# Section 7
# GREENHOUSE GAS EMISSIONS IMPACT ANALYSIS

This section provides an analysis of the environmental impact, in terms of greenhouse gas (GHG) emission reductions, of recycling in Iowa. The analysis presented in this section considers the recycling and composting activities that contribute to GHG emission reductions throughout the materials use cycle.

## 7.1 Overview of Greenhouse Gas Emissions

### 7.1.1 The Relationship between Solid Waste Management Practices and Climate Change

Greenhouse gases can be produced by a number of human activities, including solid waste disposal. In fact, disposed materials represent a long series of steps that have the potential to produce GHG emissions. These steps, which are also referred to as a product's "lifecycle", result in emissions, which are often categorized into two levels:

- Upstream emissions - A number of steps that may produce GHG emissions occur prior to the production of materials that are disposed. These steps may include the extraction of raw materials, the transportation of raw materials to manufacturers and processors, and the manufacture of products. These activities require considerable energy and the burning of fossil fuels which, in turn, generate carbon dioxide.
- Downstream emissions - When products are disposed GHG emissions are produced through combustion or landfilling.

Conversely, materials that are recycled may result in reducing some GHG emissions.

When carbon is stored or sequestered[1] in a sink, such as a forest, it is precluded from entering the atmosphere and contributing to the "greenhouse effect". For example when paper is recycled and fewer trees are harvested to make new paper products, more carbon may be sequestered, which reduces the amount of carbon in the atmosphere.

[1] Carbon sequestration refers to natural or man-made processes that remove carbon from the atmosphere and store it for long-periods or permanently. If carbon is stored, it is not emitted as carbon dioxide into the atmosphere contributing to the "greenhouse effect". Therefore, carbon sequestration reduces GHG concentrations.

Landfills may act as a sink because much of the organic matter disposed in landfills does not decompose and release carbon into the atmosphere. However, the benefit of using landfills as a carbon sink may be negated if the landfill does not have a methane gas collection system to preclude most of the methane from being released into the atmosphere. It should be noted that even in cases where landfills have gas collection systems, they do not capture 100 percent of the methane produced and some methane invariably gets released into the atmosphere.

Greenhouse gas emissions from the life cycle of solid waste include[2]:

- Carbon Dioxide ($CO_2$) - Most carbon dioxide emissions result from energy production, particularly fossil fuel combustion. Fossil fuels are frequently required for 1) extracting and processing raw materials; 2) manufacturing products; 3) managing products at the end of their useful life; and 4) transporting materials and products between each stage of their life cycles.
- Methane ($CH_4$) - Methane is produced when organic waste decomposes in an anaerobic (oxygen-free) environment, such as a landfill. Landfills are the largest source of methane gas, created solely by human activities, in the United States.
- Nitrous Oxide ($N_2O$) - Nitrous oxides can be emitted when solid waste is combusted. $N_2O$ also results from the use of commercial and organic fertilizers.
- Perfluorocarbons (PFLs) - Perfluorocarbons are emitted during the aluminum smelting process when the raw material alumina is reduced to make aluminum.

## 7.1.2 The Impact of Specific Solid Waste Management Practices on Climate Change

### 7.1.2.1 Source Reduction

Source reduction, waste prevention and "pre-cycling" are different terms for the same activity—reducing the amount of waste that is generated. When less waste is generated, the emissions associated with generation and managing the materials are avoided. Source reduction can be achieved by practices such as light-weighting (i.e., making beverage containers lighter by using less material), double-sided copying, and material reuse.

### 7.1.2.2 Recycling

When a material is recycled, it is used in place of virgin inputs in the manufacturing process, rather than being disposed of and managed as waste. Thus, recycling avoids the $CO_2$ emissions from the combustion of fuels used to operate the equipment associated with locating, extracting and processing raw materials. Additionally, manufacturing a product from recycled inputs often requires less fossil fuels than making a product from virgin inputs. Finally, paper recycling results in additional carbon sequestration in forests.

