ENERGY IMPACTS

Other chapters in EPA's Waste Reduction Model (WARM) focus on the effects of materials management decisions on greenhouse gases (GHG). Generally, a large portion of GHG emissions is related to energy use in resource acquisition, manufacturing, transportation, and end-of-life life-cycle stages. Not all GHG emissions are related to energy, however, and the effects of GHG are not directly translatable to energy impacts. One of the benefits of WARM is to help users see results in terms of both GHG (metric tons of carbon dioxide equivalent or carbon equivalent) and energy (millions of Btu). For background, see the Background and Overview chapter.

The energy effects of materials occur in each life-cycle stage—source reduction, recycling and reuse, manufacturing—and knowledge of those effects can reduce the demand for raw materials and energy. Energy savings can also result from some waste disposal practices, including waste-to-energy combustors and landfill gas-to-energy systems.

To better understand the relationship between materials management and energy use, WARM provides energy factors for four management scenarios (source reduction, recycling, combustion, and landfilling). This chapter discusses how these energy factors affect the relationship between energy savings and GHG benefits.

1. METHODOLOGY FOR DEVELOPING ENERGY FACTORS

The WARM methodology described in the other chapters is similar; the methodology in this chapter focuses on all life-cycle components as they appear through the lens of energy consumption or savings, rather than GHG emissions. Components such as forest carbon storage and landfill carbon sequestration are not components in the energy life cycle, and thus we have not included them as energy factors. We base energy factors primarily on the amount of energy required to produce one ton of a given material. The total energy consumed is a result of direct fuel and electricity consumption associated with raw material acquisition and manufacturing, fuel consumption for transportation, and embedded energy. The other WARM chapters on specific materials describe the energy required for processing and transporting virgin and recycled materials. Although the GHG emission factors are a product of the electricity fuel mix and the carbon coefficients of fuels, our methodology in this chapter is based only on energy consumption; therefore, the energy required for the total process to make one ton of a particular material is the sum of energy consumed across all fuel types.

The total energy, or embodied energy, required to manufacture each material comprises two components: (1) process and transportation energy, and (2) embedded energy (i.e., energy content of the raw material). The first component, to process and transport a material, is conceptually straightforward; but the second component, embedded energy, is more complex. Embedded energy is the energy inherently contained in the raw materials used to manufacture a product. For example, the embedded energy of plastics comes from the petroleum needed to make them. Because petroleum has an inherent energy value, the amount of energy that is saved through plastic recycling and source reduction is directly related to the energy that could have been produced if the petroleum had been used as an energy source rather than as a raw material input. Another example is aluminum, which includes an embedded energy component. The aluminum smelting process requires a carbon anode, which is consumed during the electrolytic reduction process; carbon anodes are made from coal, itself an energy source. Additional examples are carpet and personal computers that contain embedded energy in their plastic (carpet, computers) and aluminum (computers only) components. Total energy values also include both nonrenewable and renewable sources. For example, some aspects of the paper life-cycle include renewable fuel sources that have little effect on GHG emissions.

