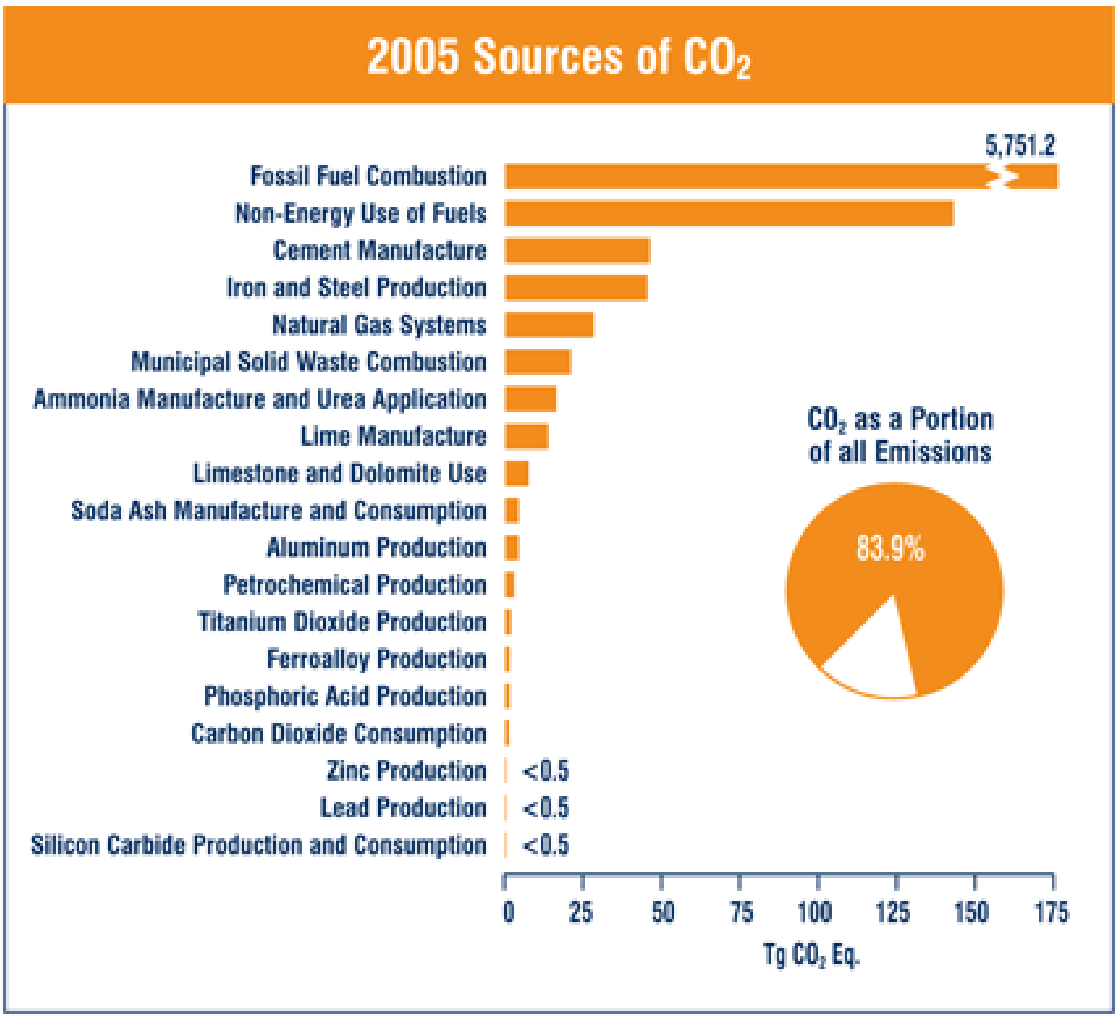
Lands Council/Northwest Climate Change Center Research
June 24, 2008
"What produces less carbon dioxide, a landfill or incinerator?"

Carbon Dioxide

The figure below displays a breakdown of sources of CO2 emissions in the U.S. in 2005. By far the largest source is fossil fuel combustion:



Source: U.S. Greenhouse Gas Emissions Inventory (y-axis units are teragrams of CO2 equivalent)

EPA website: http://www.epa.gov/climatechange/emissions/co2_human.html

Disposal of Municipal Solid Waste (MSW) is a potentially large source of greenhouse gas emissions. The Spokane Waste to Energy (WTE) Facility processed 275 thousand tons of MSW and produced 315 thousand total tons of CO_2 in 2006. This analysis will compare incineration with the other main disposal method, landfilling.

