the covers offer the possibility of controlling these emissions in a cost-effective manner. This technology is particularly promising for small landfills, where landfill gas collection is not required and the economics of landfill gas-to-energy projects are not attractive. Ancillary benefits also might arise in the compost market from this technique if using compost as a landfill cover becomes a widespread practice. An increase in composting could reduce the quantity of organic waste disposed of at MSW landfills, thereby reducing CH_4 emissions. Given the recent development of this practice, quantifying its GHG impacts will likely prove useful as landfill owners consider adopting the technology.
- Bioreactors. Bioreactors are a form of controlled landfilling with the potential to provide reliable energy generation from solid waste, as well as significant environmental and solid waste management benefits. The concept is to accelerate the decomposition process of landfill waste through controlled additions of liquid and leachate recirculation, which enhances the growth of the microbes responsible for solid waste decomposition. The result is to shorten the period of landfill gas generation, thereby rendering projections of landfill gas generation rates and yields that are much more reliable for landfill gas recovery.
- Anaerobic digestion. Several facilities are using this technique to produce CH_4 from mixed waste, which is then used to fuel energy recovery. The approach generates CH_4 more quickly and captures it more completely than in a landfill environment, and thus, from a GHG perspective, offers a potentially attractive waste management option.[9]
- The paperless office. The rise of computer technology for research, communications, and other everyday workplace functions has presented a major opportunity for source reduction in the modern office. Today's offices are commonly equipped with all the necessary technologies to bypass paper entirely and rely instead on electronic communication. This form of "comprehensive" source reduction comes with significant GHG benefits, as described in Chapter 4. Therefore, attempting to quantify and communicate these benefits to the business community will be an important task in the coming years.
- Product stewardship. More and more companies, and even entire industries, are moving toward redesigning their products to reduce their environmental footprint. By necessity, this trend involves rethinking how their products are managed at end-of-life so that valuable materials can be recovered and reused. The electronics industry is reducing the energy usage of their products as well as reducing reliance on toxic inputs in their products. They are also redesigning their products to make them easier to recycle. The packaging industry is moving towards package designs that use less material (reducing GHG emissions from transportation) and are more easily recyclable (reducing GHG emissions and energy investments in processing virgin materials). Many other industries, such as the carpet, office furniture, and textile industries, are in the process of developing sustainability standards for their products. Companies committed to this kind of change are very interested in metrics that will help them measure the environmental benefits of the changes they are making to their products.

EPA will continue to evaluate new opportunities to reduce emissions from waste management as they become known. EPA also encourages readers to consider creative approaches to waste management, particularly those with associated life-cycle energy benefits or carbon storage implications. All of the exhibits presented so far in this report have expressed GHG emissions in units of MTCE, calculated as the sum of the individual gases (CO_2, CH_4, N_2O, and PFCs) weighted by their global warming potential. In

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[9] Environment Canada. 2001. *Determination of the Impact of Waste Management Activities on Greenhouse Gas Emissions.* Submitted by ICF Consulting, Torrie-Smith Associates, and Enviros-RIS.

the Voluntary Reporting of GHG Program—also known as the 1605(b) program—established by DOE's Energy Information Administration, reporting companies are asked to provide emission reductions for each of the individual gases. In addition, the 1605(b) program requires emission reductions to be reported in the year they are achieved and does not allow participants to take credit for future emission reductions. Because the GHG emission factors presented in this report reflect the "present value" of future emissions and sinks as well as emissions and sinks occurring in the reporting year, these emission factors are not directly transferable to the 1605(b) program. For purposes of supporting the program, EPA developed a revised set of 1605(b) program emission factors that reflect emissions by gas and by year. Those emission factors provide incremental emissions for a baseline of landfilling and alternative scenarios of source reduction and recycling, although as noted above, savings calculated in this manner can no longer be directly counted under the revised 1605(b) reporting guidelines. Detailed reporting instructions and forms are available on DOE's website at: http://www.pi.energy.gov/enhancingGHGregistry/generalguidelines.html.

