Report

Greenhouse Gas Systems for Landfill and Refuse Derived Fuel (RDF) Analysis

Project I.D.: 17D006

Prepared For
Dakota County
Apple Valley, Minnesota

June 12, 2017

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June 12, 2017

Kristi Otterson, Environmental Specialist – Waste Regulation
Dakota County - Western Services Center
14955 Galaxie Avenue
Apple Valley, MN55124-8579

Dear Ms. Otterson:

RE: Greenhouse Gas Systems for Landfill and Refuse Derived Fuel (RDF) Analysis

This letter transmits the Greenhouse Gas (GHG) Systems Analysis for the scenarios analyzed for residential and commercial waste management. The report details the analysis of GHG emissions and the comparison of options for waste management using landfilling only (Base Case) or landfilling combined with processing and combustion (Alternative Case) for Dakota County. This report is intended to be a comparative analysis of two scenarios and not an all-inclusive life cycle GHG analysis of specific waste management systems. Items that generated the same GHG emissions between the systems were not accounted for in the GHG systems analysis such as the life cycle of a collection truck. In order to analyze the major components of residential and commercial collection, as well as the various processes, GHG analysis was analyzed by modules. Using this method of modules allowed for input changes to a module but retained the basic calculations to ensure comparable results.

This report includes components completed with the assistance of Great Plains Institute (GPI). GPI was consulted to provide data for electrical offsets for the Great River Energy combustion facility. GPI's report *Waste-to-Energy: Avoided Greenhouse Gas Emissions for Dakota County Municipal Solid Waste* is included in Appendix A.

Thank you for the opportunity to provide this GHG analysis.

Sincerely,

Foth Infrastructure & Environment, LLC

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Dakota County
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Executive Summary

The purpose of this Greenhouse Gas Systems Analysis is to develop, analyze, and compare the estimated greenhouse gas (GHG) emissions from different potential municipal solid waste (MSW) management scenarios for Dakota County (County). This comparative analysis was completed with a goal of using the same assumptions for each scenario and using readily available data including its inherent limitations. The intent was to treat each scenario equally such that the results are comparable. This is not intended to be an all-inclusive GHG life cycle analysis of each scenario.

The MSW management scenarios analyzed for a one-year period in this report include:

- **Landfilling Only (Base Case)** – Model the current system of landfilling MSW (202,516 tons per year) at the Pine Bend and Burnsville landfills.
- **Landfilling and GRE (Alternative Case)** – Transfer haul 60,000 tons per year of MSW to the GRE facility in Elk River for RDF processing and combustion. The remaining MSW would be landfilled at Pine Bend and Burnsville landfills.

GHG estimates were calculated from collection systems through transfer and transportation systems to final disposal. There is an extensive mathematical analysis using various computer models and calculations to develop the appropriate emission factors for each system. The emissions factors for each component of each scenario and the tons managed are multiplied together to provide the estimates for GHG emissions.

The collection system modeled both residential and commercial collection in Dakota County. Foth used the MPCA study from 2009, *Analysis of Waste Collection Service Arrangements* for determining the expected GHG emissions from collection of waste. Foth modeled residential collection for multiple haulers based on previous studies and experience in waste collection consulting. The collection system for commercial garbage collection was based on similar studies completed in Ramsey and Washington County. Since there are multiple licensed haulers and businesses in Dakota County, our goal was to model commercial collection in Dakota County that is likely representative of actual collection. Foth modeled transportation to the landfill from the centroid of the County, then to the landfill. GHG emissions for transportation are based on estimated fuel usage for transport of waste. From the estimated fuel usage, GHG emissions factors are applied to determine total emissions for transportation.

Landfills modeled in the study were Pine Bend (25% of the MSW) and Burnsville (75% of the MSW) landfills. Each were modeled to have active landfill gas collection with energy recovery sent to the electrical grid. Foth used the USEPA WARM model to estimate the emissions from the landfills. The base case modeled is for all waste collected in Dakota County to be sent to the landfill. The alternative case was based on 60,000 tpy being sent to GRE with the remainder being landfilled. Since the available capacity of GRE is limited to 60,000 tpy, this amount was assumed to be collected, sent to the SET transfer station and then hauled to GRE for processing. All other waste was modeled as going to the landfills using the disposal percentages provided by Dakota County.

Once at the GRE facility, Foth modeled GHG emissions for RDF processing using the annual electric use at the GRE Elk River facility and applying a carbon intensity factor for electrical use that was provided by the Great Plains Institute (GPI). Additionally, Foth modeled additional GHG emissions from the yard equipment used at the facility (like loaders, fork lifts, etc.) based on diesel fuel used. Once the waste is made into RDF it is combusted to produce electricity. Combustion of RDF emits GHGs to the atmosphere. Making electricity from RDF combustion results in the reduction of GHG since the power production offsets more GHG intensive electrical production (like coal). Factors for GHG emissions were taken from the WARM model. Factors on GHG offsets for electrical generation were provided by GPI based on the overall GHG performance for GRE's full fleet of generating facilities.

The results from the study indicate that the base case (all landfilled) and the alternative case (GRE and landfilling) have similar GHG emissions. This is due to the transportation required to get the waste to GRE and also the remaining landfilled waste even if 60,000 tons of waste is converted to electricity by GRE. A summary of emissions if provided in Table ES-1 below.

Table ES-1
Summary of Results
GHG Emissions per Year

Item	Base Case (Landfill)	Alternative Case (GRE + Landfill)
Residential Collection of MSW	3,742	3,742
Commercial Collection of MSW	5,239	5,239
Transfer of MSW to Landfill, Transfer Station or GRE	2,910	3,723
Transportation Subtotal	**11,891**	**12,704**
RDF Processing at GRE[1]	0	2,606
Landfill Emissions[2]	17,932	12,847
GRE Emissions[3]	0	22,800
Electrical Offset to the Grid[4]	0	(22,484)
Total	**29,823**	**28,473**

1. GRE Processing includes electrical use for processing and fuel use for yard tractors. Electrical GHG intensity per GPF report.
2. Landfill emissions from the WARM model.
3. GRE stack emissions from emission factors in WARM model.
4. Electrical offset emissions from GPI report. Average value used.

List of Abbreviations, Acronyms, and Symbols

Biogenic	CO_2 emissions-related to the natural carbon cycle
C & D	Construction and Demolition
Carbon Cycle	The movement of carbon as it is recycled and reused in the biosphere
CH_4	Methane
CO_2	Carbon Dioxide
Dakota	Dakota County, Minnesota
EPA	Environmental Protection Agency
Foth	Foth Infrastructure & Environment, LLC
GHG	Greenhouse Gas
GPI	Great Plain Institute
GRE	Great River Energy
HDPE	High Density Polyethylene
LFG	Landfill Gas
mpg	Miles per Gallon
MSW	Municipal Solid Waste
$MtCO_{2e}$	Metric Tons of Carbon Dioxide Equivalent
N_2O	Nitrous Oxide
Non-biogenic	CO_2 emissions-not related to the natural carbon cycle
OCC	Old Corrugated Containers
PET	Polyethylene Terephthalate
Project Board	Ramsey/Washington Counties Resource Recovery Project Board
tpy	Tons per Year
WARM	EPA's Waste Reduction Model

1 Introduction

The purpose of this Greenhouse Gas Systems Analysis is to develop, analyze, and compare the estimated greenhouse gas (GHG) emissions from different potential municipal solid waste (MSW) management scenarios for Dakota County (County). The County contracted Foth Infrastructure & Environment, LLC (Foth) to conduct this analysis to evaluate and compare the potential environmental impacts of the County selected scenarios using GHG emissions as an indicator.

This comparative analysis was completed with a goal of using the same assumptions for each scenario and using readily available data including its inherent limitations. The intent was to treat each scenario equally such that the results are comparable. This is not intended to be an all-inclusive GHG life cycle analysis of each scenario.

