COMBUSTION

This document presents an overview of combustion as a waste management strategy in relation to the development of material-specific emission factors for EPA's Waste Reduction Model (WARM). Included are estimates of the net greenhouse gas (GHG) emissions from combustion of most of the materials considered in WARM and several categories of mixed waste.

1. A SUMMARY OF THE GHG IMPLICATIONS OF COMBUSTION

Combustion of municipal solid waste (MSW) results in emissions of CO_2 and N_2O. Note that CO_2 from combustion of biomass (such as paper products and yard trimmings) is not counted because it is biogenic (as explained in the Introduction & Overview chapter). WARM estimates emissions from combustion of MSW in waste-to-energy (WTE) facilities. WARM does not consider any recovery of materials from the MSW stream that may occur before MSW is delivered to the combustor.

In the United States, about 80 WTE facilities process more than 30 million tons of MSW annually (ERC, 2014). WTE facilities can be divided into three categories: (1) mass burn, (2) modular and (3) refuse-derived fuel (RDF). A mass burn facility generates electricity and/or steam from the combustion of mixed MSW. Most of the facilities (76 percent) employ mass burn technology. Modular WTE plants are generally smaller than mass burn plants, and are prefabricated off-site so that they can be assembled quickly where they are needed. Because of their similarity to mass burn facilities, modular facilities are treated as part of the mass burn category for the purposes of this analysis.

An RDF facility combusts MSW that has undergone varying degrees of processing, from simple removal of bulky and noncombustible items to more complex processes (such as shredding and material recovery) that result in a finely divided fuel. Processing MSW into RDF yields a more uniform fuel that has a higher heating value than that used by mass burn or modular WTE. MSW processing into RDF involves both manual and mechanical separation to remove materials such as glass and metals that have little or no fuel value. In the United States, approximately 14 facilities combust RDF (ERC, 2010).

This study analyzed the net GHG emissions from combustion of all individual and mixed waste streams in WARM at mass burn and RDF facilities, with the exception of asphalt concrete, drywall and fiberglass insulation. These three materials were excluded because EPA determined that they are not typically combusted at end of life. Note that **WARM incorporates only the emission factors for mass burn facilities**, due to (1) the relatively small number of RDF facilities in the United States and (2) the fact that the RDF emission factors are based on data from only one RDF facility.

Net emissions consist of (1) emissions from the transportation of waste to a combustion facility, (2) emissions of non-biogenic CO_2, and (3) emissions of N_2O minus (4) avoided GHG emissions from the electric utility sector and (5) avoided GHG emissions due to the recovery and recycling of ferrous metals at the combustor. There is some evidence that as combustor ash ages, it absorbs CO_2 from the atmosphere. However, EPA did not count absorbed CO_2 because the quantity is estimated to be less than 0.02 $MTCO_2E$ per ton of MSW combusted.[1] The results of this analysis for the materials contained in WARM and the explanations for each of these results are discussed in section 3.[2]

[1] Based on data provided by Dr. Jürgen Vehlow of the Institut für Technische Chemie in Karlsruhe, Germany, EPA estimated that the ash from one ton of MSW would absorb roughly 0.004 MTCE of CO_2.

[2] Note that Exhibit 1, Exhibit 2, and Exhibit 6 do not show mixed paper. Mixed paper is shown in the summary exhibit. The summary values for mixed paper are based on the proportions of the four paper types (newspaper,

2. CALCULATING THE GHG IMPACTS OF COMBUSTION

This study's general approach was to estimate (1) the gross emissions of CO_2 and N_2O from MSW combustion (including emissions from transportation of waste to the combustor and ash from the combustor to a landfill) and (2) the CO_2 emissions avoided because of displaced electric utility generation and decreased energy requirements for production processes using recycled inputs. A comprehensive evaluation would also consider the fate of carbon remaining in combustor ash. Depending on its chemical form, carbon may be aerobically degraded to CO_2, anaerobically degraded to CH_4, or remain in a relatively inert form and be stored. Unless the ash carbon is converted to CH_4 (which EPA considers unlikely), the effect on the net GHG emissions will be very small. To obtain an estimate of the *net* GHG emissions from MSW combustion, the GHG emissions avoided were subtracted from the direct GHG emissions. EPA estimated the net GHG emissions from waste combustion per ton of mixed MSW and per ton of each selected material in MSW. The remainder of this section describes how EPA developed these estimates.

2.1 EMISSIONS OF CO_2 FROM WTE FACILITIES

The carbon in MSW has two distinct origins: some of it is derived from sustainably harvested biomass (i.e., carbon in plant matter that was converted from CO_2 in the atmosphere through photosynthesis), and the remainder is from non-biomass sources, e.g., plastic and synthetic rubber derived from petroleum.

As explained in the Background and Overview chapter, WARM considers only CO_2 that derives from fossil sources and does not consider biogenic CO_2 emissions. Therefore, only CO_2 emissions from the combustion of non-biomass components of MSW—plastic, textiles and rubber—were counted. These components make up a relatively small share of total MSW, so only a small portion of the total CO_2 emissions from combustion are considered in WARM.

To estimate the non-biogenic carbon content of the plastics, textiles, rubber and leather contained in one ton of mixed MSW, EPA first establishes assumptions for the non-biogenic share of carbon in these materials. For plastics in products in MSW, EPA assumes that all carbon is non-biogenic carbon, because biogenic plastics likely make up a small but unknown portion of products. For rubber and leather products in MSW, EPA assumes that the non-biogenic share of carbon contained in clothing and footwear is 25 percent; this assumption is based on expert judgment. The non-biogenic share of carbon in containers, packaging, and other durables is 100 percent; and the non-biogenic share of carbon in other nondurables is 75 percent (EPA, 2010). For textile products in MSW, EPA assumes that the non-biogenic share of carbon is 55 percent (DeZan, 2000). EPA then calculates the non-biogenic carbon content of each of these material groups. For plastics in products in MSW, EPA uses the molecular formula of each resin type to assume that PET is 63 percent carbon; PVC is 38 percent carbon; polystyrene is 92 percent carbon; HDPE, LDPE, and polypropylene are 86 percent carbon; and a weighted average of all other resins is 66 percent carbon (by weight). Based on the amount of each plastic discarded in 2010 (EPA, 2014c), EPA calculates a weighted carbon content of 78 percent for plastics in mixed MSW. For rubber and leather products, EPA uses the weighted average carbon content of rubbers consumed in 2002 to estimate a carbon content of 85 percent (by weight) for rubber and leather products in mixed MSW. For textiles, EPA uses the average carbon content of the four main synthetic fiber types to estimate a carbon content of 70 percent (by weight) for textiles in mixed MSW. Next, using data from BioCycle's *The State of Garbage in America* (Van Haaren et al., 2010), EPA assumes

office paper, corrugated containers, and magazines/third-class mail) that make up the different "mixed paper" definitions.

that 7 percent of discards are combusted in the United States. Data from BioCycle is used instead of EPA's *Municipal Solid Waste Generation, Recycling, and Disposal in the United States: Facts and Figures* report (EPA, 2014c), because it is based off of direct reporting, and provides a more accurate representation of the amount of materials discarded at WTE facilities. Additionally, these data are also used in order to maintain consistency with the data source used in EPA's annual *Inventory of U.S. Greenhouse Gas Emissions and Sinks* report. Based on these assumptions, EPA estimates that there are 0.10 tons of non-biogenic carbon in the plastic, textiles, rubber and leather contained in one ton of mixed MSW (EPA, 2014c; Van Haaren et al., 2010).

