Estimating GHG Reductions From State Actions to Improve Municipal Solid Waste (MSW) Management Practices

This appendix contains three sections: (1) Background, (2) A Life Cycle Approach: Evaluating and Incorporating Solid Waste Management Actions in a Statewide GHG Mitigation Plan, and (3) Example Plan for Waste Management Mitigation Actions. The background section sketches some national trends in solid waste management actions, identifies solid waste management actions which may yield GHG reductions, and discusses the importance of integrating solid waste management actions into a statewide GHG mitigation action plan. The next section discusses the importance of using a life cycle approach for evaluating the GHG impacts of current and future solid waste management actions. In the last section of this appendix, an example MSW management scenario is presented for a hypothetical state looking to evaluate its current and future solid waste management actions from a GHG perspective. The example establishes a baseline scenario of solid waste management actions and compares it to a future scenario; the future scenario uses solid waste management as part a statewide GHG mitigation action plan.

Background

To achieve statewide source reduction and recycling goals, many states and municipalities develop municipal solid waste (MSW) management plans which include a variety of measures such as curbside collection and recycling programs, recycling drop-off centers, and yard trimmings composting facilities. Nationwide, there are about 9,700 curbside recycling programs serving approximately 51 percent of the US population.[1]

Additional MSW management measures provide opportunities for states to meet and exceed their source reduction and recycling goals. Such measures include introducing "Pay As You Throw" (PAYT) pricing for waste collection, increasing the service area or improving collection efficiency of curbside recycling programs, increasing commercial sector recycling, and banning landfilling of organic wastes such as yard trimmings. Note that in most states, the role of state government is to develop plans and standards; local governments implement solid waste policy. Thus, any state actions addressing solid waste should start with full coordination and consultation with local officials.

Many states are in the process of reevaluating their MSW management goals. This reevaluation process provides the opportunity for state and local authorities to consider the GHG reduction benefits of different MSW management strategies currently in place, and identify opportunities to further achieve GHG reductions in the MSW sector. Viewing MSW management actions from a GHG perspective provides the basis for including and integrating these management actions into a statewide GHG mitigation action plan.

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[1] BioCycle, *The State of Garbage in America*, December, 2001.

A Life Cycle Approach: Evaluating and Incorporating MSW Management Actions in a Statewide GHG Mitigation Plan

To incorporate MSW management actions into a statewide GHG mitigation action plan, one must first identify the impacts of MSW management actions on GHG emissions. Heretofore, most of the focus on GHG emissions associated with waste management has been on methane emissions from landfills. There are, however, many emissions and sinks upstream of the point of disposal that are affected by MSW management. A life cycle approach provides an analytic framework for evaluating the full range of GHG emissions and sinks. Major GHG sources associated with MSW include carbon dioxide from fossil fuel burning associated with raw material extraction manufacturing processes, and transportation; process non-energy emissions; landfill methane; and waste combustion. These emissions are offset to some degree by energy recovery at municipal waste combustors and landfill gas collection systems, and enhanced carbon sequestration by forests and landfills.

For MSW management, EPA has conducted a streamlined life cycle inventory (LCI) focusing on the GHG impacts of many MSW components (e.g., glass, paper, plastics, metals) in various ways. The EPA report *Municipal Solid Waste Management and Greenhouse Gases: A Lifecycle Assessment of Emissions and Sinks* [2] and the EPA's Waste Reduction Model (WARM)[3] provide GHG emission factors for waste stream components, based on an LCI framework. EPA's research indicates that for many materials, the effect of recycling or source reduction on net GHG emissions is more closely related to upstream energy emissions and forest carbon sinks than to landfill methane emissions, and so a life cycle approach is able to capture the benefits of solid waste management options in a more holistic way.

EPA recognizes that LCIs have limitations. Data vary with respect to quality, quantity, validity, and robustness. For example, data may vary seasonally, regionally, and locally as a result of changes in economic activity, demographics, different state and local waste regulations, or different waste accounting practices. When state or local data are not available, it is possible to use averaged national data. Application of averaged national data may not accurately reflect state or local conditions. However, in the absence of state or local data, averaged national data are a good proxy. The EPA research to date has very wide error bounds and is based on average national conditions; nevertheless, the information it provides on GHG emissions from waste management is suitable for estimating the impacts of voluntary GHG reduction activities.

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[2] EPA 530-R-02-006. May 2002. USEPA Office of Solid Waste and Emergency Response.

[3] Available on the web at http://yosemite.epa.gov/oar/globalwarming.nsf/content/ActionsWasteWARM.html.

