Appendix A. Waste Management

Overview
Greenhouse gas (GHG) emissions from waste management include:

- Solid waste management – methane (CH_4) emissions from municipal and industrial solid waste landfills (LFs), accounting for CH_4 that is flared or captured for energy production (this includes both open and closed landfills);
- Solid waste combustion – CH_4, carbon dioxide (CO_2), and nitrous oxide (N_2O) emissions from the combustion of solid waste in incinerators or waste to energy plants; and
- Wastewater management – CH_4 and N_2O from municipal wastewater and CH_4 from industrial wastewater (WW) treatment facilities.

Inventory and Reference Case Projections

Solid Waste Management
For solid waste management, we used the United States Environmental Protection Agency's (US EPA) State Greenhouse Gas Inventory Tool (SGIT) and the US EPA Landfill Methane Outreach Program (LMOP) landfills database[1] as starting points to estimate emissions. The LMOP data serve as input data to estimate annual waste emplacement for each landfill needed by SGIT. SGIT then estimates the total CH_4 generation for the set of landfill sites being analyzed. Additional post-processing outside of SGIT to account for emissions growth and controls is then performed to estimate CH_4 emissions.

The LMOP database was shared with Maryland Department of the Environment (MDE) solid waste staff, and the Center for Climate Strategies (CCS) was supplied with additional data on Maryland landfills. These additional data included information on sites that were not present in the LMOP database, as well as updated information on sites that were present in the database (e.g., waste emplacement data, information on controls).[2] The combined EPA LMOP and MDE data indicate that eleven of the State's landfills are controlled [two with landfill gas to energy (LFGTE) plants, nine with a flare]. The remaining 48 landfills throughout the state are uncontrolled.

To obtain the annual waste emplacement rate needed by SGIT for each landfill, the waste-in-place estimate was divided by the number of years of operation. This average annual disposal rate for each landfill was assumed for all years that the landfill was operating. Data were available to calculate the average emplacement rate for each of the 11 controlled sites and 48 uncontrolled sites.

[1] LMOP database is available at: http://www.epa.gov/lmop/proj/index.htm. Updated version of the database provided by Rachel Goldstein, Program Manager, EPA Landfill Methane Outreach Program, October 2006.
[2] Walter A. Simms, Public Health Engineer, Air Quality Planning Division, Air and Radiation Management Administration, MDE, personal communication with M. Mullen, CCS, July, 2007.

CCS performed three different runs of SGIT to estimate emissions from municipal solid waste (MSW) landfills: (1) uncontrolled landfills; (2) landfills with a landfill gas collection system and LFGTE plant; and (3) landfills with landfill gas collection and a flare. SGIT produced annual estimates of CH_4 emissions through 2005 for each of these landfill categories. CCS then performed post-processing of the landfill emissions to account for landfill gas controls (at LFGTE and flared sites) and to project the emissions through 2020. CCS assumed that 10% of CH_4 emissions are oxidized before being emitted to the atmosphere (consistent with the SGIT default). For the controlled landfills, CCS assumed that the overall CH_4 collection and control efficiency is 75%.[3]

Growth rates were estimated by using the historic (1995-2005) growth rates of emissions in both the controlled and uncontrolled landfill categories. The period from 1995 to 2005 was used since there were a large number of landfill closures in the U.S. during the period from 1990 to 1995 (which could have affected waste management practices). Hence, the post-1995 period is thought to be the most representative of waste emplacement rates and subsequent emissions. The annual growth rates are: -0.14% for uncontrolled sites and 1.0% for controlled landfills. The decrease in the uncontrolled category is due to smaller rates of waste emplacement at these sites in the post-1995 period.

CCS used the SGIT default for industrial landfills. This default is based on national data indicating that industrial landfilled waste is emplaced at approximately 7% of the rate of MSW emplacement. Hence the assumption is that this additional industrial waste emplacement occurs in addition to that already addressed in the emplacement rates for MSW sites. Due to a lack of data, no controls were assumed for industrial waste landfilling. For industrial landfills, the growth rate in emissions from 1995 to 2005 (0.15%/yr) was used to project emissions from 2006 to 2020 (equal to the overall growth in MSW landfill emissions).

Solid Waste Combustion

SGIT defaults (amount of solid waste combusted 1990-1998, emission factors, waste characteristics) were used to estimate emissions from solid waste combustion. Amount of MSW combusted from 1999 to 2005 were obtained from the MDE[4] and inputted in the SGIT. Sources include solid waste burning in municipal and medical waste incinerators and hazardous waste incineration. According to the MDE, all municipal incinerating facilities are controlled. No information was identified on plans for additional plants in the future or expanded capacity at the existing plants, so emissions were held constant in the forecast years.