The MSW management scenarios analyzed for a one-year period in this report include:

- Landfilling Only (Base Case) – Model the current system of landfilling MSW (202,516 tons per year) at the Pine Bend and Burnsville landfills.
- Landfilling and GRE (Alternative Case) – Transfer haul 60,000 tons per year of MSW to the GRE facility in Elk River for RDF processing and combustion. The remaining MSW would be landfilled at Pine Bend and Burnsville landfills.

Based on the 2015 County Certification Report, this analysis assumes 202,516 tons per year (tpy) of MSW in each of the scenarios. This GHG system analysis report describes the material flows in the two cases and describes the framework and modules used to develop the data to estimate GHG emissions. GHG estimates were calculated from collection systems through transfer and transportation systems to final disposal. There is an extensive mathematical analysis using various computer models and calculations to develop the appropriate emission factors for each system. The emissions factors for each component for each scenario and the tons managed are multiplied together to provide the estimates for GHG emissions. The two scenarios were compared to determine management methods with favorable GHG emissions.

2 Materials Management Systems

2.1 Collection

The collection system consists of both residential and commercial collection. Each of the two systems require assumptions on the market share for each hauler in each city; along with various other assumptions to determine GHG emissions estimates. The assumptions used are described below.

2.1.1 Residential

The collection system used to model GHG emissions for residential customers is based on standard, once per week, collection of garbage at the curb side. The modeling approach assumes a side loader is collecting the waste. Since each city in Dakota County has more than one potential hauler (open system); except for Farmington and Hastings (organized collection), Foth made assumptions on market shares and collection for haulers. Since GHG emissions from residential collection are the same for both the base case and the alternative case, modeling residential collection needs to be plausible but not exact. Foth modeled residential collection for multiple haulers based on previous studies and experience in waste collection consulting.

2.1.2 Commercial

The collection system for commercial garbage collection was based on similar studies completed in Ramsey and Washington County. In Dakota County, some cities have several commercial haulers licensed. For modeling purposes, Foth used a maximum of 10 haulers in any one city with most cities having 8 haulers of commercial garbage, except for Farmington with one hauler. Like residential collection modeling, commercial collection modeling is the same for both the base case and the alternative case. Our goal was to model commercial collection in Dakota County that is likely representative of actual collection. However, a rigorous commercial garbage collection model is beyond the scope and is not likely to provide results that would modify the overall outcome of the study.

2.2 Landfilling

Once collected, garbage is delivered to a landfill. Foth modeled transportation to the landfill from the centroid of the County, then to the landfill. Landfills modeled in the study were Pine Bend (25% of the MSW) and Burnsville (75% of the MSW) landfills. Each were modeled to have active landfill gas collection with energy recovery sent to the electrical grid. The base case is for all waste collected in Dakota County to be sent to the landfill. The alternative case was based on 60,000 tpy being sent to GRE with the remainder being landfilled.

2.3 GRE and Landfilling

Once collected, emissions were modeled to either be sent to the landfill or to GRE in Elk River to be converted to RDF, combusted and made into electricity for the grid. Since the available capacity of GRE is limited to 60,000 tpy, this amount was assumed to be collected, sent to the SET transfer station and then hauled to GRE for processing. All other waste was modeled as going to the landfills using the disposal percentages provided in the section describing landfilling.

3 GHG Modeling Framework

To analyze the major components of the residential and commercial collection, as well as the various processes, GHG analysis was categorized by modules. Using this method of modules allowed for input change to a module but retained the basic calculations to ensure comparable results. Each of the major GHG modules is described in this section.

Major module development for this analysis included:

- Collection and Hauling
- Transfer and Transportation
- Materials Management
  - Landfilling
  - RDF Processing
  - RDF Combustion
  - RDF Residue (landfilling of ash and bulky waste)

3.1 Collection and Hauling

The collection and hauling GHG model originated in a 2009, Foth study for the MPCA, *Analysis of Waste Collection Service* Arrangements (MCPA study)[1]. Dakota County has a combination of open collection and contracted "organized" systems for residential households. Open collection systems allow residents to subscribe to the licensed hauler of their choice and generally result in multiple haulers serving the same geographic area. Open collection systems have additional route truck miles traveled and fuel consumed that contributes to GHG emissions due to the multiple haulers serving the same geographic area. As the percentage of households served (or "route density") increases, there is greater efficiency in collection and less drive time (time spent driving without performing collections).

Contract or "organized" collection systems typically require 100 percent of the route to be served by only one hauler. Organized collection systems generally have greater collection efficiency, which reduces the GHG emissions as compared to open collections systems.

To estimate these fuel efficiencies for the MPCA study, Foth measured fuel consumption for collection services while on a collection route. This data allowed Foth to determine the amount of fuel used per household collected. To estimate GHG emissions, a CO_2 emission factor of 10.21 kg CO_2 per gallon of diesel fuel (22.51 pounds of CO_2 per gallon) was used, as well as other factors for N_2O and CH_4, based on an EPA emission factors[2].

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[1] MCPA report, *Analysis of Waste Collection Service Arrangements* prepared by Foth Infrastructure & Environment, LLC (June 2009): http://www.pca.state.mn.us/index.php/view-document.html?gid=4514

[2] EPA (2014) Inventory of US Greenhouse Gas Emissions and Sinks: 1990-2012. All values calculated from Table A-107. http://www.epa.gov/climateleadership/documents/emission_factors.pdf. Accessed 2/15/2015. Last modified 4/4/2014.

These factors are used for all on-road diesel fuel use.[3] As part of the MPCA study, Foth prepared a model to estimate the GHG emissions for collection vehicles based on the following variables:

- Number of households or businesses receiving collection service.
- Percentage of households or businesses participating in a collection service.
- Frequency of pick up.
- Number of haulers collecting a material in the system.
- Percentage of market share of each hauler.
- Estimated distance between each household or business.
- Estimated fuel consumption rates.

The model calculates the total annual fuel consumption and total annual GHG emissions.

3.1.1 Number of Households Receiving Collection Service

Dakota County has an estimated 152,203 household based on the breakdown of household by city as provided in Table 3-1. The approximately 5,940 household in rural Dakota County were not included in this analysis. Some of these household are assumed to be self-hauler and many of these households are in the southern portion of Dakota County.

Table 3-1
Household by City Breakdown

City	No. of Households[1]
Apple Valley, Minnesota	19,600
Burnsville, Minnesota	25,759
Eagan, Minnesota	26,414
Farmington, Minnesota	7,412
Hastings, Minnesota	9,222
Inver Grove Heights, Minnesota	14,062
Lakeville, Minnesota	19,456
Mendota Heights, Minnesota	4,620
Rosemount, Minnesota	7,853
South St. Paul, Minnesota	8,666
West St. Paul, Minnesota	9,139

1. https://www.biggestuscities.com/demographics/mn/dakota-county

3.1.2 Number of Businesses Participating in a Collection Service

Businesses in Dakota County are modeled to have MSW collection service. Approximately thirty-four thousand five hundred (34,500) businesses are modeled to have MSW collection service. This includes shared collection points utilized by multiple businesses. A summary of the number of businesses by city is provided in Table 3-2.

[3] Note: The EPA has different factors for diesel fuel use in the Mandatory GHG Reporting Rule which are applied to stationary sources

Table 3-2
Businesses by City Summary

City	Total No. of Businesses[1]
Apple Valley	3,935
Burnsville	6,506
Eagan	6,623
Farmington	1,683
Hastings	2,120
IGH	2,686
Lakeville	5,085
Mendota Heights	1,596
Rosemount	2,131
SSP	1,192
WSP	1,969

1. https://www.biggestuscities.com/demographics/mn/dakota-county

3.1.3 Frequency of Pick Up

The estimated households in Dakota County are modeled to have weekly MSW collection service. The estimated number of businesses in Dakota County are modeled to have collections once per week.

3.1.4 Number of Haulers Collecting

A review was completed of the cities in Dakota County to determine the number of licensed haulers in each city and the number of households serviced. Residential market share accounts for the differing markets in Dakota County as well as the number of licensed haulers collecting waste.

