# Appendix G. Waste Management

**Overview**
GHG emissions from waste management include:

- Solid waste management – methane ($CH_4$) emissions from landfills and waste combustion, accounting for identified $CH_4$ that is flared or captured for energy production;
- 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 treatment facilities.

**Inventory and Reference Case Projections**

*Solid Waste Management*
For solid waste management, the US EPA SGIT and the US EPA Landfill Methane Outreach Program (LMOP) landfills database[1] were used as a starting point to estimate emissions. Since the LMOP database does not include data covering all Vermont landfills, CCS gathered additional data from Vermont Department of Environmental Conservation (VTDEC).[2] The data from VTDEC included waste-in-place data for additional landfill sites, their years of operation, and use of landfill gas controls. The combined EPA LMOP and VTDEC data indicate that 6 of the State's landfills are controlled [5 with landfill gas to energy (LFGTE) plants, the other with a flare]. Two additional active landfills are uncontrolled, as are the remaining 60 or so small closed landfills throughout the State. To obtain the annual disposal needed by SGIT for each landfill, the waste-in-place 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.

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 flare; and (3) landfills with a landfill gas collection system and LFGTE plant. SGIT produced annual estimates through 2005 for each of these landfill types. CCS then performed some post-processing of the landfill emissions to account for landfill gas controls (at LFGTE and flared sites) and to project the emissions through 2030. For the controlled landfills, CCS assumed that the overall methane collection and control efficiency is 75%.[3]

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. Since VTDEC indicated that there were only 4 or 5 old and closed paper sludge landfills in the state, CCS only included the industrial landfill emissions associated only with the

[1] LMOP database is available at: http://www.epa.gov/lmop/proj/index.htm. Database downloaded June 2006.
[2] David DiDomenico, VTDEC, personal communication with S. Roe, CCS, August 2006.
[3] As per EPA's AP-42 Section on Municipal Solid Waste Landfills: http://www.epa.gov/ttn/chief/ap42/ch02/final/c02s04.pdf.

first SGIT run noted above for MSW landfills (uncontrolled sites). No controls were assumed for industrial waste landfilling.

*Solid Waste Combustion*
The only municipal waste combustion facility in VT was closed in 1998.[4] SGIT defaults were used to estimate emissions up through 1998 by assuming 1,000 tons/yr combusted consistent with previous VTDEC assumptions. From 1999, these emissions were set to zero.

*Wastewater Management*
GHG emissions from municipal wastewater treatment were also estimated. Emissions are calculated in EPA's 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 below. The only change to these defaults is the estimated fraction of VT's population not on septic systems. The estimate of 51% comes from VTDEC's 2005 GHG inventory documentation.[5]

For industrial wastewater emissions, SGIT provides default assumptions and emission factors for three industrial sectors: Fruits & Vegetables, Red Meat & Poultry, and Pulp & Paper. Based on the previous VTDEC GHG estimates and discussions with VTDEC staff, no significant activity occurs in the State in any of these industrial sectors. Although there was historical pulp and paper industrial activity in the state; due to their relative lack of importance, CCS did not gather data to estimate these historical emissions.

**Table G1. SGIT Key Default Values for Municipal Wastewater Treatment**

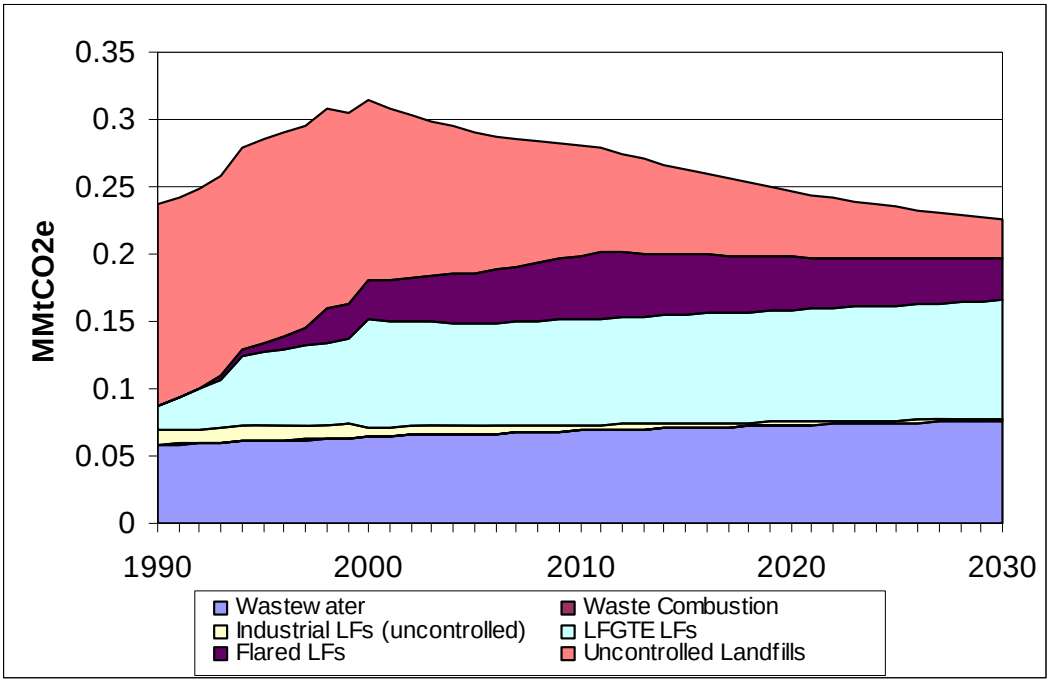
| Variable | Value |
|---|---|
| BOD | 0.065 kg /day-person |
| Amount of BOD anaerobically treated | 16.25% |
| $CH_4$ emission factor | 0.6 kg/kg BOD |
| Vermont residents not on septic | 51%[a] |
| Water treatment $N_2O$ emission factor | 4.0 g $N_2O$/person-yr |
| Biosolids emission Factor | 0.01 kg $N_2O$-N/kg sewage-N |

[a] From VTDEC, April 2005 GHG documentation.