[2] Source: U.S. EPA, "Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks", 2006.

Greenhouse gases, such as $CO_2$ and $NO_2$, may be released during the recycling process, which includes:

1. Transporting materials from the point of collection to the processing facility;
2. Processing the material;
3. Transporting materials from the recycling facility to a broker; and/or
4. Transporting materials from a broker to the plant that processes the recyclables into new products.

These emissions are usually offset by the avoidance of emissions that would have been released during locating, extracting and processing virgin raw materials.

#### 7.1.2.3 Composting

When organic materials are composted, most of their organic mass decomposes to $CO_2$. However, carbon emissions that result from composting are not considered as greenhouse gas emissions for two reasons. First, $CO_2$ emissions produced during the decomposition of compostable materials such as yard trimmings, food residuals and newspapers are considered biogenic emissions, or emissions caused by a natural process rather than human activities. Second, tree and plant materials absorb $CO_2$ during the growing process. Although composting may result in some production of methane (due to anaerobic decomposition in the center of the pile), compost researchers believe that methane is almost always oxidized to $CO_2$ before it escapes the compost pile[3]. Research of emissions resulting from the composting process continues to evaluate this issue.

Because the $CO_2$ emissions from composting generally produce no methane, the only GHG emissions from composting result from the transportation of compostable materials to composting facilities and the mechanical turning of compost piles.

#### 7.1.2.4 Combustion

When solid waste is combusted, two critical GHGs are emitted: $CO_2$ and $N_2O$. However, combustion of MSW with energy recovery in a waste-to-energy (WTE) facility results in avoided $CO_2$ emissions. The avoided emissions are due to direct electricity production and heating or cooling provided from a co-generation, or combined heat and power, type of facility. Either directly or indirectly, WTE displaces electricity that would otherwise be provided by an electric utility power plant. Because most utility power plants burn fossil fuels, and thus emit $CO_2$, the electricity produced by a WTE plant reduces utility $CO_2$ emissions.

#### 7.1.2.5 Landfilling

Decomposition of organic wastes, such as yard trimmings, household waste, food residuals and paper, occurs in landfills and produces methane. While methane emissions from landfills are affected by factors such as waste composition, moisture

[3] Ibid.

and landfill size, landfills are the largest single human source of methane emissions in the United States.

Carbon dioxide is produced during the decomposition process of food scraps, yard trimmings and paper. Significant methane production typically begins one or two years after waste disposal in a landfill and continues for 10 to 60 years[4].

## 7.2 Methodology of GHG Emissions Impact Analysis

The methodology used to estimate the GHG emission reductions in Iowa as a result of recycling efforts, was based on application of the Waste Reduction Model (WARM) developed by the United States Environmental Protection Agency (EPA). This model was developed and refined over many years, with input from a range of groups including industry experts, environmental organizations, government agencies, and academia.

The WARM model is designed to estimate GHG emission reductions from several different waste management practices. The model is based on unique assumptions tailored for 34 different material types. Inputs to the model include the scenarios to be compared (e.g., the amount of each material type and the method used to manage it including recycling, landfilling, composting or combustion), and the average shipping distance of recyclable materials to market.

In this analysis, estimated values for the amount of each type of material recycled and composted in Iowa were entered into the model. For paper, plastics, glass, metals, and wood, the estimated baseline tons collected in Iowa in 2005 from Table 4-1 were used (not including tons exported). For C&D, organics, and electronics, the collected tons reported from survey respondents were used (Table 4-3). The WARM model does not include certain items such as asphalt, shingles, drywall, and mixed C&D, so those tons were not entered into the model. Also, the tires collected in Iowa were not input because the model asks for only retreaded tire tonnage, none of which were reported from the surveys. For tons landfilled, by material type, 2005 tonnage data was used from the Iowa Statewide Waste Characterization Study.

The model's default transport distances of twenty miles were used for the average distance from the curb to the landfill, compost facility, or materials recovery facility (MRF).

