September 17, 2019 Reference No. 11178001

Mr. Darren Fry
Project Director – Southwestern Landfill
Walker Environmental
160 Carnegie Street
Ingersoll, Ontario
N5C 4A8

Dear Mr. Fry:

Re: Greenhouse Gas Quantification Report for the Southwestern Landfill Environmental Assessment

GHD is pleased to present this Greenhouse Gas Quantification Report (Report) to Walker Environmental (Walker) for the Southwestern Landfill Environmental Assessment (EA) being developed for submission to the Ministry of Environment, Conservation, and Parks (MECP). The purpose of the Report is to evaluate the greenhouse gas (GHG) impacts of the Proposed Southwestern Landfill (SWLF) and to satisfy a component of *Minister's Amendment #14 of the Notice of Approval – Terms of Reference* by assessing how the "preferred project" may contribute to greenhouse gas emissions.

The GHG impact of the proposed SWLF is assessed against the Baseline Scenario of Ontario's current landfill disposal processes for municipal solid waste generated in Ontario. The GHG emissions will be assessed over a 50-year gas generation period of the SWLF (2024 to 2074), with the operational phase of the landfill being approximately 20 years (2024 to 2044).

The intent of this Report is to provide a planning level assessment of the advantages and disadvantages associated with GHG emissions attributable to the proposed project in accordance with the *Environmental Assessment Act* and the Approved Amended Terms of Reference for the SWLF.

1. Project Background

GHD understands the EA is being conducted for submission to the MECP to assess the potential impacts of the SWLF located in the Township of Zorra, Ontario. Based on the *State of Waste in Ontario: Landfill Report*[1] developed by the Ontario Waste Management Association as well as the *Report of Solid Waste Landfilled in Michigan (2018)*[2], developed by the Michigan Department of Environmental Quality, Ontario currently exports approximately 3.5 million tonnes per year of waste to the United States. These tonnes are primarily handled in Michigan state with a small amount handled in New York state. For the purposes of this GHG assessment, it is assumed that Ontario's waste exports that would be captured by the SWLF

1 State of Waste in Ontario: Landfill Report, 2nd Annual Landfill Report, Ontario Waste Management Association, December 2018, https://www.owma.org/articles/2019-owma-landfill-report

2 Report of Solid Waste Landfilled in Michigan, Michigan Department of Environmental Quality, January 31, 2019, https://www.michigan.gov/documents/deq/SolidWasteAnnualReport_-_Fiscal_Year_2018_FINAL_645359_7.pdf

are primarily disposed of at three (3) large landfills in Michigan State, located near the city of Detroit as listed below:

1. Carleton Farms Landfill
2. Pine Tree Acres Landfill
3. Brent Run Landfill

GHD understands that each of the above noted landfills has landfill gas (LFG) collection systems in place, where the LFG is utilized for electricity generation (excluding cogeneration)[3].

It is assumed that the total volume of municipal solid, non-hazardous waste diverted from the Michigan landfills to the SWLF would be 850,000 tonnes per year, based on the proposed SWLF facility. The total anticipated fill rate for the SWLF is 1.1 million tonnes per year, which includes the municipal waste, and up to 250,000 tonnes per year of waste soils used for daily cover. GHD has assumed, for the purposes of this Report, as a Baseline Scenario, that the waste diverted to the SWLF from southern and southwestern Ontario is disposed of evenly between the three existing Michigan landfills. GHD understands that the waste soil used for daily cover is currently managed within Ontario, and therefore this GHG assessment only considers the impact associated with the solid, non-hazardous waste.

Provided in this Report is an assessment of GHG emissions associated with the Baseline Scenario (waste disposal in Michigan) and Project Scenario (waste disposed in the SWLF). Three Project Scenarios are considered in this report, as detailed in Section 3.3. In addition to the details provided in this Report, GHD has developed an Excel Spreadsheet (provided as Attachment A to this Report) that summarizes the GHG quantification along with outlining the calculations and assumptions used to quantify the GHG emissions resulting from the Baseline and Project Scenarios.

2. Definition of Terms

This section provides a summary of common terms that have been used throughout this Report and provides definition, context, and explanation of their importance. The terms used below are not linked specifically to any GHG program or jurisdiction, rather to maintain consistency with the way GHG emissions are assessed for this Report. In some cases, there are specific assumptions that are applicable to the below terms; these assumptions have been further defined in Section 3.1.

Baseline Scenario – Scenario that includes GHG emissions associated with the current transporting and disposing of waste in Michigan in the absence of the SWLF.

Capacity Factor – This term is related to LFG utilization such as LFG combustion in an engine to produce electricity and combustion in a lime kiln (Project Scenarios #2 and #3). The capacity factor is defined as the volume of LFG utilized per unit of time divided by the collection volume per unit of time. The maximum

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3 Landfill Methane Outreach Program (LMOP) – Landfill Technical Data, Environmental Protection Agency, February 2019, https://www.epa.gov/lmop/landfill-technical-data (Landfill and project level data (February 2019)

capacity of a LFG utilization system is lower than the maximum collection capacity of the site so that the utilization system is not over-sized. LFG utilization systems cannot operate at low LFG flow rates that exist in the periods shortly after the waste is placed and as the generation rates decrease over time. As a result, a capacity factor of 85% is applied to the maximum potential LFG collection volume to determine the approximate capacity of the LFG utilization system. During initial LFG collection periods, peak collection periods, and as the collection decreases over time it has been assumed that the flare would combust the low and excess LFG volumes that the utilization system is not capable of combusting, due to the upper and lower limits of the utilization system capacity.

Emission Reductions – The GHG emissions that would be reduced or avoided if the respective Project Scenarios were to be implemented and represents the total GHG emission difference between the Baseline and Project Scenarios and reduced emissions from transportation vehicles due to shorter hauling distances.

Fugitive Emissions – GHG emissions that are not captured or escape through the landfill cover. These emissions are based on the collection efficiency of the landfill gas collection systems.

GHG Emission Timeline – GHG emissions in this Report are assessed over a 50-year timeline from 2024 through 2074. This timeline represents the period of the most significant gas generation associated with the SWLF and the baseline landfills. For consistency and an accurate comparison, this timeline applies to both the Baseline and Project Scenarios.

GHG Quantification Model – The GHG Quantification Model is model/calculation spreadsheet developed by GHD and used to calculate GHG emissions from each of the major emission sources identified within the Baseline and Project scenarios. The GHG Quantification Model also summarizes the emission reduction potential for each Project Scenario compared to the Baseline Scenario.

Global Warming Potential (GWP)[4] – A value that is applied to specific GHG compounds that represents how much heat the compound traps in the atmosphere (relative to carbon dioxide). The following global warming potentials are applicable to this GHG assessment:

- Carbon dioxide GWP = 1
- Methane GWP = 25
- Nitrous oxide GWP = 298

Grid Emission Factor – Represents the GHG carbon intensity of the electricity grid and is reflective of how electricity is generated within each geographical grid (i.e. predominantly through renewable sources, fossil fuel sources, or a mix of both). The units are conveyed in tonnes of carbon dioxide equivalent per megawatt hour (tCO_2e/MWh).

4 Chapter 2 – Changes in Atmospheric Constituents and Radiative Forcing, Intergovernmental Panel on Climate Change (IPCC), 2007, https://www.ipcc.ch/site/assets/uploads/2018/02/ar4-wg1-chapter2-1.pdf

LFG – Landfill gas. Landfill gas typically contains the following compounds at the following approximate concentrations; methane at 50 percent by volume (% v/v), carbon dioxide at 45% v/v, and balance gases (mainly nitrogen) at 5% v/v.

LFG Tool – The LFG Tool uses the Scholl-Canyon Model to forecast GHG emissions associated with the production of LFG at a landfill site. The LFG Tool is an accepted model that was developed by GHD for the Ontario Waste Management Association for distribution to its members.[5] The LFG Tool was used in this GHG assessment to forecast the upper and lower limit of the GHG emissions generated from the SWLF and Michigan landfill sites.