For many wastes, the materials in MSW represent what is left over after a long series of steps: (1) extraction and processing of raw materials; (2) manufacture of products; (3) transportation of materials and products to markets; (4) use by consumers; and (5) waste management. Solid waste management decisions can reduce greenhouse gases GHGs by affecting one or more of the following:

(1) Energy consumption (specifically, combustion of fossil fuels) associated with making, transporting, using, and disposing the product or material that becomes a waste.

(2) CH_4 emissions from landfills where the waste is disposed.

(3) CO_2 and nitrous oxide (N_2O) emissions from waste combustion.

(4) Carbon sequestration, which refers to natural or manmade processes that remove carbon from the atmosphere and store it for long periods or permanently.

The first three mechanisms *add* GHGs to the atmosphere and contribute to global warming. The fourth—carbon sequestration—*reduces* GHG concentrations.

Methodology for comparing WTE to landfill

The WAste Reduction Model (WARM) was created by the U.S. Environmental Protection Agency (EPA) to help solid waste planners and organizations estimate greenhouse gas (GHG) emission reductions from several different waste management practices.
http://www.epa.gov/climatechange/wycd/waste/calculators/Warm_UsersGuide.html
(if you get an error message type Warm model into Google)

2006 waste stream material percentages were taken from the EPA website Municipal Solid Waste fact sheet: http://www.epa.gov/epaoswer/non-hw/muncpl/pubs/06data.pdf

The emissions factors assume that biogenic materials, which are derived from plants are carbon neutral, since growing the plant took in carbon dioxide, which is released when combusted. This includes food scraps, lumber, yard waste and paper.

Fossil fuel derived materials, such as plastic, therefore are counted very differently in terms of CO_2 production when incinerated. Metals are recovered from the WTE at 2.5% of MSW that are not recovered from the landfill.

2006 materials were grouped and the WARM model was run, based on a total of 275,000 tons per year. As a best case scenario the landfill was assumed to collect methane, combust that methane and produce electricity. The landfill was assumed to be 200 miles distance from the waste incinerator for calculation of transportation costs.

Spokane Waste to Energy Facility 2006:

Greenhouse Gas Production 630,000,000 Pounds CO2
Note that much of this is biogenic – not from fossil fuels

Effective maximum capacity: 290,000 Tons/yr
In 2006 processed 275,000 tons
65,043 tons were land filled at Rabanco Regional Landfill

Heat energy produced: 160 megawatts
Average sellable electricity output: 16.1 megawatts (141,000 MWh/year, 8760 hours in a year)
Efficiency: 10%

TOTAL COSTS $30.1 million
Electricity Revenue $12.1 million
Materials Recovery $0.1 million
NET COST OF DISPOSAL $17.9 million ($66 per ton)

Ash Quantity: 65% reduction by weight of original MSW weight.
Disposal: Rabanco Regional Landfill (200 miles, near Roosevelt, WA).

Metals recovery: 2.5% of original weight of MSW. (Metal is not recovered with traditional landfills).

Wheelabrator operates 15 other similar facilities in the U.S. There are over 500 plants in the world, approximately 136 using the same basic technology. More than 20 equal to or larger than 800 tons per day.

From the EPA website: http://www.epa.gov/epaoswer/non-hw/muncpl/pubs/06data.pdf

Table 1

MATERIALS GENERATED* IN THE MUNICIPAL WASTE STREAM, 1960 TO 2006
(In thousands of tons and percent of total generation)