**Results**
Figure G1 shows the emission estimates for the waste management sector. Overall, the sector accounts for less than 0.31$MMtCO_2e$ from 1990 through 2030. Emissions were estimated to be about 0.24 $MMtCO_2e$ in 1990, peak at about 0.31 $MMtCO_2e$ in 1998-2001 and then projected to decline to about 0.28 $MMtCO_2e$ in 2010, 0.25 $MMtCO_2e$ in 2020, and 0.23 $MMtCO_2e$ by 2030.

[4] Vermont Statewide Greenhouse Gas Emissions Inventory Estimates, J. Merrell, April 2005.
[5] VTDEC's source for this estimate: Windham Regional Commission (http://www.rpc.windham.vt.us/pubs/), "Nearly half of Vermont's population is served by onsite septic systems." Based on this information, the default was adjusted to 51%.

**Figure G1. Vermont GHG Emissions from Waste Management**




Note: Emissions associated with waste combustion are too small to be seen on this graph.

For the reference case projections for MSW landfills with LFGTE projects, growth from the 2005 level was assumed to follow population, because these sites are those that are currently operating and controlled in VT (emissions from future waste placed into these landfills will also likely be controlled). This is due to Federal requirements (New Source Performance Standards and Emission Guidelines), which require landfills above a certain size to collect and control landfill gas emissions. In 2005, over 26% of total emissions for the waste management sector were associated with MSW landfills with LFGTE projects. The contribution from MSW landfills with LFGTE projects is expected to increase to about 28% by 2010, 33% by 2020, and 38% by 2030.

For the uncontrolled (primarily closed) sites, emissions were assumed to decline at an annual rate of 5% from the 1998 peak based on the age of waste in place at these sites (peak landfill gas generation begins to tail off after waste has been in place for 10-15 years. For 2005, these sites accounted for about 35% of total emissions for the waste management sector. Based on the forecast assumption for these landfills, their contribution to total emissions for the waste sector was estimated to be about 29% in 2010, 20% in 2020, and 13% in 2030.

For the one flared MSW landfill, emissions were assumed to decline after the year this site is projected to close (2011). The rate of decline for the flared site was assumed to be half of the annual rate for uncontrolled landfill sites (i.e., 2.5%/yr), since the landfill is assumed to accept waste up until the closure year and the rate of landfill gas production should begin to decline

following the initial years after closure. This site accounts for about 17% of total emissions for the waste sector in 2010, 16% of total emissions in 2020, and 13% of total emissions in 2030.

Emissions from industrial landfills were forecasted based on the same rate of decline as the uncontrolled MSW sites. This category accounted for about 4% of total emissions in 1990 and is projected to account for about 1% of total emissions in 2010, and less than 1% of total emissions for the waste sector from 2020 through 2030.

Combustion of MSW occurred in Vermont from 1990 through 1998. Emissions associated with MSW combustion were estimated to be less than 0.2% of total emissions for the waste sector during the 1990 through 1998 period.

Emissions from municipal wastewater treatment were about 0.06 $MMtCO_2e$ in 1990, 0.07 $MMtCO_2e$ in 2005, and were estimated to be about 0.07 $MMtCO_2e$ in 2010, 0.07 $MMtCO_2e$ in 2020, and 0.08 $MMtCO_2e$ in 2030. Emissions were forecasted based on population growth. Emissions associated with this category are estimated to account for about 25% of total emissions for the waste sector from 1990 through 2005. Emissions are expected to increase slightly to about 28% of total waste management sector emissions by 2020 and then 34% of total emissions by 2030.

**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 (since each site that is currently controlled was modeled as always being controlled, the historic emissions estimates are lower than they should be 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 the requirements of the federal New Source Performance Standards/Emission Guidelines. However, CCS does not anticipate that this is an issue for VT landfills.

For industrial landfills, emissions were estimated using national defaults (with industrial landfill wastes buried at 7% of the rate of MSW emplacement). CCS assumed that this rate of waste emplacement occurred only as a fraction of waste emplacement at uncontrolled sites. Sources at VTDEC indicate that very little industrial waste emplacement occurred in VT, except for some forest products sites. Hence, CCS feels that the minimal contribution indicated from these sites in Figure G1 above is accurate. Any additional industrial waste emplacement is assumed to be captured within the emplacement occurring at MSW sites.

For the wastewater sector, the key uncertainties are associated with the application of SGIT default values for the parameters listed in Table G2 above (e.g., the fraction of the Vermont population on septic sewers; and the fraction of BOD that is anaerobically decomposed). The SGIT defaults for emission factors used to estimate wastewater emissions were derived from national data.