Table 7-1 below lists the estimated 2005 Iowa tons entered into the WARM model for the baseline management scenario.

[4] Source: U.S. EPA, "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005", 2007.

Table 7-1
Data Inputs for the WARM Model
2005 Iowa Estimated Tons

| Material | Tons Generated[1] | Tons Recycled[2] | Tons Landfilled[3] | Tons Combusted | Tons Composted[2] |
|---|---|---|---|---|---|
| Aluminum Cans | 28,411 | 21,979 | 6,432 | NA | NA |
| Steel Cans | 31,418 | 10,516 | 20,902 | NA | NA |
| Copper Wire | 0 | 0 | 0 | NA | NA |
| Glass | 99,872 | 63,428 | 36,444 | NA | NA |
| HDPE | 26,438 | 5,000 | 21,438 | NA | NA |
| LDPE | 610 | 610 | 0 | NA | NA |
| PET | 25,139 | 11,740 | 13,399 | NA | NA |
| Corrugated Cardboard | 330,237 | 149,625 | 180,612 | NA | NA |
| Magazines/Third-class Mail | 186,775 | 0 | 186,775 | NA | NA |
| Newspaper | 325,214 | 240,000 | 85,214 | NA | NA |
| Office Paper | 55,004 | 2,750 | 52,254 | NA | NA |
| Phonebooks | 0 | 0 | 0 | NA | NA |
| Textbooks | 0 | 0 | 0 | NA | NA |
| Dimensional Lumber | 344,525 | 167,665 | 176,860 | NA | NA |
| Medium-density Fiberboard | 0 | 0 | 0 | NA | NA |
| Food Scraps | 225,595 | 0 | 225,095 | NA | 500 |
| Yard Trimmings | 101,573 | 0 | 34,300 | NA | 67,273 |
| Grass | 0 | 0 | 0 | NA | 0 |
| Leaves | 0 | 0 | 0 | NA | 0 |
| Branches | 0 | 0 | 0 | NA | 0 |
| Mixed Paper (general) | 349,636 | 153,214 | 196,422 | NA | NA |
| Mixed Paper (primarily residential) | 0 | 0 | 0 | NA | NA |
| Mixed Paper (primarily from offices) | 0 | 0 | 0 | NA | NA |
| Mixed Metals[4] | 250,620 | 178,000 | 72,620 | NA | NA |
| Mixed Plastics[5] | 298,059 | 16,959 | 281,100 | NA | NA |
| Mixed Recyclables[6] | 0 | 0 | 0 | NA | NA |
| Mixed Organics[7] | 44,301 | 0 | 31,620 | NA | 12,681 |
| Mixed MSW[8] | 1,007,566 | 0 | 1,007,566 | NA | NA |
| Carpet | 575 | 575 | 0 | NA | NA |
| Personal Computers | 51,281 | 634 | 50,647 | NA | NA |

Table 7-1
Data Inputs for the WARM Model
2005 Iowa Estimated Tons

| Material | Tons Generated[1] | Tons Recycled[2] | Tons Landfilled[3] | Tons Combusted | Tons Composted[2] |
|---|---|---|---|---|---|
| Clay Bricks | 0 | 0 | 0 | NA | NA |
| Concrete[9] | 5,382 | 5,382 | 0 | NA | NA |
| Fly Ash[10] | 0 | 0 | 0 | NA | NA |
| Tires[11] | 0 | 0 | 0 | NA | NA |
| **Totals:** | 3,788,231 | 1,028,077 | 2,679,700 | 0 | 80,454 |