	Thousands of Tons								
Materials	**1960**	**1970**	**1980**	**1990**	**2000**	**2002**	**2004**	**2005**	**2006**
Paper and Paperboard	29,990	44,310	55,160	72,730	87,740	84,070	87,550	85,130	85,290
Glass	6,720	12,740	15,130	13,100	12,620	12,570	12,650	12,760	13,200
Metals									
Ferrous	10,300	12,360	12,620	12,640	13,530	13,560	13,980	13,820	14,220
Aluminum	340	800	1,730	2,810	3,150	3,180	3,190	3,190	3,260
Other Nonferrous	180	670	1,160	1,100	1,560	1,570	1,640	1,670	1,650
Total Metals	*10,820*	*13,830*	*15,510*	*16,550*	*18,240*	*18,310*	*18,810*	*18,680*	*19,130*
Plastics	390	2,900	6,830	17,130	25,340	27,180	29,210	28,950	29,490
Rubber and Leather	1,840	2,970	4,200	5,790	6,530	6,660	6,690	6,670	6,540
Textiles	1,760	2,040	2,530	5,810	9,440	10,320	10,930	11,280	11,840
Wood	3,030	3,720	7,010	12,210	13,020	13,340	13,730	13,900	13,930
Other **	70	770	2,520	3,190	4,190	4,280	4,460	4,540	4,550
Total Materials in Products	54,620	83,280	108,890	146,510	177,120	176,730	184,030	181,910	183,970
Other Wastes									
Food Scraps	12,200	12,800	13,000	20,800	27,110	27,920	29,730	30,480	31,250
Yard Trimmings	20,000	23,200	27,500	35,000	30,530	31,160	31,770	32,070	32,400
Miscellaneous Inorganic Wastes	1,300	1,780	2,250	2,900	3,500	3,580	3,650	3,690	3,720
Total Other Wastes	33,500	37,780	42,750	58,700	61,140	62,660	65,150	66,240	67,370
Total MSW Generated - Weight	88,120	121,060	151,640	205,210	238,260	239,390	249,180	248,150	251,340
	Percent of Total Generation								
Materials	**1960**	**1970**	**1980**	**1990**	**2000**	**2002**	**2004**	**2005**	**2006**
Paper and Paperboard	34.0%	36.6%	36.4%	35.4%	36.8%	35.1%	35.1%	34.3%	33.9%
Glass	7.6%	10.5%	10.0%	6.4%	5.3%	5.3%	5.1%	5.1%	5.3%
Metals									
Ferrous	11.7%	10.2%	8.3%	6.2%	5.7%	5.7%	5.6%	5.6%	5.7%
Aluminum	0.4%	0.7%	1.1%	1.4%	1.3%	1.3%	1.3%	1.3%	1.3%
Other Nonferrous	0.2%	0.6%	0.8%	0.5%	0.7%	0.7%	0.7%	0.7%	0.7%
Total Metals	*12.3%*	*11.4%*	*10.2%*	*8.1%*	*7.7%*	*7.6%*	*7.5%*	*7.5%*	*7.6%*
Plastics	0.4%	2.4%	4.5%	8.3%	10.6%	11.4%	11.7%	11.7%	11.7%
Rubber and Leather	2.1%	2.5%	2.8%	2.8%	2.7%	2.8%	2.7%	2.7%	2.6%
Textiles	2.0%	1.7%	1.7%	2.8%	4.0%	4.3%	4.4%	4.5%	4.7%
Wood	3.4%	3.1%	4.6%	6.0%	5.5%	5.6%	5.5%	5.6%	5.5%
Other **	0.1%	0.6%	1.7%	1.6%	1.8%	1.8%	1.8%	1.8%	1.8%
Total Materials in Products	62.0%	68.8%	71.8%	71.4%	74.3%	73.8%	73.9%	73.3%	73.2%
Other Wastes									
Food Scraps	13.8%	10.6%	8.6%	10.1%	11.4%	11.7%	11.9%	12.3%	12.4%
Yard Trimmings	22.7%	19.2%	18.1%	17.1%	12.8%	13.0%	12.7%	12.9%	12.9%
Miscellaneous Inorganic Wastes	1.5%	1.5%	1.5%	1.4%	1.5%	1.5%	1.5%	1.5%	1.5%
Total Other Wastes	38.0%	31.2%	28.2%	28.6%	25.7%	26.2%	26.1%	26.7%	26.8%
Total MSW Generated - %	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

* Generation before materials recovery or combustion. Does not include construction & demolition debris, industrial process wastes, or certain other wastes.
** Includes electrolytes in batteries and fluff pulp, feces, and urine in disposable diapers.
Details may not add to totals due to rounding.
Source: Franklin Associates, A Division of ERG