Example Plan for Waste Management Mitigation Actions

The objective of this example is to demonstrate to developers of State Action Plans the value of incorporating waste management activities in their plans. This example uses averaged national data to estimate GHG emissions resulting from the baseline and future MSW management scenarios for a hypothetical state. The initial (baseline) scenario is based on some simple assumptions about MSW management activities in the current year. This baseline scenario provides the starting point from which to consider future changes in MSW management actions. The future scenario is based on the successful implementation of a variety of waste management activities which result in increases in overall recovery and a reduction in GHG emissions.

The hypothetical scenarios focus on a set of sixteen materials[4] present in the MSW stream for which EPA has estimated GHG emission factors. EPA is conducting research to develop emission factors for additional municipal solid waste components such as carpet and personal computers.

Methodological Approach and Assumptions

To establish a baseline and future scenario for the hypothetical state, the following assumptions were made.

Waste Generation:

Total waste generation is the product of the per-capita waste generation rate and the state population. In both the baseline and future scenarios, this analysis assumes a state population of 5 million people and a per-capita waste generation rate of 4.5 pounds of waste/person/day.[5]

Baseline Scenario Assumptions:

The baseline scenario assumes the state currently landfills most of its waste, and also uses waste-to-energy as a management option. Recycling actions include curbside recycling programs in major residential areas, some recycling collection centers, some yard waste composting facilities, and a limited industrial/commercial recycling program. These assumptions are based largely on *BioCycle's* "The State of Garbage In America" which reported the number and types of MSW management programs in place for each state (December, 2001).[6]

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[4] These materials include paper (office paper, newsprint, corrugated cardboard), metals (aluminum cans, steel cans), plastics (HDPE, LDPE, and PET), food scraps, and yard trimmings.
[5] Franklin & Associates, Inc., *Municipal Solid Waste in the United States: 2000 Facts and Figures*, EPA530-R-02-001.
[6] *BioCycle* reported that 45 of 46 reporting states have curbside recycling programs, and 45 of 48 reporting states have yard waste composting facilities (for reporting purposes the District of Columbia was counted as a state).

The baseline scenario assumes these programs reflect common MSW management actions at the state and local level within the US, and that these actions result in a recovery rate of 30 percent, a combustion rate of 15 percent and a landfill rate of 55 percent.[7] The baseline data are presented in Table 1.

The baseline scenario assumes 49 percent of the waste destined for landfills is managed in landfills with landfill gas (LFG) recovery systems, and that these systems have a LFG collection efficiency of 75 percent. In addition, the baseline scenario assumes an overall waste-to-energy (WTE) efficiency rate (i.e., electrical energy output divided by energy value of waste inputs) of 18 percent.

Future Scenario Assumptions:

The future scenario assumes the state implements a set of MSW management activities designed to achieve a higher total recovery rate by the year 2010 in response to state solid waste recovery goals (see Exhibit 1). The future scenario assumes these MSW management activities result in a waste recovery rate of 50 percent, a combustion rate of 15 percent, and a landfill rate of 35 percent. The future scenario data are presented in Table 2.

Exhibit 1
Example of Future Scenario MSW Management Goals and Activities

Future Goals	Future Activities
Increase corrugated cardboard recovery rate to 75 percent.	Increase collection efficiency of commercial recyclables collection.
Increase office paper and newspaper recovery rates to 67 percent.	Expand the commercial collection of mixed paper and corrugated cardboard.
Increase yard trimmings recovery rate to 60 percent.	Promote the benefits of composting. Create yard waste drop-off centers in addition to offering seasonal curbside collection of yard waste. Ban yard waste from landfills where possible.
Increase food waste diversion rate to 25 percent.	Expand the commercial and institutional collection of food waste discards.

The future scenario assumes a statewide recovery rate of 90 percent for corrugated cardboard; 80 percent for newspaper, office paper, magazines, aluminum, steel, and yard trimmings; 50 percent for glass; 40 percent for food scraps; 34 percent for lumber; and 30 percent for plastics (HDPE, LDPE, and PET).

The future scenario also assumes 80 percent of the waste destined for landfills is managed in landfills with landfill gas (LFG) recovery systems, and that these systems have a LFG collection efficiency of 85 percent. The overall waste-to-energy (WTE) efficiency rate remains constant at 18 percent.

[7] The total and material specific generation, recovery, and disposal rates are comparable to the national average rates for 2000 reported in EPA's *Municipal Solid Waste in the United States: 2000 Facts and Figures*.

In an actual state report, the future scenario for the total and material-specific recovery, combustion, and landfill rates would be based on the state's MSW management goals and activities.