The 10 percent non-biomass carbon content of mixed MSW was then converted to units of $MTCO_2E$ per short ton of mixed MSW combusted. The resulting value for mixed MSW is shown in Exhibit 1. Note that if EPA had used a best-case assumption for textiles (i.e., assuming that they have no petrochemical-based fibers), the resulting value for mixed MSW would have been slightly lower. The values for CO_2 emissions are shown in column (b) of Exhibit 1.

Exhibit 1: Gross GHG Emissions from MSW Combustion ($MTCO_2E$/Short Ton of Material Combusted)

(a) Product/Material	(b) Combustion CO_2 Emissions From Non-Biomass per Short Ton Combusted	(c) Combustion N_2O Emissions per Short Ton Combusted	(d) Transportation CO_2 Emissions per Short Ton Combusted	(e) Gross GHG Emissions per Short Ton Combusted (e = b + c + d)
Aluminum Cans	–	–	0.03	0.03
Aluminum Ingot	–	–	0.03	0.03
Steel Cans	–	–	0.03	0.03
Copper Wire	–	–	0.03	0.03
Glass	–	–	0.03	0.03
HDPE	2.79	–	0.03	2.82
LDPE	2.79	–	0.03	2.82
PET	2.04	–	0.03	2.06
LLDPE	2.79	–	0.03	2.82
PP	2.79	–	0.03	2.82
PS	3.01	–	0.03	3.04
PVC	1.25	–	0.03	1.28
PLA	–	–	0.03	0.03
Corrugated Containers	–	0.04	0.03	0.06
Magazines/Third-Class Mail	–	0.04	0.03	0.06
Newspaper	–	0.04	0.03	0.06
Office Paper	–	0.04	0.03	0.06
Phone Books[a]	–	0.04	0.03	0.06
Textbooks[a]	–	0.04	0.03	0.06
Dimensional Lumber	–	0.04	0.03	0.06
Medium-Density Fiberboard	–	0.04	0.03	0.06
Food Waste	–	0.04	0.03	0.06
Food Waste (meat only)	–	0.04	0.03	0.06
Food Waste (non-meat)	–	0.04	0.03	0.06
Beef	–	0.04	0.03	0.06
Poultry	–	0.04	0.03	0.06
Grains	–	0.04	0.03	0.06
Bread	–	0.04	0.03	0.06
Fruits and Vegetables	–	0.04	0.03	0.06
Dairy Products	–	0.04	0.03	0.06
Yard Trimmings	–	0.04	0.03	0.06
Grass	–	0.04	0.03	0.06

(a) Product/Material	(b) Combustion CO_2 Emissions From Non-Biomass per Short Ton Combusted	(c) Combustion N_2O Emissions per Short Ton Combusted	(d) Transportation CO_2 Emissions per Short Ton Combusted	(e) Gross GHG Emissions per Short Ton Combusted (e = b + c + d)
Leaves	–	0.04	0.03	0.06
Branches	–	0.04	0.03	0.06
Mixed Paper (general)	–	0.04	0.03	0.06
Mixed Paper (primarily residential)	–	0.04	0.03	0.06
Mixed Paper (primarily from offices)	–	0.04	0.03	0.06
Mixed Metals	–	–	0.03	0.03
Mixed Plastics	2.33	–	0.03	2.36
Mixed Recyclables	0.07	0.03	0.03	0.13
Mixed Organics	–	0.04	0.03	0.06
Mixed MSW	0.36	0.04	0.03	0.43
Carpet	1.67	–	0.03	1.69
Personal Computers	0.38	–	0.03	0.41
Clay Bricks	NA	NA	NA	NA
Concrete	NA	NA	NA	NA
Fly Ash	NA	NA	NA	NA
Tires	2.20	–	0.03	2.22
Asphalt Concrete	NA	NA	NA	NA
Asphalt Shingles	0.65	0.04	0.03	0.72
Drywall	NA	NA	NA	NA
Fiberglass Insulation	NA	NA	NA	NA
Vinyl Flooring	0.28	–	0.03	0.31
Wood Flooring	–	0.04	0.05	0.08

– = Zero emissions.

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

[a] The values for phone books and textbooks are proxies, based on newspaper and office paper, respectively.

2.2 EMISSIONS OF N_2O FROM WTE FACILITIES

Studies compiled by the Intergovernmental Panel on Climate Change (IPCC) show that MSW combustion results in measurable emissions of N_2O, a GHG with a global warming potential (GWP) 298 times that of CO_2 (EPA, 2014b; IPCC, 2007; IPCC, 2006). The IPCC compiled reported ranges of N_2O emissions, per metric ton of waste combusted, from six classifications of MSW combustors. This study averaged the midpoints of each range and converted the units to $MTCO_2E$ of N_2O per ton of MSW. The resulting estimate is 0.04 $MTCO_2E$ of N_2O emissions per ton of mixed MSW combusted. Because the IPCC did not report N_2O values for combustion of individual components of MSW, EPA used the 0.04 value not only for mixed MSW, but also as a proxy for all components of MSW, except for aluminum cans, steel cans, glass, HDPE, LDPE and PET. This exception was made because at the relatively low combustion temperatures found in MSW combustors, most of the nitrogen in N_2O emissions is derived from the waste, not from the combustion air. Because aluminum and steel cans, glass, and plastics do not contain nitrogen, EPA concluded that running these materials through an MSW combustor would not result in N_2O emissions.

2.3 EMISSIONS OF CO_2 FROM TRANSPORTATION OF WASTE AND ASH

The combustion emission factors also include CO_2 emissions from the transportation of waste and the subsequent transportation of the residual waste ash to the landfill. For the CO_2 emissions from transporting waste to the combustion facility, and ash from the combustion facility to a landfill, EPA uses an estimate for transporting mixed MSW developed by FAL (1994). Transportation of any individual material in MSW is assumed to use the same amount of energy as transportation of mixed MSW.