Apple Valley, Burnsville, Eagan, Inver Grove Heights, Lakeville, Mendota Heights, Rosemont and South St. Paul were modeled using 4 haulers having 70 percent of the household collection market. Each hauler would have a 17.5 percent share of the market. The remaining haulers in each of the cities would have an equal share of the remaining 30 percent.

For example, in Burnsville and Eagan there are a total of 7 licensed residential haulers. Four of the haulers would each have a 17.5 percent share of the residential collection (approximately 4500 households (and the remaining 3 haulers would each have a 10 percent share of the market (approximately 2,600 households). The percent of market impacts GHG emissions since the model assumes a distance between households and the number of pickups to estimate GHG emission from the collection vehicle.

The cities of Farmington and Hastings were modeled as organized systems. Each of the cities has one hauler for residential collection. This single collection system has the least GHG emissions for the collection module.

West St. Paul only has 5 licensed residential collection haulers. For this City, each hauler was modeled to have a 20 percent share of the market (approximately 1,800 households per hauler).

Foth conducted a similar analysis for Ramsey/Washington counties, which was used as a basis for commercial collection assumptions for Dakota County. In that analysis, the Counties provided much of the information.

For Dakota County, some of the assumptions used for the Ramsey/Washington counties GHG study are assumed to be appropriate to use in the Dakota County study. For example, the distance between each pickup of 500 feet is reasonable based on similar business complex structures between the counties (Dakota, Ramsey and Washington). The number of businesses in each city in Dakota County was determined previously using public data sources.

The total number of haulers for each city was also determined based on City information. The market share of each commercial hauler is different in Dakota County since the County is not dominated by the same urban density as Ramsey County. Therefore, the market share assumptions are modified for the Dakota County study to account for the relative business density. Commercial collection is assumed to be modeled as route collection then from the centroid of the County to the disposal site or transfer station as was completed in the residential hauler model. A proposed summary of commercial collection modeling inputs is provided in Table 3-3.

Table 3-3
Dakota County GHG Study
Commercial Collection Analysis

City	Total No. of Haulers	Est No. of Commercial Haulers	Total No. of Businesses[1]	Proposed Assumptions[6]
Apple Valley	9	8	3,935	8 haulers . Assume 3 haulers have 20% each. One hauler with 15% and one hauler with 10%. Remainder divided. 3 haulers at 5% each.
Burnsville	7	7	6,506	7 haulers. Assume 3 haulers have 20% each. One hauler with 15% and one hauler with 10%. Remaining 2 haulers each have 7.5%
Eagan	7	7	6,623	7 haulers. Assume 3 haulers have 20% each. One hauler with 15% and one hauler with 10%. Remaining 2 haulers each have 7.5%
Farmington	1	1	1,683	One hauler has 100% of the market
Hastings[2]	28	28	2,120	10 haulers. Assume 3 haulers have 20% each. One hauler with 15% and one hauler with 10%. Remaining haulers each have 3%
IGH	17	17	2,686	10 haulers. Assume 3 haulers have 20% each. One hauler with 15% and one hauler with 10%. Remaining haulers each have 3%
Lakeville[3]	10	10	5,085	8 haulers. Assume 3 haulers have 20% each. One hauler with 15% and one

City	Total No. of Haulers	Est No. of Commercial Haulers	Total No. of Businesses[1]	Proposed Assumptions[6]
				hauler with 10%. Remainder divided. 3 haulers at 5% each.
Mendota Heights	11	11	1,596	8 haulers. Assume 3 haulers have 20% each. One hauler with 15% and one hauler with 10%. Remainder divided. 3 haulers at 5% each.
Rosemount[4]	14	14	2,131	8 haulers. Assume 3 haulers have 20% each. One hauler with 15% and one hauler with 10%. Remainder divided. 3 haulers at 5% each.
SSP[5]	16	12	1,192	8 haulers. Assume 3 haulers have 20% each. One hauler with 15% and one hauler with 10%. Remainder divided. 3 haulers at 5% each.
WSP	6	6	1,969	6 haulers. Assume 3 haulers have 20% each. Two haulers each with 15% and one hauler with 10%.

1. https://www.biggestuscities.com/demographics/mn/dakota-county
2. Hastings residential collection is by Tennis. Commercial collection is an open system with licensed haulers
3. Lakeville has 10 haulers in the market but only 6 are residential haulers. All haulers can collect commercial accounts
4. City of Rosemount has 14 haulers total but only 6 are licensed for residential collection
5. SSP has residential, commercial and roll off licensed haulers
6. Haulers were limited to no more than 10 in any one market.

3.1.5 Estimated Distance between Each Household or Business

Distances between households were estimated using average distances for previous studies. A distance of 125 feet per household was used as the average. This distance includes "dead heading" sections of road traveled between stops. In the collection model calculations, if a hauler has twenty-five percent (25%) market share they drive past four (4) households or 460 feet for each stop collected. Estimated distance between businesses for MSW collection is modeled at 500 feet. In the collection model calculations, if a hauler has twenty-five percent (25%) market share they drive past four businesses or 2,000 feet for each stop collected.

3.1.6 Estimated Fuel Consumption Rates in the Model

Fuel consumption rates for collection vehicles were taken from the MPCA study. Foth measured fuel consumption for collection services while actually on a collection route. This data allowed Foth to determine the amount of fuel used per household collected. To estimate GHG emissions, a CO_2 emission factor of 10.21 kg CO_2 per gallon of diesel fuel (22.38 pounds of CO_2 per gallon) was used and other factors for N_2O and CH_4 based on an EPA technical reference[4]. These factors are used for all on-road diesel fuel use. Fuel is first estimated in ounces per stop and then converted to annual gallons which are used to calculate GHG emissions on an annual basis.

[4] Ibid EPA (2014) Inventory of US Greenhouse Gas Emissions and Sinks: 1990-2012. All values calculated from Table A-107. http://www/epa/gov/climateleadership/documents/emission-factors.pdf . Accessed 2/15/2015. Last modified 4/4/2014.

3.2 Transfer and Transportation

The goal of this model is to quantify GHG emissions for material movements within the Dakota County system and account for diesel emissions as they pertain to GHG for the material movements. All transportation is modeled using on-road diesel fuel trucks.

The model was developed based on the total tons of the material being moved by truck (packer or transfer). Packer truck capacity was estimated to be 5 tons per load for materials hauled direct to a facility by the collection vehicle. Truck capacity was estimated to be 19 tons per load for transfer loads, MSW and residuals transport and 24 tons per load for ash transport.

Having the total tons of each material and the estimated truck capacity per load, the total number of trips was calculated for each part of the material transport. (e.g., MSW to Landfill, transfer station to GRE, etc.) Each trip was assigned an estimated mileage based on general information about distance to facilities and estimates about future systems. Where specific mileage information was available it was used in the transportation model.

For this analysis, a general mile per gallon (mpg) per truck was used based on the type of truck being used to transport the material. For residential collection, a side loader type truck was modeled. Side loader type trucks have a typical fuel efficiency rating of 3.0 mpg[5].

For trucks that transport commercial wastes directly to a facility, a front loader type waste truck was modeled. These trucks typically have a rating of 2.6 mpg[6]. For transfer haul trucks and trucks that transport MSW to GRE, a large semi-tractor trailer mpg was used. For a semi-tractor trailer an estimated 4.3 mpg was used[7].

Using the estimated miles traveled and the estimated miles per gallon per truck, the total annual gallons of diesel fuel use was calculated. Since this is a calculated field, rounding may have occurred. However, the estimated fuel use per transportation item was consistent in each model. Rounding did not impact the comparison of GHG emissions between the systems analyzed.

The amount of GHG's emitted from on-road diesel fuel consumption is based on data provided by EPA for mobile combustion sources[8]. For diesel fuel use, the GHG emissions factors were:

- 10.21kg of CO_2 per gallon
- 0.0048g of N_2O per mile
- 0.0051g of CH_4 per mile

To convert the N_2O emissions to CO_{2e} required the emissions to be multiplied by the global warming potential (GWP). The GWP for CO_2 is 1, for N_2O the GWP is 298; and for the CH_4 the

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[5] Technologies and Approaches to Reducing Fuel Consumption of Medium and heavy Duty Vehicles. Natural Academy of Science, 2010

[6] IBID

[7] Sandhu, Gurdas, et.al. "Real World Authority and Fuel Use of Diesel and CNG Refuse Trucks." Presented at 2014 PEMS International Conference and Workshop. April 3-4, 2014. Riversdale, California. Slide 31.