The Waste Reduction Model (WARM)

WARM, an EPA model for estimating GHG emissions from the waste management sector, was used to estimate GHG emissions for this analysis. Table 3 presents the GHG emission estimates for the baseline scenario, and Table 4 presents the GHG emissions for the future scenario. Table 5 compares the estimates from the two scenarios. The WARM tool is available online at http://yosemite.epa.gov/oar/globalwarming.nsf/content/ActionsWasteWARM.html.

Results of Example Analysis and Relationship to Other Mitigation Activities

WARM estimates of annual GHG emissions in the baseline and future scenarios are summarized in columns "b", "c", and "d" of Table 5. The estimated GHG emissions are -573,000 metric tons of carbon equivalent (MTCE) per year in the baseline scenario and –1,036,000 MTCE per year in the future scenario. The future scenario reduces emissions by an additional 282,000 MTCE per year.

The largest reductions in GHG emissions were for aluminum (106,000 MTCE per year), corrugated boxes (82,000 MTCE per year), and food waste (66,000 MTCE per year). Most of the reductions are attributable to reduced energy-related carbon dioxide emissions, and reduced landfill methane emissions.

The estimated 463,000 MTCE emission reduction predicted in this exercise is comparable in magnitude to some of the most significant tools available to states for reducing GHG emissions. For comparison, examples of policy and technology options that reduce GHG emissions by similar levels are found in several state action plans. In Oregon, improved natural gas efficiencies have the potential to reduce GHG emissions by approximately 655,000 MTCE by the year 2010. Washington estimates that improved food refrigeration may reduce GHG emissions by approximately 500,000 MTCE by the year 2010.

MSW management options thus represent significant opportunities for states to further reduce their GHG emissions. Because these options have other environmental benefits as well, they deserve careful consideration in Action Plans.

Table 1

Baseline Scenario for the Management of Municipal Solid Waste in the Current Year for a State "Mock-Up"

Baseline Scenario Assumptions

State Population	Annual MSW Generation, short tons[1]	Percent of Total MSW Recovered	Percent of Total MSW Combusted	Percent of Total MSW Landfilled	Percent of Landfilled Waste Managed at Landfills with LFG Recovery	Collection Efficiency of LFG Recovery	Conversion Efficiency of Waste-to-Energy Systems
5,000,000	4,106,250	30%	15%	55%	49%	75%	18%

Generation and Management of MSW in Current Year

	Current Waste Generation		Current Waste Recovery					
(a) Material	(b) Percentage of MSW Generation[2] (by weight)	(c) Amount of Waste Generated[3] (tons)	(d) Percentage of Waste Recovered[4] (by weight)	(e) Amount of Waste Recovered (tons)	(f) Amount of Waste Discarded[5] (tons)	(g) Amount of Waste Combusted (tons)	(h) Amount of Waste Landfilled with no LFG Recovery (tons)	(i) Amount of Waste Landfilled with LFG Recovery (tons)
Aluminum	1.4%	57,488	34.0%	19,546	37,942	8,130	15,204	14,608
Steel	5.8%	238,163	27.4%	65,257	172,906	37,051	69,286	66,569
Glass	5.5%	225,844	23.0%	51,944	173,900	37,264	69,684	66,951
HDPE	2.1%	86,231	9.0%	7,761	78,470	16,815	31,444	30,211
LDPE	2.5%	102,656	3.0%	3,080	99,577	21,338	39,902	38,337
PET	1.1%	45,169	17.0%	7,679	37,490	8,034	15,023	14,434
Corrugated	13.0%	533,813	70.7%	377,405	156,407	33,516	62,675	60,217
Magazines	1.0%	41,063	31.9%	13,099	27,964	5,992	11,205	10,766
Newspaper	5.3%	217,631	59.4%	129,273	88,358	18,934	35,406	34,018
Office Paper	3.2%	131,400	54.1%	71,087	60,313	12,924	24,168	23,220
Lumber	5.5%	225,844	3.8%	8,582	217,262	46,556	87,060	83,646
Food Discards	11.2%	459,900	2.6%	11,957	447,943	95,988	179,497	172,458
Yard Trimmings	12.0%	492,750	56.9%	280,375	212,375	45,509	85,102	81,764
SUBTOTAL	69.6%	2,857,950	36.6%	1,047,044	1,810,906	388,051	725,656	697,199
Other Materials	30.4%	1,248,300	14.8%	184,831	1,063,469	227,886	426,147	409,436
TOTAL	100.0%	4,106,250	30.0%	1,231,875	2,874,375	615,938	1,151,803	1,106,634

[1] Assuming a state population of 5 million people and a waste generation rate of 4.5 lbs of waste/person/day.