Methane Destruction Emissions – Methane is the predominant compound in LFG (representing on average 50 percent by volume). Methane Destruction Emissions represent the GHG emissions that are displaced through the combustion of LFG. Other predominant compounds in LFG (carbon dioxide and balance gases; mainly nitrogen) do not provide a net GHG emission benefit when combusted, therefore they are not quantified.

Point of Origin – This term refers to the assumed location where the waste originates for the purpose of calculating the transportation emissions. For the purpose of this Report, the Point of Origin has been established as the approximate intersection of the 401, 427, and 400 series of highways in southern Ontario.

Project Scenarios – Scenarios quantifying the GHG emissions of the potential LFG management options for the proposed SWLF. The three Project Scenarios are detailed in Section 3.3.

SCADA – Supervisory control and data acquisition. In this Report it applies to the software system that is used to monitor and control a LFG collection system.

SWLF – Proposed Southwestern Landfill.

SWLF Capacity – Based on the proposed design details of the SWLF, the site will accept 850,000 tonnes of waste and up to 250,000 tonnes of daily cover material per year for 20 years (2024 to 2044). This provides direct input for the waste emissions calculated in the LFG Tool.

tCO_2e – Tonnes of carbon dioxide equivalent. Represents the standardized units of GHG emissions used in the GHG industry and as the standardized units across the globe.

Transportation Emissions – GHG emissions associated with the transportation of waste in long-haul transportation vehicles.

Waste – Represents the total solid, non-hazardous waste that is disposed of at the landfills in both the Baseline and Project Scenarios.

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5 The LFG Tool uses the basis of the Scholl-Canyon Model but provides a more simplified interface and access to a wide variety of default values and factors that can be applied.

3. Quantification Methodology

GHD defined Baseline and Project Scenarios to quantify the GHG emissions associated with the current practice of transporting and disposing of waste in Michigan (Baseline Scenario) and transporting and disposing waste at the SWLF, with different potential LFG management options (Project Scenarios). The GHG quantification of the Baseline Scenario with comparison to each Project Scenario will demonstrate the GHG emissions, positive or negative, associated with the Project.

A focused set of assumptions have been established to ensure that an accurate comparison can be made between the Baseline and Project Scenarios. GHD has taken a conservative approach related to the assumptions and associated quantification of GHG emissions. GHD has utilized emission factors and default values that are believed to be the most conservative and representative of actual and proposed conditions for the Baseline and Project Scenarios, respectively.

3.1 Baseline and Project Scenarios

The Baseline and Project Scenarios are quantified to provide an estimation of the GHG emissions associated with each scenario. Provided below is a summary of the GHG emission types that are quantified and compared for both the Baseline and Project Scenarios:

- Transportation emissions
- Emissions from the anaerobic decomposition of waste
- Emissions from the utilization of LFG
- Electricity consumption emissions

Figure 1 provides a summary of the above noted GHG emissions included within each scenario. Beyond the above noted list of GHG emission types, it is assumed that there will be additional types of GHG emissions that will be equivalent or negligible across both the Baseline and Project Scenarios:

- Emissions from the operation of equipment (equivalent)
- Emissions related to leachate treatment (equivalent)

The magnitude of the above noted emissions are not anticipated to change significantly from the Baseline to the Project Scenarios.

The Baseline and Project Scenarios both involve assumptions and estimates, therefore detailed quantification or assertion of the exact GHG emissions from each scenario cannot be provided, rather a magnitude estimation of GHG emissions for comparison purposes and to accompany the EA.

Baseline and Project Scenario Assumptions

Conservative assumptions were established to ensure accurate comparison of the Baseline and Project Scenarios. In addition to being conservative, GHD also aimed to ensure that each assumption was as representative as possible of the current and forecasted conditions. Provided below is a breakdown of some of the main assumptions made that apply to both the Baseline and Project Scenarios:

- Annual inflation – Some emission factors, default values, and global warming potentials used in the calculations may change over time, however it is impossible to predict what these changes will be. Therefore, it is assumed for comparison purposes that the current values applied for the emission factors and default values will remain constant over the GHG Emission Timeline.
- Electricity consumption – Each landfill site is anticipated to consume electricity at the same rate, approximately 8,760 MWh per year based on an estimated 24 MWh per day of consumption. This electricity consumption information was provided by Walker and is based on their first-hand experience operating similar sized landfills. Electricity is consumed at landfills for a variety of operations, including leachate/condensate pumping, blowers for the LFG collection system, SCADA system operation, scales, and for administrative and operations buildings.
- Emissions from Site Operations – Landfills require various types of equipment to ensure the waste disposed at each site is placed appropriately and compacted. Tippers are used at landfill sites to unload the waste from tippable trailers and heavy-duty compactors and bulldozers are used to place and compact the waste. Additional equipment is also required for the application of daily cover material (i.e. soil) in addition to excavators, rollers, soil compactors, and bulldozers. Walker provided an estimate of the GHG footprint for the site operations at their Niagara landfill site, which was used by GHD in the GHG Quantification Model. It is assumed the same equipment would be required at the SWLF and is being utilized to manage an equivalent amount of waste at the three Michigan landfill sites. To be conservative, GHD has assumed that the emissions from site operations at the SWLF would be the same as the combined emissions from the site operations at the three Michigan landfill sites, to manage the same amount of waste. It has also been assumed that the emissions associated with site operations only apply to the period of time where waste is actively being filled (2024 – 2044) and therefore have not been calculated after waste filling is complete.
- Landfill Daily Cover – It is assumed that the daily cover for the landfills in the Baseline and Project Scenarios will consist of 250,000 tonnes per year of non-hazardous waste soil material. This material is assumed to not have any significant GHG emissions. It was assumed that the material that is used for landfill daily cover at the Michigan sites come from within an 80 kilometer (km) radius, and that the transportation emissions would be equivalent to the transportation emissions of bringing daily cover to the SWLF.
- Point of Origin – For the purposes of this GHG assessment, this location is assumed as central to where waste in southern and southwestern Ontario is generated. This location then serves as the reference point for calculating the distance and subsequent GHG emissions associated with the transportation of the solid non-hazardous portion of the waste. It is assumed that the Point of Origin is the same in the Baseline and Project Scenario assumptions and that waste is transported in similar long-haul waste vehicles from the Point of Origin to the Michigan landfills and the SWLF.

- Short-haul Waste Collection Vehicles – It is recognized that a small portion of waste generated in the local communities near the SWLF would be collected by short-haul (i.e. front loaders collecting waste from bins at local businesses) collection trucks that would transport waste directly to the SWLF. The local collection trucks would be less efficient (i.e. carrying less payload and on local roads) than the long-haul trucks but would be travelling much shorter distances and carrying much less waste. As a result, it is assumed that the small percentage of local waste being managed by short-haul vehicles would not materially affect the overall results of the transportation emissions. The emissions associated with short-haul waste collection vehicles has therefore not been included in this GHG assessment.
- Transportation Fuel – For the purposes of this Report the long-haul waste transportation vehicles are assumed to only use diesel fuel as this is industry standard. Therefore, the emissions factors and fuel consumption applied to calculate the transportation emissions only apply to the use of diesel fuel.
- Waste Composition – It is assumed that the waste composition disposed in the Baseline and the Project Scenarios would be the same. This assumption aids in comparing the landfill waste related emissions from each of the landfill sites in each scenario. It has also been assumed that the waste composition consists of a 70 (by weight) percent putrescible fraction. This assumption was developed based on a waste composition audit Walker conducted in 2012 of waste received at the South Landfill in Niagara. One of the actions in the MECP's A Made-in-Ontario Environment Plan states "*Develop a proposal to ban food waste from landfill and consult with key partners such as municipalities, businesses and the waste industry*". However, until any new organics policy is in place, the current waste composition data will be used for the purposes of this Report.
- Waste Tonnage – It is assumed that the waste tonnage (850,000 tonnes per year) will not change in the Baseline and Project Scenarios. In addition, it is assumed that the waste tonnage will not change from year-to-year through the established 20 year waste disposal timeframe (2024 to 2044)
- Waste Haulage Truck Capacity and Fuel Efficiency – The average capacity of long-haul waste trucks is assumed to be 32 tonnes of waste based on Walker's direct experience with waste hauling. GHD notes that the maximum net weight for waste hauling is 39 tonnes[6]. Walker tracks the fuel efficiency of their long-haul waste transportation vehicles and identified that the average fuel consumption of their vehicles is 0.55 liters (L) of diesel fuel per km which is in-line with waste industry standards.