2.4 ESTIMATING UTILITY CO_2 EMISSIONS AVOIDED

Most WTE plants in the United States produce electricity. Only a few cogenerate electricity and steam. In this analysis, EPA assumes that the energy recovered with MSW combustion would be in the form of electricity, with the exception of two materials that are not assumed to be combusted at WTE plants. For tires, the avoided utility CO_2 emissions per ton of tires combusted is based on the weighted average of three tire combustion pathways: combustion at cement kilns, power plants, and pulp and paper mills. For asphalt shingles, the avoided utility CO_2 emissions per ton of shingles combusted is equal to the amount of avoided refinery gas combusted at cement kilns where asphalt shingles are combusted. The avoided utility CO_2 emissions analysis is shown in Exhibit 2. EPA uses three data elements to estimate the avoided electric utility CO_2 emissions associated with combustion of waste in a WTE plant: (1) the energy content of mixed MSW and of each separate waste material considered, (2) the combustion system efficiency in converting energy in MSW to delivered electricity, and (3) the electric utility CO_2 emissions avoided per kilowatt-hour (kWh) of electricity delivered by WTE plants.

Exhibit 2: Avoided Utility GHG Emissions from Combustion at WTE Facilities

(a) Material Combusted	(b) Energy Content (Million Btu Per Ton)	(c) Mass Burn Combustion System Efficiency (%)	(d) RDF Combus-tion System Efficiency (%)	(e) Emission Factor for Utility-Generated Electricity[a] ($MTCO_2E$/ Million Btu of Electricity Delivered)	(f) Avoided Utility GHG Emissions per Ton Combusted at Mass Burn Facilities[a] ($MTCO_2E$) (f = b × c × e)	(g) Avoided Utility CO_2 per Ton Combusted at RDF Facilities ($MTCO_2E$) (g = b × d × e)
Aluminum Cans	-0.67[b]	17.8%	16.3%	0.22	-0.03	-0.02
Aluminum Ingot	-0.7	17.8%	16.3%	0.22	-0.03	-0.02
Steel Cans	-0.42[b]	17.8%	16.3%	0.22	-0.02	-0.01
Copper Wire	-0.55[c]	17.8%	16.3%	0.22	-0.02	-0.02
Glass	-0.47[b]	17.8%	16.3%	0.22	-0.02	-0.02
HDPE	40.0[d]	17.8%	16.3%	0.22	1.55	1.42
LDPE	39.8[d]	17.8%	16.3%	0.22	1.55	1.41
PET	21.2	17.8%	16.3%	0.22	0.82	0.75
LLDPE	39.9	17.8%	16.3%	0.22	1.55	1.42
PP	39.9	17.8%	16.3%	0.22	1.55	1.42
PS	36.0	17.8%	16.3%	0.22	1.40	1.28
PVC	15.8	17.8%	16.3%	0.22	0.61	0.56
PLA	16.7	17.8%	16.3%	0.22	0.65	0.59
Corrugated Containers	14.1[d]	17.8%	16.3%	0.22	0.55	0.50
Magazines/Third-Class Mail	10.5[d]	17.8%	16.3%	0.22	0.41	0.37
Newspaper	15.9[d]	17.8%	16.3%	0.22	0.62	0.56
Office Paper	13.6[d]	17.8%	16.3%	0.22	0.53	0.48
Phone Books	15.9[d]	17.8%	16.3%	0.22	0.62	0.56
Textbooks	13.6[d]	17.8%	16.3%	0.22	0.53	0.48
Dimensional Lumber	16.6[f]	17.8%	16.3%	0.22	0.65	0.59

(a) Material Combusted	(b) Energy Content (Million Btu Per Ton)	(c) Mass Burn Combustion System Efficiency (%)	(d) RDF Combus-tion System Efficiency (%)	(e) Emission Factor for Utility-Generated Electricity[a] ($MTCO_2E$/ Million Btu of Electricity Delivered)	(f) Avoided Utility GHG Emissions per Ton Combusted at Mass Burn Facilities[a] ($MTCO_2E$) (f = b × c × e)	(g) Avoided Utility CO_2 per Ton Combusted at RDF Facilities ($MTCO_2E$) (g = b × d × e)
Medium-Density Fiberboard	16.6[f]	17.8%	16.3%	0.22	0.65	0.59
Food Waste	4.7[d]	17.8%	16.3%	0.22	0.18	0.17
Food Waste (meat only)	4.7[d]	17.8%	16.3%	0.22	0.18	0.17
Food Waste (non-meat)	4.7[d]	17.8%	16.3%	0.22	0.18	0.17
Beef	4.7[d]	17.8%	16.3%	0.22	0.18	0.17
Poultry	4.7[d]	17.8%	16.3%	0.22	0.18	0.17
Grains	4.7[d]	17.8%	16.3%	0.22	0.18	0.17
Bread	4.7[d]	17.8%	16.3%	0.22	0.18	0.17
Fruits and Vegetables	4.7[d]	17.8%	16.3%	0.22	0.18	0.17
Dairy Products	4.7[d]	17.8%	16.3%	0.22	0.18	0.17
Yard Trimmings	5.6[g]	17.8%	16.3%	0.22	0.22	0.20
Grass	5.6[g]	17.8%	16.3%	0.22	0.22	0.20
Leaves	5.6[g]	17.8%	16.3%	0.22	0.22	0.20
Branches	5.6[g]	17.8%	16.3%	0.22	0.22	0.20
Mixed Paper (general)	NA	17.8%	16.3%	0.22	0.55	NA
Mixed Paper (primarily residential)	NA	17.8%	16.3%	0.22	0.55	NA
Mixed Paper (primarily from offices)	NA	17.8%	16.3%	0.22	0.51	NA
Mixed Metals	NA	17.8%	16.3%	0.22	-0.02	NA
Mixed Plastics	NA	17.8%	16.3%	0.22	1.11	NA
Mixed Recyclables	NA	17.8%	16.3%	0.22	0.51	NA
Mixed Organics	NA	17.8%	16.3%	0.22	0.20	NA
Mixed MSW	10.0[h]	17.8%	16.3%	0.22	0.39	0.35
Carpet	15.2[i]	17.8%	16.3%	0.22	0.59	0.54
Personal Computers	3.1[j]	17.8%	16.3%	0.22	0.12	0.11
Clay Bricks	NA	NA	NA	NA	NA	NA
Concrete	NA	NA	NA	NA	NA	NA
Fly Ash	NA	NA	NA	NA	NA	NA
Tires	27.8[k]	NA	NA	NA	1.57	1.57
Asphalt Concrete	NA	NA	NA	NA	NA	NA
Asphalt Shingles	8.8	NA[l]	NA[l]	NA[l]	1.05[m]	1.05[m]
Drywall	NA	NA	NA	NA	NA	NA
Fiberglass Insulation	NA	NA	NA	NA	NA	NA
Vinyl Flooring	15.8	17.8%	16.3%	0.22	0.61	0.56