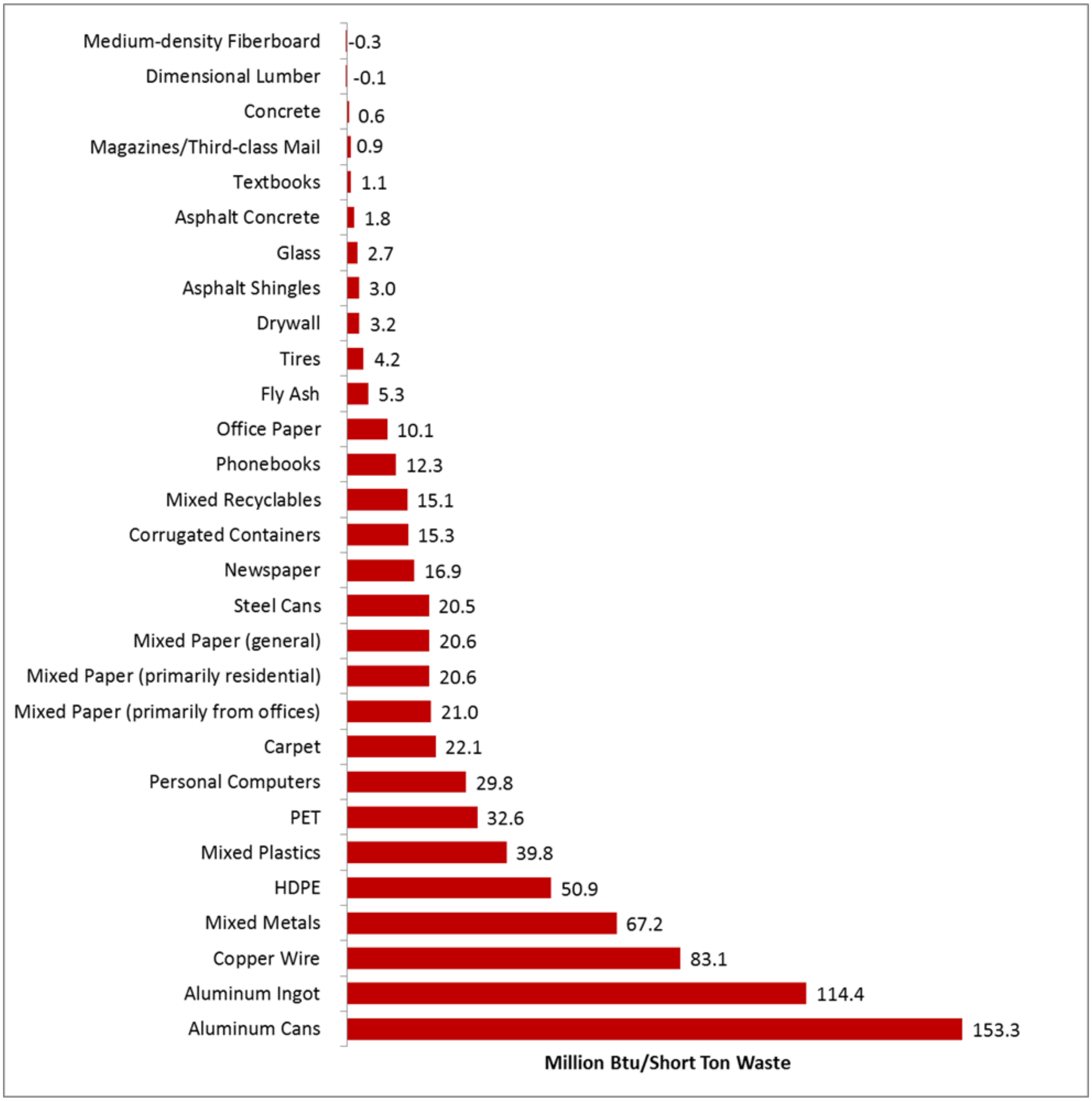
2. ENERGY IMPLICATIONS FOR WASTE MANAGEMENT OPTIONS

This chapter discusses the life-cycle energy implications for four management scenarios. As with the GHG emission factors discussed in other chapters, negative values indicate net energy savings.

Waste reduction efforts, such as source reduction and recycling, can result in significant energy savings. Source reduction techniques, such as double-sided copying, reducing the weight of products (light-weighting), and reducing generation of food waste are, in most cases, more effective at reducing energy than recycling because source reduction significantly lowers energy consumption associated with raw material extraction and manufacturing processes.

In relating recycling to landfill disposal, the greatest energy savings per ton come from aluminum cans, as shown in Exhibit 1. The savings reflect the nature of aluminum production—manufacturing aluminum cans from virgin inputs is very energy intensive, whereas relatively little energy is required to manufacture cans from recycled aluminum. Significant energy savings also result from recycling carpet because the recycled material can be used to produce secondary goods, and thus avoiding the energy-intensive processes required to manufacture those secondary goods.

Exhibit 1: Energy Savings per Short Ton of Recycled Material (Relative to Landfilling).



Note: Positive numbers indicate energy savings from recycling; negative numbers indicate that additional energy is required, compared to landfilling. This figure excludes materials in WARM for which recycling is not a viable end-of-life management option.

Some materials, such as dimensional lumber and medium-density fiberboard, actually consume more energy when they are made from recycled inputs. For those materials, the recovery and processing of recycled material is more energy intensive than making the material from virgin inputs. Although those materials may not provide an energy benefit from recycling from the perspective of GHG emissions, recycling them is still beneficial. For more information on this topic, see Section 4.

3. APPLYING ENERGY FACTORS

Fuels and energy are limited and expensive resources, and it is increasingly important to examine the effects of waste management practices on energy. Organizations can use the energy factors presented in Exhibit 6 through Exhibit 11 to quantify energy savings associated with waste management practices. Organizations can use these comparisons to weigh the benefits of switching from landfilling to another waste management option. For example, researchers used the comparisons to evaluate the benefits of voluntary programs aimed at source reduction and recycling, such as EPA's WasteWise and Pay-as-You-Throw programs. Additional information about the methodology of deriving and applying these factors is available in the chapters on individual materials.

To apply the WARM energy factors, two scenarios are necessary: (1) a baseline scenario that represents current management practices (e.g., disposing of one ton of steel cans in a landfill), and (2) an alternative scenario that represents the alternative management practice (e.g., recycling a ton of steel cans).[1] With these scenarios, it is possible to calculate the amount of energy consumed or avoided in the baseline and alternative management practices and then to calculate the difference between the alternative scenario and the baseline scenario. The result represents the energy consumed or avoided that is attributable to the alternative management scenario.

Exhibit 2 illustrates the application of these factors. The baseline management scenario in the example uses disposal in a landfill that has national average conditions. The Btu number represents the amount of energy required to transport and process the ton. The alternate scenario is based on recycling the ton of cans. The difference, shown as a negative number, indicates that recycling one ton of steel cans rather than landfilling them reduces the energy consumed by 20.5 million Btu.

Exhibit 2: Comparison of Waste Reduction Scenarios

Baseline: landfill 1 ton of steel cans	1 ton x 0.53 million Btu/ton = 0.53 million Btu
Alternate: recycle 1 ton of steel cans	1 ton x −19.97 million Btu/ton = −19.97 million Btu
Energy Impacts: −19.97 million Btu – 0.53 million Btu = - 20.5 million Btu	

Note: Negative numbers indicate avoided emissions or energy savings.