The stated assumptions allow the Report to be focused on conservative values that are also representative of the current and proposed conditions. In addition, the application of the assumptions for both the Baseline and Project Scenario aid in providing a more accurate comparison. Additional assumptions are defined for the Baseline and Project Scenarios individually.

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[6] Ontario Regulation 413/05 – Vehicle Weights and Dimensions – For Safe, Productive, and Infrastructure-Friendly Vehicles, Table 3, https://www.ontario.ca/laws/regulation/050413

3.2 Baseline Scenario

The Baseline Scenario consists of the transport of waste from the Point of Origin to the three (3) major landfill sites located in Michigan for disposal. For comparison purposes, GHD only analyzed the amount of waste slated for disposal at the SWLF (i.e. 850,000 tonnes) and did not include the emissions from the existing waste-in-place at the sites or is received at the sites from other sources.

Baseline Assumptions

In addition to the assumptions that have been applied to both the Baseline and Project Scenarios, the following additional assumptions apply exclusively to the Baseline Scenario:

- Existing waste-in-place not included – To create an accurate comparison between the Baseline and Project Scenarios, existing waste currently disposed at the Michigan landfill sites would artificially inflate the emissions from the Michigan sites. Therefore, to be conservative, and provide an accurate comparison, it was established that calculating GHG emissions from existing waste-in-place at the three Michigan landfills is not conservative or appropriate.
- Landfill capacity – The remaining fill capacities of the three Michigan landfills have not been factored into the GHG assessment for the Baseline Scenario in order to provide an accurate comparison of emissions related to the SWLF waste capacity of 20 years. It is assumed that in the Baseline Scenario, waste would continue to go to the Michigan landfills for the 20-year timeframe regardless of the remaining waste capacity at the sites. It is assumed that if the Michigan sites were to reach capacity within the 20-year timeframe of comparison for waste disposal, the sites would be expanded to accommodate the additional waste.
- LFG Tool – There were a number of assumptions and default factors applied through the use of the LFG Tool. These assumptions and default factors are detailed in Attachment B.
- LFG Tool Modelling – It was assumed that each of the three Michigan landfills could be modelled with the same characteristics as they are located in the same general geographical area, the tonnage is the same, and GHD applied an average LFG collection efficiency (53%)[7] based on available data.
- Waste tonnage – The total annual anticipated waste tonnage (850,000 tonnes) for the SWLF was evenly divided across each of the three Michigan landfill sites (i.e. 283,333 tonnes per site per year each)

[7] Landfill Technical Data, Landfill Methane Outreach Program (LMOP), US EPA, February 2019; https://www.epa.gov/lmop/landfill-technical-data

Baseline Quantification

Emissions quantified for the Baseline Scenario include the following:

- Transportation Emissions:
  - Transportation of the waste from the Point of Origin to the landfill sites in Michigan, average distance of 382 km one-way.
  - Emissions have been calculated for two-way/roundtrip travel (764 km total), as there are only very rare conditions where a long-haul waste transportation vehicle would not perform the return travel distance.
- Emissions from anaerobic decomposition of waste:
  - This includes analysis of both Fugitive and Methane Destruction Emissions from the destruction of methane based on the documented collection efficiency of the Michigan landfills.
  - GHD used the LFG Tool to develop a combined emissions profile that was used for analyzing the emissions from the three Michigan sites.
  - GHD used site-specific data from each landfill, where available, to improve the accuracy of the results from the LFG Tool. Specifically, GHD applied LFG collection efficiency values and published utilization infrastructure destruction efficiencies to more accurately evaluate emissions from the three Michigan sites[8]. Where site-specific data was not available, GHD applied modelled or assumed values that were as representative as possible. Refer to Attachment B for further details regarding the LFG Tool inputs and associated references.
- Emissions associated with the production of renewable electricity to be supplied to the local grid:
  - The Michigan sites each have LFG collection systems where collected LFG is utilized to generate electricity.
  - The eGrid emission factor for Michigan (0.58 tCO_2e/MWh) was applied to determine the baseline benefit of providing renewable electricity to the grid in Michigan.
  - GHD applied the Capacity Factor of 85% to flow of LFG to the utilization engines. The Capacity Factor accounts for the upper and lower bounds of LFG flows that cannot be processed by the utilization engines.
- Emissions associated with electricity consumption from the grid:
  - The eGrid emission factor for Michigan (0.58 tCO_2e/MWh) was applied to determine the emission intensity associated with the consumption of electricity from the grid. This is a worst-case scenario given that each Michigan landfill produces renewable electricity on-site and could use their electricity generation to displace electricity consumption from the grid.

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8 Landfill Methane Outreach Program (LMOP) – Landfill Technical Data, Environmental Protection Agency, February 2019, https://www.epa.gov/lmop/landfill-technical-data (Landfill and project level data (February 2019)

- Emissions from site operations:
  - It is assumed that an equivalent amount of equipment for site operations would be required for the disposal of an equivalent amount of waste at the SWLF and the three Michigan landfills (combined).

3.3 Project Scenarios

Three different Project Scenarios were considered as part of the GHG assessment for the SWLF:

1. Flaring of LFG
2. Utilization of LFG to generate electricity with flaring
3. Utilization of LFG in a lime kiln adjacent to the SWLF with flaring

Flaring is included in each of the Project Scenarios as O. Reg. 232/98 as amended, requires LFG collection at a landfill of this size (e.g. greater than 1.5 million cubic meters). In addition, the utilization methods for LFG are not often sized for the maximum capacity of LFG that can be generated from the landfill and therefore flaring is often required during the periods of peak LFG generation or during planned and unplanned outages of the utilization facility. As a result, GHD has applied the Capacity Factor to the Project Scenarios to account for the capacity limitations of the utilization facilities, as applicable.

Project Assumptions

In addition to the assumptions that have been applied to both the Baseline and Project Scenarios, the following assumptions apply exclusively to the Project Scenarios:

- Transportation emissions associated with each of the three Project Scenarios is the same.
- Flaring is included in each Project Scenario.
- Emissions associated with processing LFG for direct use in the lime kiln are attributed to the consumption of electricity.
- It is assumed the lime kiln is currently using 50 percent natural gas and 50 percent coal as fuel. Therefore, LFG used in the kiln will displace 50 percent natural gas and 50 percent coal combustion.

Project Quantification

Each Project Scenario represents a potential LFG management/utilization option for the SWLF.

Project Scenario #1 – In this scenario, the SWLF is assumed to have an LFG collection system that will only flare LFG through the GHG Emission Timeline. Emissions quantified for Project Scenario #1 included the following:

- Transportation emissions:
  - Associated with trucking the waste from the Point of Origin to the SWLF, total round-trip distance of approximately 272 km.