Exhibit 8-2
GHG Emissions for Source Reduction (MTCE/Ton)

	(a) Raw Materials Acquisition and Manufacturing		(b) Forest Carbon Sequestration		(c)	(d) Net Emissions (d = a + b + c)	
Material	Source Reduction Displaces Current Mix of Virgin and Recycled Inputs	Source Reduction Displaces Virgin Inputs	Source Reduction Displaces Current Mix of Virgin and Recycled Inputs	Source Reduction Displaces Virgin Inputs	Waste Management Emissions	Source Reduction Displaces Current Mix of Virgin and Recycled Inputs	Source Reduction Displaces Virgin Inputs
Aluminum Cans	-2.24	-4.27	0.00	0.00	0.00	-2.24	-4.27
Steel Cans	-0.87	-1.01	0.00	0.00	0.00	-0.87	-1.01
Copper Wire	-2.00	-2.02	0.00	0.00	0.00	-2.00	-2.02
Glass	-0.16	-0.18	0.00	0.00	0.00	-0.16	-0.18
HDPE	-0.49	-0.54	0.00	0.00	0.00	-0.49	-0.54
LDPE	-0.62	-0.64	0.00	0.00	0.00	-0.62	-0.64
PET	-0.57	-0.59	0.00	0.00	0.00	-0.57	-0.59
Corrugated Cardboard	-0.24	-0.23	-1.29	-1.98	0.00	-1.52	-2.21
Magazines/Third-class Mail	-0.46	-0.46	-1.90	-1.98	0.00	-2.36	-2.44
Newspaper	-0.52	-0.58	-0.80	-1.04	0.00	-1.33	-1.62
Office Paper	-0.28	-0.28	-1.90	-1.98	0.00	-2.18	-2.26
Phonebooks	-0.68	-0.68	-1.04	-1.04	0.00	-1.72	-1.72
Textbooks	-0.60	-0.60	-1.90	-1.98	0.00	-2.50	-2.58
Dimensional Lumber	-0.05	-0.05	-0.50	-0.50	0.00	-0.55	-0.55
Medium-density Fiberboard	-0.10	-0.10	-0.50	-0.50	0.00	-0.60	-0.60
Food Discards	NA	NA	NA	NA	NA	NA	NA
Yard Trimmings	NA	NA	NA	NA	NA	NA	NA
Mixed Paper							
Broad Definition	NA	NA	NA	NA	NA	NA	NA
Residential Definition	NA	NA	NA	NA	NA	NA	NA
Office Paper Definition	NA	NA	NA	NA	NA	NA	NA
Mixed Metals	NA	NA	NA	NA	NA	NA	NA
Mixed Plastics	NA	NA	NA	NA	NA	NA	NA
Mixed Recyclables	NA	NA	NA	NA	NA	NA	NA
Mixed Organics	NA	NA	NA	NA	NA	NA	NA
Mixed MSW (as disposed)	NA	NA	NA	NA	NA	NA	NA
Carpet	-1.09	-1.09	0.00	0.00	0.00	-1.09	-1.09
Personal Computers	-15.13	-15.13	0.00	0.00	0.00	-15.13	-15.13
Clay Bricks	-0.08	-0.08	0.00	0.00	0.00	-0.08	-0.08
Concrete	NA	NA	NA	NA	NA	NA	NA
Fly Ash	NA	NA	NA	NA	NA	NA	NA
Tires	-1.09	-1.09	0.00	0.00	0.00	-1.09	-1.09

Note that totals may not add due to rounding, and more digits may be displayed than are significant.
NA: Not applicable, or in the case of composting of paper, not analyzed.