(a) Material Combusted	(b) Energy Content (Million Btu Per Ton)	(c) Mass Burn Combustion System Efficiency (%)	(d) RDF Combus-tion System Efficiency (%)	(e) Emission Factor for Utility-Generated Electricity[a] ($MTCO_2E$/ Million Btu of Electricity Delivered)	(f) Avoided Utility GHG Emissions per Ton Combusted at Mass Burn Facilities[a] ($MTCO_2E$) (f = b × c × e)	(g) Avoided Utility CO_2 per Ton Combusted at RDF Facilities ($MTCO_2E$) (g = b × d × e)
Wood Flooring	18.0[n]	21.5%[o]	16.3%	0.22	0.85	0.64

NA = Not applicable.
Note that totals may not add due to rounding, and more digits may be displayed than are significant.
[a] The values in this column are based on national average emissions from utility-generated electricity. The Excel version of WARM also allows users to choose region-specific utility-generated factors, which are contained in Exhibit 4.
[b] EPA developed these estimates based on data on the specific heat of aluminum, steel and glass and calculated the energy required to raise the temperature of aluminum, steel and glass from ambient temperature to the temperature found in a combustor (about 750° Celsius), based on Incropera and DeWitt (1990).
[c] Average of aluminum and steel.
[d] Source: EPA (1995). "Magazines" used as proxy for magazines/third-class mail; "mixed paper" used as a proxy for the value for office paper and textbooks; "newspapers" used as a proxy for phone books.
[e] Source: Gaines and Stodolsky (1993).
[f] EPA used the higher end of the MMBtu factor for basswood from the USDA-FS. Basswood is a relatively soft wood, so its high-end MMBtu content should be similar to an average factor for all wood types (Fons et al., 1962).
[g] Proctor and Redfern, Ltd. and ORTECH International (1993).
[h] Source: IWSA and American Ref-Fuel (personal communication, October 28, 1997). Mixed MSW represents the entire waste stream as disposed of.
[i] Source: Realff, M. (2010).
[j] Source: FAL (2002b).
[k] Tires used as tire-derived fuel substitute for coal in cement kilns and electric utilities; used as a substitute for natural gas in pulp and paper facilities. Therefore, columns (d) through (h) are a weighted average of multiple tire combustion pathways, and are not calculated in the same manner as the other materials and products in the table.
[l] The avoided utility GHG emissions are assumed to equal avoided cement kiln refinery gas combustion, so this factor is not used.
[m] Assumes avoided cement kiln refinery gas combustion.
[n] Bergman and Bowe (2008), Table 3, p. 454. Note that this is in good agreement with values already in WARM for lumber and medium-density fiberboard.
[o] Based on average heat rate of U.S. dedicated biomass electricity plants.

2.4.1 Energy Content

The energy content of each of the combustible materials in WARM is contained in column (b) of Exhibit 2. For the energy content of mixed MSW, EPA used a value of 10.0 million Btu (MMBtu) per short ton of mixed MSW combusted, which is a value commonly used in the WTE industry (IWSA and American Ref-Fuel, 1997). This estimate is within the range of values (9.0 to 13.0 MMBtu per ton) reported by FAL (1994) and is slightly higher than the 9.6 MMBtu per ton value reported in EPA's *MSW Fact Book* (EPA, 1995). For the energy content of RDF, a value of 11.4 MMBtu per ton of RDF combusted was used (Harrington 1997). This estimate is within the range of values (9.6 to 12.8 MMBtu per ton) reported by the DOE's National Renewable Energy Laboratory (NREL, 1992). For the energy content of specific materials in MSW, EPA consulted three sources: (1) EPA's *MSW Fact Book* (1995), a compilation of data from primary sources, (2) a report by Environment Canada (Procter and Redfern, Ltd. and ORTECH International, 1993), and (3) a report by Argonne National Laboratories (Gaines and Stodolsky, 1993). EPA assumes that the energy contents reported in the first two of these sources were for materials with moisture contents typically found for the materials in MSW (the sources imply this but do not explicitly state it). The Argonne study reports energy content on a dry weight basis.

2.4.2 Combustion System Efficiency

To estimate the combustion system efficiency of mass burn plants, EPA uses a net value of 550 kWh generated by mass burn plants per ton of mixed MSW combusted (Zannes, M. 1997).

To estimate the combustion system efficiency of RDF plants, EPA evaluated three sources: (1) data supplied by an RDF processing facility located in Newport, MN (Harrington, 1997); (2) the Integrated Waste Services Association report, *The 2000 Waste-to-Energy Directory: Year 2000* (IWSA, 2000); and (3) the National Renewable Energy Laboratory (NREL, 1992). EPA uses the Newport Processing Facility's reported net value of 572 kWh generated per ton of RDF for two reasons. First, this value is within the range of values reported by the other sources. Second, the Newport Processing Facility provides a complete set of data for evaluating the overall system efficiency of an RDF plant. The net energy value reported accounts for the estimated energy required to process MSW into RDF and the estimated energy consumed by the RDF combustion facility. The dataset includes estimates on the composition and amount of MSW delivered to the processing facility, as well as estimates for the heat value of RDF, the amount of energy required to process MSW into RDF, and the amount of energy used to operate the RDF facility.

Next, EPA considers losses in transmission and distribution of electricity specific to WTE combustion facilities. The U.S. average transmission and distribution ("line") loss rate is about 9 percent, although for some facilities or cities, this rate may be lower. According to IWSA and American Ref-Fuel (1997), this rate could be as low as 4 percent. IWSA supports a 5-percent line loss rate, and for purposes of this analysis, we assume this value. Using the 5-percent loss rate, EPA estimates that 523 kWh are delivered per ton of waste combusted at mass burn facilities, and 544 kWh are delivered per ton of waste input at RDF facilities.