4. RELATING ENERGY SAVINGS TO GHG BENEFITS

Because it can be difficult to conceptualize energy savings in Btu and GHG emissions reductions in metric ton carbon dioxide equivalent (MTCO2E), the common way to express the amount, the results can be converted to common equivalents such as barrels of crude oil or gallons of gasoline, as shown in Exhibit 3. These interpreted results produce important nuances, particularly when applied to convert MTCO2E savings to equivalent energy savings. The conversion is complicated for two reasons: (1) GHG reductions reflect both energy and non-energy savings, and (2) the energy savings reflect savings across a range of fossil fuels. Thus, conversions from total GHG reductions to an equivalency for barrels of oil must be done with caution.

[1] The energy factors are expressed in terms of million Btu of energy per short ton of material managed. In the case of recycling, EPA defines one ton of material managed as one ton *collected* for recycling.

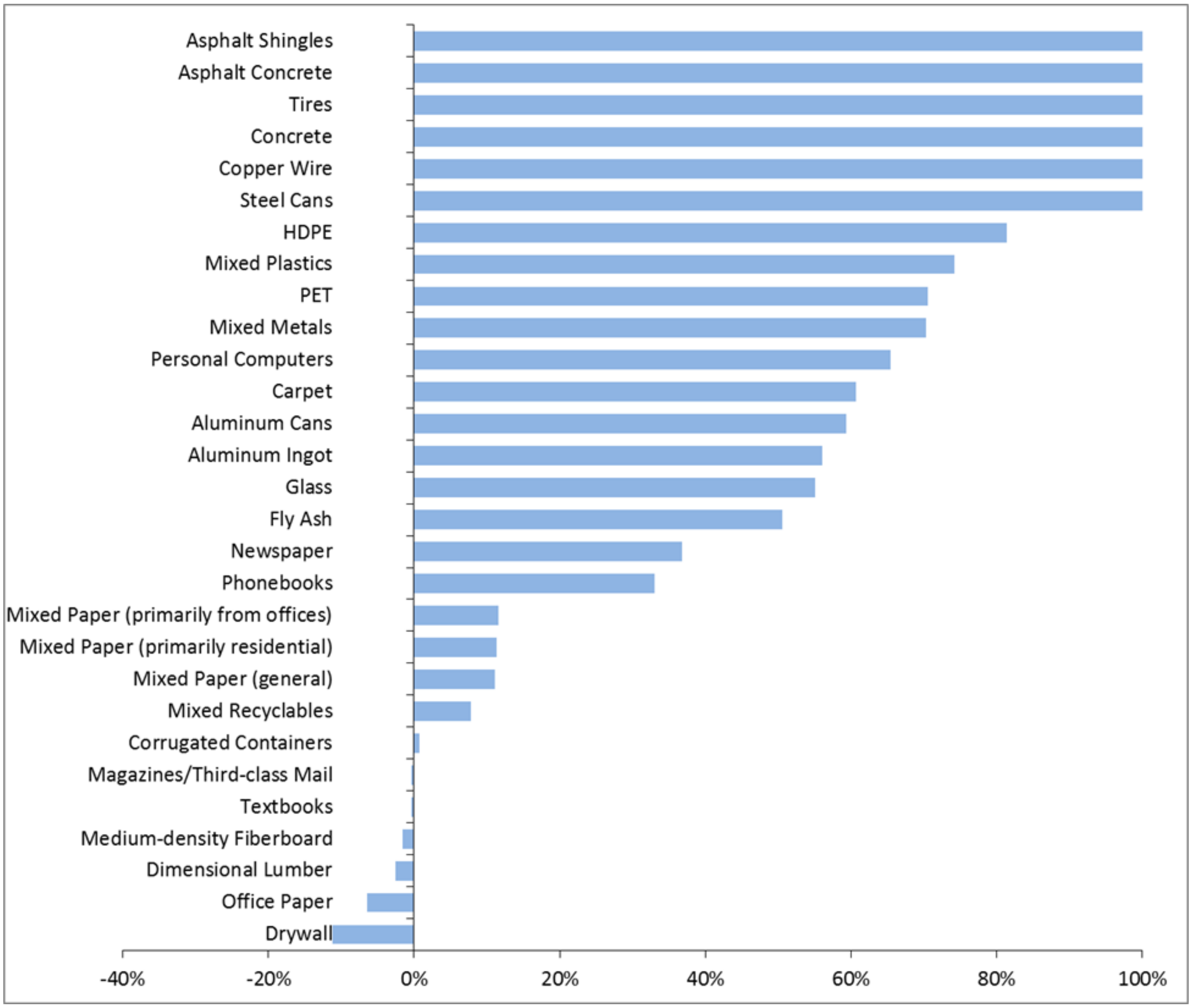
Exhibit 3: Common Energy Conversion Factors and Emissions Equivalencies

Common Energy Conversion Factors	Emissions Equivalencies
Fuel: • Million Btu per Barrel of Oil: 5.8 • Gallons per Barrel of Oil: 42 • Million Btu per Gallon of Gasoline: 0.125 ***Cars (average passenger car over one year):*** • Fuel Consumption (gallons of gas): 529 • Fuel Consumption (Million Btu/year): 66 ***Household (average household per year):*** • Million Btu per day: 0.30 Source: EPA, 2014	***Propane Cylinders Used for Home BBQs:*** • CO_2 emissions per cylinder (metric tons): 0.024 ***Railroad Cars Worth of Coal:*** • CO_2 emissions per Railcar (metric tons): 186.5 ***Cars (average passenger car over one year):*** • CO_2 Emissions (metric tons): 4.8 Source: EPA, 2014