Exhibit 8-3
GHG Emissions for Recycling (MTCE/Ton)

	Raw Materials Acquisition and Manufacturing (RMAM)		Recycled Input Credit[a]					
Material	(a) RMAM Emissions Not Included in Baseline (Current Mix of Inputs)	(b) Waste Generation Baseline	(c) Process Energy	(d) Transportation Energy	(e) Process Nonenergy	(f) Forest Carbon Sequestration	(g) Waste Management Emissions	(h) (h = b+c+d+e+f+g) Net Emissions
Aluminum Cans	2.24	0.00	-2.92	-0.12	-0.66	0.00	0.00	-3.70
Steel Cans	0.87	0.00	-0.48	-0.01	0.00	0.00	0.00	-0.49
Copper Wire	2.00	0.00	-1.33	-0.02	0.00	0.00	0.00	-1.34
Glass	0.16	0.00	-0.03	0.00	-0.04	0.00	0.00	-0.08
HDPE	0.49	0.00	-0.34	0.00	-0.04	0.00	0.00	-0.38
LDPE	0.62	0.00	-0.42	0.00	-0.04	0.00	0.00	-0.46
PET	0.57	0.00	-0.40	0.00	-0.02	0.00	0.00	-0.42
Corrugated Cardboard	0.24	0.00	0.00	-0.01	0.00	-0.83	0.00	-0.85
Magazines/Third-class Mail	0.46	0.00	0.00	0.00	0.00	-0.83	0.00	-0.84
Newspaper	0.52	0.00	-0.20	-0.01	0.00	-0.55	0.00	-0.76
Office Paper	0.28	0.00	0.06	0.00	0.00	-0.83	0.00	-0.78
Phonebooks	0.68	0.00	-0.17	0.00	0.00	-0.55	0.00	-0.72
Textbooks	0.60	0.00	-0.01	0.00	0.00	-0.83	0.00	-0.85
Dimensional Lumber	0.05	0.00	0.02	0.00	0.00	-0.69	0.00	-0.67
Medium-density Fiberboard	0.10	0.00	0.01	0.00	0.00	-0.69	0.00	-0.67
Food Discards	NA	NA	NA	NA	NA	NA	NA	NA
Yard Trimmings	NA	NA	NA	NA	NA	NA	NA	NA
Mixed Paper								
Broad Definition	0.29	0.00	-0.10	-0.03	0.00	-0.83	0.00	-0.96
Residential Definition	0.29	0.00	-0.10	-0.03	0.00	-0.83	0.00	-0.96
Office Paper Definition	0.88	0.00	-0.08	-0.02	0.00	-0.83	0.00	-0.93
Mixed Metals	NA	NA	-1.20	-0.04	-0.20	0.00	NA	-1.43
Mixed Plastics	NA	NA	-0.38	0.00	-0.03	0.00	NA	-0.41
Mixed Recyclables	NA	NA	-0.11	-0.01	-0.01	0.00	NA	-0.79
Mixed Organics	NA	NA	NA	NA	NA	NA	NA	NA
Mixed MSW (as disposed)	NA	NA	NA	NA	NA	NA	NA	NA
Carpet	1.09	0.00	-1.47	-0.02	-0.47	0.00	0.00	-1.96
Personal Computers	15.13	0.00	-0.41	-0.01	-0.20	0.00	0.00	-0.62
Clay Bricks	0.08	0.00	NA	NA	NA	NA	NA	NA
Concrete	NA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fly Ash	NA	0.00	-0.11	0.00	-0.12	0.00	0.00	-0.24
Tires[b]	1.09	0.00	-0.50	0.00	0.00	0.00	0.00	-0.50

Note that totals may not add due to rounding, and more digits may be displayed than are significant.

NA: Not applicable, or in the case of composting of paper, not analyzed.

[a] Material that is recycled after use is then substituted for virgin inputs in the production of new products. This credit represents the difference in emissions that results from using recycled inputs.

[a] Recycling of tires, as modeled in this analysis, consists only of retreading the tires.