- Emissions from anaerobic decomposition of waste:
  - This includes assessment of both fugitive and methane destruction emissions based on the anticipated collection efficiency of the SWLF (assumed to be 85%).
  - GHD used the LFG Tool for the SWLF based on the total aggregated waste disposal tonnages (850,000 tonnes per year) used in the Baseline Scenario.
- Emission associated with electricity consumption from the grid:
  - GHD applied the NIR grid emission factor for Ontario (0.04 tCO_2e/MWh) to assess the carbon intensity from consuming grid electricity in Ontario.
- Emissions from Site Operations:
  - Associated with on-Site landfill mobile equipment

Project Scenario #2 – In this scenario, the SWLF is assumed to have a LFG utilization system to generate electricity on-site in addition to flaring, through the GHG Emission Timeline. Emissions quantified for Project Scenario #2 included the following:

- Transportation Emissions:
  - Associated with trucking the waste from the Point of Origin to the SWLF, total round-trip distance of approximately 272 km.
- Emissions from anaerobic decomposition of waste:
  - This includes assessment of both fugitive and methane destruction emissions based on the anticipated collection efficiency of the SWLF (assumed to be 85%).
  - GHD used the LFG Tool for the SWLF based on the total aggregated waste disposal tonnages (850,000 tonnes per year) used in the Baseline Scenario.
  - In this scenario, a flare is still required for the GHG Emission Timeline of the landfill but priority will be given to the LFG-to-electricity utilization facility to generate renewable electricity that will displace the emissions associated with the generation of grid electricity. GHD has applied the Capacity Factor to this Project Scenario assuming that the LFG-to-electricity facility is designed for 85% of the total maximum LFG collected through the GHG Emission Timeline. It is assumed that the excess LFG collected during the peak LFG production years will be flared.
- Emissions associated with the use of electricity and from displacing grid electricity with renewable electricity generated on-site:
  - GHD applied the Ontario electricity consumption factor to quantify the benefit of displacing grid electricity.
  - GHD applied the Capacity Factor for the utilization of LFG in the LFG-to-electricity facility. It has been assumed that the LFG-to-electricity facility would not have the capacity to process/combust the maximum potential LFG collected, therefore, the Capacity Factor of 85% was applied to the maximum anticipated LFG collection volume. The Capacity Factor is also intended to account for

the periods of time when the LFG flow rates are too low to be able to be utilized in the LFG-to-electricity facility. The Capacity Factor is intended to represent upper and lower bounds of LFG flows that cannot be used in the LFG-to-electricity facility.

- Emission associated with electricity consumption from the grid:
  - GHD applied the NIR grid emission factor for Ontario (0.04 tCO_2e/MWh) to assess the carbon intensity from consuming grid electricity in Ontario.
- Emissions from site operations:
  - Associated with on-site landfill mobile equipment.

Project Scenario #3 – In this scenario, the SWLF is assumed to have a LFG utilization system that will capture LFG, and use it as a renewable fuel at the lime kiln adjacent to the SWLF through the GHG Emission Timeline. Emissions to be quantified for Project Scenario #3 include the following:

- Transportation emissions:
  - Associated with trucking the waste from the Point of Origin to the SWLF, total round-trip distance of approximately 272 km.
- Emissions from anaerobic decomposition of waste:
  - This includes assessment of both fugitive and methane destruction emissions based on the anticipated collection efficiency (85%) of the SWLF.
  - GHD used the LFG Tool for the SWLF based on the total aggregated waste disposal tonnages (850,000 tonnes per year) used in the Baseline Scenario.
  - In this scenario, a flare is still required for the GHG Emission Timeline of the landfill but priority will be given to the lime kiln to utilize LFG that will displace the emissions associated with the combustion of fossil fuels (coal and natural gas). GHD has applied the Capacity Factor to this Project Scenario assuming that the lime kiln LFG flow capacity is 85% of the total maximum LFG collected through the GHG Emission Timeline. It is assumed that the excess LFG collected during the peak LFG production years will be flared.
- Emissions from replacing fossil fuels at the lime kiln:
  - Specifically displacing the use of coal and natural gas with LFG.
  - LFG is anticipated to be used for stationary combustion purposes.
  - GHD applied the Capacity Factor for the utilization of LFG in the lime kiln. It has been assumed that the lime kiln would not have the capacity to process/combust the maximum potential LFG collected, therefore, the Capacity Factor of 85% was applied to the maximum anticipated LFG collection volume. The Capacity Factor is also intended to account for the periods of time when the LFG flow rates are too low to be able to be utilized in the lime kiln. The Capacity Factor is intended to represent upper and lower bounds of LFG flows that cannot be used in the lime kiln.

- Emissions associated with electricity consumption from the grid:
  - GHD applied the NIR grid emission factor for Ontario (0.04 tCO_2e/MWh) to assess the carbon intensity from consuming grid electricity in Ontario.
  - Electricity consumptions from LFG processing to provide LFG as a fuel to the lime kiln
- Emissions from site operations:
  - Associated with on-site landfill mobile equipment.

3.4 Leachate Treatment and Other Emissions

In addition to the emissions noted above and listed in the assumptions, GHD has identified one other potential source of emissions that would exist within a landfill site, which is the processing and treatment of leachate (impacted liquid generated within the landfill). Processing leachate from a landfill often includes the following key components; passive collection via leachate collection piping at the base of the landfill, pumping leachate from the landfill perimeter to a primary location, and the processing and treatment of leachate. The electricity required for pumping would be the main source of emissions related to leachate at a landfill along with electricity associated with the treatment process that often occurs outside of the landfill property boundary. GHD has assumed that leachate collection, processing, and treatment would be the same in both the Baseline and the Project Scenarios. In addition, GHD has assumed that the emissions associated with leachate collection and processing are negligible (less than 10 tCO_2e per year) due to the limited amount of electricity required for pumping leachate at the landfill. Leachate treatment often occurs outside the boundary of the landfill and therefore emissions associated with leachate treatment are outside the boundary of this assessment and not included.

GHD attests that there are no other significant emissions sources that exist in either the Baseline or Project Scenarios that have not been included in the GHG assessment for the purposes of this Report. Therefore, the focus of the GHG assessment remains on the major emissions sources previously noted and the associated quantification methodologies that are available for each.

3.5 Quantification Approach

There are many different sources that are available for quantifying GHG emissions from each of the major emissions sources identified. GHD has taken a conservative approach to quantifying GHG emissions and has utilized emission factors, default values, and global warming potentials that are believed to be the most representative of actual and proposed conditions for the Baseline and Project Scenarios, respectively.

GHD utilized a significant portion of publicly available data for the quantification of GHG emissions. Reputable publicly available sources were selected based on jurisdictional relevance (i.e. the NIR and MECP Guideline for Quantification, Reporting and Verification of Greenhouse Gas Emissions for Ontario emission factors and defaults, and sources from the United States Environmental Protection Agency for

Michigan emission factors and defaults values). GHD also assessed available data from the following sources:

- Walker was used as a resource for first-hand information (e.g. transportation vehicle fuel efficiency, site operations equipment details, and landfill electricity consumption).
- Location-specific emission factors and parameters (e.g. Michigan and Ontario) were applied where appropriate.
- Estimated values from online sources were also used (e.g. fuel efficiencies of landfill equipment).
- Where data or information was unavailable, conservative assumptions or estimates based on surrogate parameters were used.

Where publicly available sources outlined a range of emission factors or defaults, GHD assessed the data as follows:

1. Overall appropriateness of the value based on site-specific conditions and assumptions.
2. Level of conservativeness.

Notably, the accuracy of the use of publicly available and well-referenced data improves the accuracy and certainty in the emissions calculations. Conservative assumptions and approaches were used where required. Further details regarding each of values applied and the associated references are provided in Attachment B.

GHD used the available data to develop a GHG Quantification Model. The GHG Quantification Model was used to calculate emissions from each of the major emission sources identified within each of the scenarios detailed in Sections 3.2 and 3.3. The GHG Quantification Model also summarizes the emission reduction potential for each Project Scenario compared to the Baseline Scenario. The GHG types quantified for each scenario include:

- Carbon dioxide (CO_2)
- Methane (CH_4) and,
- Nitrous oxide (N_2O)

Global Warming Potentials (GWPs) for each GHG type were applied to quantify total GHG emissions in tCO_2e.

The quantification was completed in accordance with the ISO 14064-2 standard: *Specification with guidance at the project level for quantification, monitoring, and reporting of greenhouse gas emission reductions or removal enhancements*.

3.5.1 Landfill Gas Generation Quantification

The LFG Tool uses the Scholl-Canyon Model to forecast GHG emissions associated with the production of LFG at a landfill site. The LFG Tool therefore provides an accurate representation of the LFG generated in the Baseline Scenario and Project Scenarios.