Although energy savings are often associated with GHG emissions savings, it is inaccurate to directly convert overall GHG emission benefits into energy savings equivalents. Equivalencies must remain consistent within the energy category or the GHG emission context in which they were created. Exhibit 4 illustrates GHG benefits derived from energy savings achieved through recycling relative to landfilling. For example, for asphalt shingles, 100 percent of the GHG savings associated with recycling rather than landfilling are energy-related, whereas for glass, only about half of the GHG savings are energy-related. Because the GHG benefits of glass recycling consist of some energy and some non-energy-related savings, this material type demonstrates the difficulties of converting GHG savings to energy equivalents.[2]

[2] The percentage of emissions savings derived from energy is negative for some paper and wood products because the entire comparative benefit of recycling over landfilling for these materials results from non-energy factors, such as forest carbon storage and landfill carbon sequestration. For more information, see the Forest Carbon Storage and Landfilling chapters.

Exhibit 4: Recycling GHG Benefits Attributable to Energy Savings (Relative to Landfilling)



Note: Positive numbers indicate GHG benefits attributable to energy savings from recycling; negative numbers indicate that additional energy GHG emissions result from energy required for recycling, compared to landfilling. This figure excludes materials in WARM for which recycling is not a viable end-of-life management option.

Exhibit 5 shows how energy savings and GHG savings can differ for a single scenario. The example is for total derived GHG benefits from recycling glass and the conversion of energy savings is to barrels of oil. Using the common equivalency factors, the GHG emission benefits are equivalent to GHG emissions from the combustion of 74 barrels of oil. In contrast, the energy savings associated with recycling glass are equivalent to the energy content of 46 barrels of oil.

Exhibit 5: Comparison of Emissions and Energy Benefits from Recycling

Recycling 100 Short Tons of Glass Compared to Landfilling	
GHG Emission Benefits: 32 $MTCO_2E$	Equivalent to the combustion emissions from **74** barrels of oil.
Energy Savings: 265 Million Btu	Equivalent to the energy contained in **46** barrels of oil.

The difference between the benefits and the conversions has important implications. The term "energy savings" covers a diverse mix of fuels (petroleum, electricity, natural gas, coal). In reality, glass manufacturing depends mainly on energy produced from electricity, coal, and natural gas, not from petroleum. The equivalency, stated as "barrels of oil," is only a simplified and recognizable energy equivalent; little or no petroleum is actually saved. Exhibit 6, Exhibit 7, Exhibit 8 and Exhibit 9 show the components of the energy impact factors for source reduction, recycling, combustion, and landfilling, respectively. Exhibit 10 shows the net energy impacts of the four materials management options and Exhibit 11 compares the energy impacts of source reduction, recycling, and combustion to a baseline of landfilling.

Exhibit 6: Energy Impacts for Source Reduction (Million Btu/Ton of Material Source Reduced)

(a)	(b) Raw Materials Acquisition and Manufacturing Process Energy		(c) Raw Materials Acquisition and Manufacturing Transport Energy		(d) Net Energy (d = b + c)	
Material/Product	Displace Current Mix of Virgin and Recycled Inputs	Displace Virgin Inputs	Displace Current Mix of Virgin and Recycled Inputs	Displace Virgin Inputs	Displace Current Mix of Virgin and Recycled Inputs	Displace Virgin Inputs
Aluminum Cans	-88.74	-199.30	-0.91	-1.23	-89.66	-200.53
Aluminum Ingot	-126.03	-126.03	-0.89	-0.89	-126.92	-126.92
Steel Cans	-25.11	-31.58	-4.74	-4.93	-29.85	-36.51
Copper Wire	-121.45	-122.52	-0.88	-0.79	-122.32	-123.31
Glass	-5.99	-6.49	-0.88	-0.93	-6.87	-7.43
HDPE	-58.06	-63.88	-3.16	-3.23	-61.22	-67.11
LDPE	-67.77	-67.77	-3.28	-3.28	-71.05	-71.05
PET	-48.85	-49.97	-1.53	-1.49	-50.38	-51.46
LDPE	-67.77	-67.77	-3.28	-3.28	-71.05	-71.05
PP	-63.78	-63.78	-2.85	-2.85	-66.63	-66.63
PS	-72.21	-72.21	-2.81	-2.81	-75.02	-75.02
PVC	-46.52	-46.52	-1.94	-1.94	-48.47	-48.47
PLA	-29.19	-29.19	-0.64	-0.64	-29.83	-29.83
Corrugated Containers	-20.45	-25.13	-1.80	-1.98	-22.25	-27.11
Magazines/Third-class Mail	-32.95	-32.99	-0.25	-0.25	-33.20	-33.24
Newspaper	-35.80	-39.92	-0.64	-0.75	-36.44	-40.67
Office Paper	-36.32	-37.01	-0.25	-0.25	-36.57	-37.27
Phonebooks	-39.61	-39.61	-0.54	-0.54	-40.14	-40.14
Textbooks	-35.01	-35.07	-0.54	-0.54	-35.55	-35.61
Dimensional Lumber	-2.53	-2.53	-1.12	-1.12	-3.65	-3.65
Medium-density Fiberboard	-10.18	-10.18	-1.68	-1.68	-11.85	-11.85
Food Waste	-12.81	-12.81	-1.74	-1.74	-14.56	-14.56
Food Waste (meat only)	-40.86	-40.86	-2.74	-2.74	-43.60	-43.60
Food Waste (non-meat)	-5.71	-5.71	-1.49	-1.49	-7.20	-7.20
Beef	-62.25	-62.25	-1.63	-1.63	-63.88	-63.88
Poultry	-22.80	-22.80	-3.68	-3.68	-26.48	-26.48
Grains	-5.35	-5.35	-0.26	-0.26	-5.62	-5.62
Bread	-6.34	-6.34	-0.17	-0.17	-6.51	-6.51
Fruits and Vegetables	-2.95	-2.95	-2.12	-2.12	-5.07	-5.07
Dairy Products	-13.61	-13.61	-0.65	-0.65	-14.27	-14.27
Yard Trimmings	NA	NA	NA	NA	NA	NA
Grass	NA	NA	NA	NA	NA	NA
Leaves	NA	NA	NA	NA	NA	NA
Branches	NA	NA	NA	NA	NA	NA
Mixed Paper						
Mixed Paper (general)	-28.31	-31.68	-1.09	-1.20	-29.40	-32.89
Mixed Paper (primarily residential)	-27.45	-30.98	-1.16	-1.28	-28.62	-32.26
Mixed Paper (primarily from offices)	-34.20	-35.58	-0.41	-0.44	-34.61	-36.02
Mixed Metals	-47.47	-85.42	-3.40	-3.63	-50.87	-89.05
Mixed Plastics	-52.47	-26.86	-2.17	-2.17	-54.64	-29.03
Mixed Recyclables	NA	NA	NA	NA	NA	NA
Mixed Organics	NA	NA	NA	NA	NA	NA
Mixed MSW	NA	NA	NA	NA	NA	NA
Carpet	-89.70	-89.70	-1.36	-1.36	-91.06	-91.06