[1] Tons Generated equals tons recycled + tons landfilled + tons combusted + tons composted.
[2] Source: Tables 4-1 and 4-3 of this report.
[3] Source: Iowa Statewide Solid Waste Composition, 2005 solid waste tons (Table 5-5), Iowa Statewide Waste Characterization Study, February 2006.
[4] Mixed Metals is defined as: Steel 71%, Aluminum 29%.
[5] Mixed Plastics is defined as: HDPE 46%, LDPE 15%, PET 40%.
[6] Mixed Recyclables is defined as: Aluminum Cans 1.4%, Steel 3.4%, Glass 5.2%, HDPE 1.0%, LDPE 0.3%, PET 0.9%, Corrugated Cardboard 46.8%, Magazines/Third-class Mail 5.5%, Newspaper 23%, Office Paper 8.8%, Phonebooks 0.2%, Textbooks 0.4%, Dimensional Lumber 2.8%.
[7] Mixed Organics is defined as: Food Scraps 48%, Yard Trimmings 52%.
[8] Mixed MSW represents the entire municipal solid waste stream as disposed.
[9] Recycled concrete used as aggregate in the production of new concrete.
[10] Recycled fly ash is utilized to displace Portland cement in concrete production.
[11] Recycling tires is defined in this analysis as retreading and does not include other recycling activities (i.e. crumb rubber applications).

The following section presents the model results.

# 7.3 Greenhouse Gas Emissions Impacts

Table 7-2 shows the greenhouse gas emissions of each waste management practice,[5] based on the WARM model results for the state of Iowa. The annual GHG emissions are reported as Metric Tons of Carbon Equivalent (MTCE). A negative value (i.e., a value in parentheses) indicates an emission reduction; a positive value indicates an emission increase.

Environmental impacts beyond greenhouse gas emissions were not evaluated. It also should be noted that this analysis does not constitute a full-fledged environmental life-cycle analysis study, but rather only an inventory of impacts based on WARM model results.

[5] The model results are based on tons recycled, landfilled, combusted, and composted. Source Reduction was not included in the analysis.

Table 7-2
Iowa Greenhouse Gas Emissions[1] From Baseline Management of Municipal Solid Wastes

| Material | Baseline Generation of Material (Tons) | Estimated Recycling (Tons) | Annual GHG Emissions from Recycling (MTCE) | Estimated Landfilling (Tons) | Annual GHG Emissions from Landfilling (MTCE) | Estimated Combustion (Tons) | Annual GHG Emissions from Combustion (MTCE) | Estimated Composting (Tons) | Annual GHG Emissions from Composting (MTCE) | Total Annual GHG Emissions (MTCE) |
|---|---|---|---|---|---|---|---|---|---|---|
| Aluminum Cans | 28,411 | 21,979 | (81,341) | 6,432 | 67 | 0 | 0 | NA | NA | (81,274) |
| Steel Cans | 31,418 | 10,516 | (5,145) | 20,902 | 217 | 0 | 0 | NA | NA | (4,929) |
| Copper Wire | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NA | NA | 0 |
| Glass | 99,872 | 63,428 | (4,807) | 36,444 | 378 | 0 | 0 | NA | NA | (4,429) |
| HDPE | 26,438 | 5,000 | (1,898) | 21,438 | 222 | 0 | 0 | NA | NA | (1,676) |
| LDPE | 610 | 610 | (282) | 0 | 0 | 0 | 0 | NA | NA | (282) |
| PET | 25,139 | 11,740 | (4,924) | 13,399 | 139 | 0 | 0 | NA | NA | (4,785) |
| Corrugated Cardboard | 330,237 | 149,625 | (126,961) | 180,612 | 19,718 | 0 | 0 | NA | NA | (107,243) |
| Magazines/third-class mail | 186,775 | 0 | 0 | 186,775 | (15,337) | 0 | 0 | NA | NA | (15,337) |
| Newspaper | 325,214 | 240,000 | (182,719) | 85,214 | (20,176) | 0 | 0 | NA | NA | (202,895) |
| Office Paper | 55,004 | 2,750 | (2,139) | 52,254 | 27,683 | 0 | 0 | NA | NA | 25,544 |
| Phonebooks | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NA | NA | 0 |
| Textbooks | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NA | NA | 0 |
| Dimensional Lumber | 344,525 | 167,665 | (112,302) | 176,860 | (23,523) | 0 | 0 | NA | NA | (135,825) |
| Medium Density Fiberboard | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NA | NA | 0 |
| Food Scraps | 225,595 | NA | NA | 225,095 | 44,428 | 0 | 0 | 500 | (27) | 44,401 |
| Yard Trimmings | 101,573 | NA | NA | 34,300 | (2,049) | 0 | 0 | 67,273 | (3,643) | (5,692) |
| Grass | 0 | NA | NA | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Leaves | 0 | NA | NA | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 7-2
Iowa Greenhouse Gas Emissions[1] From Baseline Management of Municipal Solid Wastes

