

# NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION

Division of Environmental Permits, Region 4

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January 17, 2023

Curt Taylor  
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*Document transmitted electronically*

RE: **Notice of Incomplete Application**  
S.A. Dunn Mine and C&D Facility  
DEC #4-3899-00006  
Part 360 Permit Renewal and Modification  
MLR Permit Renewal and Modification

Curt Taylor,

On January 14, 2022, the Department received applications to renew and modify the Part 360 Solid Waste permit and Mined Land Reclamation permit for the above-referenced facility. Upon review of the submitted materials the Department determined that the applications were incomplete, and a Notice of Incomplete Application (NOIA) was issued to the facility on January 28, 2022. The facility resubmitted materials in response to the NOIA on March 16, 2022. The Department issued a NOIA to the facility on March 30, 2022 with a resubmission from the facility received on November 17, 2022.

Upon review of the resubmitted materials, the application has been determined to be incomplete. Please address the following items:

## **Comments on Climate Leadership and Community Protection Act-**

- 1) The submitted CLCPA GHG Assessment Memorandum prepared by GHD, dated November 4, 2022 ("the analysis"), states several times that, "The landfill gas (LFG) generated within the Dunn Facility is assumed to be approximately 25 percent methane (CH<sub>4</sub>) and 75 percent carbon dioxide (CO<sub>2</sub>)." Please expand on how this assumption was derived.
- 2) The landfill gas collection system currently in place at the facility is discussed throughout the analysis as a mitigation measure. Please expand the analysis to discuss potential mitigation measures which are not currently required by the permit that the facility could implement to reduce current and future emissions. Evaluate feasibility and implementation of the potential mitigation measures.
- 3) Please clarify whether the emissions from the leachate collection tank are included in the fugitive emissions calculations.
- 4) Section 4 of the analysis discusses insignificant emissions. Please clarify how the sources listed in this section were determined to be insignificant emission sources.
- 5) As depicted in Section 2.2, Figure 1 of the analysis, the facility's landfill gas emissions are expected to increase until the peak emissions year in 2032. In Section 6.1 of the analysis, consistency with CLCPA is discussed only in terms of the projected 2030 and 2050 emission

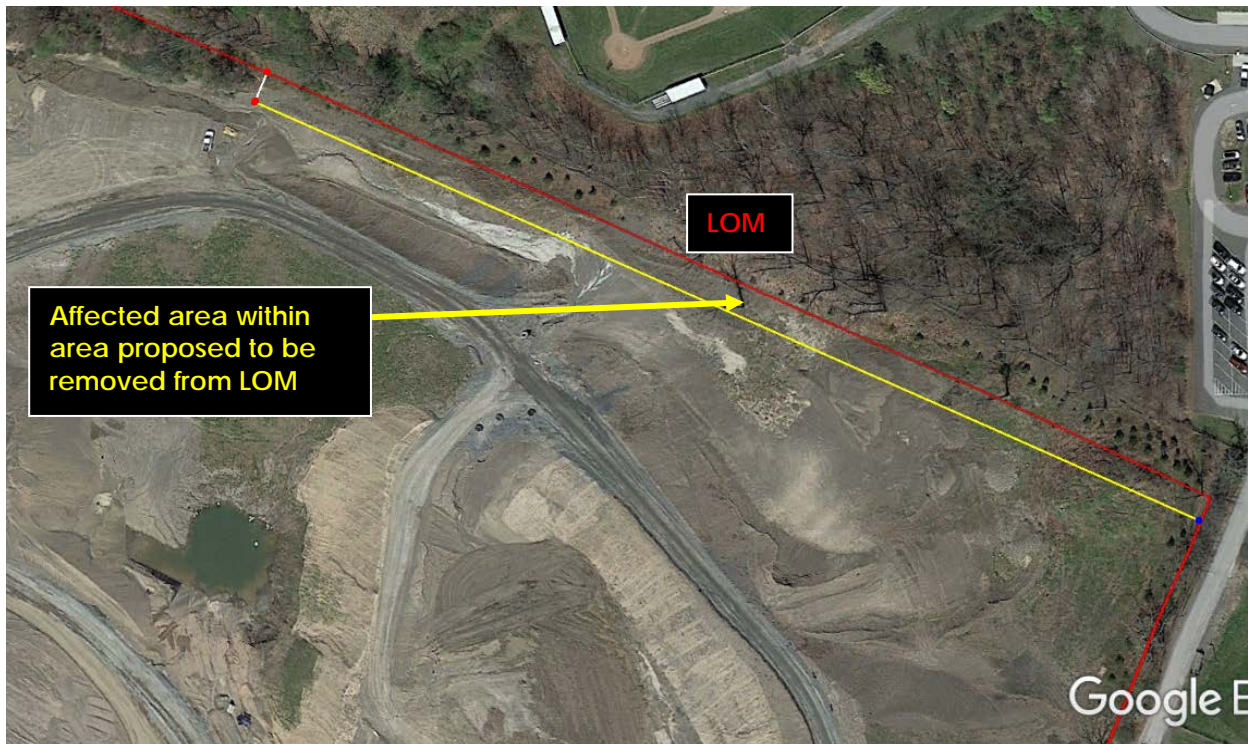
- levels. Within the analysis, please include a discussion about the increase in greenhouse gas (GHG) emissions until the peak year in 2032, and how this relates to the goals of CLCPA.
- 6) Section 7 of the analysis states, “Approximately 20 percent of GHG emissions and 27 percent of HAP emissions in 2030 occur due to the transport of waste from the point of generation to the Dunn Facility, which does not impact the draft Disadvantaged Communities (DAC) located around the Dunn Facility.” Please clarify how this conclusion was derived.
  - 7) The facility’s potential impacts on the surrounding disadvantaged communities related to emissions of GHGs and co-pollutants must be evaluated. The department’s DECinfo Locator tool should be used to find the most up-to-date draft disadvantaged community maps: [DECinfo Locator - NYS Dept. of Environmental Conservation](#). This evaluation must include the potential impacts of mobile sources operating on site as well as transporting material and leachate through the local community. Please provide the following information:
    - a. The facility submitted a map, prepared by CEC PLLC and titled Residents at Large Distribution Area, as part of the approved Public Participation Plan. This map identifies the local truck delivery and return route(s) near facility. Please use this predefined truck route in evaluating the facility’s potential impacts on the surrounding DAC. Calculations of annual miles traveled per vehicle type on the identified route must be provided, based on round-trip distance.
    - b. To the extent not previously provided, please identify sources of emissions (facility vehicles and fossil fuel powered equipment) that will operate within the facility and their daily and annual estimated hours of operation.
    - c. For all the on- and off-site sources identified above, estimate and summarize GHG and co-pollutant emissions using the following emission factors, as appropriate:
      - i. To estimate emissions of CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O, use the EPA emission factors in Tables 2-4 at the following link: <https://www.epa.gov/climateleadership/ghg-emission-factors-hub>. Emissions calculations for on-road vehicles should be based on the total annual miles traveled as referenced in Item a above. Emissions calculations for non-road vehicles and fossil fuel powered equipment should be based on the estimated annual hours of operation as calculated in Item b above. When calculating carbon dioxide equivalents, please use the 20-year global warming potentials found in 6 NYCRR Section 496.5.
      - ii. To estimate emissions of particulate matter (PM), a co-pollutant, use the AFLEET tool at the following link: <https://afleet.es.anl.gov/afleet/>. The ‘Footprint – Onroad’ and ‘Footprint – Offroad’ tabs should be used in conjunction with the data identified in Items a and b above to calculate co-pollutant emissions. Note that while the spreadsheet provides an estimate of GHG emissions as well it should not be used for the purposes of Item i above as the calculation methodology is inconsistent with the requirements of CLCPA. Please also include an electronic copy of the completed spreadsheet with the application materials for this facility.
    - d. Evaluate how estimated GHG and co-pollutants identified above may be reduced by an equal or greater amount within the disadvantaged community.
  - 8) Please show how the Hazardous Air Pollution (HAP) emissions calculated in Tables 3 and 4 were determined.
  - 9) In Table 7 of the analysis, the actual upstream emissions of propane are calculated. Please provide calculations for the upstream emissions of propane on a potential to emit (PTE) basis as well.
  - 10) Emissions projections for 2030 and 2050 are provided on an actual emissions basis. Please provide calculations for the 2030 and 2050 emissions projections on a PTE basis as well.

- 11) The value calculated for the total 2030 CH<sub>4</sub> generated (metric tons) in Attachment A may be inaccurate. Please check this calculation. If the calculation is accurate, please provide a description of how this value was determined.
- 12) In the analysis, the 2030 and 2050 projected direct emissions for stationary sources are calculated. Please provide calculations for the direct emissions from the existing stationary sources at the facility and for the proposed operations described in the renewal/modification applications. The calculations for each scenario should be provided on a PTE and actual emissions basis.
- 13) The HAP emissions from stationary sources are calculated in the emissions projections for 2030 and 2050. Please provide calculations for the HAP emissions from the stationary sources at the facility and for the proposed operations described in the renewal/modification applications. The calculations for each scenario should be provided on a PTE and actual emissions basis.
- 14) Please provide a source reference and/or explain from where the heating value used in Tables B.2 and C.2 came.
- 15) Please describe how the escape CH<sub>4</sub> value was calculated in Tables B.2 and C.2.
- 16) Tables B.3, B.5, C.3, and C.5 utilize emission factors compiled by the Waste Industry Air Coalition (WAIC) to calculate emissions of speciated HAP compounds. Please utilize the AP-42 emission factors in Chapter 2, Solid Waste Disposal, instead. The AP-42 Chapter 2 factors are enclosed for your convenience.
- 17) Please clarify how the cover oxidation factor of 10% was utilized in the fugitive landfill gas calculations for the years 2030 and 2050.
- 18) The 2022 Statewide GHG Emissions Report has been released, which means the "Appendix A" emission factors have been updated. Please utilize these updated emission factors in the analysis. The 2022 version of Appendix A is attached.
- 19) The EPA AP-42 Chapter 3 table cited in footnotes 15 and 16 to Tables 3 and 4, respectively, is Table 3.3-2, which does not include a factor for PM. The EPA AP-42 table that includes an emission factor for PM is Table 3.3-1. Please correct.