(a) Material/Product	(b) Raw Materials Acquisition and Manufacturing Process Energy		(c) Raw Materials Acquisition and Manufacturing Transport Energy		(d) Net Energy (d = b + c)	
	Displace Current Mix of Virgin and Recycled Inputs	Displace Virgin Inputs	Displace Current Mix of Virgin and Recycled Inputs	Displace Virgin Inputs	Displace Current Mix of Virgin and Recycled Inputs	Displace Virgin Inputs
Personal Computers	-951.71	-951.71	-5.03	-5.03	-956.74	-956.74
Clay Bricks	-5.10	-5.10	-0.03	-0.03	-5.13	-5.13
Concrete	NA	-0.05	NA	-0.19	NA	-0.24
Fly Ash	NA	-4.77	NA	-0.10	NA	-4.87
Tires	-71.14	-73.79	-0.52	-0.49	-71.66	-74.28
Asphalt Concrete	-0.95	-0.95	-0.73	-0.73	-1.68	-1.68
Asphalt Shingles	-2.19	-2.19	-0.93	-0.93	-3.11	-3.11
Drywall	-3.08	-3.08	-0.45	-0.45	-3.53	-3.53
Fiberglass Insulation	-3.97	-4.74	-0.73	-0.79	-4.70	-5.53
Vinyl Flooring	-9.58	-9.58	-1.14	-1.14	-10.73	-10.73
Wood Flooring	-13.13	-13.13	-1.36	-1.36	-14.49	-14.49

Note: Negative numbers = Energy savings. NA = Not applicable.

Exhibit 7: Energy Impacts for Recycling (Million Btu/Ton of Material Recycled)

Material/Product	Recycled Input Credit Process Energy	Recycled Input Credit Transportation Energy	Net Energy (Post-Consumer)
Aluminum Cans	-152.32	-0.44	-152.76
Aluminum Ingot	-113.53	-0.32	-113.85
Steel Cans	-19.40	-0.56	-19.97
Copper Wire	-81.64	-0.95	-82.59
Glass	-1.91	-0.21	-2.13
HDPE	-49.79	-0.56	-50.36
LDPE	NA	NA	NA
PET	-33.25	1.19	-32.05
LLDPE	NA	NA	NA
PP	NA	NA	NA
PS	NA	NA	NA
PVC	NA	NA	NA
PLA	NA	NA	NA
Corrugated Containers	-14.32	-0.74	-15.05
Magazines/Third-class Mail	-0.69	0.00	-0.69
Newspaper	-16.07	-0.42	-16.49
Office Paper	-10.08	0.00	-10.08
Phonebooks	-11.93	0.00	-11.93
Textbooks	-1.03	0.00	-1.03
Dimensional Lumber	0.52	0.07	0.59
Medium-density Fiberboard	0.65	0.21	0.86
Food Waste	NA	0.58	0.58
Food Waste (meat only)	NA	0.58	0.58
Food Waste (non-meat)	NA	0.58	0.58
Beef	NA	0.58	0.58
Poultry	NA	0.58	0.58
Grains	NA	0.58	0.58
Bread	NA	0.58	0.58
Fruits and Vegetables	NA	0.58	0.58
Dairy Products	NA	0.58	0.58
Yard Trimmings	NA	0.58	0.58
Grass	NA	0.58	0.58
Leaves	NA	0.58	0.58
Branches	NA	0.58	0.58
Mixed Paper (general)	-18.92	-1.45	-20.37
Mixed Paper (primarily residential)	-18.92	-1.45	-20.37
Mixed Paper (primarily from offices)	-19.39	-1.46	-20.85
Mixed Metals	-66.12	-0.52	-66.64
Mixed Plastics	-39.75	0.50	-39.25
Mixed Recyclables	-14.39	-0.46	-14.85
Mixed Organics	NA	0.58	0.58
Mixed MSW	NA	NA	NA
Carpet	-21.84	0.27	-21.57
Personal Computers	-29.52	0.27	-29.24
Clay Bricks	NA	NA	NA
Concrete	-0.01	-0.09	-0.11
Fly Ash	-4.77	0.00	-4.77
Tires	-4.91	1.24	-3.67
Asphalt Concrete	-0.54	-0.69	-1.22
Asphalt Shingles	-2.00	-0.46	-2.46
Drywall	-2.15	-0.50	-2.65