[8] EPA (2014) Inventory of US Greenhouse Gas Emissions and Sinks: 1990-2012. All values calculated from Table A-107. http://www/epa/gov/climateleadership/documents/emission-factors.pdf. Accessed 2/15/2015. Last modified 4/4/2014.

GWP is 25[9]. Therefore, all transportation GHG emissions were converted to carbon equivalents (CO_{2e}) using the GWP.

The transportation model is not intended to provide a GHG lifecycle emissions of the vehicles used in transport. Rather it looks at fuel usage and compares the GHG generated from fuel usage between the systems. All emissions are based on the annual tonnage of 202,516 tons. Outputs are in $MtCO_{2e}$ per year.

3.3 WARM Model Background

The USEPA WARM model was created as a tool to estimate GHG emissions and reductions for various solid waste management scenarios. WARM estimates GHG emissions for baseline solid waste systems and various alterative scenarios. Emission factors for various solid waste materials and management options are available in WARM in units of $MtCO_{2e}$.
WARM also can consider transportation of the materials. Since GHG emissions from transportation are analyzed in the transportation module, the WARM model travel distances were set to zero so the emission factors presented would represent GHG emissions not including any transportation.

The WARM model was used for the various systems for recycling materials, landfill materials and combustion of materials. For the landfill option, WARM model was set to include landfill gas (LFG) recovery which would be converted to energy (electricity). LFG system parameters were set to WARM model defaults (typical LFG) collection. The default means phased-in collection with an improved cover, judged to represent the average U.S. landfill, although every landfill is unique. A typical landfill, as modeled in WARM, approximates reality and national average decay coefficient (values used in the model) to account for variations in landfills that may receive Dakota County waste. Both landfills that receive Dakota County waste currently have active LFG collection systems with conversion to energy. The WARM model emission factor also accounts for soil oxidation of methane not collected by the collection system. The WARM model estimated emissions from the landfill as 0.14 $MtCO_{2e}$ per ton of mixed MSW disposed.

3.4 RDF Processing

GHG emissions for RDF processing were calculated using the annual electric use at the GRE Elk River facility. To estimate the GHG emissions associated with RDF production, Foth used the available data based on electric use for the GRE facility to determine the estimated kilowatt hours (kWh) needed per ton of processed waste. Based on the available information, Foth estimated 23.25 kWh is required per ton of material processed.

Since Dakota County would be limited to 60,000 tons of MSW per year for processing into RDF, the total electrical need for processing RDF would be 1,395,000 kWh. Electrical emissions data for GHG intensities are based on many factors including utility fuel mixes, plant efficiencies and renewables. Foth contracted with Great Plains Institute to conduct a study on emissions from

9 100-Year Global Warming Potentials, IPCC Fourth Assessment Report. https://www.ipcc.ch

GRE in Elk River and estimate intensities for electric generation and use in the GRE portfolio. The Great Plains Report is provided in Appendix A.

The report indicates that according to the Great River Energy's Resource Plan 2015-2029, expected GHG intensity for Great River is approximately 750kg CO_{2e}/MWh in 2013 to 642kg CO_{2e}/MWh 2030. For 2017, GPI estimates GHG intensity for the GRE grid to be 724kg CO_{2e}/MWh.

Based on the estimated GHG intensity and estimated MWh used to convert 60,000 tons of MSW to RDF, estimated GHG emission for processing RDF would be 1,567.37 $MtCO_{2e}$.

Foth also obtained data from the U.S. Department of Energy's e-GRID database. In 2014, the e-GRID database indicated the GHG emissions based on electrical use for the GRE Elk River plant to be 0.0011 $mtCO_{2e}$ per kWh. Using the e-GRID data, the estimated GHG emission for RDF processing would be 2,432.35 $MtCO_{2e}$.

Another source of GHG emission data is the EPA Facility Level Information on Greenhouse Gas Tool (FLIGHT)[10]. This tool summarizes data submitted to the EPA each year due to the mandatory GHG reporting rule. The most recent data available for the FLIGHT database is from 2015.

In 2015 the GRE Elk River facility emitted a total of 125,708 $mtCO_{2e}$. Since this plant combusts other fuels, the FLIGHT database provides a detailed facility report by fuel type. In 2015, GRE reported 7,134 $MtCO_{2e}$ for methane and nitrous oxide and 95,496.7 $MtCO_{2e}$ for non-biogenic carbon dioxide. Total of 102,630.9 $MtCO_{2e}$ for RDF combustion at GRE. In 2015 GRE received 270,893 tons of MSW.

Using actual GHG emission and tonnage data provides a structured GHG emission rate of 0.38 $mtCO_{2e}$ per ton of MSW. This emissions rate is slightly higher than the WARM model rate of 0.36 $MtCO_{2e}$ per ton of MSW. To be conservative, this factor was used in the estimate of GHG emissions for RDF combustion (Table 4-5).

3.5 RDF Conversion

Once the MSW from Dakota County is converted to RDF, the RDF is combusted to make electricity for the grid. Combustion of RDF also results in emissions from the stack. In order to estimate the avoided emission from RDF combustion to electricity, Foth contracted with GPI to provide an estimate of avoided GHG emissions.

GPI estimated that the electrical generation rate for the GRE facility is 0.567 MWh per ton of MSW. With 60,000 tons of garbage from Dakota County destined for GRE, the annual electrical production would be 34,000 MWh. GPI estimated avoided emissions from RDF combustion to range from 20,552 to 24,416 $MtCO_{2e}$ per year depending on where the electricity generated will be off set.

[10] FLIGHT: http:// ghgdata.epa.gov/ghgp/main

Foth estimated GHG emissions from combustion of RDF using a factor of 0.38 $mtCO_{2e}$ per ton of MSW based on the actual GHG emission and tonnage data. For the estimated 60,000 tons of MSW sent to GRE for Dakota County in the alternative case, total estimate GHG emission could be 22,800 $MtCO_{2e}$ per year.

3.6 Ash Disposal

Combustion of RDF will create ash that must be transported to a landfill for disposal. For this GHG study, Foth used a conversion factor of 0.267 to convert tons of waste to ash. The ash is loaded onto a truck and hauled to a landfill. For this study, Foth modeled ash trucks hauling 24 tons to the Becker Ash landfill. The Becker Ash landfill is 18 miles one way. Modeling was conducted similar to the transfer and transportation module and used the same emissions factors for on road diesel fuel consumption.

Ash disposal is estimated to produce 57 $MtCO_{2e}$ per year for the 60,000 tons of garbage sent to GRE, processed into RDF, combusted and ash disposed at Becker Ash landfill.

3.7 Landfilling

Landfilling was modeled using the WARM model with no hauling, active LFG collection that is converted to electricity and placed on the electrical grid. The WARM model is based on broad assumption on GHG emissions from landfilling materials.

In addition to carbon emissions, some of the carbon in these materials (i.e., food waste, yard trimmings, paper and wood) is stored in the landfill because these materials are not completely natural conditions (virtually all the biodegradable material would degrade to CO_2, completing the photosynthesis/respiration cycle), this is counted as an anthropogenic sink. However, carbon in plastics and rubber that remains in the landfill is not counted as stored carbon because it is of fossil origin. Fossil carbon (e.g., petroleum, coal) is already considered “stored” in its natural state; converting it to plastic or rubber and putting it in a landfill only moves the carbon from one storage site to another.

Therefore, the landfill modeling of GHG considers various processes that contribute to GHG generation. The WARM model does allow for specific materials to be entered into the model. For the Dakota County study, the mixed MSW category was used in the WARM model to estimate GHG emissions. The rational for selecting the mixed MSW category in WARM is discussed in section 3.8.