Exhibit 8-4
GHG Emissions for Composting (MTCE/Ton)

	Raw Materials Acquisition and Manufacturing (RMAM)				
Material	(a) RMAM Emissions Not Included in Baseline[a]	(b) Waste Generation Baseline	(c) Transportation to Composting	(d) Soil Carbon Sequestration	(e) (e = b+c+d) Net Emissions (Postconsumer)
Aluminum Cans	2.24	0.00	NA	NA	NA
Steel Cans	0.87	0.00	NA	NA	NA
Copper Wire	2.00	0.00	NA	NA	NA
Glass	0.16	0.00	NA	NA	NA
HDPE	0.49	0.00	NA	NA	NA
LDPE	0.62	0.00	NA	NA	NA
PET	0.57	0.00	NA	NA	NA
Corrugated Cardboard	0.24	0.00	NA	NA	NA
Magazines/Third-class Mail	0.46	0.00	NA	NA	NA
Newspaper	0.52	0.00	NA	NA	NA
Office Paper	0.28	0.00	NA	NA	NA
Phonebooks	0.68	0.00	NA	NA	NA
Textbooks	0.60	0.00	NA	NA	NA
Dimensional Lumber	0.05	0.00	NA	NA	NA
Medium-density Fiberboard	0.10	0.00	NA	NA	NA
Food Discards	NA	0.00	0.01	-0.07	-0.05
Yard Trimmings	NA	0.00	0.01	-0.07	-0.05
Mixed Paper					
Broad Definition	0.29	0.00	NA	NA	NA
Residential Definition	0.29	0.00	NA	NA	NA
Office Paper Definition	0.88	0.00	NA	NA	NA
Mixed Metals	NA	0.00	NA	NA	NA
Mixed Plastics	NA	0.00	NA	NA	NA
Mixed Recyclables	NA	0.00	NA	NA	NA
Mixed Organics	NA	0.00	0.01	-0.07	-0.05
Mixed MSW (as disposed)	NA	NA	NA	NA	NA
Carpet	1.09	0.00	NA	NA	NA
Personal Computers	15.13	0.00	NA	NA	NA
Clay Bricks	0.08	0.00	NA	NA	NA
Concrete	NA	0.00	NA	NA	NA
Fly Ash	NA	0.00	NA	NA	NA
Tires	1.09	0.00	NA	NA	NA

Note that totals may not add due to rounding, and more digits may be displayed than are significant.

NA: Not applicable, or in the case of composting of paper, not analyzed.

[a] The value for mixed MSW is the weighted average of the RMAM emissions for those materials EPA studied.

Exhibit 8-5
GHG Emissions for Combustion (MTCE/Ton)

Values are for Mass Burn Facilities with National Average Rate of Ferrous Recovery.

	RMAM							
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h) (h = b+c+d+e+f+g)
Material	RMAM Emissions Not Included in Baseline[a]	Waste Generation Baseline	Transportation to Combustion	CO_2 from Combustion	N_2O from Combustion	Avoided Utility Emissions	Ferrous Recovery	Net Emissions (Postconsumer)
Aluminum Cans	2.24	0.00	0.01	0.00	0.00	0.01	0.00	0.02
Steel Cans	0.87	0.00	0.01	0.00	0.00	0.01	-0.43	-0.42
Copper Wire	2.00	0.00	0.01	0.00	0.00	0.01	0.00	0.01
Glass	0.16	0.00	0.01	0.00	0.00	0.01	0.00	0.01
HDPE	0.49	0.00	0.01	0.76	0.00	-0.52	0.00	0.25
LDPE	0.62	0.00	0.01	0.76	0.00	-0.52	0.00	0.25
PET	0.57	0.00	0.01	0.56	0.00	-0.27	0.00	0.30
Corrugated Cardboard	0.24	0.00	0.01	0.00	0.01	-0.19	0.00	-0.18
Magazines/Third-class Mail	0.46	0.00	0.01	0.00	0.01	-0.15	0.00	-0.13
Newspaper	0.52	0.00	0.01	0.00	0.01	-0.22	0.00	-0.20
Office Paper	0.28	0.00	0.01	0.00	0.01	-0.19	0.00	-0.17
Phonebooks	0.68	0.00	0.01	0.00	0.01	-0.22	0.00	-0.20
Textbooks	0.60	0.00	0.01	0.00	0.01	-0.19	0.00	-0.17
Dimensional Lumber	0.05	0.00	0.01	0.00	0.01	-0.23	0.00	-0.21
Medium-density Fiberboard	0.10	0.00	0.01	0.00	0.01	-0.23	0.00	-0.21
Food Discards	NA	0.00	0.01	0.00	0.01	-0.07	0.00	-0.05
Yard Trimmings	NA	0.00	0.01	0.00	0.01	-0.08	0.00	-0.06
Mixed Paper								
Broad Definition	0.29	0.00	0.01	0.00	0.01	-0.20	0.00	-0.18
Residential Definition	0.29	0.00	0.01	0.00	0.01	-0.19	0.00	-0.18
Office Paper Definition	0.88	0.00	0.01	0.00	0.01	-0.18	0.00	-0.16
Mixed Metals	NA	0.00	0.01	0.00	0.00	0.01	-0.30	-0.29
Mixed Plastics	NA	0.00	0.01	0.68	0.00	-0.42	0.00	0.27
Mixed Recyclables	NA	0.00	0.01	0.02	0.01	-0.18	-0.01	-0.17
Mixed Organics	NA	0.00	0.01	0.00	0.01	-0.07	0.00	-0.05
Mixed MSW (as disposed)	NA	0.00	0.01	0.10	0.01	-0.14	-0.01	-0.03
Carpet	1.09	0.00	0.01	0.47	0.00	-0.37	0.00	0.11
Personal Computers	15.13	0.00	0.01	0.10	0.00	-0.04	-0.12	-0.05
Clay Bricks	0.08	0.00	0.01	NA	NA	NA	NA	0.01
Concrete	NA	0.00	NA	NA	NA	NA	NA	NA
Fly Ash	NA	0.00	NA	NA	NA	NA	NA	NA
Tires	1.09	0.00	0.01	2.05	0.00	-1.98	-0.03	0.05