Open burning of MSW at residential sites also contributes to GHG emissions. According to a Mid-Atlantic/Northeast Visibility Union (MANE-VU) report on open burning in residential areas, 62,404 tons of MSW was burned in Maryland in 2000.[5] This contributes to only 0.03 $MMtCO_2e$ in GHG emissions in 2000. Due to deficient historical data from other years, it is

[3] As per EPA's AP-42 Section on Municipal Solid Waste Landfills: http://www.epa.gov/ttn/chief/ap42/ch02/final/c02s04.pdf.
[4] Annual Report Solid Waste Management in Maryland 1999-2005, MDE: http://www.mde.state.md.us/ResearchCenter/Publications/Land/index.asp#solidwaste.
[5] Open Burning in Residential Areas, Emissions Inventory Development Report, MANE-VU, prepared by E. H. Pechan & Associates, Inc, January, 2004.

assumed that open burning of MSW stays constant from 1990-2005. Emissions are assumed to be held constant after 2005 due to uncertainty in projections.

Wastewater Management
GHG emissions from municipal and industrial wastewater treatment were also estimated. For municipal wastewater treatment, emissions were calculated in SGIT based on State population, assumed biochemical oxygen demand (BOD) and protein consumption per capita, and emission factors for N_2O and CH_4. The key SGIT default values are shown in Table G1.

For industrial wastewater emissions, SGIT provides default assumptions and emission factors for three industrial sectors: Fruits & Vegetables, Red Meat & Poultry, and Pulp & Paper. Default data for Red Meat & Poultry were used for Maryland, but the emissions are very small (about 0.001 MMtCO2e per year) and are not significant compared to the total waste sector emissions.

Table G1. SGIT Key Default Values for Municipal Wastewater Treatment

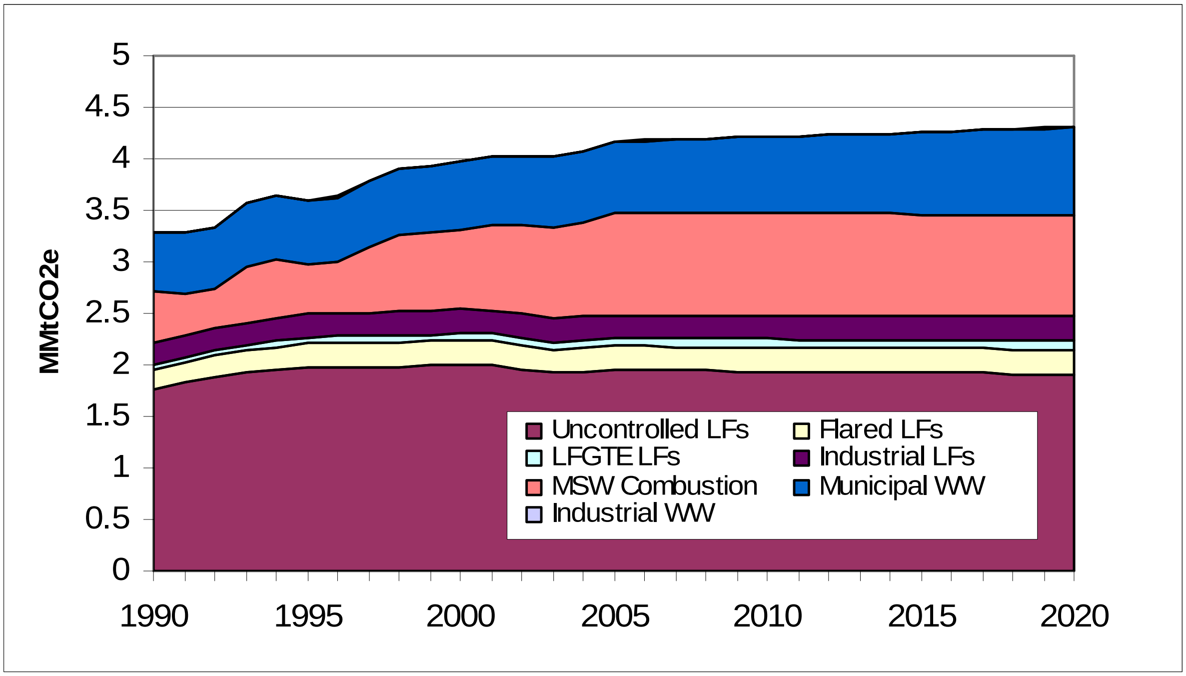
Variable	Value
BOD	0.09 kg /day-person
Amount of BOD anaerobically treated	16.25%
CH_4 emission factor	0.6 kg/kg BOD
MD residents not on septic	75%
Water treatment N_2O emission factor	4.0 g N_20/person-yr
Biosolids emission Factor	0.01 kg N_2O-N/kg sewage-N

Source: US EPA SGIT – Wastewater Module; methodology and factors taken from US EPA, Emission Inventory Improvement Program, Volume 8, Chapter 12, October 1999: www.epa.gov/ttn/chief/eiip/techreport/volume08/.