Material/Product	Recycled Input Credit Process Energy	Recycled Input Credit Transportation Energy	Net Energy (Post-Consumer)
Fiberglass Insulation	NA	NA	NA
Vinyl Flooring	NA	NA	NA
Wood Flooring	NA	NA	NA

Note: Negative energy impacts = Energy savings. NA = Not applicable.

Exhibit 8: Energy Impacts for Combustion (Million Btu/Ton of Material Combusted)

Material/Product	Electric Utility Fuel Consumption	Energy Impacts due to Steel Recovery	Transportation to Combustion Facility	Net Energy (Post-Consumer)
Aluminum Cans	0.34	NA	0.30	0.63
Aluminum Ingot	0.34	NA	0.30	0.63
Steel Cans	0.21	-17.61	0.30	-17.10
Copper Wire	0.27	NA	0.30	0.57
Glass	0.24	NA	0.30	0.53
HDPE	-20.00	NA	0.30	-19.71
LDPE	-19.89	NA	0.30	-19.60
PET	-10.61	NA	0.30	-10.31
LLDPE	-19.96	NA	0.30	-19.67
PP	-19.97	NA	0.30	-19.67
PS	-18.02	NA	0.30	-17.72
PVC	-7.88	NA	0.30	-7.59
PLA	-8.38	NA	0.30	-8.08
Corrugated Containers	-7.05	NA	0.30	-6.75
Magazines/Third-class Mail	-5.26	NA	0.30	-4.97
Newspaper	-7.96	NA	0.30	-7.66
Office Paper	-6.81	NA	0.30	-6.51
Phonebooks	-7.96	NA	0.30	-7.66
Textbooks	-6.81	NA	0.30	-6.51
Dimensional Lumber	-8.31	NA	0.30	-8.01
Medium-density Fiberboard	-8.31	NA	0.30	-8.01
Food Waste	-2.37	NA	0.30	-2.08
Food Waste (meat only)	-2.37	NA	0.30	-2.08
Food Waste (non-meat)	-2.37	NA	0.30	-2.08
Beef	-2.37	NA	0.30	-2.08
Poultry	-2.37	NA	0.30	-2.08
Grains	-2.37	NA	0.30	-2.08
Bread	-2.37	NA	0.30	-2.08
Fruits and Vegetables	-2.37	NA	0.30	-2.08
Dairy Products	-2.37	NA	0.30	-2.08
Yard Trimmings	-2.80	NA	0.30	-2.51
Grass	-2.80	NA	0.30	-2.51
Leaves	-2.80	NA	0.30	-2.51
Branches	-2.80	NA	0.30	-2.51
Mixed Paper (general)	-7.08	NA	0.30	-6.78
Mixed Paper (primarily residential)	-7.05	NA	0.30	-6.75
Mixed Paper (primarily from offices)	-6.50	NA	0.30	-6.21
Mixed Metals	0.25	-11.42	0.30	-10.87
Mixed Plastics	-14.30	NA	0.30	-14.01
Mixed Recyclables	-6.51	-0.46	0.30	-6.68
Mixed Organics	-2.58	NA	0.30	-2.28
Mixed MSW	-5.00	NA	0.30	-4.71
Carpet	-7.61	NA	0.30	-7.31
Personal Computers	-1.53	-5.04	0.30	-6.27
Clay Bricks	NA	NA	NA	NA
Concrete	NA	NA	NA	NA
Fly Ash	NA	NA	NA	NA
Tires	-27.78	-1.01	0.30	-28.49
Asphalt Concrete	NA	NA	NA	NA
Asphalt Shingles	-8.80	NA	0.30	-8.50
Drywall	NA	NA	NA	NA

Material/Product	Electric Utility Fuel Consumption	Energy Impacts due to Steel Recovery	Transportation to Combustion Facility	Net Energy (Post-Consumer)
Fiberglass Insulation	NA	NA	NA	NA
Vinyl Flooring	-7.88	NA	0.30	-7.59
Wood Flooring	-10.87	NA	0.30	-10.58

Note: Negative energy impacts = Energy savings. NA = Not applicable.