3.8 Waste Composition

The waste composition data used for GHG emissions studies can impact the outcome considerably depending on the specific composition. For example, if considerable food waste is disposed in a landfill versus combusted for waste to energy, the difference in GHG emissions factors is 0.45 $MtCO_{2e}$ per ton of food waste for landfilling versus -0.12 $MtCO_{2e}$ per ton of food waste for combustion.

In order to understand the input waste composition of the Dakota County waste versus WARM categories, Foth examined the waste composition study results from Pine Bend, Statewide and compared them to the mixed MSW composition in WARM. Table 3-4 provides a summary of results from the comparison. WARM used the EPA national waste composition and laboratory studies to determine GHG emissions.

Table 3-4
Waste Characterization Comparison
WARM Model Mixed MSW

Category	EPA 2003	EPA 2008	Pine Bend 2013	Statewide 2013
Paper & Paperboard	34.3	31.0	23.3	24.5
Glass	5.2	4.9	2.0	2.2
Metals				
Ferrous	6.1	6.3	0.3	0.7
Aluminum	1.3	1.4	0.5	0.4
Other Non-Ferrous	0.7	0.7	2.3	3.3
Plastics	11.5	12.0	20.0	17.9
Rubber & Leather	2.9	3.0	5.3	4.7
Textiles[1]	4.4	5.0	NA	NA
Wood	5.6	6.6	5.9	5.7
Other [2]	1.7	1.8	12.0	15.3
Food Scraps	11.8	12.7	16.2	17.8
Yard Trimmings	13.0	13.1	2.4	2.8
Misc. Organic Wastes	1.5	1.5	9.8	4.7

Notes:

All values are in percent

1 Textiles and leather were combined in the Minnesota studies and are included in the rubber and leather category

2 For the Minnesota studies, the other category included waste not categorized in the EPA studies.

Since the Statewide waste composition study and the Pine Bend study were completed between May and August of 2013, the study is not considered representative of the overall long term waste composition in Dakota County. For purpose of this study, Foth used the default mixed MSW category for determining GHG emissions in the WARM model.

4 Results and Observations

A summary of the results and observations as to the model outputs is provided. It is important to note that transportation of the materials has a relatively low GHG emissions profile versus landfilling and conversion at GRE. Foth modeled both the base case (all the waste is landfilled) and the alternative case (60,000 tons to GRE, remainder is landfilled). For both cases, the collection of the waste is the same.

Waste collection was modeled based on the MPCA collection model. The number of households and the number of licensed haulers in each community. The MPCA model results are provided in Table 4-1.

Table 4-1
MPCA Model
Residential Collection GHG Emissions

City	Estimated GHG Emissions ($MtCO_{2e}$ /year)
Apple Valley	506
Burnsville	665
Eagan	682
Farmington	65
Hastings	81
Inver Grove Heights	363
Lakeville	571
Mendota Heights	119
Rosemount	230
South St. Paul	224
West St. Paul	235
Total	3,742

Similarly, commercial waste collection was modeled using the MPCA model and the total number of businesses and haulers in each city. A summary of GHG emissions from commercial waste collection is provided in Table 4-2. The emissions are the same for the base case and the alternative case of using GRE for conversion combustion.

Table 4-2
MPCA Collection Model
Commercial Collection GHG Emission

City	Estimated GHG Emissions ($MtCO_{2e}$ /year)
Apple Valley	622
Burnsville	894
Eagan	910
Farmington	41
Hastings	423
Inver Grove Heights	536
Lakeville	804
Mendota Heights	252
Rosemount	337
South St. Paul	189
West St. Paul	230
Total	5,239

Foth also modeled the hauling miles once the collection vehicle was full (off route) to the landfill and back to the route (on route). For the Dakota County model base case, 25% of the collected waste is disposed at the Pine Bend landfill and 75% is disposed at the Burnsville landfill. The centroid used to determine haul distance was 12561 Danbury Way in Rosemount (as provided by Dakota County). The centroid to the Pine Bend landfill is 13 miles and the centroid to the Burnsville landfill is 23.8 miles. Foth understands that collection vehicles will not first come to the centroid, then the landfill. Collection vehicles, when full, will take the shortest route to the landfill. However, this modeling method allocates GHG emissions for collection vehicle mileage to the landfill equitably without conducting a rigorous study to determine each individual hauler's actual off route miles traveled. A summary of the GHG emission for off route miles for the base case is provided in Table 4-3. The information in Table 4-3 applies only to the base case.

Table 4-3
Base Case (Landfilling)
Off Route GHG Emissions

Item	Unit	Annual Value
From population centroid to Pine Bend Landfill	miles	13.0
From population centroid to Burnsville Landfill	miles	23.8
Pine Bend Landfill Disposal (25%)	tons	50,629
Burnsville Landfill Disposal (75%)	tons	151,887
Pine Bend Landfill -Packer Truck trips[1]	trips	10,126
Burnsville Landfill - Packer Truck trips[1]	trips	30,377
Pine Bend Landfill -Packer Truck miles	miles	131,635

Item	Unit	Annual Value
Burnsville Landfill - Packer Truck miles	miles	722,981
Pine Bend Landfill -Packer Trucks fuel used[2]	gallons	43,878
Burnsville Landfill - Packer Trucks fuel used[2]	gallons	240,994
GHG emissions[3]	MTCO2e	2,910

1. Packer truck capacity set at 5 tons
2. Packer truck fuel economy set at 3.0 mpg
3. GHG Emission factors and GWP from EPA Emission Factors for GHG Inventories 2014, Tables 2 & 4

Note: population centroid is 12561 Danbury Way, Rosemount

For the alternative case, 60,000 tons per year of MSW would be sent to the SET-Empire transfer station and then to GRE for processing. GHG emissions for the off route fuel use are different than the base case because of the change in tonnage going to the landfills and the allocation of waste transfer to GRE. A summary of GHG emission for off route waste hauling is provided in Table 4-4. The table also includes GHG emissions for transportation of the ash material from GRE to the Becker Ash landfill and process residue to the Elk River landfill.

Table 4-4
MPCA Collection Model
Residential Collection GHG Emission

Item	Unit	Annual Value
From population centroid to Pine Bend Landfill	miles	13.0
From population centroid to Burnsville Landfill	miles	23.8
From population centroid to SET - Empire Transfer Station	miles	19.0
From SET - Empire Transfer Station to GRE	miles	110.4
From GRE to Elk River Landfill	miles	12.8
From GRE to Becker Ash Landfill	miles	36.0
Pine Bend Landfill Disposal (25%)	tons	35,629
Burnsville Landfill Disposal (75%)	tons	106,887
GRE	tons	60,000
Elk River Landfill (process residue)	tons	2,580
Becker Ash Landfill (ash)	tons	16,003
Pine Bend Landfill -Packer Truck trips[1]	trips	7,126
Burnsville Landfill - Packer Truck trips[1]	trips	21,377
SET -Empire Transfer Station - Packer Trucks[1]	trips	12,000
GRE - Transfer Trailers[2]	trips	3,158
Elk River - Transfer Trailers[2]	trips	136
Becker Ash Landfill - Transfer Trailers[3]	trips	667
Pine Bend Landfill -Packer Truck miles	miles	92,635
Burnsville Landfill - Packer Truck miles	miles	508,781

Item	Unit	Annual Value
SET -Empire Transfer Station - Packer Trucks	miles	228,000
GRE - Transfer Trailers	miles	348,632
Elk River - Transfer Trailers	miles	1,738
Becker Ash Landfill - Transfer Trailers	miles	24,004
Pine Bend Landfill -Packer Trucks fuel used[4]	gallons	30,878
Burnsville Landfill - Packer Trucks fuel used[4]	gallons	169,594
SET -Empire Transfer Station - Packer Trucks[4]	gallons	76,000
GRE - Transfer Trailers[5]	gallons	82,031
Elk River - Transfer Trailers[5]	gallons	409
Becker Ash Landfill - Transfer Trailers[5]	gallons	5,582
GHG emissions[6]	MtCO2e	3,723

1. Packer truck capacity set at 5 tons
2. Transfer trailer capacity set at 19 tons
3. Ash transfer trailer capacity set at 24 tons
4. Packer truck fuel economy set at 3.0 mpg
5. Transfer trailer fuel economy set at 4.3 mpg
6. GHG Emission factors and GWP from EPA Emission Factors for GHG Inventories 2014, Tables 2 & 4

Note: population centroid is 12561 Danbury Way, Rosemount

The base case and the alternative case indicate that transferring the waste to GRE increased off route GHG emissions by 28%.