GHD assessed the LFG emissions annually over the 50-year GHG Emission Timeline of the SWLF. The LFG Tool was run four (4) times for each scenario (one Baseline Scenario and three Project Scenarios). The LFG Tool produces the following output parameters that are used as inputs in the subsequent GHG Quantification Model:

- Annual Methane Production (upper and lower limits) (tCO_2e)
- LFG Recovery (cubic metres per hour [m^3/hour] and cubic feet per minute [cfm])
- Annual Methane Destruction (upper and lower limits) (tCO_2e)

In addition to the above parameters the LFG Tool also allows for calculation of the annual methane that is not collected (i.e. fugitive emissions subtracted from the total production). The annual methane that is not collected by an on-site LFG collection system is classified as fugitive emissions that either escape through the landfill cover or are stored in the landfill and released over time. The collection efficiency of LFG via the LFG collection system is one of the main parameters of the LFG Tool that can have an impact on the annual Methane Destruction Emissions and annual Fugitive Emissions.

Detailed in the sub-sections below is an outline of the relevant parameters used in the LFG Tool to provide an accurate representation of the Baseline and Project Scenarios. Table B.1 of Attachment B summarizes the relevant parameters used in the LFG Tool for each scenario.

Methane Generation Rate (k)

The LFG Tool allows for upper and lower methane generation rate values to be specified, resulting in an upper and lower range of associated emissions. The methane generation rate is dependent on a number of factors, but one of the most important, and most variable between the proposed SWLF and the existing Michigan sites, is precipitation. The upper and lower methane generation rates for the Baseline and Project Scenarios were adjusted based on the location of the landfills in question and the associated precipitation, Table 3.1 conveys the values applied for each Scenario.

Table 3.1 Methane Generation Rates (Upper and Lower)

Scenario	Upper Value (k)	Lower Value (k)
Baseline – Michigan Landfills	0.040	0.035
Project Scenarios – SWLF	0.046	0.040

Baseline Scenario – Michigan Landfills

Using the Alberta Environment and Sustainable Resource Development method, the lower value for the methane generation rate (k) for the Michigan landfills was averaged to 0.035. A methane generation rate of 0.04 was specified as the upper limit value which was assumed by GHD and represents a 15% increase from the lower limit value.

Project Scenarios - SWLF

A methane generation rate of 0.04 was specified as a lower value for the SWLF. This value is consistent with published values recommended by the Ontario Ministry of Environment Conservation and Parks (MECP, formerly Ministry of the Environment)[9] and United States Environmental Protection Agency (US EPA)[10] as well as a precipitation-dependent estimation method developed by Alberta Environment and Sustainable Resource Development (AESRD)[11]. A methane generation rate of 0.046 was specified as the upper limit value which was assumed by GHD and represents a 15% increase from the lower limit value.

To maintain consistency between the magnitude difference of the lower methane generation rate values GHD applied the same 15% assumption for both of the upper values. The difference between the established lower methane generation rate values is 0.005 which is consistent with the difference in climate data between the landfills in the Baseline and Project Scenarios based on the CLEEN model developed by the University of Texas at Arlington[12]. Refer to Table B.1 in Attachment B for a full summary of the values applied in the LFG Tool.

Methane Production Potential (L_0)

A methane production potential of 125 m^3/tonne was used as a lower value and 144 m^3/tonne was used as an upper value for both the Baseline and Project Scenarios, given that the waste composition is anticipated to be the same in each scenario based on the Point of Origin. A methane production potential of 125 m^3/tonne is recommended by the Ontario MECP[13] and 144 m^3/tonne, representing a worst-case scenario of waste that contains a high decomposable fraction[14] and an approximate 13 percent increase from the lower limit value. Since a higher decomposable fraction is more conservative, the 125-144 m^3/tonne range is conservative by comparison and is consistent between the Baseline and Project Scenarios.

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9 Interim Guide to Estimate and Assess Landfill Air Impacts, Ontario Ministry of the Environment, Air Resources Branch, October 1992.

10 USEPA AP-42 Compilation of Air Pollutant Emission Factors, Chapter 2.4 Municipal Solid Waste Landfills. Final Nov. 1998 and Draft Oct. 2008, and Landfill Methane Outreach Program (LMOP) LandGEM V302, May 2005.

11 Carbon Offset Emission Factors Handbook, Alberta Environment and Sustainable Resource Development, March 31, 2015.

12 Estimating methane emissions from landfills based on rainfall, ambient temperature, and waste composition: The CLEEN model, Journal of Waste Management, Richa V. Karanjekar, Arpita Bhatt, Said Altouqui, Neda Jangikhatoonabad, Vennila Durai, Melanie L. Sattler, M.D. Sahadat Hossain, and Victoria Chen, 2015.

13 Ontario Ministry of the Environment, Air Resources Branch. Interim Guide to Estimate and Assess Landfill Air Impacts. October 1992.

14 Landfill Gas Generation Assessment Procedure Guidelines, Conestoga-Rovers & Associates, 2009 https://www2.gov.bc.ca/assets/gov/environment/waste-management/garbage/lgassessment.pdf

Landfill Gas Collection System Efficiency

To establish the LFG collection efficiency of the Baseline Scenario GHD used site-specific data from the US EPA Landfill Methane Outreach Project (LMOP). The US EPA provides details on the LFG production for each Michigan site along with the amount of LFG currently being collected. GHD used these two values to establish an average LFG collection efficiency that was representative of each of the three sites. The collection efficiency applied in the Baseline Scenario is approximately 53 percent based on available data[15].

The SWLF is planned to be filled in four stages, each containing five cells to be filled over a period of approximately one year before intermediate cover is applied. Final cap is generally applied to each stage as it is completed, approximately every five (5) years. SWLF's LFG collection system will consist of both horizontal and vertical collection wells, allowing LFG collection to begin within two-to-three years of operation of the Site (2026). As a result, the collection efficiency at the SWLF is anticipated to be 85 percent, which is consistent with LFG collection efficiencies which are used for reporting purposes at Walker's similarly designed and operated South Landfill in Niagara Falls.

Appliance and Utilization Destruction Efficiencies

Destruction devices are used to combust LFG from the LFG collection systems, however, the destruction devices are not capable of destroying LFG at 100 percent efficiency. Therefore, the destruction efficiencies applied in the LFG Tool for each scenario are provided in Table 3.2

Table 3.2 Destruction Device Efficiencies[16]

Applicable Scenario	Eligible Destruction Device	Efficiency (Fraction)
Baseline	Internal Combustion Engine	0.972
	Enclosed Flare	0.977
Project Scenario #1, #2, and #3	Enclosed Flare	0.977
Project Scenario #2	Internal Combustion Engine	0.972
Project Scenario #3	Kiln (i.e. Stationary Combustion)	0.986

The destruction efficiencies presented in Table 3.2 are representative of each of the LFG utilization devices in each scenario. The destruction efficiency values themselves represent the degree of combustion through each device (i.e. a value of 1.000 would represent complete combustion or 100 percent efficiency).

Flare Uptime

The flare uptime represents the percentage of the year that the flare is anticipated to operate (i.e. 100 percent represents 24 hours a day for 365 days). This percentage is intended to encompass flare

15 Landfill Methane Outreach Program (LMOP) – Landfill Technical Data, Environmental Protection Agency, https://www.epa.gov/lmop/landfill-technical-data (Landfill and project level data (February 2019)

16 USEPA AP-42 Compilation of Air Pollutant Emission Factors, Chapter 2.4 Municipal Solid Waste Landfills. Final Nov. 1998 and Draft Oct. 2008, and Landfill Methane Outreach Program (LMOP) LandGEM V302, May 2005.

downtime that may occur through each year related to but not limited to maintenance, high oxygen concentrations, low methane concentrations, testing, and operational alarms. Flares are typically designed to operate under a broad range of conditions when compared to utilization engines or other stationary combustion devices, therefore assuming a relatively high flare uptime is common. Therefore, in all of the scenarios, a conservative flare uptime of 97 percent was assumed, which represents the lower range of expected annual uptime.