### **Comments on Mined Land Reclamation Permit -**

- 20) According to the January 2022 Mining Plan Map and Mined Land Use Plan, a total of 2.27 acres are proposed to be removed from the Life of Mine (LOM) along the northern and western boundaries of the mine. According to the most recent satellite imagery, a portion of the area proposed to be removed from the LOM along the northern perimeter of the site has been affected by mining activity (see image on Page 4 below). There is stockpiled material within this area and a portion of the perimeter storm water containment berm intersects this area. Provide a schedule for reclaiming all areas affected by mining activity within the area proposed to be removed from the LOM by *June 1, 2022*. Describe how the area will be reclaimed and provide details with regard to how the area will be covered with 6 inches of fertile cover material and planted to ensure that it is capable of achieving 75% vegetative coverage in the second year after planting.

## Mining Plan Map overlaid onto 2022 Google Earth Imagery



### Comments on Noise Analysis -

- 21) The Facility Sound Survey prepared by Aurora Acoustical Consultants Inc., dated November 14, 2022 (“noise analysis”), is deficient in not including the anticipated noise levels associated with the construction of the mechanically stabilized earthen (MSE) berm and focuses primarily on fill progression activities within the landfill footprint. Provide a revised noise analysis that describes:
- the proposed equipment to be utilized during the construction of the MSE berm and specific quantitative noise levels associated with the equipment models;
  - the duration of the proposed berm construction activity, including any necessary phasing or time-of-year construction constraints;
  - the anticipated noise levels at the nearest receptors to the proposed berm construction area in comparison to the measured ambient sound levels. The Rensselaer school athletic fields which are adjacent to the northern side of the facility should be identified as a receptor location;
  - the anticipated noise levels related to activity proposed to occur on top of the berm (such as traffic, earth moving, etc.) as well as landfill activities proposed to occur in the new landfill space just behind the berm (waste unloading, spreading, compacting, etc.);
  - clarification of the following statement on Page 53: “Facility sound levels were calculated using an environmental noise modeling program to determine the sound levels received at residential boundaries and at residential locations beyond the facility boundaries, for existing operations both with and without construction sources, and for planned modified operations at the northern end of the facility.”
- 22) The noise analysis deviates from the operating requirements under Part 360.19(j), which states that noise resulting from equipment or operations at the facility must not exceed the Leq sound

levels beyond the property line owned or controlled by the owner or operator at locations authorized for residential purposes. Please provide a narrative discussion on how the noise level exceedances will be addressed and mitigated.

**Comments on Dust Management Plan -**

23) Please note that the facility's Dust Management Plan should be incorporated as a Best Management Practice in the SWPPP under the facility's existing Multi-Sector General Permit.

The Solid Waste and Mined Land Reclamation permit applications will remain in an incomplete status per Uniform Procedures Act, 6 NYCRR Part 621, until all Department comments have been addressed.

Please feel free to contact me at [kate.kornak@dec.ny.gov](mailto:kate.kornak@dec.ny.gov) with questions.

Sincerely,



Kate Kornak  
Regional Permit Administrator

Encls: 2008 Draft EPA AP-42  
2022 Statewide GHG Emissions Report, Appendix A

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File

## 2.4 Municipal Solid Waste Landfills

### 2.4.1 General<sup>1-4</sup>

A municipal solid waste (MSW) landfill unit is a discrete area of land or an excavation that receives household waste, and that is not a land application unit, surface impoundment, injection well, or waste pile. An MSW landfill unit may also receive other types of wastes, such as commercial solid waste, nonhazardous sludge, and industrial solid waste. In addition to household and commercial wastes, the other waste types potentially accepted by MSW landfills include (most landfills accept only a few of the following categories):

- Municipal sludge,
- Municipal waste combustion ash,
- Infectious waste,
- Small-quantity generated hazardous waste;
- Waste tires,
- Industrial non-hazardous waste,
- Conditionally exempt small quantity generator (CESQG) hazardous waste,
- Construction and demolition waste,
- Agricultural wastes,
- Oil and gas wastes, and
- Mining wastes.

The information presented in this section applies only to landfills which receive primarily MSW. This information is not intended to be used to estimate emissions from landfills which receive large quantities of other waste types such as industrial waste, or construction and demolition wastes. These other wastes exhibit emissions unique to the waste being landfilled.

In the United States in 2006, approximately 55 percent of solid waste was landfilled, 13 percent was incinerated, and 32 percent was recycled or composted. There were an estimated 1,754 active MSW landfills in the United States in 2006. These landfills were estimated to receive 138 million tons of waste annually, with 55 to 60 percent reported as household waste, and 35 to 45 percent reported as commercial waste.<sup>79</sup>

### 2.4.2 Process Description<sup>2,5</sup>

The majority of landfills currently use the “area fill” method which involves placing waste on a landfill liner, spreading it in layers, and compacting it with heavy equipment. A daily soil cover is spread over the compacted waste to prevent wind-blown trash and to protect the trash from scavengers and vectors. The landfill liners are constructed of soil (i.e., recompacted clay) and synthetics (i.e., high density polyethylene) to provide an impermeable barrier to leachate (i.e., water that has passed through the landfill) and gas migration from the landfill. Once an area of the landfill is completed, it is covered with a “cap” or “final cover” composed of various combinations of clay, synthetics, soil and cover vegetation to control the incursion of precipitation, the erosion of the cover, and the release of gases and odors from the landfill.

### 2.4.3 Control Technology<sup>2,5,6</sup>

The New Source Performance Standards (NSPS) and Emission Guidelines for air emissions from MSW landfills for certain new and existing landfills were published in the Federal Register on March 1, 1996. Current versions of the NSPS and Emission Guidelines can

be found at 40 CFR 60 subparts WWW and Cb, respectively. The regulation requires that Best Demonstrated Technology (BDT) be used to reduce MSW landfill emissions from affected new and existing MSW landfills if (1) the landfill has a design capacity of 2.5 million Mg (2.75 million tons) and 2.5 million cubic meters or more, and (2) the calculated uncontrolled emissions from the landfill are greater than or equal to 50 Mg/yr (55 tons/yr) of nonmethane organic compounds (NMOCs). The MSW landfills that are affected by the NSPS/Emission Guidelines are each new MSW landfill, and each existing MSW landfill that has accepted waste since November 8, 1987 or that has capacity available for future use. Control systems require: (1) a well-designed and well-operated gas collection system, and (2) a control device capable of reducing non-methane organic compounds (NMOCs) in the collected gas by 98 weight-percent (or to 20 ppmv, dry basis as hexane at 3% oxygen for an enclosed combustion device). Other compliance options include use of a flare that meets specified design and operating requirements or treatment of landfill gas (LFG) for use as a fuel. The National Emission Standards for Hazardous Air Pollutants (NESHAP) for MSW landfills was published in the Federal Register on January 16, 2003. It requires control of the same landfills, and the same types of gas collection and control systems as the NSPS. The NESHAP also requires earlier control of bioreactor landfills and contains a few additional reporting requirements for MSW landfills.

Landfill gas collection systems consist of a series of vertical or horizontal perforated pipes that penetrate the waste mass and collect the gases produced by the decaying waste. These collection systems are classified as either active or passive systems. Active collection systems use mechanical blowers or compressors to create a vacuum in the collection piping to optimize the collection of LFG. Passive systems use the natural pressure gradient established between the encapsulated waste and the atmosphere to move the gas through the collection system.

LFG control and treatment options include: (1) combustion of the LFG, and (2) treatment of the LFG for subsequent sale or use. Combustion techniques include techniques that do not recover energy (i.e., flares and thermal incinerators), and techniques that recover energy and generate electricity from the combustion of the LFG (i.e., gas turbines and reciprocating engines). Boilers can also be employed to recover energy from LFG in the form of steam. Flares combust the LFG without the recovery of energy, and are classified by their burner design as being either open or enclosed. Purification techniques are used to process raw LFG to either a medium-BTU gas using dehydration and filtration or as a higher-BTU gas by removal of inert constituents using adsorption, absorption, and membranes.

#### 2.4.4 Emissions<sup>2,7</sup>

Methane (CH<sub>4</sub>) and carbon dioxide (CO<sub>2</sub>) are the primary constituents of LFG, and are produced by microorganisms within the landfill under anaerobic conditions. Transformations of CH<sub>4</sub> and CO<sub>2</sub> are mediated by microbial populations that are adapted to the cycling of materials in anaerobic environments. Landfill gas generation proceeds through four phases. The first phase is aerobic [i.e., with oxygen (O<sub>2</sub>) available from air trapped in the waste] and the primary gas produced is CO<sub>2</sub>. The second phase is characterized by O<sub>2</sub> depletion, resulting in an anaerobic environment, where large amounts of CO<sub>2</sub> and some hydrogen (H<sub>2</sub>) are produced. In the third phase, CH<sub>4</sub> production begins, with an accompanying reduction in the amount of CO<sub>2</sub> produced. Nitrogen (N<sub>2</sub>) content is initially high in LFG in the first phase, and declines sharply as the landfill proceeds through the second and third phases. In the fourth phase, gas production of CH<sub>4</sub>, CO<sub>2</sub>, and N<sub>2</sub> becomes fairly steady. The duration of each phase and the total time of gas generation vary with landfill conditions (i.e., waste composition, design management, and anaerobic state).

Typically, LFG also contains NMOC and volatile organic compounds (VOC). NMOC result from either decomposition by-products or volatilization of biodegradable wastes. Although NMOC are considered trace constituents in LFG, the NMOC and VOC emission rates could be “major” with respect to Prevention of Significant Deterioration (PSD) and New Source Review (NSR) requirements. This NMOC fraction often contains various organic hazardous air pollutants (HAP), greenhouse gases (GHG), compounds associated with stratospheric ozone depletion and volatile organic compounds (VOC). However, in MSW landfills where contaminated soils from storage tank cleanups are used as daily cover, much higher levels of NMOC have been observed. As LFG migrates through the contaminated soil, it adsorbs the organics, resulting in the higher concentrations of NMOC and any other contaminant in the soil. In one landfill where contaminated soil was used as daily cover, the NMOC concentration in the LFG was 5,870 ppm as compared to the AP-42 average value of 838 ppm. While there is insufficient data to develop a factor or algorithm for estimating NMOC from contaminated daily cover, the emissions inventory developer should be aware to expect elevated NMOC concentrations from these landfills.