Exhibit 9: Energy Impacts for Landfilling (Million Btu/Ton of Material Landfilled)

Material/Product	Transportation to Landfill	Electric Utility Fuel Consumption	Net Energy (Post-Consumer)
Aluminum Cans	0.53	NA	0.53
Aluminum Ingot	0.53	NA	0.53
Steel Cans	0.53	NA	0.53
Copper Wire	0.53	NA	0.53
Glass	0.53	NA	0.53
HDPE	0.53	NA	0.53
LDPE	0.53	NA	0.53
PET	0.53	NA	0.53
LLDPE	0.53	NA	0.53
PP	0.53	NA	0.53
PS	0.53	NA	0.53
PVC	0.53	NA	0.53
PLA	0.53	NA	0.53
Corrugated Containers	0.53	-0.31	0.21
Magazines/Third-class Mail	0.53	-0.29	0.23
Newspaper	0.53	-0.13	0.40
Office Paper	0.53	-0.48	0.04
Phonebooks	0.53	-0.13	0.40
Textbooks	0.53	-0.48	0.04
Dimensional Lumber	0.53	-0.02	0.51
Medium-density Fiberboard	0.53	-0.01	0.52
Food Waste	0.53	-0.19	0.34
Food Waste (meat only)	0.53	-0.19	0.34
Food Waste (non-meat)	0.53	-0.19	0.34
Beef	0.53	-0.19	0.34
Poultry	0.53	-0.19	0.34
Grains	0.53	-0.19	0.34
Bread	0.53	-0.19	0.34
Fruits and Vegetables	0.53	-0.19	0.34
Dairy Products	0.53	-0.19	0.34
Yard Trimmings	0.53	-0.07	0.46
Grass	0.53	-0.05	0.48
Leaves	0.53	-0.07	0.46
Branches	0.53	-0.10	0.43
Mixed Paper (general)	0.53	-0.30	0.22
Mixed Paper (primarily residential)	0.53	-0.29	0.23
Mixed Paper (primarily from offices)	0.53	-0.33	0.19
Mixed Metals	0.53	NA	0.53
Mixed Plastics	0.53	NA	0.53
Mixed Recyclables	0.53	-0.22	0.31
Mixed Organics	0.53	-0.13	0.40
Mixed MSW	0.53	-0.21	0.32
Carpet	0.53	NA	0.53
Personal Computers	0.53	NA	0.53
Clay Bricks	0.53	NA	0.53
Concrete	0.53	NA	0.53
Fly Ash	0.53	NA	0.53
Tires	0.53	NA	0.53
Asphalt Concrete	0.53	NA	0.53
Asphalt Shingles	0.53	NA	0.53
Drywall	0.53	NA	0.53

Material/Product	Transportation to Landfill	Electric Utility Fuel Consumption	Net Energy (Post-Consumer)
Fiberglass Insulation	0.53	NA	0.53
Vinyl Flooring	0.53	NA	0.53
Wood Flooring	0.53	NA	0.53

Note: Negative energy impacts = Energy savings. NA = Not applicable.

Exhibit 10: Net Energy Impacts from Source Reduction and MSW Management Options (Million Btu/Ton)

Material/Product	Source Reduction for Current Mix of Inputs	Recycling	Combustion	Landfilling
Aluminum Cans	-89.66	-152.76	0.63	0.53
Aluminum Ingot	-126.92	-113.85	0.63	0.53
Steel Cans	-29.85	-19.97	-17.10	0.53
Copper Wire	-122.32	-82.59	0.57	0.53
Glass	-6.87	-2.13	0.53	0.53
HDPE	-61.22	-50.36	-19.71	0.53
LDPE	-71.05	NA	-19.60	0.53
PET	-50.38	-32.05	-10.31	0.53
LLDPE	-66.38	NA	-19.67	0.53
PP	-66.63	NA	-19.67	0.53
PS	-75.02	NA	-17.72	0.53
PVC	-48.47	NA	-7.59	0.53
PLA	-29.83	NA	-8.08	0.53
Corrugated Containers	-22.25	-15.05	-6.75	0.21
Magazines/Third-class Mail	-33.20	-0.69	-4.97	0.23
Newspaper	-36.44	-16.49	-7.66	0.40
Office Paper	-36.57	-10.08	-6.51	0.04
Phonebooks	-40.14	-11.93	-7.66	0.40
Textbooks	-35.55	-1.03	-6.51	0.04
Dimensional Lumber	-3.65	0.59	-8.01	0.51
Medium-density Fiberboard	-11.85	0.86	-8.01	0.52
Food Waste	-14.56	0.58	-2.08	0.34
Food Waste (meat only)	-43.60	0.58	-2.08	0.34
Food Waste (non-meat)	-7.20	0.58	-2.08	0.34
Beef	-63.88	0.58	-2.08	0.34
Poultry	-26.48	0.58	-2.08	0.34
Grains	-5.62	0.58	-2.08	0.34
Bread	-6.51	0.58	-2.08	0.34
Fruits and Vegetables	-5.07	0.58	-2.08	0.34
Dairy Products	-14.27	0.58	-2.08	0.34
Yard Trimmings	NA	0.58	-2.51	0.46
Grass	NA	0.58	-2.51	0.48
Leaves	NA	0.58	-2.51	0.46
Branches	NA	0.58	-2.51	0.43
Mixed Paper (general)	-28.93	-20.37	-6.78	0.22
Mixed Paper (primarily residential)	-28.64	-20.37	-6.75	0.23
Mixed Paper (primarily from offices)	-73.26	-20.85	-6.21	0.19
Mixed Metals	-59.51	-66.64	-10.87	0.53
Mixed Plastics	-28.09	-39.25	-14.01	0.53
Mixed Recyclables	-26.53	-14.85	-6.68	0.31
Mixed Organics	NA	0.58	-2.28	0.40
Mixed MSW	NA	NA	-4.71	0.32
Carpet	-91.06	-21.57	-7.31	0.53
Personal Computers	-956.74	-29.24	-6.27	0.53
Clay Bricks	-5.13	NA	NA	0.53
Concrete	NA	-0.11	NA	0.53
Fly Ash	NA	-4.77	NA	0.53
Tires	-71.66	-3.67	-28.49	0.53
Asphalt Concrete	-1.68	-1.22	NA	0.53
Asphalt Shingles	-3.11	-2.46	-8.50	0.53
Drywall	-3.53	-2.65	NA	0.53
Fiberglass Insulation	-4.70	NA	NA	0.53

Material/Product	Source Reduction for Current Mix of Inputs	Recycling	Combustion	Landfilling
Vinyl Flooring	-10.73	NA	-7.59	0.53
Wood Flooring	-14.49	NA	-10.58	0.53

Note: Negative energy impacts = Energy savings. NA = Not applicable.
– = Zero impact.