Once the material base has been collected and transferred to either the landfill or GRE, GHG emission estimates were developed. For the landfill, the USEPA WARM model was used to estimate GHG emissions from landfilling 202,516 tons. The WARM model was established using 1,013 tons (0.05%) as aluminum, 608 tons as ferrous and 200,895 tons as mixed MSW. WARM model assumed the landfill has active landfill gas collection and the electricity is sold to the grid. The WARM model results for the base case for landfilling all the waste in Dakota County estimated GHG emissions of 17,932 $MtCO_{2e}$ per year.

For the alternative case, the WARM model was used to estimate GHG emissions based on 60,000 tons per year being processed at GRE to create 56,940 tons of RDF for combustion and 145,096 tons per year being landfilled. As with the base case analysis, aluminum and ferrous were detailed in the WARM model for both landfilling and incineration. The landfilled portion of waste stream also included active landfill gas collection with electricity to the grid.

Processing the waste at GRE results in additional GHG emissions. These emissions include electricity used for turning MSW into RDF (2,432.35 $MtCO_{2e}$), stack emissions for RDF combustion (22,800 $MtCO_{2e}$) and emissions for yard equipment (173.42 $MtCO_{2e}$). Total estimated GHG emissions for RDF processing are 2,605.77 $MtCO_{2e}$ per year.

Finally, the electricity generated at GRE will likely offset other more carbon intensive power generation in the GRE portfolio. GPI estimated this offset to be from 20,552 to 24,416 $MtCO_{2e}$ per year in offset negative.

A summary of the estimated GHG emission is provided in Table 4-5.

Table 4-5
Summary of Results
GHG Emissions per Year

Item	Base Case (Landfill)	Alternative Case (GRE + Landfill)
Residential Collection of MSW	3,742	3,742
Commercial Collection of MSW	5,239	5,239
Transfer of MSW to Landfill, Transfer Station or GRE	2,910	3,723
Transportation Subtotal	**11,891**	**12,704**
RDF Processing at GRE[1]	0	2,606
Landfill Emissions[2]	17,932	12,847
GRE Emissions[3]	0	22,800
Electrical Offset to the Grid[4]	0	(22,484)
Total	**29,823**	**28,473**

1. GRE Processing includes electrical use for processing and fuel use for yard tractors. Electrical GHG intensity per GPI report.
2. Landfill emissions from the WARM model.
3. GRE stack emissions from emission factors in WARM model.
4. Electrical offset emissions from GPI report. Average valve used.

Appendix A

Great Plains Institute, Waste to Energy: Avoided Greenhouse Gas Emissions for Dakota County Municipal Solid Waste

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Waste-to-Energy: Avoided Greenhouse Gas Emissions for Dakota County Municipal Solid Waste

A report from the Great Plains Institute to Foth Infrastructure & Environment, LLC, and Dakota County

Dane McFarlane, Senior Research Analyst
Brendan Jordan, Vice President

April 25, 2017

Executive Summary

The Great Plains Institute (GPI) and Foth Infrastructure & Environment (Foth) were tasked with estimating avoided emissions under Task 2d of the Dakota County Environmental Analysis of Landfilling & Incinerating Mixed MSW project. Subsequent discussions over the course of this project established two scenarios for analysis:

1) The entire amount of municipal solid waste (MSW) collected from Dakota County (202,516 tons as per the 2015 County Certification Report) to be landfilled, with 75% delivered to the Burnsville landfill and 25% delivered to the Pine Bend landfill
2) 60,000 tons of Dakota County MSW delivered to and processed at the GRE Elk River Station Waste to Energy plant. The remaining MSW will be delivered to Burnsville and Pine Bend at the same allocations as in Scenario 1.

Foth performed extensive analysis on energy use and emissions relating to the collection, transportation and processing of waste under both scenarios. Both scenarios also involve the generation of electricity from MSW, which is likely to displace electricity on the grid within the service territories of Xcel Energy or Great River Energy (GRE). To establish a displaced or avoided emissions credit, GPI analyzed the current and expected greenhouse gas (GHG) intensity of electricity from Xcel, GRE, and more broadly the Midcontinent Independent System Operator (MISO).

Based on data on the Elk River Station plant published by GRE, GPI estimated the amount of electricity generated by 60,000 tons of Dakota County MSW per year. This estimate was then used to calculate annual avoided emissions for Scenario 2 from 2018 to 2030 based on the emission intensities mentioned above. Due to lack of information on landfill gas collection and electric generation at the Burnsville and Pine Bend landfills, avoided emissions were not calculated for the landfilling component in either scenario.

Table ES-1. Annual Emission Intensities and Scenario 2 Avoided Emissions

Utility / Region	Emission Intensity			Scenario 2 Annual Avoided Emissions		
	2018	2025	2030	2018	2025	2030
GRE	718,121.8	673,481.2	641,595.2	24,416.1	22,898.4	21,814.2
Xcel	378,099.1	302,217.3	248,016.0	12,855.4	10,275.4	8,432.5
MISO	604,469.9	531,276.3	478,995.1	20,552.0	18,063.4	16,285.8
	g CO2e / MWh			Metric Tons CO2e		

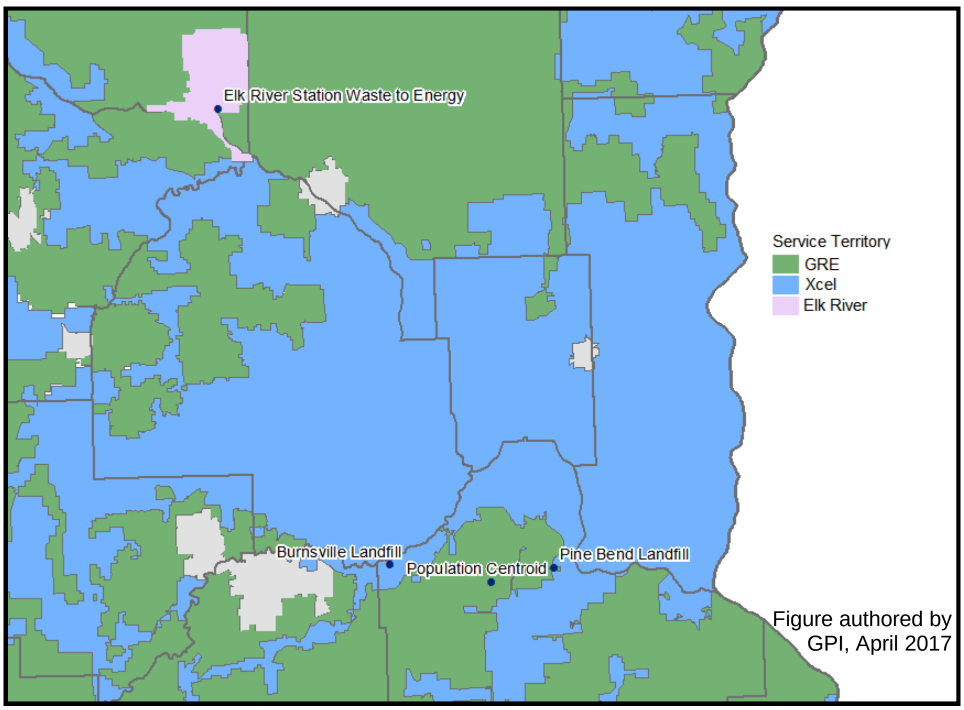
Annual emission intensities and avoided emissions are presented in the appendix of this report.