Other emissions associated with MSW landfills include combustion products from LFG control and utilization equipment (i.e., flares, engines, turbines, and boilers). These include carbon monoxide (CO), oxides of nitrogen (NO<sub>x</sub>), sulfur dioxide (SO<sub>2</sub>), hydrogen chloride (HCl), particulate matter (PM) and other combustion products (including HAPs). PM emissions can also be generated in the form of fugitive dust created by mobile sources (i.e., garbage trucks) traveling along paved and unpaved surfaces. The reader should consult AP-42 Volume I Sections 13.2.1 and 13.2.2 for information on estimating fugitive dust emissions from paved and unpaved roads.

One pollutant that can vary greatly between landfills is hydrogen sulfide (H<sub>2</sub>S). H<sub>2</sub>S is normally present in LFG at levels ranging from 0 to 90 ppm, with an average concentration of 33 ppm. However, a recent trend at some landfills has been the use of construction and demolition waste (C&D) as daily cover. Under certain conditions that are not well understood, some microorganisms will convert the sulfur in the wall-board of C&D waste to H<sub>2</sub>S. At these landfills, H<sub>2</sub>S concentrations can be significantly higher than at landfills that do not use C&D waste as daily cover. While H<sub>2</sub>S measurements are not available for landfills using C&D for daily cover, the State of New Hampshire among others have noted elevated H<sub>2</sub>S odor problems at these landfills and have assumed that H<sub>2</sub>S concentrations have increased, similarly. In a series of studies at 10 landfills in Florida where a majority of the waste is composed of C&D material, the concentration of H<sub>2</sub>S concentration spanned a range from less than the detection limit of the instrument (0.003 ppmv) up to 12,000 ppmv.<sup>8</sup> Another study that was conducted used flux boxes to measure uncontrolled emissions of H<sub>2</sub>S at five landfills in Florida. This study reported a range of H<sub>2</sub>S emissions between 0.192 and 1.76 mg/(m<sup>2</sup>-d).<sup>9</sup> At any MSW landfill where C&D waste was used as daily cover or was comingled with the MSW, it is recommended that direct H<sub>2</sub>S measurements be used to develop specific H<sub>2</sub>S emissions for the landfill.

The rate of emissions from a landfill is governed by gas production and transport mechanisms. Production mechanisms involve the production of the emission constituent in its vapor phase through vaporization, biological decomposition, or chemical reaction. Transport mechanisms involve the transportation of a volatile constituent in its vapor phase to the surface of the landfill, through the air boundary layer above the landfill, and into the atmosphere. The three major transport mechanisms that enable transport of a volatile constituent in its vapor phase are diffusion, convection, and displacement.

Although relatively uncommon, fires can occur on the surface of the landfill or underground. The smoke from a landfill fire frequently contains many dangerous chemical



compounds, including: carbon monoxide, particulate matter and hazardous gases that are the products of incomplete combustion, and very elevated concentrations of the many gaseous constituents normally occurring in LFG. Of particular concern in landfill fires is the emission of dioxins/furans. Accidental fires at landfills and the uncontrolled burning of residential waste are considered the largest sources of dioxin emissions in the United States.<sup>10</sup> The composition of the gases from landfill fires is highly variable and dependent on numerous site specific factors, including: the composition of the material burning, the composition of the surrounding waste, the temperature of the burning waste, and the presence of oxygen. The only reliable method for estimating the emissions from a landfill fire involves testing the emissions directly. More information is available on landfill fires and their emissions from reference 11.

#### 2.4.4.1 Uncontrolled Emissions -

Several methods have been developed by EPA to determine the uncontrolled emissions of the various compounds present in LFG. The newest measurement method is optical remote sensing with radial plume mapping (ORS-RPM). This method uses an optical emission detector such as open-path Fourier transform infrared spectroscopy (FTIR), ultraviolet differential absorption spectroscopy (UV-DOAS), or open-path tunable diode laser absorption spectroscopy (OP-TDLAS); coupled with radial plume mapping software that processes path-integrated emission concentration data and meteorological data to yield an estimate of uncontrolled emissions. More information on this newest method is described in *Evaluation of Fugitive Emissions Using Ground-Based Optical Remote Sensing Technology* (EPA/600/R-07/032).<sup>12</sup> Additional research is ongoing to provide additional guidance on the use of optical remote sensing for application at landfills. Evaluating uncontrolled emissions from landfills can be a challenge. This is due to the changing nature of landfills, scale and complexity of the site, topography, and spatial and temporal variability in emissions. Additional guidance is being developed for application of EPA's test method for area sources emissions. This is expected to be released by the spring of 2009. For more information, refer to the Emission Measurement Center of EPA's Technology Transfer Network (<http://www.epa.gov/ttn/emc/tmethods.html>). Additional information on ORS technology can also be found on EPA's website for Measurement and Monitoring Technologies for 21<sup>st</sup> Century (21M<sup>2</sup>) which provided funding to identify improved technologies for quantifying area source emissions (<http://www.clu-in.org/programs/21m2/openpath/>).

Often flux data are used to evaluate LFG collection efficiency. The concern with the use of this data is that it does not capture emission losses from header pipes or extraction wells. The other concern is that depending upon the design of the study, the emission variability across a landfill surface is not captured. Emission losses can occur from cracks and fissures or difference in landfill cover material. Often, alternative cover material is used to help promote infiltration, particularly for wet landfill operation. This can result in larger loss of fugitive emissions. Another loss of landfill gas is through the leachate collection pumps and wells. For many of these potential losses, a flux box is not considered adequate to capture the total loss of fugitive gas. The use of ORS technology is considered more reliable.

When direct measurement data are not available, the most commonly used EPA method to estimate the uncontrolled emissions associated with LFG is based on a biological decay model. In this method, the generation of CH<sub>4</sub> must first be estimated by using a theoretical first-order kinetic model of CH<sub>4</sub> production developed by the EPA<sup>13</sup>:

$$Q_{CH_4} = 1.3 L_o R (e^{-kc} - e^{-kt}) \quad (1)$$

where:

- $Q_{CH_4}$  = Methane generation rate at time  $t$ ,  $m^3/yr$ ;
- $L_o$  = Methane generation potential,  $m^3 CH_4/Mg$  of “wet” or “as received” refuse;
- $R$  = Average annual refuse acceptance rate during active life,  $Mg$  of “wet” or “as received” refuse /yr;
- $e$  = Base log, unitless;
- $k$  = Methane generation rate constant,  $yr^{-1}$ ;
- $c$  = Time since landfill closure, yrs ( $c = 0$  for active landfills); and
- $t$  = Time since the initial refuse placement, yrs.

When annual refuse acceptance data is available, the following form of Equation (1) is used. This is the general form of the equation that is used in EPA’s Landfill Gas Emissions Model (LandGEM). Due to the complexity of the double summation, Equation (1 alt) is normally implemented within a computer model. Equation (1 alt.) is more accurate because it accounts for the varying annual refuse flows and it calculates each year’s gas flow in  $1/10$ th year increments.

$$Q_{CH_4} = 1.3 \sum_{i=1}^n \sum_{j=0.1}^1 k L_o \frac{R_i}{10} e^{-kt_j} \quad (1 \text{ alternate})$$

where:

- $Q_{CH_4}$  = Methane generation rate at time  $t$ ,  $m^3/yr$ ;
- $L_o$  = Methane generation potential,  $m^3 CH_4/Mg$  of “wet” or “as received” refuse;
- $R_i$  = Annual refuse acceptance rate for year  $i$ ,  $Mg$  of “wet” or “as received” refuse /yr;
- $e$  = Base log, unitless;
- $k$  = Methane generation rate constant,  $yr^{-1}$ ;
- $c$  = Time since landfill closure, yrs ( $c = 0$  for active landfills); and
- $t$  = Time since the initial refuse placement, yrs.
- $i$  = year in life of the landfill
- $j$  =  $1/10$ th year increment in the calculation.

It should be noted that Equation (1) is provided for estimating  $CH_4$  emissions to the atmosphere. Other fates may exist for the gas generated in a landfill, including capture and subsequent microbial degradation within the landfill’s surface layer. Currently, there are no data that adequately address this fate. It is generally accepted that the bulk of the  $CH_4$  generated will be emitted through cracks or other openings in the landfill surface and that Equation (1) can be used to approximate  $CH_4$  emissions from an uncontrolled landfill. It should also be noted that Equation (1) is different from the equation used in other models such as LandGEM by the addition of the constant 1.3 at the front of the equation. This constant is included to compensate for  $L_o$  which is typically determined by the amount of gas collected by LFG collection systems. The design of these systems will typically result in a gas capture efficiency of only 75%. Therefore, 25% of the gas generated by the landfill is not captured and included in the development of  $L_o$ . The ratio of total gas to captured gas is a ratio of 100/75 or equivalent to 1.3.

Site-specific landfill information is generally available for variables  $R$ ,  $c$ , and  $t$ . When refuse acceptance rate information is scant or unknown,  $R$  can be determined by dividing the refuse in place by the age of the landfill. If a facility has documentation that a certain segment

(cell) of a landfill received *only* nondegradable refuse, then the waste from this segment of the landfill can be excluded from the calculation of R. Nondegradable refuse includes concrete, brick, stone, glass, plaster, wallboard, piping, plastics, and metal objects. The average annual acceptance rate should only be estimated by this method when there is inadequate information available on the actual average acceptance rate. The time variable, t, includes the total number of years that the refuse has been in place (including the number of years that the landfill has accepted waste and, if applicable, has been closed).