Results
Figure G1 shows the emission estimates for the waste management sector. Overall, the sector accounts for 4.2 $MMtCO_2e$ in 2005. By 2020, emissions are expected to increase slightly to 4.3 $MMtCO_2e$/yr. In 2005, 52% of the emissions were contributed by the uncontrolled landfills sector, and by 2020, the contribution from these sites is expected to decline slightly to about 50%. Controlled landfills (flared and LFGTE sites) contributed 7% of total waste emissions in 2005 and are expected to grow to 8% in 2020.

As mentioned above, CCS modeled only emissions from Red Meat & Poultry processors in the industrial wastewater treatment sector. Less than 0.01% of the emissions were contributed by the industrial wastewater treatment sector. In 2005, 17% of the waste management sector emissions were contributed from municipal wastewater treatment systems. The contribution is expected to increase to 20% by 2020. Note that these estimates are based on the default parameters listed in Table G1 and might not adequately account for existing controls (e.g., anaerobic digesters served by a flare or other combustion device) or specific wastewater treatment methods in MD (e.g., anaerobic digestion versus aerobic digestion).

Figure G1. Maryland GHG Emissions from Waste Management



Source: CCS calculations based on approach described in text.
Notes: LF – landfill; WW – wastewater; LFGTE – landfill gas to energy.

LFGTE landfills, along with MSW combustion (with the exception of residential open burning), are not included in the waste sector total emissions in this report; this is shown in Table ES-1. The reason is to prevent double counting as emissions from LFGTE and MSW combustion are already estimated in the electric sector. These two categories are included in this appendix for the purpose of comparing GHG emissions with other sources within the waste sector.

Key Uncertainties

The methods used to model landfill gas emissions do not adequately account for the points in time when controls were applied at individual sites. Hence, for landfills, the historical emissions are less certain than current emissions and future emissions for this reason (since each site that is currently controlled was modeled as always being controlled, the historic emissions are low as a result). The modeling also does not account for uncontrolled sites that will need to apply controls during the period of analysis due to triggering requirements of the federal New Source Performance Standards/Emission Guidelines.

In addition to the inherent uncertainties in modeling CH_4 emissions from landfills, there are two important variables in adjusting these emissions to account for the amount emitted to the atmosphere. The first is the EPA assumption that 10% of the methane generated is oxidized in the surface layers of the landfill. There is little empirical evidence to assess the validity of this assumption. More importantly, for controlled sites, the EPA default assumption is that 75% of the methane is collected by the LFG collection system. Currently, this assumption is fairly contentious with estimates from differing entities ranging from 20% to 99%. EPA is currently planning studies using remote sensing techniques in an attempt to better address this issue.

Several different factors affect the amount of LFG collected: landfill design, including whether the site is fully lined and capped, as well as the surrounding soil type; quality of the LFG collection system (e.g. proper siting of wells); and proper operation of the collection system (landfills are dynamic systems, so the LFG collection system must be continually monitored and adjusted to assure optimum collection efficiency; also, there sites trying to optimize collection for gas quality (methane content) for energy use have to balance quality versus overall collection efficiency.

For industrial landfills, these were estimated using national defaults (7% of the rate of MSW emplacement). It could be that the available MSW emplacement data within the combined LMOP/MDE data used to model the MSW emissions already captures industrial LF waste emplacement. As with overall MSW landfill emissions, industrial landfill emissions are projected to increase between 2005 and 2020. Hence, the industrial landfill inventory and forecast has a significant level of uncertainty and should be investigated further. For example, the existence of active industrial landfills that are not already represented in the LMOP database should be determined.

For Solid Waste Combustion, emissions from open burning of MSW are calculated using national defaults. These defaults, especially the categorization of the waste burned, may not accurately reflect residential open burning in Maryland. Also, state data was available only for year 2000, and that was extrapolated to all inventory years. Hence, historical and projected emissions from open burning of MSW contain a high level of uncertainty.

For the wastewater sector, the key uncertainties are associated with the application of SGIT default values for the parameters listed in Table G1 (e.g., fraction of the MD population on septic; fraction of BOD which is anaerobically decomposed). The SGIT defaults were derived from national data. Hence, they may not adequately characterize the wastewater treatment processes currently employed or to be employed in the future.