Utilization Uptime

Similar to the flare uptime, the utilization uptime represents the percentage of the year that the utilization device is anticipated to operate (i.e. 100 percent represents 24 hours a day for 365 days). For all scenarios using LFG utilization devices, an uptime of 85% was applied and was qualified based on Walker's experience as a landfill owner/operator and Canada's largest landfill gas utilization project developer. GHD has assumed that during downtime periods with the engine that the flare will be used.

For Project Scenario #3, kiln uptime was modelled as 97%. Kiln uptime is higher due to lower operation and maintenance requirements, similar to the flare. Project Scenario #1 was modelled by setting utilization uptime to 0% to account for the lack of LFG utilization in this scenario (use of the flare only).

GHD notes that the utilization uptime and the Capacity Factor are two different parameters, the Capacity Factor (also 85 percent) applies to the LFG flow capacity limitations of the LFG utilization systems whereas the utilization uptime value applies to the amount of time per year that the utilization device is able to operate. Both the utilization uptime and Capacity Factor are applied to the utilization device emissions in Project Scenarios #2 and #3 with the excess LFG not combusted by the utilization devices, combusted in the flare.

3.5.2 GHG Quantification Model

The LFG Tool provided the annual methane production and capture volumes for each scenario, which GHD then inputted into the GHG Quantification Model. These results were then used to quantify the GHG emission sources that were dependent on the results of the LFG Tool (i.e. Methane Destruction Emissions, Fugitive Emissions and emissions associated with LFG utilization). The following sections of the GHG assessment provide further background and justification for the default values, parameters, and emission factors used in the GHG Quantification Model and some of the differentiators used between scenarios. Table B.2 of Attachment B summarizes the relevant parameters used in the GHG Quantification Model for each scenario.

Emissions from Transportation of Waste

One of the major differentiators between the Baseline and the Project Scenarios is the distance required for transportation of the waste from the Point of Origin to where it is disposed. In the Baseline Scenario, the waste transportation vehicles are travelling approximately 764 km round-trip from the Point of Origin to the Michigan landfills. In the Project Scenario the waste transportation vehicles are travelling a much less distance of 272 km round-trip from the Point of Origin to the SWLF.

GHD estimated the number of annual trips (26,565) required to transport the total anticipated waste tonnage (850,000 tonnes) based on the capacity of the waste transportation vehicles (approximately 32 tonnes of waste). GHD assumed two-way/round-trip travel was required in the quantification, and that the long-haul transportation vehicles used only diesel fuel. As previously noted, the fuel efficiency of the transportation vehicles has been calculated based on first-hand information available from Walker's long-haul waste haulage experience.

The total travel distance, number of trips, and fuel efficiency of the waste transportation vehicles was used to calculate the volume of diesel fuel required for transportation each year. GHD then used the emission factors associated with Heavy-duty Diesel Vehicles – Advanced Control from Environment Canada's NIR to calculate the Transportation Emissions attributed to transportation of the waste. GHD selected the most conservative and representative emission factor from Environment Canada's NIR and crosschecked it against other available sources (The Climate Registry and 1996 IPCC default values) to ensure it was appropriate.

Emissions from Anaerobic Decomposition of Waste

The emissions from anaerobic decomposition of waste are broken down into two categories:

1. Methane Destruction Emissions – Methane is the predominant compound in LFG (representing on average 50 percent by volume). Methane Destruction Emissions represent the GHG emissions that are avoided through the combustion of LFG. Other predominant compounds in LFG (carbon dioxide and balance gases; mainly nitrogen) do not provide a net GHG emission benefit when combusted, therefore they are not quantified.
2. Fugitive Emissions – GHG emissions that are not captured or escape through the landfill cover. These emissions are based on the collection efficiency of the LFG collection systems. These emissions are attributed to the release of uncollected methane contained in the LFG.

The LFG Tool outputs the total annual methane production (m^3/hr and cfm) and total annual Methane Destruction emissions in tCO_2e which allows for the straight forward subtraction of the Methane Destruction emissions from the total production to calculate the Fugitive Emissions. The upper and lower values are both presented in Section 4 and the GHG Quantification Model presented in Attachment A.

Emissions from Displacing Grid Electricity with Renewable Electricity

Renewable electricity generation associated with LFG utilization varies depending on the capacity of the LFG utilization engines and conversion efficiency located at each site along with the collection efficiency of the associated LFG collection systems.

GHD quantified emissions from displacing grid electricity with renewable electricity using the LFG recovery rate in cubic feet per minute (cfm) calculated by the LFG Tool. The average electricity production rate was provided by Walker (scfm/MW) for Project Scenario #2. In addition, multiple other values were applied to quantify the emissions including; engine run-time assumptions and electricity grid emissions factors.

The electricity emission factors used for electricity consumption (discussed above) were used for the quantification of emissions displaced from renewable electricity generation.

Emissions from Displacing Fossil Fuels in the Lime Kiln with Landfill Gas

GHD used the LFG Tool output of LFG recovery (m^3/hour) in combination with assumed operating parameters; methane composition, and methane energy content to determine the amount of energy in mega joules (MJ) that would be supplied to the lime kiln, in the form of LFG, for Project Scenario #3. GHD assumed this energy directly displaces the energy produced by the combustion of coal and natural gas in the lime kiln with a 50/50 split. The energy contents and combustion emission factors of coal and natural gas[17] were used to determine the Emission Reductions associated with displacing the energy from the combustion of natural gas and coal fossil fuels with LFG.

Emissions from Electricity Consumption

Electricity usage (i.e. total MWh) is assumed to be equivalent in both the Baseline and Project Scenarios (approximately 8,760 MWh per year). It is assumed that the total energy consumption in the Baseline Scenario is divided evenly across each of the three Michigan landfill sites. To calculate the emissions from electricity consumption in the Baseline Scenario, GHD used the eGRID[18] emission rate for the RFC Michigan eGRID sub-region to calculate emissions from electricity consumption for the landfill sites in Michigan. To calculate the emissions from the electricity consumption in the Project Scenarios, GHD used the Electricity Consumption Intensity factor (grid emission factor) for Ontario from Environment Canada's NIR to calculate emissions from electricity consumption for the SWLF.

GHD notes that the grid emission factors applied are significantly different based on the efforts Ontario has undergone to decarbonize its electrical grid in comparison to Michigan, as detailed in Table 3.3.

Table 3.3 Grid Electricity Emission Factors

Emission Factor	Reference	Reference Value	Value (Normalized Units)
Ontario Grid Electricity Emission Factor	Environment Canada NIR	40 g CO_2/kWh	0.04 tCO_2e/MWh
Michigan Grid Electricity Emission Factor	eGRID Summary Tables 2016	1,278.9 lb CO_2e/MWh	0.58 tCO_2e/MWh

The Michigan grid emission factor is more than 10 times greater than the Ontario grid emission factor. These emission factors represent how carbon intensive the electricity grid is in either area. For example if a grid contains electricity generation from renewable sources such as wind power and hydro power it will

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17 National Inventory Report (1996-2016): Greenhouse Gas Sources and Sinks in Canada, 2018, Environment and Climate Change Canada.

18 eGrid Summary Tables 2016, United States Environmental Protection Agency, 2016 https://www.epa.gov/sites/production/files/2018-02/documents/egrid2016_summarytables.pdf.

have a much lower grid emission factor than a grid where the electricity is produced from the combustion of coal or other fossil fuels. The Ontario electricity grid (mostly comprised of hydroelectric and nuclear power) is much less carbon intensive than the electricity grid in Michigan which is comprised of more carbon intensive electricity generation facilities (i.e. coal and natural gas power plants).

GHD assumed that emission factors related to the grid electricity will remain constant over the GHG Emission Timeline of the SWLF and through the assessment. Grid emission factors in both Ontario and Michigan will change over time. However, it is very difficult to accurately forecast this reduction over the 50-year GHG Emission Timeline of the assessment.

Emissions from Electricity Consumption for LFG Processing for Use in Engines and Lime Kiln

LFG processing consists of conditioning the LFG prior to use in utilization engines and lime kiln. Processing of the LFG occurs in a closed system and consists of the removal of small concentrations of contaminants in the LFG that may harm the utilization engines or impact the lime kilns (e.g. siloxanes, hydrogen sulfide, etc.).