Values for variables  $L_o$  and k are normally estimated. Estimation of the potential  $CH_4$  generation capacity of refuse ( $L_o$ ) is generally treated as a function of the moisture and organic content of the refuse. Estimation of the  $CH_4$  generation constant (k) is a function of a variety of factors, including moisture, pH, temperature, and other environmental factors, and landfill operating conditions.

Recommended AP-42 defaults for k are:

<b>k Value</b>	<b>Landfill Conditions</b>
<b>0.02</b>	<b>Areas receiving &lt;25 inches/yr rainfall</b>
<b>0.04</b>	<b>Areas receiving &gt;25 inches/yr rainfall</b>
<b>0.3</b>	<b>Wet landfills<sup>14</sup></b>

For the purpose of the above table, wet landfills are defined as landfills which add large amounts of water to the waste. This added water may be recycled landfill leachates and condensates, or may be other sources of water such as treated wastewater.

The  $CH_4$  generation potential,  $L_o$ , has been observed to vary from 6 to 270  $m^3/Mg$  (200 to 8670  $ft^3/ton$ ), depending on the organic content of the waste material. A higher organic content results in a higher  $L_o$ . Food, textiles, paper, wood, and horticultural waste have the highest  $L_o$  value on a dry basis, while inert materials such as glass, metal and plastic have no  $L_o$  value.<sup>2</sup> Since moisture does not contribute to the value of  $L_o$ , a high moisture content waste, such as food or organic sludge, will have a lower  $L_o$  on an “as received” basis. When using Equation 1 to estimate emissions for typical MSW landfills in the U.S., a mean  $L_o$  value of 100  $m^3/Mg$  refuse (3,530  $ft^3 /ton$ , “as received” basis) is recommended.

There is a significant level of uncertainty in Equation 2 and its recommended defaults values for k and  $L_o$ . The recommended defaults k and  $L_o$  for conventional landfills, based upon the best fit to 40 different landfills, yielded predicted  $CH_4$  emissions that ranged from ~30 to 400% of measured values and had a relative standard deviation of 0.73 (Table 2-2). The default values for wet landfills were based on a more limited set of data and are expected to contain even greater uncertainty.

When gas generation reaches steady state conditions, LFG consists of approximately equal volumes of  $CO_2$  and  $CH_4$ . LFG also typically contains as much as five percent  $N_2$  and other gases, and trace amounts of NMOCs. Since the flow of  $CO_2$  is approximately equal to the flow of  $CH_4$ , the estimate derived for  $CH_4$  generation using Equation (1) can also be used to estimate  $CO_2$  generation. Addition of the  $CH_4$  and  $CO_2$  emissions will yield an estimate of total LFG emissions. If site-specific information is available on the actual  $CH_4$  and  $CO_2$  contents of the LFG, then the site-specific information should be used.

Most of the NMOC emissions from landfills result from the volatilization of organic compounds contained in the landfilled waste. Small amounts may also be created by biological

processes and chemical reactions within the landfill. Available data show that the range of values for total NMOC in LFG is from 31 ppmv to over 5,387 ppmv, and averages 838 ppmv. The proposed regulatory default of 4,000 ppmv for NMOC concentration was developed for regulatory compliance purposes and is considered more conservative. For emissions inventory purposes, site-specific information should be taken into account when determining the total NMOC concentration, whenever available. Measured pollutant concentrations (i.e., as measured by EPA Reference Method 25C), must be corrected for air infiltration which can occur by two different mechanisms: LFG sample dilution and air intrusion into the landfill. These corrections require site-specific data for the LFG CH<sub>4</sub>, CO<sub>2</sub>, N<sub>2</sub>, and O<sub>2</sub> content. If the ratio of N<sub>2</sub> to O<sub>2</sub> is less than or equal to 4.0 (as found in ambient air), then the total pollutant concentration is adjusted for sample dilution by assuming that CO<sub>2</sub> and CH<sub>4</sub> are the primary constituents of LFG (assumed to account for 100% of the LFG), and the following equation is used:

$$C_p \text{ (corrected for air infiltration)} = \frac{C_p \times (1 \times 10^6)}{C_{CO_2} + C_{CH_4}} \quad (2)$$

where:

- C<sub>p</sub> = Concentration of pollutant P in LFG (i.e., NMOC as hexane), ppmv;
- C<sub>CO<sub>2</sub></sub> = CO<sub>2</sub> concentration in LFG, ppmv;
- Q<sub>CH<sub>4</sub></sub> = CH<sub>4</sub> Concentration in LFG, ppmv; and
- 1 x 10<sup>6</sup> = Constant used to correct concentration of P to units of ppmv.

If the ratio of N<sub>2</sub> to O<sub>2</sub> concentrations (i.e., C<sub>N<sub>2</sub></sub>, C<sub>O<sub>2</sub></sub>) is greater than 4.0, then the total pollutant concentration should be adjusted for air intrusion into the landfill by using Equation (2) and adding the concentration of N<sub>2</sub> (i.e., C<sub>N<sub>2</sub></sub>) to the denominator. Values for C<sub>CO<sub>2</sub></sub>, C<sub>CH<sub>4</sub></sub>, C<sub>N<sub>2</sub></sub>, C<sub>O<sub>2</sub></sub>, can usually be found in the source test report for the particular landfill along with the total pollutant concentration data.

To estimate uncontrolled emissions of NMOC or other LFG constituents, the following equation should be used:

$$Q_p = \frac{Q_{CH_4} \times C_p}{C_{CH_4} \times (1 \times 10^6)} \quad (3)$$

where:

- Q<sub>p</sub> = Emission rate of pollutant P (i.e., NMOC), m<sup>3</sup>/yr;
- Q<sub>CH<sub>4</sub></sub> = CH<sub>4</sub> generation rate, m<sup>3</sup>/yr (from Equation 1);
- C<sub>p</sub> = Concentration of pollutant P in LFG, ppmv; and
- C<sub>CH<sub>4</sub></sub> = Concentration of CH<sub>4</sub> in the LFG (assumed to be 50% expressed as 0.5)

Uncontrolled mass emissions per year of total NMOC (as hexane) and speciated organic and inorganic compounds can be estimated by the following equation:

$$UM_p = Q_p \times \frac{MW_p \times 1 \text{ atm}}{(8.205 \times 10^{-5} \text{ m}^3 - \text{atm/gmol} - \text{ }^\circ\text{K}) \times (1000 \text{g/kg}) \times (273 + T)} \quad (4)$$

where:

$UM_p$  = Uncontrolled mass emissions of pollutant P (i.e., NMOC), kg/yr;  
 $MW_p$  = Molecular weight of P, g/gmol (i.e., 86.18 for NMOC as hexane);  
 $Q_p$  = Emission rate of pollutant P,  $m^3$ /yr; and  
 $T$  = Temperature of LFG, °C.

This equation assumes that the operating pressure of the system is approximately 1 atmosphere. If the temperature of the LFG is not known, a temperature of 25 °C (77 °F) is recommended.

Uncontrolled default concentrations of VOC, NMOC and speciated compounds are presented in Table 2.4-1 for landfills having a majority of the waste in place on or after 1992 and in Table 2.4-2 for landfills having a majority of the waste in place before 1992. These default concentrations have already been corrected for air infiltration and can be used as input parameters to Equation (3) for estimating emissions from landfills when site-specific data are not available. An analysis of the data, based on the co-disposal history (with non-residential wastes) of the individual landfills from which the concentration data were derived, indicates that for benzene, NMOC, and toluene, there is a difference in the uncontrolled concentrations.

It is important to note that the compounds listed in Tables 2.4-1 and 2.4-2 are not the only compounds likely to be present in LFG. The listed compounds are those that were identified through a review of the available landfill test reports. The reader should be aware that additional compounds are likely present, such as those associated with consumer or industrial products. Given this information, extreme caution should be exercised in the use of the default emission concentrations given in Tables 2.4-1 and 2.4-2. Available data have shown that there is a range of over two orders of magnitude in many of the pollutant concentrations among gases from various MSW landfills.

#### 2.4.4.2 Controlled Emissions —

Emissions from landfills are typically controlled by installing a gas collection system, and either combusting the collected gas through the use of internal combustion engines, flares, or turbines, or by purifying the gas for direct use in place of a fuel such as natural gas. Gas collection systems are not 100% efficient in collecting LFG, so emissions of  $CH_4$  and NMOC at a landfill with a gas recovery system still occur. To estimate controlled emissions of  $CH_4$ , NMOC, and other constituents in LFG, the collection efficiency of the system must first be estimated. Reported collection efficiencies typically range from 50 to 95%, with a default efficiency of 75% recommended by EPA for inventory purposes. The lower collection efficiencies are experienced at landfills with a large number of open cells, no liners, shallow soil covers, poor collection system and cap maintenance programs and/or a large number of cells without gas collection. The higher collection efficiencies may be achieved at closed sites employing good liners, extensive geomembrane-clay composite caps in conjunction with well engineered gas collection systems, and aggressive operation and maintenance of the cap and collection system. If documented site-specific collection efficiencies are available (i.e., through a comprehensive surface sampling program), then they may be used instead of the 75% average. An analysis showing a range in the gas collection system taking into account delays from gas collection from initial waste placement is provided in Section 2.0.

Estimates of controlled emissions may also need to account for the control efficiency of the control device. Control efficiencies for NMOC and VOC based on test data for the combustion of LFG with differing control devices are presented in Table 2.4-3. As noted in the table, these control efficiencies may also be applied to other LFG constituents. Emissions from

the control devices need to be added to the uncollected emissions to estimate total controlled emissions.