| Material | Baseline Generation of Material (Tons) | Estimated Recycling (Tons) | Annual GHG Emissions from Recycling (MTCE) | Estimated Landfilling (Tons) | Annual GHG Emissions from Landfilling (MTCE) | Estimated Combustion (Tons) | Annual GHG Emissions from Combustion (MTCE) | Estimated Composting (Tons) | Annual GHG Emissions from Composting (MTCE) | Total Annual GHG Emissions (MTCE) |
|---|---|---|---|---|---|---|---|---|---|---|
| Branches | 0 | NA | NA | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mixed Paper, Broad | 349,636 | 153,214 | (147,793) | 196,422 | 18,653 | 0 | 0 | NA | NA | (129,140) |
| Mixed Paper, Resid. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NA | NA | 0 |
| Mixed Paper, Office | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NA | NA | 0 |
| Mixed Metals | 250,620 | 178,000 | (255,225) | 72,620 | 753 | 0 | 0 | NA | NA | (254,472) |
| Mixed Plastics | 298,059 | 16,959 | (6,911) | 281,100 | 2,914 | 0 | 0 | NA | NA | (3,997) |
| Mixed Recyclables | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NA | NA | 0 |
| Mixed Organics | 44,301 | 0 | NA | 31,620 | 2,037 | 0 | 0 | 12,681 | (687) | 1,351 |
| Mixed MSW | 1,007,566 | 0 | NA | 1,007,566 | 116,498 | 0 | 0 | NA | NA | 116,498 |
| Carpet | 575 | 575 | (1,126) | 0 | 0 | 0 | 0 | NA | NA | (1,126) |
| Personal Computers | 51,281 | 634 | (391) | 50,647 | 525 | 0 | 0 | NA | NA | 134 |
| Clay Bricks | 0 | 0 | NA | 0 | 0 | NA | NA | NA | NA | 0 |
| Concrete | 5,382 | 5,382 | (11) | 0 | 0 | NA | NA | NA | NA | (11) |
| Fly Ash | 0 | 0 | 0 | 0 | 0 | NA | NA | NA | NA | 0 |
| Tires | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NA | NA | 0 |
| Total | 3,788,231 | 1,028,077 | (933,975) | 2,679,700 | 173,146 | 0 | 0 | 80,454 | (4,357) | (765,185) |

[1] The annual GHG emissions are reported as Metric Tons of Carbon Equivalent (MTCE). A negative value (i.e., a value in parentheses) indicates an emission reduction; a positive value indicates an emission increase.

## 7.4 Summary

Based on the WARM model results presented in Table 7-2, by recycling and composting in 2005, GHG emissions were reduced in Iowa by a net total of 765,185 MTCE.

The material types that provided the most net benefit in terms of reducing GHG emissions include:

1. Mixed Metals – 254,472 MTCE;
2. Newspaper – 202,895 MTCE;
3. Dimensional Lumber – 135,825 MTCE;
4. Mixed Paper – 129,140 MTCE; and
5. Corrugated Cardboard – 107,243 MTCE.

The per ton estimates of GHG emissions for various solid waste management methods, per the WARM model, are included in Table C-1 of Appendix C. The table shows that the materials which provide the greatest benefit when recycled (in MTCEs per ton) include aluminum cans, copper wire, mixed metals, and carpet.

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