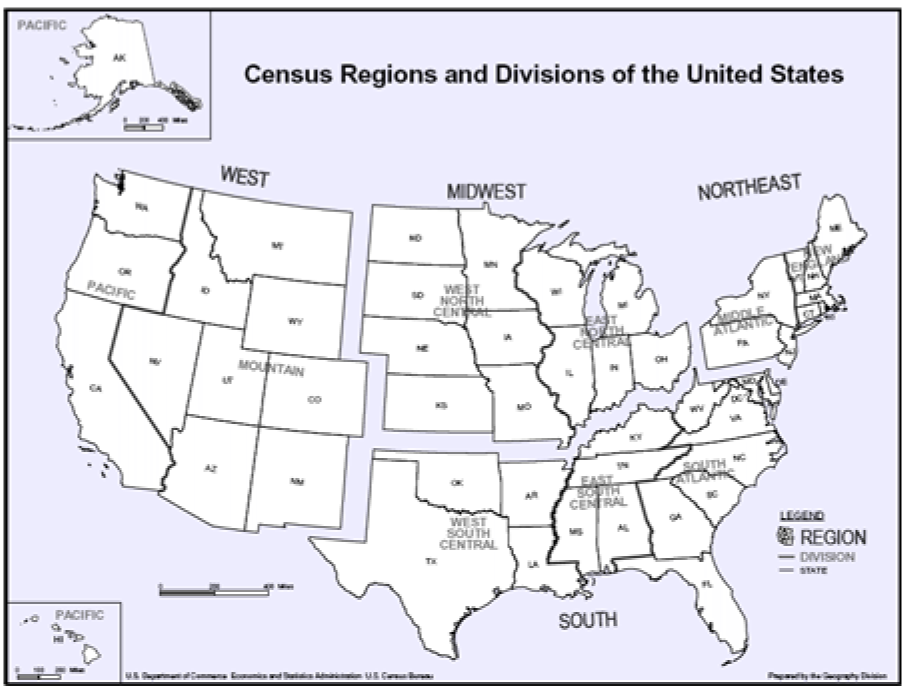
EPA then uses the value for the delivered kWh per ton of waste combusted to derive the implicit combustion system efficiency (i.e., the percentage of energy in the waste that is ultimately delivered in the form of electricity). To determine this efficiency, we estimate the MMBtu of MSW needed to deliver 1 kWh of electricity. EPA divides the MMBtu per ton of waste by the delivered kWh per ton of waste to obtain the MMBtu of waste per delivered kWh. The result is 0.0191 MMBtu per kWh for mass burn and 0.0210 MMBtu per kWh for RDF. The physical constant for the energy in 1 kWh (0.0034 MMBtu) is then divided by the MMBtu of MSW and RDF needed to deliver 1 kWh, to estimate the total system efficiency at 17.8 percent for mass burn and 16.3 percent for RDF (see Exhibit 2, columns (d) and (e)). Note that the total system efficiency is the efficiency of translating the energy content of the fuel into the energy content of delivered electricity. The estimated system efficiencies of 17.8 and 16.3 percent reflect losses in (1) converting energy in the fuel into steam, (2) converting energy in steam into electricity, and (3) delivering electricity.

2.4.3 Electric Utility Carbon Emissions Avoided

To estimate the avoided utility GHG emissions from waste combustion, EPA uses "non-baseload" emission factors from EPA's Emissions and Generation Resource Integrated Database (eGRID). EPA made the decision to use non-baseload factors rather than a national average of only fossil-fuel plants[3] because the non-baseload emission rates provide a more accurate estimate of the marginal emissions rate. The non-baseload rates scale emissions from generating units based on their capacity factor. Plants that run at more than 80 percent capacity are considered “baseload” generation and not included in the “non-baseload” emission factor; a share of generation from plants that run between 80 percent and 20 percent capacity is included in the emission factor based on a “linear relationship,” and all plants with capacity factors below 20 percent are included (E.H. Pechan & Associates, 2006).

In order to capture the regional differences in the emissions rate due to the variation in sources of electricity generation, WARM first uses state-level eGRID non-baseload emission factors and aggregates them into weighted average regional emission factors based on fossil-fuel-only state electricity generation. The geographic regions are based on U.S. Census Bureau-designated areas. Exhibit 3 contains a map, prepared by the U.S. Census Bureau, of the nine regions. Exhibit 4 shows the national average eGRID emission factor and the factors for each of the nine geographic regions. In addition to the calculated regional non-baseload emission factors, EPA also utilizes eGRID’s national non-baseload emission factor to represent the national average non-baseload avoided utility emission factor. The resulting non-baseload regional and national average estimates for utility carbon emissions avoided for each material at mass burn facilities are shown in Exhibit 5. Columns (g) and (h), respectively, of Exhibit 2 show the national average estimates for mass burn and RDF facilities.

Exhibit 3: Electric Utility Regions Used in WARM



Source: U.S. Census Bureau (2009).

[3] While coal accounts for 48 percent of U.S. primary energy consumption—and 70 percent of fossil-fuel consumption—in the electricity sector, these plants may serve as baseload power with marginal changes in electricity supply met by natural gas plants in some areas (EIA, 2010). Natural gas plants have a much lower emissions rate than the coal-dominated national average of fossil-fuel plants.

Exhibit 4: Avoided Utility Emission Factors by Region

Region	Emission Factors for Utility-Generated Electricity[a] ($MTCO_2E$/Million Btu of Electricity Delivered)
National Average	0.218
Pacific	0.145
Mountain	0.227
West-North Central	0.296
West-South Central	0.178
East-North Central	0.280
East-South Central	0.250
New England	0.162
Middle Atlantic	0.214
South Atlantic	0.230

[a] Includes transmission and distributions losses, which are assumed to be 7% (EIA, 2012).

Exhibit 5: Avoided Utility GHG Emissions at Mass Burn Facilities by Region ($MTCO_2E$/Short Ton of Material Combusted)