Note that totals may not add due to rounding, and more digits may be displayed than are significant.

NA: Not applicable, or in the case of composting of paper, not analyzed.

[a] The value for mixed MSW is the weighted average of the RMAM emissions for those materials EPA studied.

Exhibit 8-6
GHG Emissions for Landfilling (MTCE/Ton)[a]

Material	RMAM						
	(a) RMAM Emissions Not Included in Baseline[b]	(b) Waste Generation Baseline	(c) Transportation to Landfill	(d) Net Landfill CH_4	(e) Avoided Utility Emissions	(f) Landfill Carbon Sequestration	(g) (g=b+c+d+e+f) Net Emissions
Aluminum Cans	2.24	0.00	0.01	0.00	0.00	0.00	0.01
Steel Cans	0.87	0.00	0.01	0.00	0.00	0.00	0.01
Copper Wire	2.00	0.00	0.01	0.00	0.00	0.00	0.01
Glass	0.16	0.00	0.01	0.00	0.00	0.00	0.01
HDPE	0.49	0.00	0.01	0.00	0.00	0.00	0.01
LDPE	0.62	0.00	0.01	0.00	0.00	0.00	0.01
PET	0.57	0.00	0.01	0.00	0.00	0.00	0.01
Corrugated Cardboard	0.24	0.00	0.01	0.34	-0.02	-0.22	0.11
Magazines/Third-class Mail	0.46	0.00	0.01	0.14	-0.01	-0.22	-0.08
Newspaper	0.52	0.00	0.01	0.12	-0.01	-0.36	-0.24
Office Paper	0.28	0.00	0.01	0.60	-0.04	-0.04	0.53
Phonebooks	0.68	0.00	0.01	0.12	-0.01	-0.36	-0.24
Textbooks	0.60	0.00	0.01	0.60	-0.04	-0.04	0.53
Dimensional Lumber	0.05	0.00	0.01	0.18	-0.01	-0.31	-0.13
Medium-density Fiberboard	0.10	0.00	0.01	0.18	-0.01	-0.31	-0.13
Food Discards	NA	0.00	0.01	0.22	-0.01	-0.02	0.20
Yard Trimmings	NA	0.00	0.01	0.13	-0.01	-0.19	-0.06
Mixed Paper							
Broad Definition	0.29	0.00	0.01	0.33	-0.02	-0.22	0.09
Residential Definition	0.29	0.00	0.01	0.31	-0.02	-0.23	0.07
Office Paper Definition	0.88	0.00	0.01	0.32	-0.02	-0.18	0.13
Mixed Metals	NA	0.00	0.01	0.00	0.00	0.00	0.01
Mixed Plastics	NA	0.00	0.01	0.00	0.00	0.00	0.01
Mixed Recyclables	NA	0.00	0.01	0.26	-0.02	-0.21	0.04
Mixed Organics	NA	0.00	0.01	0.18	-0.01	-0.11	0.06
Mixed MSW (as disposed)	NA	0.00	0.01	0.29	-0.02	-0.17	0.12
Carpet	1.09	0.00	0.01	0.00	0.00	0.00	0.01
Personal Computers	15.13	0.00	0.01	0.00	0.00	0.00	0.01
Clay Bricks	0.08	0.00	0.01	0.00	0.00	0.00	0.01
Concrete	NA	0.00	0.01	0.00	0.00	0.00	0.01
Fly Ash	NA	0.00	0.01	0.00	0.00	0.00	0.01
Tires	1.09	0.00	0.01	0.00	0.00	0.00	0.01