Controlled CH<sub>4</sub>, NMOC, VOC, and speciated emissions can be determined by either of two methods developed by EPA. The newest method is the optical remote sensing with radial plume mapping (ORS-RPM). This method uses an optical emission detector such as open-path Fourier transform infrared spectroscopy (FTIR), ultraviolet differential absorption spectroscopy (UV-DOAS), or open-path tunable diode laser absorption spectroscopy (OP-TDLAS); coupled with radial plume mapping software that processes path-integrated emission concentration data and meteorological data to yield an estimate of uncontrolled emissions. More information on this newest method is described in *Evaluation of Fugitive Emissions Using Ground-Based Optical Remote Sensing Technology* (EPA/600/R-07/032).<sup>12</sup>

Historically, controlled emissions have been calculated with Equation 5. In this equation it is assumed that the LFG collection and control system operates 100 percent of the time. Minor durations of system downtime associated with routine maintenance and repair (i.e., 5 to 7 percent) will not appreciably effect emission estimates. The first term in Equation 5 accounts for emissions from uncollected LFG, while the second term accounts for emissions of the pollutant that were collected but not fully combusted in the control or utilization device:

$$CM_p = \left[ UM_p \times \left( 1 - \frac{\eta_{col}}{100} \right) \right] + \left[ UM_p \times \frac{\eta_{col}}{100} \times \left( 1 - \frac{\eta_{cnt}}{100} \right) \right] \quad (5)$$

where:

CM<sub>p</sub> = Controlled mass emissions of pollutant P, kg/yr;

UM<sub>p</sub> = Uncontrolled mass emissions of P, kg/yr (from Equation 4);

η<sub>col</sub> = Efficiency of the LFG collection system, % (recommended default is 75%);

and

η<sub>cnt</sub> = Efficiency of the LFG control or utilization device, %.

Emission factors for the secondary compounds, CO, PM, NO<sub>x</sub> and dioxins/furans exiting the control device are presented in Table 2.4-4. These emission factors should be used when equipment vendor emission guarantees are not available.

Controlled emissions of CO<sub>2</sub> and sulfur dioxide (SO<sub>2</sub>) are best estimated using site-specific LFG constituent concentrations and mass balance methods.<sup>15</sup> If site-specific data are not available, the data in Tables 2.4-1 and 2.4-2 can be used with the mass balance methods that follow.

Controlled CO<sub>2</sub> emissions include emissions from the CO<sub>2</sub> component of LFG and additional CO<sub>2</sub> formed during the combustion of LFG. The bulk of the CO<sub>2</sub> formed during LFG combustion comes from the combustion of the CH<sub>4</sub> fraction. Small quantities will be formed during the combustion of the NMOC fraction. However, this typically amounts to less than 1 percent of total CO<sub>2</sub> emissions by weight. Also, the formation of CO through incomplete combustion of LFG will result in small quantities of CO<sub>2</sub> not being formed. This contribution to the overall mass balance picture is also very small and does not have a significant impact on overall CO<sub>2</sub> emissions.<sup>15</sup>

The following equation which assumes a 100% combustion efficiency for CH<sub>4</sub> can be used to estimate CO<sub>2</sub> emissions from controlled landfills:

$$CM_{CO_2} = UM_{CO_2} + \left( UM_{CH_4} \times \frac{\eta_{col}}{100} \times 2.75 \right) \quad (6)$$

where:

- CM<sub>CO<sub>2</sub></sub> = Controlled mass emissions of CO<sub>2</sub>, kg/yr;
- UM<sub>CO<sub>2</sub></sub> = Uncontrolled mass emissions of CO<sub>2</sub>, kg/yr (from Equation 4);
- UM<sub>CH<sub>4</sub></sub> = Uncontrolled mass emissions of CH<sub>4</sub>, kg/yr (from Equation 4);
- η<sub>col</sub> = Efficiency of the LFG collection system, % (recommended default is 75%);
- and
- 2.75 = Ratio of the molecular weight of CO<sub>2</sub> to the molecular weight of CH<sub>4</sub>.

To prepare estimates of SO<sub>2</sub> emissions, data on the concentration of reduced sulfur compounds within the LFG are needed. The best way to prepare this estimate is with site-specific information on the total reduced sulfur content of the LFG. Often these data are expressed in ppmv as sulfur (S). Equations 3 and 4 should be used first to determine the uncontrolled mass emission rate of reduced sulfur compounds as sulfur. Then, the following equation can be used to estimate SO<sub>2</sub> emissions:

$$CM_{SO_2} = UM_S \times \frac{\eta_{col}}{100} \times 2.0 \quad (7)$$

where:

- CM<sub>SO<sub>2</sub></sub> = Controlled mass emissions of SO<sub>2</sub>, kg/yr;
- UM<sub>S</sub> = Uncontrolled emissions of reduced sulfur compounds as sulfur, kg/yr (from Equations 3 and 4);
- η<sub>col</sub> = Efficiency of the LFG collection system, %; and
- 2.0 = Ratio of the molecular weight of SO<sub>2</sub> to the molecular weight of S.

The next best method to estimate SO<sub>2</sub> concentrations, if site-specific data for total reduced sulfur compounds as sulfur are not available, is to use site-specific data for speciated reduced sulfur compound concentrations. These data can be converted to ppmv as S with Equation 8. After the total reduced sulfur as S has been obtained from Equation 8, then Equations 3, 4, and 7 can be used to derive SO<sub>2</sub> emissions.

$$C_S = \sum_{i=1}^n C_p \times S_p \quad (8)$$

where:

- C<sub>S</sub> = Concentration of total reduced sulfur compounds, ppmv as S (for use in Equation 3);
- C<sub>p</sub> = Concentration of each reduced sulfur compound, ppmv;
- S<sub>p</sub> = Number of moles of S produced from the combustion of each reduced sulfur compound (i.e., 1 for sulfides, 2 for disulfides); and
- n = Number of reduced sulfur compounds available for summation.

If no site-specific data are available, values of 47 and 33 ppmv can be used for  $C_S$  in the gas from landfills having a majority of the waste in place before 1992 and from landfills having a majority of the waste in place after 1992, respectively. These values were obtained by using the default concentrations presented in Tables 2.4-1 and 2.4-2 for reduced sulfur compounds and Equation 8.

Hydrochloric acid [Hydrogen Chloride (HCl)] emissions are formed when chlorinated compounds in LFG are combusted in control equipment. The best methods to estimate HCl emissions are mass balance methods that are analogous to those presented above for estimating  $SO_2$  emissions. Hence, the best source of data to estimate HCl emissions is site-specific LFG data on total chloride [expressed in ppmv as the chloride ion ( $Cl^-$ )]. However, emission estimates may be underestimated, since not every chlorinated compound in the LFG will be represented in the site test report (i.e., only those that the analytical method specifies). If these data are not available, then total chloride can be estimated from data on individual chlorinated species using Equation 9 below.

$$C_{Cl} = \sum_{i=1}^n C_p \times Cl_p \quad (9)$$

where:

- $C_{Cl}$  = Concentration of total chloride, ppmv as  $Cl^-$  (for use in Equation 3);
- $C_p$  = Concentration of each chlorinated compound, ppmv;
- $Cl_p$  = Number of moles of  $Cl^-$  produced from the combustion of each mole of chlorinated compound (i.e., 3 for 1,1,1-trichloroethane); and
- $n$  = Number of chlorinated compounds available for summation.

After the total chloride concentration ( $C_{Cl}$ ) has been estimated, Equations 3 and 4 should be used to determine the total uncontrolled mass emission rate of chlorinated compounds as chloride ion ( $UM_{Cl}$ ). This value is then used in Equation 10, below, to derive HCl emission estimates:

$$CM_{HCl} = UM_{Cl} \times \frac{\eta_{col}}{100} \times 1.03 \times \frac{\eta_{cnt}}{100} \quad (10)$$

where:

- $CM_{HCl}$  = Controlled mass emissions of HCl, kg/yr;
- $UM_{Cl}$  = Uncontrolled mass emissions of chlorinated compounds as chloride, kg/yr (from Equations 3 and 4);
- $\eta_{col}$  = Efficiency of the LFG collection system, percent;
- 1.03 = Ratio of the molecular weight of HCl to the molecular weight of  $Cl^-$ ; and
- $\eta_{cnt}$  = Control efficiency of the LFG control or utilization device, percent.

In estimating HCl emissions, it is assumed that all of the chloride ion from the combustion of chlorinated LFG constituents is converted to HCl. If an estimate of the control efficiency,  $\eta_{cnt}$ , is not available, then the control efficiency for the equipment listed in Table 2.4-3 should be used. This assumption is recommended to assume that HCl emissions are not underestimated.

If site-specific data on total chloride or speciated chlorinated compounds are not available, then default values of 42 and 74 ppmv can be used for  $C_{Cl}$  in the gas from landfills having a majority of the waste in place before 1992 and from landfills having a majority of the



waste in place after 1992, respectively. These values were derived from the default LFG constituent concentrations presented in Tables 2.4-1 and 2.4-2. As mentioned above, use of this default may produce underestimates of HCl emissions since it is based only on those compounds for which analyses have been performed. The constituents listed in Table 2.4-1 and 2.4-2 are likely not all of the chlorinated compounds present in LFG.

The reader is referred to AP-42 Volume I, Sections 13.2.1 and 13.2.2 for information on estimating fugitive dust emissions from paved and unpaved roads, and to Section 13.2.3 for information on estimating fugitive dust emissions from heavy construction operations; and to AP-42 Volume II Section II-7 for estimating exhaust emissions from construction equipment.

#### 2.4.5 Updates Since the Fifth Edition

The Fifth Edition was released in January 1995. The November 1998 revision includes major revisions of the text and recommended emission factors contained in the section. The most significant revisions to this section since publication in the Fifth Edition are summarized below.

- The equations to calculate the CH<sub>4</sub>, CO<sub>2</sub> and other constituents were simplified.
- The default L<sub>0</sub> and k were revised based upon an expanded base of gas generation data.
- The default ratio of CO<sub>2</sub> to CH<sub>4</sub> was revised based upon averages observed in available source test reports.
- The default concentrations of LFG constituents were revised based upon additional data. References 16-148 are the emission test reports from which data were obtained for this section.
- Additional control efficiencies were included and existing efficiencies were revised based upon additional emission test data.
- Revised and expanded the recommended emission factors for secondary compounds emitted from typical control devices.