The main emissions generated from the processing of LFG are applicable to the consumption of electricity during the processing. GHD used the output flow of LFG (m^3/hour) from the LFG Tool in combination with assumed operating parameters, to determine the volume of LFG that would be supplied to the electricity generating facility or the lime kiln. GHD used an estimate of electricity consumption for processing (per cubic metre of LFG) obtained through GHD's industry experience. GHD then applied the grid emission factor for Ontario from Table 3.3 to calculate emissions from electricity consumption for LFG processing.

Emissions from Site Operations

As stated in Section 3.1, there is a governing assumption related to the emissions from site operations. It has been established that the emissions from site operations are generally equivalent between the Baseline and Project Scenarios.

GHG emissions from site operations associated with on-site fuel use can vary depending on the technology used, types of operations, types of vehicles, types of construction equipment etc. However, the magnitude of emissions associated with site operations are often very similar. When emissions from site operations are calculated during actual operations, there is generally a low level of uncertainty as the emissions are based on total quantities of fossil fuels (e.g. gasoline or diesel) combusted. The equations used to calculate the emissions are also straight forward, as they are based on total fuel consumption and a reference emission factor for that specific fossil fuel type. Accuracy of the GHG emissions estimates can be improved through tracking and measurement of site-specific data (i.e. fuel use for each individual piece of equipment), if applicable, or estimates based on operations at similar facilities. Tracking of energy use through third-party meters or invoicing provides the highest level of verifiable, and reliable data (such as natural gas and electricity invoices).

For the purpose of this assessment, it has been assumed that the magnitude of emissions from site operations are equivalent as specific fuel consumption data associated with each of the Michigan landfills and the SWLF is not available. To ensure the estimates are conservative, GHD assumed that the emissions from site operations are equivalent in both the Baseline and Project Scenarios. This is a conservative assumption because in actuality the emissions from site operations at three landfill sites in Michigan (Baseline Scenario), would likely be higher than the site operations at the single SWLF (Project Scenarios), therefore, this assumption prevents over estimating potential Emission Reductions from the SWLF associated with site operations.

4. Quantification Results and Discussion

4.1 Summary of Results

Table 4.1 below outlines the estimated GHG emissions for each scenario by emission source. Emission totals are presented for the GHG Emission Timeline of the SWLF.

Upper limits and lower limits have been provided for emission sources which are dependent on the results of the LFG Tool. The LFG Tool presents outputs in terms of upper limits and lower limits that are calculated based on the upper and lower boundaries of variables (defaults) that are used in the calculations.

Table 4.1 Greenhouse Gas Emissions by Scenario and Emission Source (tCO_2e)

Emission Source	Baseline Scenario – Waste Exported to Michigan	Project Scenario #1 – Flaring	Project Scenario #2 – Electricity Generation	Project Scenario #3 – Lime Kiln
Emissions from Transportation (tCO_2e)	609,199	216,888	216,888	216,888
Fugitive Emissions from Anaerobic Decomposition of Waste (tCO_2e)				
Upper Limit	12,264,997	5,186,737	4,655,519	4,348,137
Lower Limit	10,346,558	4,264,138	4,357,057	3,574,662
Emissions from Displacing Grid Electricity with Renewable Electricity (tCO_2e)				
Upper Limit	-1,055,524	N/A	-123,248	N/A
Lower Limit	-863,656	N/A	-101,325	N/A
Emissions from Displacing Fossil Fuels (Coal) with LFG (tCO_2e)				
Upper Limit	N/A	N/A	N/A	-23,640
Lower Limit	N/A	N/A	N/A	-22,865

Table 4.1 Greenhouse Gas Emissions by Scenario and Emission Source (tCO_2e)

Emission Source	Baseline Scenario – Waste Exported to Michigan	Project Scenario #1 – Flaring	Project Scenario #2 – Electricity Generation	Project Scenario #3 – Lime Kiln
Emissions from Displacing Fossil Fuels (Natural Gas) with LFG (tCO_2e)				
Upper Limit	N/A	N/A	N/A	-10,396
Lower Limit	N/A	N/A	N/A	-10,055
Emissions from Electricity Consumption	259,165	17,870	17,870	17,870
Emissions from Site Operations	33,759	33,759	33,759	33,759
Emissions from Electricity Consumption for LFG Processing				
Upper Limit	N/A	N/A	N/A	384
Lower Limit	N/A	N/A	N/A	315
Emission Summary				
Total Emissions (Upper Limit)	**12,111,596**	**5,455,254**	**4,800,788**	**4,583,002**
Total Emissions (Lower Limit)	**10,385,524**	**4,297,897**	**4,524,249**	**3,810,574**

Where the 850,000 tonnes per year of solid, non-hazardous waste from Ontario is disposed of in Michigan landfills (Baseline Scenario) with lower LFG collection efficiencies and LFG utilization systems it will produce approximately 10-12 million tCO_2e of GHG emissions over the 50 year GHG Emission Timeline.

In comparison, where the waste is disposed of at the SWLF it will produce approximately 3.8-5.5 million tonnes of emissions over the GHG Emission Timeline. This is due to higher LFG collection system efficiencies, thereby reducing the total fugitive emissions from the site. Shorter hauling distances of the waste and the associated reduction in fuel consumption also aids in reducing the emissions from the Project Scenarios. The utilization of LFG in either utilization engines or the lime kiln only has a marginal benefit to emissions from the SWLF compared to the benefit of utilization in the Baseline Scenario, which is largely attributed to the eGrid emission factor in Michigan.

The emissions in each emission category can be presented as either positive or negative based on whether or not the emission category is resulting in the release of emissions to the atmosphere (e.g. combustion of diesel fuel for transportation would be positive), or the emission category is mitigating/reducing emissions that would have otherwise been emitted (e.g. mitigating the direct release of LFG to the atmosphere through combustion would be negative). Provided below is a summary of each of the emission categories and justification for whether or not the emissions are presented as positive or negative:

- Emissions from Transportation – Positive
  - The emissions associated with transportation are attributed to the combustion of fossil fuel (diesel) therefore these emissions are presented as positive values.
  - Based on the results presented in Tables 4.1, each Project Scenario generates a net emission reduction over the baseline scenario which is associated with the decrease in transportation emissions that amounts to -329,311 tCO2e. The differential between the Baseline and the Project Scenarios is representative of the change in transportation distances between the landfills. The transportation distance to the SWLF (272 km round-trip) is approximately one third of the transportation distance to the Michigan landfills (764 km round-trip). GHD notes that the transportation Emission Reductions only apply to the initial 20 years (2024 – 2044) that waste will be transported to and disposed of at the SWLF.
- Methane Destruction Emissions from the Anaerobic Decomposition of Waste – Negative
  - The emissions associated with the destruction of methane in LFG are considered negative because in the absence of a LFG collection system and associated flaring or utilization, the LFG would be released to the atmosphere as fugitive emissions. Methane destruction emissions are not considered in the emission comparison scenarios because it is best management practices for modern landfills to capture and destroy landfill gas.
- Fugitive Emissions from the Anaerobic Decomposition of Waste – Positive
  - Fugitive emissions represent the direct or indirect release of LFG to the atmosphere without being collected or combusted in the LFG collection system, therefore these emissions are considered to represent a positive value in the Baseline and Project Scenarios.
  - Each Project Scenario has a net GHG emission benefit over the Baseline Scenario ranging from, (5.9) – (7.9) million tCO2e. The desirable environmental impacts from these emission categories are largely based on the improved LFG collection efficiency at the SWLF compared to the average LFG collection efficiency at the Michigan landfill sites, given that the waste tonnage and composition is the same in both the Baseline and Project Scenarios. This is because Methane Destruction Emissions are increased (more methane destroyed) and Fugitive Emissions are decreased in the Project Scenarios, based on the increased LFG collection efficiency of the SWLF. This net emission savings then compounds through the 50-year GHG Emission Timeline. These results present the GHG emission impact/benefit of the proactive management of LFG at the SWLF, in accordance with Ontario regulations, and the importance of effective LFG collection systems over the lifetime of the sites.
- Emissions from Displacing Grid Electricity with Renewable Electricity – Negative
  - The combustion of LFG to generate renewable electricity displaces grid electricity that would have normally been generated by fossil fuels or other carbon intensive practices (based on the grid emission factors). Therefore these emissions represent a negative value in the Baseline and applicable Project Scenario.