Geographic Analysis and the Electric Grid

In order to establish an avoided emissions credit, the GHG emission intensity of the electricity being displaced must be determined. Therefore, the location of each operation involving converting MSW to electricity is important. This study primarily involves three locations in addition to the Dakota County solid waste service area. These are: the Pine Bend Landfill; the Burnsville Landfill; and the Elk River Station Waste to Energy plant.

As shown in Figure 1, below, while the Burnsville and Pine Bend landfills are both in Dakota County, the Burnsville landfill falls within Xcel's service territory while Pine Bend is located within GRE's service territory. Meanwhile, Elk River Station is located in Elk River in Sherburne County. While electric service within the city of Elk River is provided by the Elk River Municipal Utilities, the Elk River Station Waste to Energy Plant is operated by Great River Energy.

Figure 1. Geographic Location of Study Locations and Electric Utility Service Territories

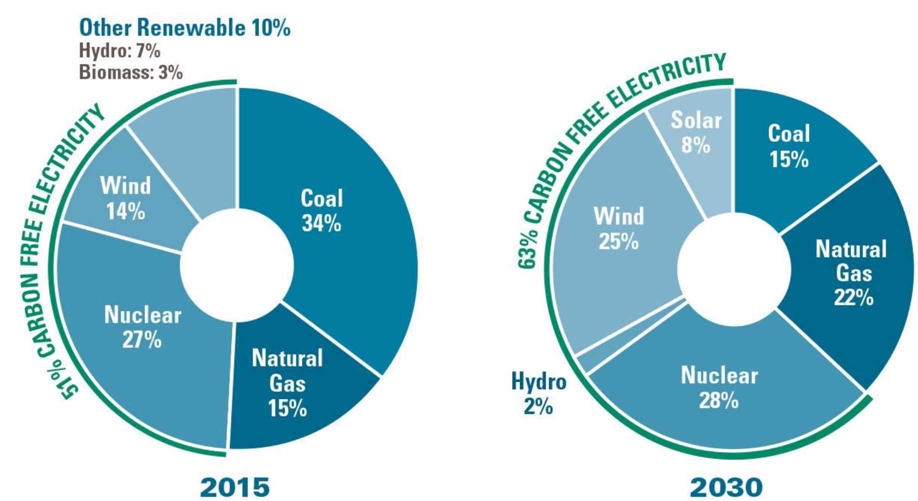


For the purposes of this analysis, GHG emission intensities calculated for Xcel are used for electricity displaced at the Burnsville landfill while those calculated for GRE are used for electricity displaced at Pine Bend and Elk River Station. Because of the nature of electric grid operations, however, it may be decided that it is more appropriate to use emission intensities for the northern region of MISO for all study locations. Emission intensities for all three entities (Xcel, GRE, and MISO) are presented in this report.

Electric Fuel Mixes and Resource Plans

In Minnesota, electric utilities must file resource plans with the Minnesota Public Utilities Commission. Resource plans lay out each utility's current mix of electric generation sources and its proposed change over the near term future. Xcel's *Upper Midwest 2016-2030 Resource Plan*[1], filed in January 2016, reported a generation fuel mix that included 34% coal, 15% natural gas, and 51% "carbon free electricity" from sources such as nuclear and wind (see Figure 2). Xcel's filing also presented a plan for a 2030 fuel mix that included only 15% coal, and increase to 22% natural gas, and 63% carbon free electricity from nuclear, wind, solar, and other sources. This would result in a 2015 GHG emission intensity of 411 kilograms of CO2 equivalent per megawatt-hour (kg CO2e/MWh) that declines to 248 kg CO2e/MWh in 2030.

Figure 2. Xcel Energy's 2015 and 2030 Generation Fuel Mixes



Source: Xcel Energy, *Upper Midwest 2016-2030 Resource Plan*, January 2016.

In October, 2014, Great River Energy's *Resource Plan 2015-2029*[2] similarly reported a 2013 generation fuel mix of 67% coal, 3% natural gas, 11% renewable, 10% hydroelectric, and 9% grid purchased electricity. According to the resource plan, GRE expects a 2029 fuel mix of 58% coal, 2% natural gas, 18% renewable, 14% hydroelectric, and 8% grid purchase. This would result in a 2013 GHG intensity of 750 kg CO2e/MWh that declines to 648 kg CO2e/MWh in 2029.

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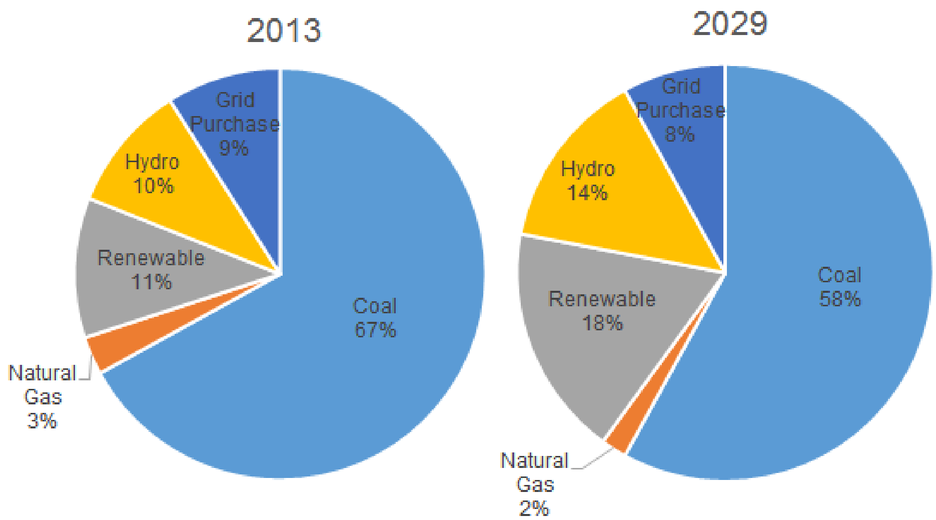
[1] Xcel Energy, *Upper Midwest 2016-2030 Resource Plan*, January 2016. https://www.xcelenergy.com/company/rates_and_regulations/filings/upper_midwest_2016-2030_resource_plan

[2] Great River Energy, *Resource Plan 2015-2029*, October 31, 2014. http://greatriverenergy.com/wp-content/uploads/2016/02/2014_irp.pdf