Note that totals may not add due to rounding, and more digits may be displayed than are significant.

NA: Not applicable, or in the case of composting of paper, not analyzed.

[a] Values for landfill CH_4 and net emissions reflect projected national average CH4 recovery in year 2004.

[b] The value for mixed MSW is the weighted average of the RMAM emissions for those materials EPA studied.

Exhibit 8-7
Net GHG Emissions from Source Reduction and MSW Management Options (MTCE/Ton)

Material	Source Reduction[a]	Recycling	Composting	Combustion[b]	Landfilling[c]
Aluminum Cans	-2.24	-3.70	NA	0.02	0.01
Steel Cans	-0.87	-0.49	NA	-0.42	0.01
Copper Wire	-2.00	-1.34	NA	0.01	0.01
Glass	-0.16	-0.08	NA	0.01	0.01
HDPE	-0.49	-0.38	NA	0.25	0.01
LDPE	-0.62	-0.46	NA	0.25	0.01
PET	-0.57	-0.42	NA	0.30	0.01
Corrugated Cardboard	-1.52	-0.85	NA	-0.18	0.11
Magazines/Third-class Mail	-2.36	-0.84	NA	-0.13	-0.08
Newspaper	-1.33	-0.76	NA	-0.20	-0.24
Office Paper	-2.18	-0.78	NA	-0.17	0.53
Phonebooks	-1.72	-0.72	NA	-0.20	-0.24
Textbooks	-2.50	-0.85	NA	-0.17	0.53
Dimensional Lumber	-0.55	-0.67	NA	-0.21	-0.13
Medium-density Fiberboard	-0.60	-0.67	NA	-0.21	-0.13
Food Discards	NA	NA	-0.05	-0.05	0.20
Yard Trimmings	NA	NA	-0.05	-0.06	-0.06
Mixed Paper					
Broad Definition	NA	-0.96	NA	-0.18	0.09
Residential Definition	NA	-0.96	NA	-0.18	0.07
Office Paper Definition	NA	-0.93	NA	-0.16	0.13
Mixed Metals	NA	-1.43	NA	-0.29	0.01
Mixed Plastics	NA	-0.41	NA	0.27	0.01
Mixed Recyclables	NA	-0.79	NA	-0.17	0.04
Mixed Organics	NA	NA	-0.05	-0.05	0.06
Mixed MSW (as disposed)	NA	NA	NA	-0.03	0.12
Carpet	-1.09	-1.96	NA	0.11	0.01
Personal Computers	-15.13	-0.62	NA	-0.05	0.01
Clay Bricks	-0.08	NA	NA	NA	0.01
Concrete	NA	0.00	NA	NA	0.01
Fly Ash	NA	-0.24	NA	NA	0.01
Tires	-1.09	-0.50[d]	NA	0.05	0.01

Note that totals may not add due to rounding, and more digits may be displayed than are significant.

NA: Not applicable, or in the case of composting of paper, not analyzed.

[a] Source reduction assumes displacement of current mix of virgin and recycled inputs.

[b] Values are for mass burn facilities with a national average rate of ferrous recovery.