GHG Emissions Analysis -- Energy recovered at landfill and WTE

GHG Emissions from Waste to Energy (MTCO2E): -71,705

Material	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Total MTCO2E
Glass	0	0	14,575	N/A	702
Dimensional Lumber	0	0	15,125	N/A	-11,790
Food Scraps	N/A	0	34,100	0	-6,102
Yard Trimmings	N/A	0	35,475	0	-7,893
Mixed Paper (general)	0	0	93,225	N/A	-61,049
Mixed Metals	0	0	20,900	N/A	-22,312
Mixed Plastics	0	0	32,175	N/A	31,757
Carpet	0	0	12,925	N/A	4,982
Tires	0	0	7,150	N/A	0

GHG Emissions from Landfill (MTCO2E): -72,755

Material	Tons Reduced	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Total MTCO2E
Glass	0	0	14,575	0	N/A	919
Dimensional Lumber	0	0	15,125	0	N/A	-13,971
Food Scraps	N/A	N/A	34,100	0	0	5,962
Yard Trimmings	N/A	N/A	35,475	0	0	-27,033
Mixed Paper (general)	N/A	0	93,225	0	N/A	-43,248
Mixed Metals	N/A	0	20,900	0	N/A	1,318
Mixed Plastics	N/A	0	32,175	0	N/A	2,030
Carpet	0	0	12,925	0	N/A	815
Tires	0	0	7,150	0	N/A	451

Landfill with energy recovery has less GHG Emissions: -1,050 MTCO2E

GHG Emissions Analysis – Landfill gas is flared

GHG Emissions from WTE Waste Management (MTCO2E): -71,705

Material	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Total MTCO2E
Glass	0	0	14,575	N/A	702
Dimensional Lumber	0	0	15,125	N/A	-11,790
Food Scraps	N/A	0	34,100	0	-6,102
Yard Trimmings	N/A	0	35,475	0	-7,893
Mixed Paper (general)	0	0	93,225	N/A	-61,049
Mixed Metals	0	0	20,900	N/A	-22,312
Mixed Plastics	0	0	32,175	N/A	31,757
Carpet	0	0	12,925	N/A	4,982
Tires	0	0	7,150	N/A	0

GHG Emissions from Landfill with flaring (MTCO2E): -37,101

Material	Tons Reduced	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Total MTCO2E
Glass	0	0	14,575	0	N/A	919
Dimensional Lumber	0	0	15,125	0	N/A	-11,855
Food Scraps	N/A	N/A	34,100	0	0	11,933
Yard Trimmings	N/A	N/A	35,475	0	0	-23,344
Mixed Paper (general)	N/A	0	93,225	0	N/A	-19,369
Mixed Metals	N/A	0	20,900	0	N/A	1,318
Mixed Plastics	N/A	0	32,175	0	N/A	2,030
Carpet	0	0	12,925	0	N/A	815
Tires	0	0	7,150	0	N/A	451

Total Change in GHG Emissions: 34,604 MTCO2E
More CO2 generated at landfill vs WTE

GHG Emissions Analysis – No Landfill Gas Recovery

GHG Emissions from WTE Waste Management (MTCO2E): -71,705

Material	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Total MTCO2E
Glass	0	0	14,575	N/A	702
Dimensional Lumber	0	0	15,125	N/A	-11,790
Food Scraps	N/A	0	34,100	0	-6,102
Yard Trimmings	N/A	0	35,475	0	-7,893
Mixed Paper (general)	0	0	93,225	N/A	-61,049
Mixed Metals	0	0	20,900	N/A	-22,312
Mixed Plastics	0	0	32,175	N/A	31,757
Carpet	0	0	12,925	N/A	4,982
Tires	0	0	7,150	N/A	0

GHG Emissions from Landfill Management Scenario (MTCO2E): 187,017

Material	Tons Reduced	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Total MTCO2E
Glass	0	0	14,575	0	N/A	919
Dimensional Lumber	0	0	15,125	0	N/A	1,447
Food Scraps	N/A	N/A	34,100	0	0	49,462
Yard Trimmings	N/A	N/A	35,475	0	0	-157
Mixed Paper (general)	N/A	0	93,225	0	N/A	130,732
Mixed Metals	N/A	0	20,900	0	N/A	1,318
Mixed Plastics	N/A	0	32,175	0	N/A	2,030
Carpet	0	0	12,925	0	N/A	815
Tires	0	0	7,150	0	N/A	451

Total Change in GHG Emissions: 258,722 MTCO2E
More CO2 produced at landfill

Notes from analysis:

- A landfill 200 miles away and the Spokane WTE facility have a similar carbon footprint IF the landfill captures and produces energy from methane.