Exhibit 11: Energy Impacts for MSW Management Options Compared to Landfilling (Million Btu/Ton)

Material/Product	Source Reduction Minus Landfilling		Recycling Minus Landfilling	Combustion Minus Landfilling
	Current Mix of Inputs	100% Virgin Inputs		
Aluminum Cans	-90.19	-201.06	-153.29	0.10
Aluminum Ingot	-127.44	-127.44	-114.37	0.10
Steel Cans	-30.37	-37.04	-20.49	-17.63
Copper Wire	-122.85	-123.84	-83.12	0.04
Glass	-7.40	-7.95	-2.65	0.00
HDPE	-61.75	-67.64	-50.88	-20.23
LDPE	-71.58	-71.58	-0.53	-20.13
PET	-50.91	-51.98	-32.58	-10.84
LLDPE	-66.91	-66.91	-0.53	-20.19
PP	-67.16	-67.16	-0.53	-20.20
PS	-75.54	-75.54	-0.53	-18.25
PVC	-48.99	-48.99	-0.53	-8.11
PLA	-30.36	-30.36	NA	-8.61
Corrugated Containers	-22.47	-27.32	-15.27	-6.97
Magazines/Third-class Mail	-33.43	-33.47	-0.92	-5.20
Newspaper	-36.83	-41.07	-16.88	-8.06
Office Paper	-36.62	-37.31	-10.12	-6.55
Phonebooks	-40.54	-40.54	-12.33	-8.06
Textbooks	-35.59	-35.65	-1.07	-6.55
Dimensional Lumber	-4.16	-4.16	0.08	-8.52
Medium-density Fiberboard	-12.37	-12.37	0.34	-8.53
Food Waste	-14.89	-14.89	0.25	-2.41
Food Waste (meat only)	-43.94	-43.94	0.25	-2.41
Food Waste (non-meat)	-7.53	-7.53	0.25	-2.41
Beef	-64.22	-64.22	0.25	-2.41
Poultry	-26.82	-26.82	0.25	-2.41
Grains	-5.95	-5.95	0.25	-2.41
Bread	-6.84	-6.84	0.25	-2.41
Fruits and Vegetables	-5.41	-5.41	0.25	-2.41
Dairy Products	-14.60	-14.60	0.25	-2.41
Yard Trimmings	NA	NA	0.12	-2.97
Grass	NA	NA	0.11	-2.98
Leaves	NA	NA	0.13	-2.96
Branches	NA	NA	0.15	-2.94
Mixed Paper (general)	-29.16	-34.28	-20.60	-7.00
Mixed Paper (primarily residential)	-28.87	-34.29	-20.60	-6.98
Mixed Paper (primarily from offices)	-73.45	-75.70	-21.04	-6.40
Mixed Metals	-60.04	-89.57	-67.17	-11.40
Mixed Plastics	-28.62	-29.56	-39.78	-14.53
Mixed Recyclables	NA	NA	-15.13	-6.95
Mixed Organics	NA	NA	0.18	-2.68
Mixed MSW	NA	NA	-0.32	-5.03
Carpet	-91.59	-91.59	-22.10	-7.84
Personal Computers	-957.27	-957.27	-29.77	-6.80
Clay Bricks	-5.66	-5.66	NA	NA
Concrete	NA	NA	-0.63	NA
Fly Ash	NA	NA	-5.29	NA
Tires	-72.19	-74.80	-4.20	-29.02
Asphalt Concrete	-2.21	-2.21	-1.75	-0.53
Asphalt Shingles	-3.64	-3.64	-2.99	-9.03
Drywall	-4.05	-4.05	-3.17	-0.53
Fiberglass Insulation	-5.23	-6.06	-0.53	-0.53

Material/Product	Source Reduction Minus Landfilling		Recycling Minus Landfilling	Combustion Minus Landfilling
	Current Mix of Inputs	100% Virgin Inputs		
Vinyl Flooring	-11.25	-11.25	-0.53	-8.11
Wood Flooring	-15.02	-15.02	-0.53	-11.10

Note: Negative energy impacts = Energy savings. NA = Not applicable.

5. REFERENCES

EPA. (2014). Greenhouse Gas Equivalencies Calculator. U.S. Environmental Protection Agency, Washington, DC. http://www.epa.gov/cleanenergy/energy-resources/calculator.html

FAL. (2002). Franklin Associates, "Energy and Greenhouse Gas Factors for Personal Computers." August 7, 2002.

EPA. (2006). *Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks.* U.S. Environmental Protection Agency (EPA). Retrieved October 22, 2008, from http://epa.gov/epawaste/conserve/tools/warm/SWMGHGreport.html#background