- The Baseline Scenario maintains a significant environmental benefit associated with the emissions from displacing grid electricity with renewable electricity approximately (863,656) - (1,055,524) tCO2e. This benefit in the Baseline Scenario is attributed to the relatively high eGrid emission factor in Michigan which is primarily comprised of non-renewable energy sources, as noted Table 3.3. As identified in Project Scenario #2 (Table 2), the magnitude of the GHG benefit in Ontario is an order of magnitude less (101,325) to (123,248) tCO2e based on the relatively low electrical grid emission factor in Ontario, as noted in Table 3.3.

- Emissions from Displacing Fossil Fuels (Coal and Natural Gas) with LFG – Negative
  - Similar to displacing grid electricity, LFG can be combusted in a lime kiln lieu of combusting fossil fuels such as natural gas and coal, which results in these emissions representing a negative value in Project Scenario #3.
  - A portion of the net negative emissions in Project Scenario #3 are attributed to the displacement of coal and natural gas that would normally be used in a lime kiln, with the use of biogas instead. Project Scenario #3 represents approximately a (22,865) – (23,640) tCO_2e benefit compared to the Baseline Scenario where there is no displacement of fossil fuels.
- Emissions from Electricity Consumption (including LFG processing) – Positive
  - Electricity consumption from the grid is carbon intensive based on the grid emission factor that is applied for the jurisdiction, therefore these emissions represent a positive value in the Baseline and Project Scenarios.
- Emissions from Site Operations – Positive
  - Similar to the emissions from transportation, the emissions from Site Operations are attributed to the combustion of fossil fuels, therefore these emissions represent a positive value in the Baseline and Project Scenarios.

Based on the above, when adding the emissions from each emissions category together, if the total emissions are positive this represents a scenario that is more carbon intensive and therefore has an undesirable impact on the environment. If the total emissions are negative, this presents a scenario where emissions are being reduced and therefore resulting in a more desirable impact on the environment. As a result, the more negative the total emissions are the more desirable impact the scenario is having on the environment. Table 4.2 provides a summary of the net GHG emission benefits of each Project Scenario compared to the Baseline Scenario where the Baseline Scenario has a net zero (0) benefit.

Table 4.2 Net GHG Emissions Comparison – Baseline vs. Project Scenarios

Emission Source	Baseline Scenario – Waste Exported to Michigan	Project Scenario #1 – Flaring	Project Scenario #2 – Electricity Generation	Project Scenario #3 – Natural Gas Displacement
Net GHG Emissions (Upper Limit)	0	(6,656,342)	(7,310,808)	(7,528,593)
Net GHG Emissions (Upper Limit)	0	(5,852,370)	(5,562,314)	(5,800,974)

Table 4.2 provides a summary of the net GHG emission differential between the Baseline Scenario and the three Project Scenarios. The SWLF, depending on the final Project Scenario that is adapted, will reduce GHG emissions from Ontario's waste management practices by approximately 5.8 - 7.5 million tCO_2e over the GHG Emission Timeline. Emissions presented in Table 4.2 are calculated for each Project Scenario and compared to the Baseline Scenario over the 50-year GHG Emission Timeline based on the following example equation:

Net GHG Emission Reductions = Baseline Scenario Emissions – Project Scenario Emissions

The Baseline Emissions remain constant while the Project Scenario Emissions change based on the based on the individual Project Scenario conditions outlined in Section 3.3 and presented in Table 4.1. The results presented in Table 4.2 indicate that Project Scenario #3 has the most negative and therefore most desirable impact on the environment, followed by Project Scenarios' #2 and #1.

4.2 Emission Reduction Equivalencies

To provide context for the net Emission Reductions presented in Tables 1, 2, and 3, GHD has provided a correlation between the net Emission Reductions and the equivalent removal of vehicles from the road. The US EPA's Greenhouse Gas Emissions from a Typical Passenger Vehicle estimates that a typical passenger vehicle emits 4.6 tCO_2e annually. Therefore, the annual carbon reduction for the Project Scenario resulting in the most significant amount of net Emission Reductions is Project Scenario #3, which represents the equivalent of removing more than 32,000 vehicles from the road per year. Provided in Table 4.3 provides a summary of the relative impact of the net Emission Reductions from each of the Project Scenarios.

Table 4.3 Estimated Vehicles Removed Annually from the Road by Project Scenario

Total Numbers of Vehicles on an Annual Basis	Project Scenario #1	Project Scenario #2	Project Scenario #3
Upper Limit	28,941	31,786	32,733
Lower Limit	25,445	24,184	25,222

5. Conclusion

Each of the Project Scenarios assessed in this Report provide a significant degree of GHG emission reductions over the 50-year GHG Emission Timeline when compared to the baseline scenario. The SWLF project will provide a significant net positive effect by reducing Ontario's GHG emissions associated with waste management activities by 5.8 – 7.5 M tonnes of CO2e. For comparison, this is equivalent to removing 24,184 – 32,733 cars from the road every year.

The most significant emission reductions are generated through Project Scenario #3 (refer to Table 4.2), which has an added benefit (compared to the other two Project Scenarios) of displacing fossil fuels (coal and natural gas).

GHD also identified the following parameters where there were additional impacts on the total emission reductions in each Project Scenario:

- Overall reduction in the total transportation distance required for waste with regards to Transportation Emissions
- Destruction efficiency of the flare and stationary combustion equipment compared to LFG utilization to generate electricity
- Limited impact of displacing grid electricity in Ontario
- Minor benefit related to electricity consumption in Ontario
- Limited impact of emissions from electricity consumption for LFG processing

Through this assessment it was identified that effective collection of LFG at landfills has the most significant impact on GHG emissions from landfill sites.

6. References

A detailed summary of the references used in this Report are provided in Attachment B.

7. Closing

This Report provides an evaluation of the GHG emission impacts that the SWLF can provide compared to current landfill practices and serves to satisfy a component of *Minister's Amendment #14 of the Notice of Approval – Terms of Reference*. The GHG emission estimates in this Report are based on modelled LFG generation from the Michigan Landfills (Baseline Scenario) and SWLF (Project Scenarios).

This Report accompanies the EA for the SWLF that also includes an Air Quality Assessment completed by RWDI[19]. GHD has completed this Report independent of the Air Quality Assessment. The Air Quality Assessment provides a more pointed understanding of the air quality emissions from the SWLF that pertain to specific compounds generated from the degradation of waste within the SWLF (e.g. NMOCs, VOCs, ethane, octane, etc.) along with the core components of LFG (i.e. methane and carbon dioxide). However, the GHG emission estimates contained in this Report and the results of the Air Quality Assessment are both based on a similar foundation that consists of modelling the anticipated LFG generation from the SWLF over the GHG Emission Timeline. GHD used the foundation of the Scholl-Canyon Model in the LFG Tool and RWDI applied the LandGEM Model[20]. Both models, achieve a very similar magnitude of LFG generation potential through the GHG Emission Timeline. Therefore, GHD has determined that the GHG emissions forecasted within this letter report are consistent with the associated

19 Air Quality Assessment, RWDI, 2019

20 Landfill Gas Emission Model (LandGEM), Version 3.02, 2005, https://www3.epa.gov/ttn/catc/dir1/landgem-v302.xls

LFG generation estimates provided in the Air Quality Assessment. As a result, the GHG emission estimates provided in this Report provide an accurate representation of the proposed conditions at the SWLF based on the information available at the date of issuance.

Please do not hesitate to contact me if you have questions or require any additional information.

Sincerely,

GHD

Jason Clarke

JC/mg/2 rev.2

Encl.

cc: Bobbie Thoman, Walker
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