The current (i.e., 2008) update includes text revisions and additional discussion, as well as revised recommended emission factors contained within the section. The more significant revisions are summarized below:

- Default concentrations of LFG constituents were developed for landfills with the majority of their waste in place on or after 1992 (proposal of RCRA Subtitle D). The LFG constituent list from the last update reflects data from landfills with waste in place prior to 1992, so Table 2.4-2 was renamed to reflect this.
- Control efficiencies were updated to incorporate additional emission test data and the table was revised to show the NMOC and VOC control efficiencies.
- Revised and expanded the recommended emission factors for secondary compounds emitted from typical control devices.
- The description of modern landfills and statistics about waste disposition in the U.S. were updated with 2006 information.

- EPA's newest measurement method for determining landfill emissions, Optical Remote Sensing with Radial Plume Mapping (ORS-RPM), was added to the discussion of available options for measuring landfill emissions.
- A factor of 1.3 was added to Equation (1) to account for the fact that  $L_0$  is typically determined by the amount of  $CH_4$  collected at landfills using equipment that typically has a capture efficiency of only 75%.
- A k value of 0.3 was added to the list of recommended k values for use in Equation (1).

Table 2.4-1. DEFAULT CONCENTRATIONS FOR LFG CONSTITUENTS FOR LANDFILLS WITH WASTE IN PLACE ON OR AFTER 1992

Compound	CAS Number	Molecular Weight	Default Concentration (ppmv)	Recommended Emission Factor Rating
NMOC (as hexane) <sup>a</sup>		86.18	8.38E+02	A
VOC <sup>b</sup>		NA	8.35E+02	A
1,1,1-Trichloroethane <sup>c</sup>	71556	133.40	2.43E-01	A
1,1,2,2-Tetrachloroethane <sup>c</sup>	79345	167.85	5.35E-01	E
1,1,2,3,4,4-Hexachloro-1,3-butadiene (Hexachlorobutadiene) <sup>c</sup>	87683	260.76	3.49E-03	D
1,1,2-Trichloro-1,2,2-Trifluoroethane (Freon 113)	76131	187.37	6.72E-02	C
1,1,2-Trichloroethane <sup>c</sup>	79005	133.40	1.58E-01	D
1,1-Dichloroethane <sup>c</sup>	75343	98.96	2.08E+00	A
1,1-Dichloroethene (1,1-Dichloroethylene) <sup>c</sup>	75354	96.94	1.60E-01	A
1,2,3-Trimethylbenzene	526738	120.19	3.59E-01	D
1,2,4-Trichlorobenzene <sup>c</sup>	120821	181.45	5.51E-03	C
1,2,4-Trimethylbenzene	95636	120.19	1.37E+00	B
1,2-Dibromoethane (Ethylene dibromide) <sup>c</sup>	106934	187.86	4.80E-03	B
1,2-Dichloro-1,1,2,2-tetrafluoroethane (Freon 114)	76142	170.92	1.06E-01	B
1,2-Dichloroethane (Ethylene dichloride) <sup>c</sup>	107062	98.96	1.59E-01	A
1,2-Dichloroethene	540590	96.94	1.14E+01	E
1,2-Dichloropropane <sup>c</sup>	78875	112.99	5.20E-02	D
1,2-Diethylbenzene	135013	134.22	1.99E-02	D
1,3,5-Trimethylbenzene	108678	120.19	6.23E-01	C
1,3-Butadiene (Vinyl ethylene) <sup>c</sup>	106990	54.09	1.66E-01	C
1,3-Diethylbenzene	141935	134.22	6.55E-02	D
1,4-Diethylbenzene	105055	134.22	2.62E-01	D
1,4-Dioxane (1,4-Diethylene dioxide) <sup>c</sup>	123911	88.11	8.29E-03	D
1-Butene / 2-Methylbutene	106989 / 513359	56.11 / 70.13	1.22E+00	D
1-Butene / 2-Methylpropene	106989 / 115117	56.11	1.10E+00	E

Table 2.4-1 (CONTINUED). DEFAULT CONCENTRATIONS FOR LFG CONSTITUENTS FOR LANDFILLS WITH WASTE IN PLACE ON OR AFTER 1992

Compound	CAS Number	Molecular Weight	Default Concentration (ppmv)	Recommended Emission Factor Rating
1-Ethyl-4-methylbenzene (4-Ethyl toluene)	622968	120.19	9.89E-01	C
1-Ethyl-4-methylbenzene (4-Ethyl toluene) + 1,3,5-Trimethylbenzene	622968 / 108678	120.19	5.79E-01	D
1-Heptene	592767	98.19	6.25E-01	E
1-Hexene / 2-Methyl-1-pentene	592416 / 763291	84.16	8.88E-02	D
1-Methylcyclohexene	591491	96.17	2.27E-02	D
1-Methylcyclopentene	693890	82.14	2.52E-02	D
1-Pentene	109671	70.13	2.20E-01	D
1-Propanethiol (n-Propyl mercaptan)	107039	76.16	1.25E-01	A
2,2,3-Trimethylbutane	464062	100.20	9.19E-03	D
2,2,4-Trimethylpentane <sup>c</sup>	540841	114.23	6.14E-01	D
2,2,5-Trimethylhexane	3522949	128.26	1.56E-01	D
2,2-Dimethylbutane	75832	86.18	1.56E-01	D
2,2-Dimethylpentane	590352	100.20	6.08E-02	D
2,2-Dimethylpropane	463821	72.15	2.74E-02	E
2,3,4-Trimethylpentane	565753	114.23	3.12E-01	D
2,3-Dimethylbutane	79298	86.18	1.67E-01	D
2,3-Dimethylpentane	565593	100.20	3.10E-01	D
2,4-Dimethylhexane	589435	114.23	2.22E-01	D
2,4-Dimethylpentane	108087	100.20	1.00E-01	D
2,5-Dimethylhexane	592132	114.23	1.66E-01	D
2,5-Dimethylthiophene	638028	112.19	6.44E-02	E
2-Butanone (Methyl ethyl ketone) <sup>c</sup>	78933	72.11	4.01E+00	C
2-Ethyl-1-butene	760214	84.16	1.77E-02	D
2-Ethylthiophene	872559	112.19	6.29E-02	E
2-Ethyltoluene	611143	120.19	3.23E-01	D
2-Hexanone (Methyl butyl ketone)	591786	100.16	6.13E-01	E
2-Methyl-1-butene	563462	70.13	1.79E-01	D
2-Methyl-1-propanethiol (Isobutyl mercaptan)	513440	90.19	1.70E-01	E
2-Methyl-2-butene	513359	70.13	3.03E-01	D
2-Methyl-2-propanethiol (tert-Butylmercaptan)	75661	90.19	3.25E-01	E
2-Methylbutane	78784	72.15	2.26E+00	D
2-Methylheptane	592278	114.23	7.16E-01	D
2-Methylhexane	591764	100.20	8.16E-01	D
2-Methylpentane	107835	86.18	6.88E-01	D
2-Propanol (Isopropyl alcohol)	67630	60.10	1.80E+00	C

Table 2.4-1 (CONTINUED). DEFAULT CONCENTRATIONS FOR LFG CONSTITUENTS FOR LANDFILLS WITH WASTE IN PLACE ON OR AFTER 1992

Compound	CAS Number	Molecular Weight	Default Concentration (ppmv)	Recommended Emission Factor Rating
3,6-Dimethyloctane	15869940	142.28	7.85E-01	D
3-Ethyltoluene	620144	120.19	7.80E-01	D
3-Methyl-1-pentene	760203	84.16	6.99E-03	D
3-Methylheptane	589811	114.23	7.63E-01	D
3-Methylhexane	589344	100.20	1.13E+00	D
3-Methylpentane	96140	86.18	7.40E-01	D
3-Methylthiophene	616444	98.17	9.25E-02	E
4-Methyl-1-pentene	691372	84.16	2.33E-02	E
4-Methyl-2-pentanone (MIBK) <sup>c</sup>	108101	100.16	8.83E-01	C
4-Methylheptane	589537	114.23	2.49E-01	D
Acetaldehyde <sup>c</sup>	75070	44.05	7.74E-02	D
Acetone	67641	58.08	6.70E+00	C
Acetonitrile <sup>c</sup>	75058	41.05	5.56E-01	A
Acrylonitrile <sup>c,d</sup>	107131	53.06	BDL	
Benzene <sup>c</sup>	71432	78.11	2.40E+00	A
Benzyl chloride <sup>c</sup>	100447	126.58	1.81E-02	A
Bromodichloromethane	75274	163.83	8.78E-03	E
Bromomethane (Methyl bromide) <sup>c</sup>	74839	94.94	2.10E-02	C
Butane	106978	58.12	6.22E+00	C
Carbon disulfide <sup>c</sup>	75150	76.14	1.47E-01	A
Carbon monoxide	630080	28.01	2.44E+01	C
Carbon tetrachloride <sup>c</sup>	56235	153.82	7.98E-03	A
Carbon tetrafluoride (Freon 14)	75730	88.00	1.51E-01	E
Carbonyl sulfide (Carbon oxysulfide) <sup>c</sup>	463581	60.08	1.22E-01	A
Chlorobenzene	108907	112.56	4.84E-01	A
Chlorodifluoromethane (Freon 22) <sup>c</sup>	75456	86.47	7.96E-01	D
Chloroethane (Ethyl chloride) <sup>c</sup>	75003	64.51	3.95E+00	B
Chloromethane (Methyl chloride) <sup>c</sup>	74873	50.49	2.44E-01	B
cis-1,2-Dichloroethene	156592	96.94	1.24E+00	B
cis-1,2-Dimethylcyclohexane	2207014	112.21	8.10E-02	D
cis-1,3-Dichloropropene	10061015	110.97	3.03E-03	D
cis-1,3-Dimethylcyclohexane	638040	112.21	5.01E-01	D
cis-1,4-Dimethylcyclohexane / trans-1,3-Dimethylcyclohexane	624293 / 2207036	112.21	2.48E-01	D
cis-2-Butene	590181	56.11	1.05E-01	D
cis-2-Heptene	6443921	98.19	2.45E-02	E
cis-2-Hexene	7688213	84.16	1.72E-02	D
cis-2-Octene	7642048	112.21	2.20E-01	D
cis-2-Pentene	627203	70.13	4.79E-02	D