Material Combusted	National Average	Pacific	Mount-ain	West-North Central	West-South Central	East-North Central	East-South Central	New England	Middle Atlantic	South Atlantic
Aluminum Cans	-0.03	-0.02	-0.03	-0.04	-0.02	-0.03	-0.03	-0.02	-0.03	-0.03
Aluminum Ingot	-0.03	-0.02	-0.03	-0.04	-0.02	-0.03	-0.03	-0.02	-0.03	-0.03
Steel Cans	-0.02	-0.01	-0.02	-0.02	-0.01	-0.02	-0.02	-0.01	-0.02	-0.02
Copper Wire	-0.02	-0.01	-0.02	-0.03	-0.02	-0.03	-0.02	-0.02	-0.02	-0.02
Glass	-0.02	-0.01	-0.02	-0.02	-0.01	-0.02	-0.02	-0.01	-0.02	-0.02
HDPE	1.55	1.03	1.62	2.11	1.27	2.00	1.78	1.15	1.53	1.64
LDPE	1.55	1.03	1.61	2.10	1.26	1.99	1.77	1.14	1.52	1.63
PET	0.82	0.55	0.86	1.12	0.67	1.06	0.95	0.61	0.81	0.87
LLDPE	1.55	1.03	1.62	2.11	1.27	1.99	1.78	1.15	1.52	1.63
PP	1.55	1.03	1.62	2.11	1.27	1.99	1.78	1.15	1.52	1.63
PS	1.40	0.93	1.46	1.90	1.14	1.80	1.61	1.04	1.37	1.47
PVC	0.61	0.41	0.64	0.83	0.50	0.79	0.70	0.45	0.60	0.65
PLA	0.65	0.43	0.68	0.88	0.53	0.84	0.75	0.48	0.64	0.69
Corrugated Containers	0.55	0.36	0.57	0.74	0.45	0.70	0.63	0.41	0.54	0.58
Magazines/Third-Class Mail	0.41	0.27	0.43	0.56	0.33	0.53	0.47	0.30	0.40	0.43
Newspaper	0.62	0.41	0.64	0.84	0.50	0.79	0.71	0.46	0.61	0.65
Office Paper	0.53	0.35	0.55	0.72	0.43	0.68	0.61	0.39	0.52	0.56
Phone Books	0.62	0.41	0.64	0.84	0.50	0.79	0.71	0.46	0.61	0.65
Textbooks	0.53	0.35	0.55	0.72	0.43	0.68	0.61	0.39	0.52	0.56
Dimensional Lumber	0.65	0.43	0.67	0.88	0.53	0.83	0.74	0.48	0.63	0.68
Medium-Density Fiberboard	0.65	0.43	0.67	0.88	0.53	0.83	0.74	0.48	0.63	0.68
Food Waste	0.18	0.12	0.19	0.25	0.15	0.24	0.21	0.14	0.18	0.19
Food Waste (meat only)	0.18	0.12	0.19	0.25	0.15	0.24	0.21	0.14	0.18	0.19
Food Waste (non-meat)	0.18	0.12	0.19	0.25	0.15	0.24	0.21	0.14	0.18	0.19
Beef	0.18	0.12	0.19	0.25	0.15	0.24	0.21	0.14	0.18	0.19
Poultry	0.18	0.12	0.19	0.25	0.15	0.24	0.21	0.14	0.18	0.19
Grains	0.18	0.12	0.19	0.25	0.15	0.24	0.21	0.14	0.18	0.19
Bread	0.18	0.12	0.19	0.25	0.15	0.24	0.21	0.14	0.18	0.19

Material Combusted	National Average	Pacific	Mount-ain	West-North Central	West-South Central	East-North Central	East-South Central	New England	Middle Atlantic	South Atlantic
Fruits and Vegetables	0.18	0.12	0.19	0.25	0.15	0.24	0.21	0.14	0.18	0.19
Dairy Products	0.18	0.12	0.19	0.25	0.15	0.24	0.21	0.14	0.18	0.19
Yard Trimmings	0.22	0.14	0.23	0.30	0.18	0.28	0.25	0.16	0.21	0.23
Mixed MSW	0.39	0.26	0.41	0.53	0.32	0.50	0.45	0.29	0.38	0.41
Carpet	0.59	0.39	0.62	0.80	0.48	0.76	0.68	0.44	0.58	0.62
Personal Computers	0.12	0.08	0.12	0.16	0.10	0.15	0.14	0.09	0.12	0.13
Tires[a]	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57
Asphalt Shingles[b]	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05
Vinyl Flooring	0.61	0.41	0.64	0.83	0.50	0.79	0.70	0.45	0.60	0.65
Wood Flooring	0.85	0.56	0.88	1.15	0.69	1.09	0.97	0.63	0.83	0.89

Note that the "National Average" column is also represented in column (g) of Exhibit 2.

[a] Assumes weighted average avoided utility GHG emissions for multiple tire combustion pathways.

[b] Assumes avoided cement kiln refinery gas combustion.

2.5 AVOIDED CO_2 EMISSIONS DUE TO STEEL RECYCLING

WARM estimates the avoided CO_2 emissions from increased steel recycling made possible by steel recovery from WTE plants for steel cans, mixed MSW, personal computers and tires. Most MSW combusted with energy recovery in the United States is combusted at WTE plants that recover ferrous metals (e.g., iron and steel).[4] Note that EPA does not credit increased recycling of nonferrous materials due to a lack of data on the proportions of those materials being recovered. Therefore, the result tends to overestimate net GHG emissions from combustion.

For mixed MSW, EPA estimates the amount of steel recovered per ton of mixed MSW combusted, based on (1) the amount of MSW combusted in the United States, and (2) the amount of steel recovered, post-combustion. Ferrous metals are recovered at approximately 98 percent of WTE facilities in the United States (Bahor, 2010) and at five RDF processing facilities that do not generate power on-site. These facilities recovered a total of nearly 706,000 short tons per year of ferrous metals in 2004 (IWSA, 2004). By dividing 706,000 short tons (total U.S. steel recovery at combustors) by total U.S. combustion of MSW, which is 28.5 million tons (Van Haaren al., 2010), EPA estimates that 0.02 short tons of steel are recovered per short ton of mixed MSW combusted (as a national average).

For steel cans, EPA first estimates the national average proportion of steel cans entering WTE plants that would be recovered. As noted above, approximately 98 percent of MSW destined for combustion goes to facilities with a ferrous recovery system. At these plants, approximately 90 percent of steel is recovered (Bahor, 2010). EPA multiplies these percentages to estimate the weight of steel cans recovered per ton of MSW combusted—about 0.88 tons recovered per ton combusted.

[4] EPA did not consider any recovery of materials from the MSW stream that might occur before MSW is delivered to the combustor. EPA considered such prior recovery to be unrelated to the combustion operation—unlike the recovery of steel from combustor ash, an activity that is an integral part of the operation of many combustors.

Finally, to estimate the avoided CO_2 emissions due to increased recycling of steel, EPA multiplies (1) the weight of steel recovered by (2) the avoided CO_2 emissions per ton of steel recovered. The estimated avoided CO_2 emissions results are in column (d) of Exhibit 6. For more information on the GHG benefits of recycling, see the Recycling and Metals chapters.

Exhibit 6: Avoided GHG Emissions Due to Increased Steel Recovery from MSW at WTE Facilities

(a) Material Combusted	(b) Short Tons of Steel Recovered per Short Ton of Waste Combusted (Short Tons)	(c) Avoided CO_2 Emissions per Short Ton of Steel Recovered ($MTCO_2E$/Short Ton)	(d) Avoided CO_2 Emissions per Short Ton of Waste Combusted ($MTCO_2E$/Short Ton)[a]
Aluminum Cans	–	–	–
Aluminum Ingot	–	–	–
Steel Cans	0.88	1.81	-1.60
Copper Wire	–	–	–
Glass	–	–	–
HDPE	–	–	–
LDPE	–	–	–
PET	–	–	–
LLDPE	–	–	–
PP	–	–	–
PS	–	–	–
PVC	–	–	–
PLA	–	–	–
Corrugated Containers	–	–	–
Magazines/Third-Class Mail	–	–	–
Newspaper	–	–	–
Office Paper	–	–	–
Phone Books	–	–	–
Textbooks	–	–	–
Dimensional Lumber	–	–	–
Medium-Density Fiberboard	–	–	–
Food Waste	–	–	–
Food Waste (meat only)	–	–	–
Food Waste (non-meat)	–	–	–
Beef	–	–	–
Poultry	–	–	–
Grains	–	–	–
Bread	–	–	–
Fruits and Vegetables	–	–	–
Dairy Products	–	–	–
Yard Trimmings	–	–	–
Mixed Paper (general)	–	–	–
Mixed Paper (primarily residential)	–	–	–
Mixed Paper (primarily from offices)	–	–	–
Mixed Metals	–	–	–
Mixed Plastics	–	–	–
Mixed Recyclables	–	–	–
Mixed Organics	–	–	–
Mixed MSW	0.03	1.81	-0.05
Carpet	–	–	–
Personal Computers	0.25	1.81	-0.46