[2] Franklin Associates, Ltd. *Municipal Solid Waste in the United States: 2000 Facts and Figures* , EPA 530-R-02-001.

[3] The product of total MSW generation and percent of MSW generation for each material.

[4] Percentage of recovery for each material based on data from EPA 530-R-01-001.

[5] The difference between the amount of waste generated and the amount of waste recovered.

Table 2

Future Scenario for the Management of Municipal Solid Waste by the Year 2010 for a State "Mock-Up": Assuming Increased Material Recovery

Future Scenario Assumptions

State Population	Annual MSW Generation[1]	Percent of Total MSW Recovered	Percent of Total MSW Combusted	Percent of Total MSW Landfilled	Percent of Landfilled Waste Managed at Landfills with LFG Recovery	Collection Efficiency of LFG Recovery	Conversion Efficiency of Waste-to-Energy Systems
5,000,000	4,106,250	50%	15%	35%	80%	85%	18%

Generation and Management of MSW in Year 2010

	Current Waste Generation		Current Waste Recovery					
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)
Material	Percentage of MSW Generation[2] (by weight)	Amount of Waste Generated[3] (tons)	Percentage of Waste Recovered[4] (by weight)	Amount of Waste Recovered (tons)	Amount of Waste Discarded[5] (tons)	Amount of Waste Combusted (tons)	Amount of Waste Landfilled with no LFG Recovery (tons)	Amount of Waste Landfilled with LFG Recovery (tons)
Aluminum	1.4%	57,488	80.0%	45,990	11,498	3,449	1,610	6,439
Steel	5.8%	238,163	80.0%	190,530	47,633	14,290	6,669	26,674
Glass	5.5%	225,844	50.0%	112,922	112,922	33,877	15,809	63,236
HDPE	2.1%	86,231	30.0%	25,869	60,362	18,109	8,451	33,803
LDPE	2.5%	102,656	30.0%	30,797	71,859	21,558	10,060	40,241
PET	1.1%	45,169	30.0%	13,551	31,618	9,485	4,427	17,706
Corrugated	13.0%	533,813	90.0%	480,431	53,381	16,014	7,473	29,894
Magazines	1.0%	41,063	80.0%	32,850	8,213	2,464	1,150	4,599
Newspaper	5.3%	217,631	80.0%	174,105	43,526	13,058	6,094	24,375
Office Paper	3.2%	131,400	80.0%	105,120	26,280	7,884	3,679	14,717
Lumber	5.5%	225,844	34.0%	76,787	149,057	44,717	20,868	83,472
Food Discards	11.2%	459,900	40.0%	183,960	275,940	82,782	38,632	154,526
Yard Trimmings	12.0%	492,750	80.0%	394,200	98,550	29,565	13,797	55,188
SUBTOTAL	69.6%	2,857,950	65.3%	1,867,112	990,838	297,251	138,717	554,869
Other Materials	30.4%	1,248,300	14.9%	186,013	1,062,287	318,686	148,720	594,881
TOTAL	100.0%	4,106,250	50.0%	2,053,125	2,053,125	615,938	287,438	1,149,750

[1] Assuming the state population of 5 million people and the waste generation rate of 4.5 lbs of waste/person/day have not changed in year 2010.

[2] Franklin Associates, Ltd. *Municipal Solid Waste in the United States: 2000 Facts and Figures* , EPA 530-R-02-001.

[3] The product of total MSW generation and percent of MSW generation for each material.

[4] Assuming these are the recovery rate goals achieved in 2010, yard trimmings includes back yard and centralized composting.

[5] The difference between the amount of waste generated and the amount of waste recovered.

Table 3
Estimated GHG Emissions from MSW Management Actions in the Baseline Scenario (Estimated Using WARM)