Table 2.4-1 (CONTINUED). DEFAULT CONCENTRATIONS FOR LFG CONSTITUENTS FOR LANDFILLS WITH WASTE IN PLACE ON OR AFTER 1992

Compound	CAS Number	Molecular Weight	Default Concentration (ppmv)	Recommended Emission Factor Rating
cis-3-Methyl-2-pentene	922623	84.16	1.79E-02	D
Cyclohexane	110827	84.16	1.01E+00	B
Cyclohexene	110838	82.14	1.84E-02	D
Cyclopentane	287923	70.13	2.21E-02	D
Cyclopentene	142290	68.12	1.21E-02	D
Decane	124185	142.28	3.80E+00	D
Dibromochloromethane	124481	208.28	1.51E-02	D
Dibromomethane (Methylene dibromide)	74953	173.84	8.35E-04	E
Dichlorobenzene <sup>c,e</sup>	106467	147.00	9.40E-01	A
Dichlorodifluoromethane (Freon 12)	75718	120.91	1.18E+00	B
Dichloromethane (Methylene chloride) <sup>c</sup>	75092	84.93	6.15E+00	A
Diethyl sulfide	352932	90.19	8.62E-02	E
Dimethyl disulfide	624920	94.20	1.37E-01	A
Dimethyl sulfide	75183	62.14	5.66E+00	A
Dodecane (n-Dodecane)	112403	170.33	2.21E-01	D
Ethane	74840	30.07	9.05E+00	D
Ethanol	64175	46.07	2.30E-01	D
Ethyl acetate	141786	88.11	1.88E+00	C
Ethyl mercaptan (Ethanediol)	75081	62.14	1.98E-01	A
Ethyl methyl sulfide	624895	76.16	3.67E-02	E
Ethylbenzene <sup>c</sup>	100414	106.17	4.86E+00	B
Formaldehyde <sup>c</sup>	50000	30.03	1.17E-02	D
Heptane	142825	100.20	1.34E+00	B
Hexanec	110543	86.18	3.10E+00	B
Hydrogen sulfide	7783064	34.08	3.20E+01	A
Indane (2,3-Dihydroindene)	496117	34.08	6.66E-02	D
Isobutane (2-Methylpropane)	75285	58.12	8.16E+00	D
Isobutylbenzene	538932	134.22	4.07E-02	D
Isoprene (2-Methyl-1,3-butadiene)	78795	68.12	1.65E-02	D
Isopropyl mercaptan	75332	76.16	1.75E-01	A
Isopropylbenzene (Cumene) <sup>c</sup>	98828	120.19	4.30E-01	D
Mercury (total) <sup>c</sup>	7439976	200.59	1.22E-04	B
Mercury (elemental) <sup>c</sup>	7439976	200.59	7.70E-05	C
Mercury (monomethyl) <sup>c</sup>	51176126	216.63	3.84E-07	C
Mercury (dimethyl) <sup>c</sup>	627441	258.71	2.53E-06	B
Methanethiol (Methyl mercaptan)	74931	48.11	1.37E+00	A
Methyl tert-butyl ether (MTBE) <sup>c</sup>	1634044	88.15	1.18E-01	D
Methylcyclohexane	108872	98.19	1.29E+00	D

Table 2.4-1 (CONTINUED). DEFAULT CONCENTRATIONS FOR LFG CONSTITUENTS FOR LANDFILLS WITH WASTE IN PLACE ON OR AFTER 1992

Compound	CAS Number	Molecular Weight	Default Concentration (ppmv)	Recommended Emission Factor Rating
Methylcyclopentane	96377	84.16	6.50E-01	D
Naphthalene <sup>c</sup>	91203	128.17	1.07E-01	D
n-Butylbenzene	104518	134.22	6.80E-02	D
Nonane	111842	128.26	2.37E+00	D
n-Propylbenzene (Propylbenzene)	103651	120.19	4.13E-01	D
Octane	111659	114.23	1.08E+00	D
p-Cymene (1-Methyl-4-Isopropylbenzene)	99876	134.22	3.58E+00	D
Pentane	109660	72.15	4.46E+00	C
Propane	74986	44.10	1.55E+01	C
Propene	115071	42.08	3.32E+00	D
Propyne	74997	40.06	3.80E-02	E
sec-Butylbenzene	135988	134.22	6.75E-02	D
Styrene (Vinylbenzene) <sup>c</sup>	100425	104.15	4.11E-01	B
Tetrachloroethylene (Perchloroethylene) <sup>c</sup>	127184	165.83	2.03E+00	A
Tetrahydrofuran (Diethylene oxide)	109999	72.11	9.69E-01	C
Thiophene	110021	84.14	3.49E-01	E
Toluene (Methyl benzene) <sup>c</sup>	108883	92.14	2.95E+01	A
trans-1,2-Dichloroethene	156605	96.94	2.87E-02	C
trans-1,2-Dimethylcyclohexane	6876239	112.21	4.04E-01	D
trans-1,3-Dichloropropene	10061026	110.97	9.43E-03	D
trans-1,4-Dimethylcyclohexane	2207047	112.21	2.05E-01	D
trans-2-Butene	624646	56.11	1.04E-01	D
trans-2-Heptene	14686136	98.19	2.50E-03	E
trans-2-Hexene	4050457	84.16	2.06E-02	D
trans-2-Octene	13389429	112.21	2.41E-01	D
trans-2-Pentene	646048	70.13	3.47E-02	D
trans-3-Methyl-2-pentene	616126	84.16	1.55E-02	D
Tribromomethane (Bromoform) <sup>c</sup>	75252	252.73	1.24E-02	D
Trichloroethylene (Trichloroethene) <sup>c</sup>	79016	131.39	8.28E-01	A
Trichlorofluoromethane (Freon 11)	91315616	137.37	2.48E-01	B
Trichloromethane (Chloroform) <sup>c</sup>	8013545	119.38	7.08E-02	A
Undecane	1120214	156.31	1.67E+00	D
Vinyl acetate <sup>c</sup>	85306269	86.09	2.48E-01	C
Vinyl chloride (Chloroethene) <sup>c</sup>	75014	62.50	1.42E+00	A
Xylenes (o-, m-, p-, mixtures)	8026093	106.17	9.23E+00	A

NOTE: This is not an all-inclusive list of potential LFG constituents, only those for which test data were available at multiple sites. References 83-148.

<sup>a</sup> For NSPS/Emission Guideline compliance purposes, the default concentration for NMOC as specified in the final rule must be used.

<sup>b</sup> Calculated as 99.7% of NMOC, based on speciated emission test data.

<sup>c</sup> Hazardous Air Pollutant listed in Title III of the 1990 Clean Air Act Amendments.

<sup>d</sup> All tests below detection limit. Method detection limits are available for three tests, and are as follows: MDL = 2.00E-04, 4.00E-03, and 2.00E-02 ppm

<sup>e</sup> Many source tests did not indicate whether this compound was the ortho-, meta-, or para- isomer. The para isomer is a Title III listed HAP.

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Table 2.4-2. DEFAULT CONCENTRATIONS FOR LFG CONSTITUENTS FOR LANDFILLS WITH WASTE IN PLACE PRIOR TO 1992

Compound	Molecular Weight	Default Concentration (ppmv)	Emission Factor Rating
NMOC (as hexane) <sup>c</sup>	86.18		
Co-disposal (SCC 50300603)		2,420	D
No or Unknown co-disposal (SCC 50100402)		595	B
1,1,1-Trichloroethane (methyl chloroform) <sup>a</sup>	133.42	0.48	B
1,1,2,2-Tetrachloroethane <sup>a</sup>	167.85	1.11	C
1,1-Dichloroethane (ethylidene dichloride) <sup>a</sup>	98.95	2.35	B
1,1-Dichloroethene (vinylidene chloride) <sup>a</sup>	96.94	0.20	B
1,2-Dichloroethane (ethylene dichloride) <sup>a</sup>	98.96	0.41	B
1,2-Dichloropropane (propylene dichloride) <sup>a</sup>	112.98	0.18	D
2-Propanol (isopropyl alcohol)	60.11	50.1	E
Acetone	58.08	7.01	B
Acrylonitrile <sup>a</sup>	53.06	6.33	D
Benzene <sup>a</sup>	78.11		
Co-disposal (SCC 50300603)		11.1	D
No or Unknown co-disposal (SCC 50100402)		1.91	B
Bromodichloromethane	163.83	3.13	C
Butane	58.12	5.03	C
Carbon disulfide <sup>a</sup>	76.13	0.58	C
Carbon monoxide <sup>b</sup>	28.01	141	E
Carbon tetrachloride <sup>a</sup>	153.84	0.004	B
Carbonyl sulfide <sup>a</sup>	60.07	0.49	D
Chlorobenzene <sup>a</sup>	112.56	0.25	C
Chlorodifluoromethane	86.47	1.30	C
Chloroethane (ethyl chloride) <sup>a</sup>	64.52	1.25	B
Chloroform <sup>a</sup>	119.39	0.03	B
Chloromethane	50.49	1.21	B
Dichlorobenzene <sup>c</sup>	147	0.21	E
Dichlorodifluoromethane	120.91	15.7	A
Dichlorofluoromethane	102.92	2.62	D
Dichloromethane (methylene chloride) <sup>a</sup>	84.94	14.3	A
Dimethyl sulfide (methyl sulfide)	62.13	7.82	C
Ethane	30.07	889	C



Table 2.4-2 (CONTINUED). DEFAULT CONCENTRATIONS FOR LFG CONSTITUENTS FOR LANDFILLS WITH WASTE IN PLACE PRIOR TO 1992

Compound	Molecular Weight	Default Concentration (ppmv)	Emission Factor Rating
Ethanol	46.08	27.2	E
Ethyl mercaptan (ethanethiol)	62.13	2.28	D
Ethylbenzene <sup>a</sup>	106.16	4.61	B
Ethylene dibromide	187.88	0.001	E
Fluorotrichloromethane	137.38	0.76	B
Hexane <sup>a</sup>	86.18	6.57	B
Hydrogen sulfide	34.08	35.5	B
Mercury (total) <sup>a,d</sup>	200.61	2.92x10 <sup>-4</sup>	E
Methyl ethyl ketone <sup>a</sup>	72.11	7.09	A
Methyl isobutyl ketone <sup>a</sup>	100.16	1.87	B
Methyl mercaptan	48.11	2.49	C
Pentane	72.15	3.29	C
Perchloroethylene (tetrachloroethylene) <sup>a</sup>	165.83	3.73	B
Propane	44.09	11.1	B
t-1,2-dichloroethene	96.94	2.84	B
Toluene <sup>a</sup>	92.13		
Co-disposal (SCC 50300603)		165	D
No or Unknown co-disposal (SCC 50100402)		39.3	A
Trichloroethylene (trichloroethene) <sup>a</sup>	131.38	2.82	B
Vinyl chloride <sup>a</sup>	62.50	7.34	B
Xylenes <sup>a</sup>	106.16	12.1	B

NOTE: This is not an all-inclusive list of potential LFG constituents, only those for which test data were available at multiple sites. References 16-82. Source Classification Codes in parentheses.