(a) Material Combusted	(b) Short Tons of Steel Recovered per Short Ton of Waste Combusted (Short Tons)	(c) Avoided CO_2 Emissions per Short Ton of Steel Recovered ($MTCO_2E$/Short Ton)	(d) Avoided CO_2 Emissions per Short Ton of Waste Combusted ($MTCO_2E$/Short Ton)[a]
Clay Bricks	–	–	–
Concrete	–	–	–
Fly Ash	–	–	–
Tires	0.06	1.80	-0.10
Asphalt Concrete	–	–	–
Asphalt Shingles	–	–	–
Drywall	–	–	–
Fiberglass Insulation	–	–	–
Vinyl Flooring	–	–	–
Wood Flooring	–	–	–

– = Zero emissions.
Note that totals may not sum due to independent rounding, and more digits may be displayed than are significant.
[a] The value in column (d) is a national average and is weighted to reflect 90 percent recovery at the 98 percent of facilities that recover ferrous metals.
[b] Assumes that only 68 percent of facilities that use TDF recover ferrous metals.

3. RESULTS

The national average results of this analysis are shown in Exhibit 7. The results from the last column of Exhibit 1, the last two columns of Exhibit 2, and the last column of Exhibit 6 are shown in columns (b) through (e) in Exhibit 7. The net GHG emissions from combustion of each material at mass burn and RDF facilities are shown in columns (f) and (g), respectively. These net values represent the gross GHG emissions (column (b)), minus the avoided GHG emissions (columns (c), (d) and (e)). As stated earlier, these estimates of net GHG emissions are expressed for combustion in absolute terms, and are not values relative to another waste management option, although they must be used comparatively, as all WARM emission factors must be. They are expressed in terms of short tons of waste input (i.e., tons of waste prior to processing).

Exhibit 7: Net National Average GHG Emissions from Combustion at WTE Facilities

(a) Material Combusted	(b) Gross GHG Emissions per Ton Combusted ($MTCO_2E$/ Short Ton)	(c) Avoided Utility GHG Emissions per Ton Combusted at Mass Burn Facilities ($MTCO_2E$ / Short Ton)[a]	(d) Avoided Utility GHG Emissions per Ton Combusted at RDF Facilities ($MTCO_2E$ / Short Ton)	(e) Avoided CO2 Emissions per Ton Combusted Due to Steel Recovery ($MTCO_2E$ / Short Ton)	(f = b – c – e) Net GHG Emissions from Combustion at Mass Burn Facilities ($MTCO_2E$ / Short Ton)	(g = b – d – e) Net GHG Emissions from Combustion at RDF Facilities ($MTCO_2E$ / Short Ton)
Aluminum Cans	0.03	-0.03	-0.02	–	0.05	0.05
Aluminum Ingot	0.03	-0.03	-0.02	–	0.05	0.05
Steel Cans	0.03	-0.02	-0.01	1.60	-1.55	-1.56
Copper Wire	0.03	-0.02	-0.02	–	0.05	0.05
Glass	0.03	-0.02	-0.02	–	0.05	0.04
HDPE	2.82	1.55	1.42	–	1.27	1.40
LDPE	2.82	1.55	1.41	–	1.27	1.41
PET	2.06	0.82	0.75	–	1.24	1.31
LLDPE	2.82	1.55	1.42	–	1.27	1.41
PP	2.82	1.55	1.42	–	1.27	1.41
PS	3.04	1.40	1.28	–	1.64	1.76
PVC	1.28	0.61	0.56	–	0.67	0.72

(a) Material Combusted	(b) Gross GHG Emissions per Ton Combusted ($MTCO_2E$/ Short Ton)	(c) Avoided Utility GHG Emissions per Ton Combusted at Mass Burn Facilities ($MTCO_2E$ / Short Ton)[a]	(d) Avoided Utility GHG Emissions per Ton Combusted at RDF Facilities ($MTCO_2E$ / Short Ton)	(e) Avoided CO2 Emissions per Ton Combusted Due to Steel Recovery ($MTCO_2E$ / Short Ton)	(f = b – c – e) Net GHG Emissions from Combustion at Mass Burn Facilities ($MTCO_2E$ / Short Ton)	(g = b – d – e) Net GHG Emissions from Combustion at RDF Facilities ($MTCO_2E$ / Short Ton)
PLA	0.03	0.65	0.59	–	-0.62	-0.57
Corrugated Containers	0.06	0.55	0.50	–	-0.48	-0.44
Magazines/Third-Class Mail	0.06	0.41	0.37	–	-0.35	-0.31
Newspaper	0.06	0.62	0.56	–	-0.55	-0.50
Office Paper	0.06	0.53	0.48	–	-0.47	-0.42
Phone Books	0.06	0.62	0.56	–	-0.55	-0.50
Textbooks	0.06	0.53	0.48	–	-0.47	-0.42
Dimensional Lumber	0.06	0.65	0.59	–	-0.58	-0.53
Medium-Density Fiberboard	0.06	0.65	0.59	–	-0.58	-0.53
Food Waste	0.06	0.18	0.17	–	-0.12	-0.10
Food Waste (meat only)	0.06	0.18	0.17	–	-0.12	-0.10
Food Waste (non-meat)	0.06	0.18	0.17	–	-0.12	-0.10
Beef	0.06	0.18	0.17	–	-0.12	-0.10
Poultry	0.06	0.18	0.17	–	-0.12	-0.10
Grains	0.06	0.18	0.17	–	-0.12	-0.10
Bread	0.06	0.18	0.17	–	-0.12	-0.10
Fruits and Vegetables	0.06	0.18	0.17	–	-0.12	-0.10
Dairy Products	0.06	0.18	0.17	–	-0.12	-0.10
Yard Trimmings	0.06	0.22	0.20	–	-0.15	-0.13
Grass	0.06	0.22	0.20	–	-0.15	-0.13
Leaves	0.06	0.22	0.20	–	-0.15	-0.13
Branches	0.06	0.22	0.20	–	-0.15	-0.13
Mixed Paper (general)[b]	0.06	0.55	NA	–	-0.49	-0.44
Mixed Paper (primarily residential)[b]	0.06	0.55	NA	–	-0.48	-0.44
Mixed Paper (primarily from offices)[b]	0.06	0.51	NA	–	-0.44	-0.40
Mixed Metals	0.03	-0.02	NA	1.04	-0.99	-1.06
Mixed Plastics	2.36	1.11	NA	–	1.25	1.36
Mixed Recyclables	0.13	0.51	NA	0.04	-0.42	-0.38
Mixed Organics	0.06	0.20	NA	–	-0.14	-0.12
Mixed MSW	0.43	0.39	0.35	0.05	-0.01	0.02
Carpet	1.69	0.59	0.54	–	1.10	1.15
Personal Computers	0.41	0.12	0.11	0.46	-0.17	-0.16
Clay Bricks	NA	NA	NA	NA	NA	NA