[c] Values reflect national average CH_4 recovery in year 2004.

[d] Recycling of tires, as modeled in this analysis, consists only of retreading the tires.

Exhibit 8-8
Net GHG Emissions of MSW Management Options Compared to Landfilling[a] (MTCE/Ton)

Material	Source Reduction Net Emissions Minus Landfilling Net Emissions		Recycling Net Emissions Minus Landfilling Net Emissions	Composting Net Emissions Minus Landfilling Net Emissions	Combustion[b] Net Emissions Minus Landfilling Net Emissions
	Current Mix of Inputs	100% Virgin Inputs			
Aluminum Cans	-2.26	-4.28	-3.71	NA	0.01
Steel Cans	-0.88	-1.02	-0.50	NA	-0.43
Copper Wire	-2.01	-2.03	-1.35	NA	0.00
Glass	-0.17	-0.19	-0.09	NA	0.00
HDPE	-0.50	-0.55	-0.39	NA	0.24
LDPE	-0.63	-0.65	-0.47	NA	0.24
PET	-0.58	-0.60	-0.43	NA	0.28
Corrugated Cardboard	-1.63	-2.32	-0.96	NA	-0.29
Magazines/Third-class Mail	-2.28	-2.36	-0.76	NA	-0.05
Newspaper	-1.09	-1.39	-0.52	NA	0.03
Office Paper	-2.71	-2.79	-1.31	NA	-0.70
Phonebooks	-1.49	-1.49	-0.49	NA	0.03
Textbooks	-3.03	-3.11	-1.38	NA	-0.70
Dimensional Lumber	-0.42	-0.42	-0.54	NA	-0.08
Medium-density Fiberboard	-0.47	-0.47	-0.54	NA	-0.08
Food Discards	NA	NA	NA	-0.25	-0.25
Yard Trimmings	NA	NA	NA	0.01	0.00
Mixed Paper					
Broad Definition	NA	NA	-1.06	NA	-0.27
Residential Definition	NA	NA	-1.03	NA	-0.25
Office Paper Definition	NA	NA	-1.06	NA	-0.29
Mixed Metals	NA	NA	-1.44	NA	-0.30
Mixed Plastics	NA	NA	-0.42	NA	0.26
Mixed Recyclables	NA	NA	-0.83	NA	-0.20
Mixed Organics	NA	NA	NA	-0.12	-0.12
Mixed MSW (as disposed)	NA	NA	NA	NA	-0.15
Carpet	-1.10	-1.10	-1.97	NA	0.10
Personal Computers	-15.14	-15.14	-0.63	NA	-0.06
Clay Bricks	-0.09	-0.09	-0.01	NA	-0.01
Concrete	-0.01	-0.01	-0.01	NA	-0.01
Fly Ash	-0.01	-0.01	-0.25	NA	-0.01
Tires	-1.10	-1.10	-0.51[c]	NA	0.04

Note that totals may not add due to rounding, and more digits may be displayed than are significant.

NA: Not applicable, or in the case of composting of paper, not analyzed.

[a] Values for landfilling reflect national average CH_4 recovery in year 2004.

[b] Values are for mass burn facilities with national average rate of ferrous recovery.

[c] Recycling of tires, as modeled in this analysis, consists only of retreading the tires.

* * * * *

A final note about the limitations of the GHG emission and energy consumption estimates presented in this report. EPA based its analysis on what was believed to be the best available data; where necessary, reasonable assumptions were made. The accuracy of the estimates is limited, however, by the use of these assumptions and limitations in the data sources, as discussed throughout this report. Where possible, the emission and energy factors reported here can be improved by substituting process- or site-specific data to increase the accuracy of the estimates. For example, a commercial firm with a large aluminum recycling program may have better data on the specific fuel mix of its source of aluminum and could thus calculate a more exact value for the emission factor. Despite the uncertainty in the emission and energy factors, they provide a reasonable first approximation of the GHG and energy impacts of solid waste management, and EPA believes that they provide a sound basis for evaluating voluntary actions to reduce GHG emissions and energy consumption in the waste management arena.