<sup>a</sup> Hazardous Air Pollutants listed in Title III of the 1990 Clean Air Act Amendments.

<sup>b</sup> Carbon monoxide is not a typical constituent of LFG, but does exist in instances involving landfill (underground) combustion. Therefore, this default value should be used with caution. Of 18 sites where CO was measured, only 2 showed detectable levels of CO.

<sup>c</sup> Source tests did not indicate whether this compound was the para- or ortho- isomer. The para isomer is a Title III-listed HAP.

<sup>d</sup> No data were available to speciate total Hg into the elemental and organic forms.

<sup>e</sup> For NSPS/Emission Guideline compliance purposes, the default concentration for NMOC as specified in the final rule must be used. For purposes not associated with NSPS/Emission Guideline compliance, the default VOC content at co-disposal sites can be estimated by 85 percent by weight (2,060 ppmv as hexane); at No or Unknown sites can be estimated by 39 percent by weight 235 ppmv as hexane).

Table 2.4-3. CONTROL EFFICIENCIES FOR LFG NMOC and VOC<sup>a</sup>

Control Device	Control Efficiency (%) <sup>b</sup>		
	Typical	Range	Rating
Boiler/Steam Turbine (50100423)	98.6	96-99+	D
Flare <sup>c</sup> (50100410) (50300601)	97.7	86-99+	A
Gas Turbine (50100420)	94.4	92-97	E
IC Engine (50100421)	97.2	95-99+	D

<sup>a</sup> References 16-148. Source Classification Codes in parentheses.

<sup>b</sup> Control efficiency may also be applied to LFG constituents in Tables 2-4.1 and 2.4-2, except for mercury. For any combustion equipment, the control efficiency for mercury should be assumed to be 0.

<sup>c</sup> Where information on equipment was given in the reference, test data were taken from enclosed flares. Control efficiencies are assumed to be equally representative of open flares.

Table 2.4-4. EMISSION FACTORS FOR SECONDARY COMPOUNDS EXITING CONTROL DEVICES<sup>a</sup>

Control Device	Pollutant <sup>b</sup>	Typical Rate, kg/10 <sup>6</sup> dscm CH <sub>4</sub>	Typical Rate, lb/10 <sup>6</sup> dscf CH <sub>4</sub>	Emission Factor Rating
Flare <sup>c</sup> (50100410) (50300601)	Nitrogen dioxide	631	39	A
	Carbon monoxide	737	46	A
	Particulate matter	238	15	A
	Dioxin/Furan	6.7x10 <sup>-6</sup>	4.2x10 <sup>-7</sup>	E
IC Engine (50100421)	Nitrogen dioxide	11,620	725	C
	Carbon monoxide	8,462	528	C
	Particulate matter	232	15	D
Boiler/Steam Turbine <sup>d</sup> (50100423)	Nitrogen dioxide	677	42	D
	Carbon monoxide	116	7	D
	Particulate matter	41	3	D
	Dioxin/Furan	5.1x10 <sup>-6</sup>	3.2x10 <sup>-7</sup>	D
Gas Turbine (50100420)	Nitrogen dioxide	1,400	87	D
	Carbon monoxide	3,600	230	E
	Particulate matter	350	22	E

<sup>a</sup> Source Classification Codes in parentheses.

<sup>b</sup> No data on PM size distributions were available, however for other gas-fired combustion sources, most of the particulate matter is less than 2.5 microns in diameter. Hence, this emission factor can be used to provide estimates of PM-10 or PM-2.5 emissions. See section 2.4.4.2 for methods to estimate CO<sub>2</sub>, SO<sub>2</sub>, and HCl.

<sup>c</sup> Where information on equipment was given in the reference, test data were taken from enclosed flares. Control efficiencies are assumed to be equally representative of open flares.

<sup>d</sup> All source tests were conducted on boilers, however emission factors should also be representative of steam turbines. Emission factors are representative of boilers equipped with low-NO<sub>x</sub> burners and flue gas recirculation. No data were available for uncontrolled NO<sub>x</sub> emissions.

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## Appendix: Emission Factors for Use by State Agencies and Applicants

The following tables provide information on the greenhouse gas emissions associated with different types of fuels. This information can be used by any entity to estimate emissions that result from the use of fuels following the same CLCPA-compliant accounting used in this report and in the adoption of 6 NYCRR Part 496. These emission factors can be applied to generic (not source-specific) fossil fuels at the high heating content (see High Heating Values). The emission factors included in this document are derived from the same analyses described in the accompanying “*Sectoral Report #1: Energy*” for calculating Imported Fossil Fuels and Fugitive Emissions. The emission factors presented in this document are a work in progress, subject to future stakeholder comment, and will be subject to a continual improvement process as additional information becomes available. These factors do not include the direct emissions resulting from the combustion of the fuel.

### Current Upstream and Out-of-State Emission Factors for Imported Fossil Fuels

Emission factors in Table A1 reflect greenhouse gas emissions associated with the extraction, production, and transmission of fossil fuels imported into New York State for the most recent year available, or 2019. This does not include extraction, production, or transmission of fuels within New York State (see below). Users may wish to adjust the specified emission factors for blended fuels. The gasoline emission factors represent 100% fossil fuel content gasoline, equivalent to gasoline blend stock, if evaluating blends with oxygenates (e.g., ethanol) these blends can be apportioned to the fraction of emissions associated with the energy fraction of the blend that is from fossil fuels (e.g., E85 is a blend of ethanol and gasoline estimated here to have the energy content of approximately 28% gasoline and 72% ethanol). Finally, units in grams can be converted to pounds by dividing by 453.6.

**Table A1: 2020 Emission Rates for Upstream Out-of-State Sources (g/mmbtu)**

<b>Fuel Type</b>	<b>CO<sub>2</sub></b>	<b>CH<sub>4</sub></b>	<b>N<sub>2</sub>O</b>	<b>Total CO<sub>2</sub>e</b>
Natural Gas	12,206	350	0.14	41,671
Diesel/ Distillate Fuel	14,599	119	0.25	24,638
Coal	3,297	401	0.10	37,029
Kerosene/Jet Fuel	9,449	106	0.16	18,413
Gasoline (E85)	4,915	33	0.08	7,671
Gasoline	18,902	125	0.32	29,504
LPG	16,582	119	0.26	26,648
Petroleum Coke	11,030	110	0.20	20,342
Residual Fuel	11,183	109	0.19	20,423

Note: Total CO<sub>2</sub>e conversion uses GWP20 per 6 NYCRR Part 496

### Current Emission Factors for Non-Energy Fuel Use

Emission factors in Table A2 reflect the upstream out of state emissions associated with fossil fuel derived products that are not primary combustion fuels but have other consumption uses within the state.

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**Table A2: 2019 Emission Rates for Fossil Fuel Products (g/mmbtu)**

Fuel Type	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Total CO <sub>2e</sub>
Asphalt and Road Oil	7,961	103	0.12	16,663
Lubricants	19,402	114	0.37	29,063
Waxes	18,743	113	0.36	28,336
Miscellaneous Petroleum Products	10,142	107	0.17	19,208
Special Naphthas	13,795	115	0.25	23,521

Note: Total CO<sub>2e</sub> conversion uses GWP20 per 6 NYCRR Part 496

### Current Downstream and In-State Emission Factors for Fossil Fuels

Emission factors in Table A3 reflect fugitive emissions within New York State associated with fuel throughput for the most recent year available, or 2019. Emission factors were generated by summing emissions from natural gas distribution, or downstream infrastructure and dividing by the instate consumption of natural gas in industry, commercial, residential, transportation sectors.

**Table A3: 2019 Emission Rates for Downstream In-State Sources (g/mmbtu)**

Fuel Type	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Total CO <sub>2e</sub>
Natural Gas and Renewable Natural Gas (RNG/biogas)	2.17	73	n/a	6,145

Note: Total CO<sub>2e</sub> conversion uses GWP20 per 6 NYCRR Part 496

### High Heating Value

The following table is reproduced from the Energy Information Administration (EIA) State Energy Data System (SEDS), with btu values divided by physical units. Renewable Natural Gas is assumed to be pipeline quality with equivalent energy content. Raw landfill gas has substantially different energy content per standard cubic foot. E85 is assumed to have the energy content of 28% gasoline and 72% ethanol.

**Table A4: High Heating Value of Select Fuels (mmbtu)**

Fuel Type	High Heating Value	Unit of volume or mass
Natural Gas/RNG	0.001034	Standard cubic foot
Diesel/Distillate Fuel	0.137	U.S. gallon
Coal	25.53	Short Ton
Kerosene/Jet Fuel	0.135	U.S. gallon
Gasoline E85	0.094	U.S. gallon
Gasoline	0.125	U.S. gallon
LPG	0.120	U.S. gallon
Petroleum Coke	0.083	U.S. gallon
Residual Fuel	0.091	U.S. gallon
Asphalt and Road Oil	0.136	U.S. gallon
Lubricants	0.150	U.S. gallon
Waxes	0.158	U.S. gallon
Misc. Petroleum Products	0.144	U.S. gallon
Special Naphthas	0.131	U.S. gallon
Biodiesel	0.138	U.S. gallon