(a) Material	(b) Baseline Generation of Material (tons)	(c) Estimated Recycling (tons)	(d) Annual GHG Emissions from Recycling (MTCE)	(e) Estimated Landfilling (tons)	(f) Annual GHG Emissions from Landfilling (MTCE)			(g) Estimated Combustion (tons)	(h) Annual GHG Emissions from Combustion (MTCE)	(i) Estimated Composting (tons)	(j) Annual GHG Emissions from Composting (MTCE)	(k) Total Annual GHG Emissions (MTCE)
					LFs w/o Recovery	LFs with Recovery	Total					
Aluminum	57,488	19,546	-78,342	29,811	159	153	312	8,130	139	0	0	-77,891
Steel	238,163	65,257	-31,930	135,855	726	698	1,424	37,051	-15,492	0	0	-45,998
Glass	225,844	51,944	-3,957	136,635	730	702	1,432	37,264	528	0	0	-1,997
HDPE	86,231	7,761	-2,973	61,655	330	317	646	16,815	3,907	0	0	1,580
LDPE	102,656	3,080	-1,437	78,239	418	402	820	21,338	4,958	0	0	4,341
PET	45,169	7,679	-3,252	29,456	157	151	309	8,034	2,283	0	0	-660
Corrugated	533,813	377,405	-267,347	122,891	16,872	-7,387	9,485	33,516	-6,201	0	0	-264,063
Magazines	41,063	13,099	-9,660	21,971	-169	-2,476	-2,645	5,992	-801	0	0	-13,106
Newspaper	217,631	129,273	-122,706	69,424	-4,088	-10,354	-14,442	18,934	-3,996	0	0	-141,145
Office Paper	131,400	71,087	-48,144	47,388	25,475	4,021	29,497	12,924	-2,301	0	0	-20,948
Lumber	225,844	8,582	-5,744	170,706	-3,820	-14,042	-17,863	46,556	-10,295	0	0	-33,902
Food Discards	459,900	0	0	351,955	52,049	7,871	59,920	95,988	-4,867	11,957	-646	54,407
Yard Trimmings	492,750	0	0	166,866	-2,185	-13,505	-15,690	45,509	-2,870	280,375	-15,148	-33,707
Total	2,857,950	754,712	-575,492	1,422,854	86,656	-33,451	53,205	388,051	-35,008	292,332	-15,794	-573,089

Table 4

Estimated GHG Emissions from MSW Management Actions in the Future Scenario (Estimated Using WARM)

(a)	(b)	(c)	(d)	(e)	(f)			(g)	(h)	(i)	(j)	(k)
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)
					LFs w/o Recovery	LFs with Recovery	Total					
Aluminum	57,488	45,990	-184,333	8,048	17	67	84	3,449	59	0	0	-184,190
Steel	238,163	190,530	-93,226	33,343	70	280	349	14,290	-5,975	0	0	-98,852
Glass	225,844	112,922	-8,601	79,045	166	663	828	33,877	480	0	0	-7,293
HDPE	86,231	25,869	-9,911	42,253	89	354	443	18,109	4,208	0	0	-5,261
LDPE	102,656	30,797	-14,366	50,302	105	422	527	21,558	5,009	0	0	-8,830
PET	45,169	13,551	-5,739	22,133	46	186	232	9,485	2,696	0	0	-2,811
Corrugated	533,813	480,431	-340,329	37,367	2,012	-5,229	-3,217	16,014	-2,963	0	0	-346,509
Magazines	41,063	32,850	-24,227	5,749	-17	-1,189	-1,207	2,464	-329	0	0	-25,763
Newspaper	217,631	174,105	-165,261	30,468	-704	-8,033	-8,737	13,058	-2,756	0	0	-176,753
Office Paper	131,400	105,120	-71,193	18,396	3,878	820	4,698	7,884	-1,404	0	0	-67,898
Lumber	225,844	76,787	-51,393	104,340	-916	-15,393	-16,309	44,717	-9,888	0	0	-77,590
Food Discards	459,900	0	0	193,158	11,202	2,018	13,221	82,782	-4,197	183,960	-9,939	-916
Yard Trimmings	492,750	0	0	68,985	-354	-10,142	-10,496	29,565	-1,864	394,200	-21,297	-33,658
Total	2,857,950	1,288,952	-968,580	693,587	15,594	-35,177	-19,583	297,251	-16,926	578,160	-31,236	-1,036,325

Table 5
Comparison of Total Estimated GHG Emissions For the Baseline and Future Scenarios

(a) Material	(b) Baseline Scenario: Estimated Total Annual GHG Emissions (MTCE)	(c) Future Scenario: Estimated Total Annual GHG Emissions (MTCE)	(d) Difference Between Baseline and Future Scenario Estimates (MTCE)
Aluminum	-77,891	-184,190	-106,299
Steel	-45,998	-98,852	-52,854
Glass	-1,997	-7,293	-5,296
HDPE	1,580	-5,261	-6,841
LDPE	4,341	-8,830	-13,171
PET	-660	-2,811	-2,151
Corrugated	-264,063	-346,509	-82,446
Magazines	-13,106	-25,763	-12,657
Newspaper	-141,145	-176,753	-35,609
Office Paper	-20,948	-67,898	-46,950
Lumber	-33,902	-77,590	-43,689
Food Discards	54,407	-916	-55,323
Yard Trimmings	-33,707	-33,658	49
Total	-573,089	-1,036,325	-463,236

Note: These data were obtained from Tables 3 and 4.