(a) Material Combusted	(b) Gross GHG Emissions per Ton Combusted ($MTCO_2E$/ Short Ton)	(c) Avoided Utility GHG Emissions per Ton Combusted at Mass Burn Facilities ($MTCO_2E$ / Short Ton)[a]	(d) Avoided Utility GHG Emissions per Ton Combusted at RDF Facilities ($MTCO_2E$ / Short Ton)	(e) Avoided CO2 Emissions per Ton Combusted Due to Steel Recovery ($MTCO_2E$ / Short Ton)	(f = b – c – e) Net GHG Emissions from Combustion at Mass Burn Facilities ($MTCO_2E$ / Short Ton)	(g = b – d – e) Net GHG Emissions from Combustion at RDF Facilities ($MTCO_2E$ / Short Ton)
Concrete	NA	NA	NA	NA	NA	NA
Fly Ash	NA	NA	NA	NA	NA	NA
Tires[c]	2.22	1.57	1.57	0.13	0.52	0.52
Asphalt Concrete	NA	NA	NA	NA	NA	NA
Asphalt Shingles	0.72	1.05[m]	1.05[m]	–	-0.34	-0.34
Drywall	NA	NA	NA	NA	NA	NA
Fiberglass Insulation	NA	NA	NA	NA	NA	NA
Vinyl Flooring	0.31	0.61	0.56	–	-0.30	-0.25
Wood Flooring	0.08	0.85	0.64	–	-0.76	-0.55

Note that totals may not sum due to independent rounding, and more digits may be displayed than are significant.
[a] The values in this column represent the national average avoided utility GHG emissions. WARM also allows users to use region-specific avoided utility emissions, which are contained in Exhibit 5.
[b] The summary values for mixed paper are based on the proportions of the four paper types (corrugated containers, magazines/third-class mail, newspaper and office paper) that constitute the different “mixed paper” definitions.
[c] Tires used as TDF substitute for coal in cement kilns and utility boilers and as a substitute for natural gas, coal and biomass in pulp and paper facilities.

In the Excel version of WARM, the user can select the state where the waste is being disposed of to determine the combustion emissions based on regional avoided utility emission factors. This functionality is not available in the online version of WARM, which only allows for national average emissions calculations.

Net GHG emissions are estimated to be negative for all biogenic sources of carbon (paper and wood products, organics) because CO_2 emissions from these sources are not counted, as discussed earlier.

As shown in Exhibit 7, combustion of plastics results in substantial net GHG emissions. This result is primarily because of the high content of non-biomass carbon in plastics. Also, when combustion of plastics results in electricity generation, the utility carbon emissions avoided (due to displaced utility fossil fuel combustion) are much lower than the carbon emissions from the combustion of plastics. This result is largely due to the lower system efficiency of WTE plants compared with electric utility plants. Recovery of ferrous metals at combustors results in negative net GHG emissions for steel cans, due to the increased steel recycling made possible by ferrous metal recovery at WTE plants. Combustion of mixed MSW results in slightly negative GHG emissions because of the high proportion of biogenic carbon and steel.

4. LIMITATIONS

The certainty of the analysis presented in this chapter is limited by the reliability of the various data elements used. The most significant limitations are as follows:

- Combustion system efficiency of WTE plants may be improving. If efficiency improves, more utility CO_2 will be displaced per ton of waste combusted (assuming no change in utility emissions per kWh), and the net GHG emissions from combustion of MSW will decrease.

- Data for the RDF analysis were provided by the Minnesota Office of Environmental Assistance and were obtained from a single RDF processing facility and a separate RDF combustion facility. Research indicates that each RDF processing and combustion facility is different. For example, some RDF combustion facilities may generate steam for sale off-site, which can affect overall system efficiency. In addition, the amount of energy required to process MSW into RDF and the amount of energy used to operate RDF combustion facilities can be difficult to quantify and can vary among facilities on daily, seasonal and annual bases. This is one of the reasons that RDF factors are not included in WARM.
- The reported ranges for N_2O emissions were broad. In some cases, the high end of the range was 10 times the low end of the range. Research has indicated that N_2O emissions vary with the type of waste burned. Thus, the average value used for mixed MSW and for all MSW components should be interpreted as approximate values.
- For mixed MSW, the study assumes that all carbon in textiles is from synthetic fibers derived from petrochemicals (whereas, in fact, some textiles are made from cotton, wool and other natural fibers). Because EPA assumed that all carbon in textiles is non-biogenic, all of the CO_2 emissions from combustion of textiles as GHG emissions were counted. This assumption will slightly overstate the net GHG emissions from combustion of mixed MSW, but the magnitude of the error is small because textiles represent only a small fraction of the MSW stream. Similarly, the MSW category of “rubber and leather” contains some biogenic carbon from leather and natural rubber. By not considering this small amount of biogenic carbon, the analysis slightly overstates the GHG emissions from MSW combustion.
- Because the makeup of a given community’s mixed MSW may vary from the national average, the energy content also may vary from the national average energy content used in this analysis. For example, MSW from communities with a higher- or lower-than-average recycling rate may have a different energy content, and MSW with more than the average proportion of dry leaves and branches will have a higher energy content.
- In this analysis, EPA used the national average recovery rate for steel. Where waste is sent to a WTE plant with steel recovery, the net GHG emissions for steel cans will be slightly lower (i.e., more negative). Where waste is sent to a WTE plant without steel recovery, the net GHG emissions for steel cans will be the same as for aluminum cans (i.e., close to zero). EPA did not credit increased recycling of nonferrous materials, because of a lack of information on the proportions of those materials. This assumption tends to result in overstated net GHG emissions from combustion.
- This analysis uses the “non-baseload” emission factors for electricity as the proxy for fuel displaced at the margin when WTE plants displace utility electricity. These non-baseload emission factors vary depending on the state where the waste is assumed to be combusted. If some other fuel or mix of fuels is displaced at the margin (e.g., a more coal-heavy fuel mix), the avoided utility CO_2 would be different.

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