- It is unclear why combusting metals in the WTE gives a net reduction of CO2 – but it appears they assume ferrous recovery.

- Non-carbon materials such as glass are best to be removed completely from the waste stream to avoid transportation costs – if they are recycled and re-used locally

- Plastics are best land filled, since the CO2 produced during incineration is counted as a greenhouse gas, but they are basically considered inert in landfills

- While this is a comparison of landfill vs WTE, recycling has a clear advantage in that recycling a material uses far less energy than the extraction and processing of virgin materials. A Canadian study found that recycling saves three to five times as much energy as is produced by incinerating that same material. Composting food and yard scraps also allows some of the carbon to remain fixed in the soil, as opposed to combusting.

- Another emerging technology is gasification. It has the promise of reducing the amount of solid waste beyond incineration and can produce a gas that runs a turbine very efficiently compared to regular combustion-steam cycles. New technologies highly compress the MSW so that a consistent gasification process occurs. It also has the potential to produce hydrogen, used in fuel cells.

Additional information

Transportation To & From Landfills & Incinerators:

- Almost all of energy consumed in this sector is petroleum based (gas and diesel)
- Depends on # of trips / miles by each vehicle per year.
- The ash from incineration must be transported and is assumed to be 35% of the total MSW – this would add another 6,000 tons of CO2 equivalent to the WTE option.

Exhibit ES-5
GHG Emissions of MSW Management Options Compared to Landfilling (MTCE/Ton)[a]
(Management Option Net Emissions Minus Landfilling Net Emissions)

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

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

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

[a] Values for landfilling reflect projected national average CH_4 recovery in year 2003.

[b] Source reduction assumes initial production using the current mix of virgin and recycled inputs.

[c] Calculation is based on assuming zero net emissions for composting.

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

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

The ordering of combustion, land filling, and composting is affected by (1) the GHG inventory accounting methods, which do not count CO_2 emissions from sustainable biogenic sources,[29] but do count emissions from sources such as plastics; and (2) a series of assumptions on sequestration, future use of CH_4 recovery systems, system efficiency for landfill gas recovery, ferrous metal recovery, and avoided utility fossil fuels. On a site-specific basis, the ordering of results between a combustor and a landfill could be different from the ordering provided here, which is based on national average conditions.

EPA conducted sensitivity analyses to examine the GHG emissions from land filling under varying assumptions about (1) the percentage of land filled waste sent to landfills with gas recovery, and (2) CH_4 oxidation rate and gas collection system efficiency. The sensitivity analyses demonstrate that the results for landfills are very sensitive to these factors, which are site-specific.[30] Thus, using a national average value when making generalizations about emissions from landfills masks some of the variability that exists from site to site.

The scope of this report is limited to developing emission factors that can be used to evaluate GHG implications of solid waste decisions. EPA does not analyze policy options in this report. Nevertheless, the differences in emission factors across various waste management options are sufficiently large as to imply that GHG mitigation policies in the waste sector can make a significant contribution to U.S. emission reductions. A number of examples, using the emission factors in this report, illustrate this point.

• At the firm level, targeted recycling programs can reduce GHGs. For example, a commercial facility that shifts from (a) a baseline practice of land filling (in a landfill with no gas collection system) 50 tons office paper and 4 tons of aluminum cans to (b) recycling the same materials can reduce GHG emissions by more than 100 MTCE.

• At the community level, a city of 100,000 with average waste generation (4.5 lbs/day per capita), recycling (30 percent), and baseline disposal in a landfill with no gas collection system could increase its recycling rate to 40 percent—for example, by implementing a pay-as-you-throw program—and reduce emissions by more than 3,400 MTCE per year. (Note that further growth in recycling would be possible; some communities already are exceeding recycling rates of 50 percent).

• A city of 1 million, disposing of 650,000 tons per year in a landfill without gas collection, could reduce its GHG emissions by about 260,000 MTCE per year by managing waste in a mass burn combustor unit.

• A town of 50,000 people land filling a total of 30,000 tons per year could install a landfill gas recovery system with electricity generation and reduce emissions by about 13,500 MTCE per year.

• At the national level, if the United States attains the goal of a 35 percent recycling rate by 2008, emissions will be nearly 59 million MTCE per year lower than if no recycling took place.