Figure 3. Great River Energy's 2013 and 2029 Generation Fuel Mixes

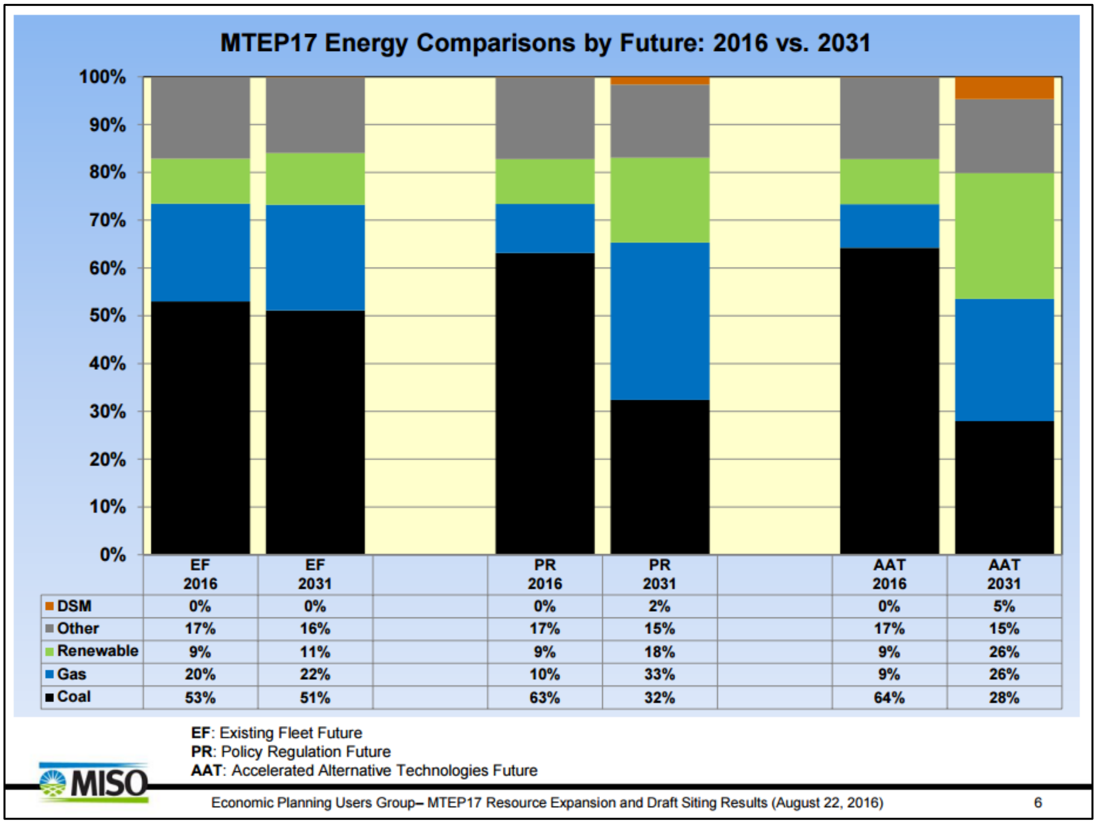


Source: Great River Energy, *Resource Plan 2015-2029*, October 31, 2014.
Figure authored by GPI, April, 2017.

At a recent MISO Transmission Expansion Planning presentation, MISO laid out three scenarios for its expected fuel mix: Existing Fleet Future (EF), Policy Regulation Future (PR), and Accelerated Alternative Technologies Future (AAT). The EF scenario assumes basically no changes from the current fuel mix, while the AAT scenario assesses the impact of unexpectedly rapid advancement and adoption of new distributed energy resources and storage technologies. Within the context of GPI's analysis for Dakota County, MISO's Policy Regulation Future is the scenario that is most consistent with the expected GHG reductions from Xcel and GRE. This scenario accounts for utility plans for increases in renewables and retirements of existing coal plants as well as state or national policy for fossil fuels.

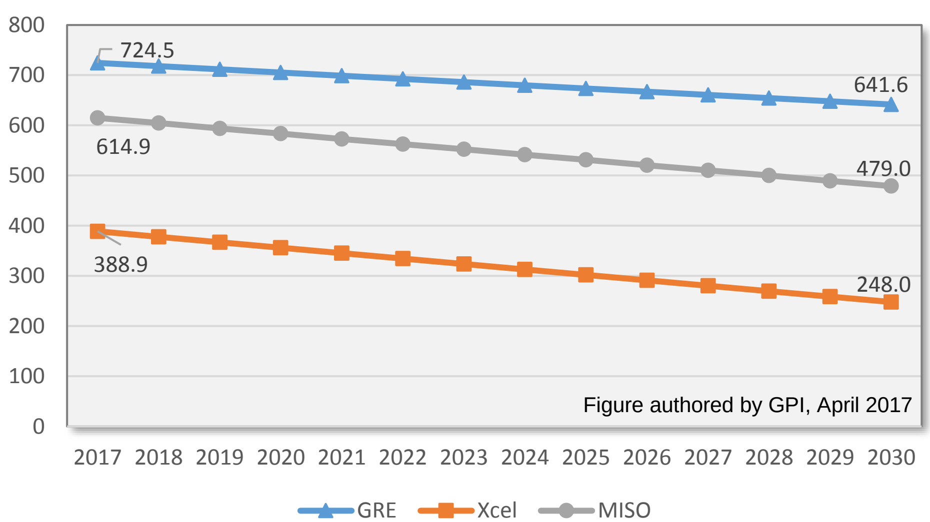
Under the PR scenario, MISO's fuel mix would see increasing renewables and natural gas, with decreased coal, by 2031. The 2016 fuel mix in the Existing Fleet scenario is reported as 53% coal, 20% natural gas, 9% renewable, and 17% other (which includes nuclear). By 2031, the PR scenario predicts a mix of 32% coal, 33% natural gas, 18% renewable, 15% other, and 2% demand side management. As a result, MISO's GHG emission intensity is reduced from 625 kg CO2e/MWh in 2016 to 469 kg CO2e/MWh in 2031.

Figure 4. MISO 2016 and 2031 Generation Fuel Mix



Source: Midcontinent Independent System Operator, *Economic Planning Users Group – MTEP17 Resource Expansion and Draft Siting Results*, August 22, 2016.

Figure 5: Emission Intensities 2017 – 2030 for GRE, Xcel, and MISO
kg CO2e / MWh

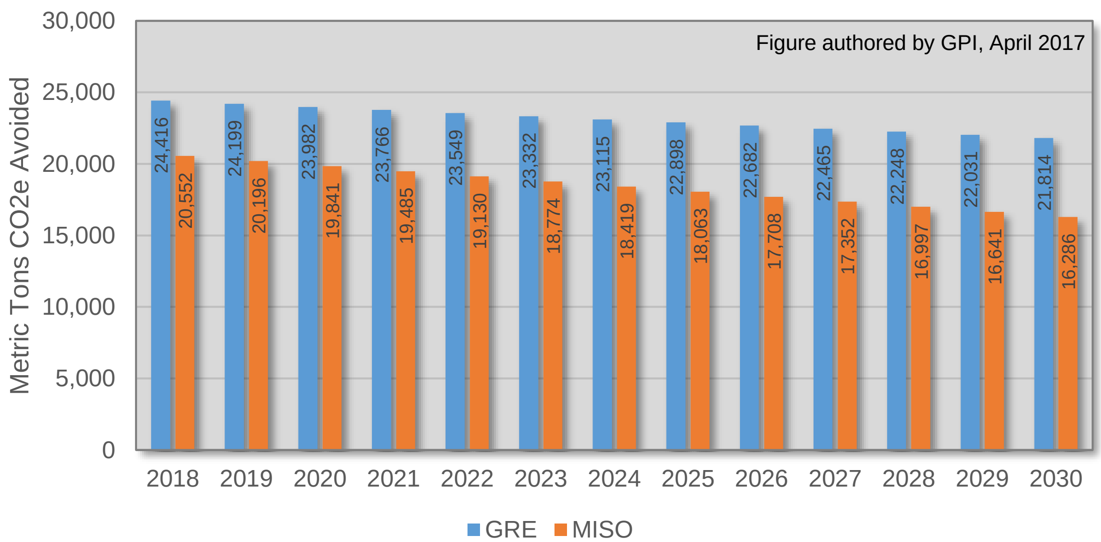


Conclusion: Avoided Emissions at Elk River Station

According to data published by Great River Energy, the Elk River Station Resource Recovery Project processes 300,000 tons of municipal solid waste (MSW) each year and produces 170 thousand megawatt-hours (MWh) of electricity each year at a capacity of 29 megawatts (MW)[3]. This equates to an electric generation rate of 0.567 MWh per ton of MSW (MWh/ton). In Scenario 2 of this analysis, 60 thousand tons of MSW from Dakota County are delivered to Elk River Station each year, thus resulting in about 34,000 MWh of electric generation each year.

Due to Elk River Station's status as a GRE operated facility, electricity generated at the facility displaces electricity either from GRE, in cases where GRE is producing electricity to serve its own customers, or more generally from MISO, in cases where GRE is producing electricity to the electric grid depending on a variety of factors such as reliability and frequency regulation needs, baseload and peak capacity requirements, and market prices. GPI produced annual avoided emissions projections for both situations (displacing electricity from either GRE or MISO). These figures do not include emissions generated by burning refuse-derived fuel at the plant, nor do they include emissions from energy use and transportation elsewhere in the MSW collection process.

Figure 6. Annual Avoided Emissions from Elk River Station Displaced Electricity



This results in a cumulative reduction in GHG emissions of either 300,497 tons of CO2e by 2030 for GRE displaced electricity, or 239,446 tons of CO2e by 2030 for MISO displaced electricity. Further discussions should be held with GRE about the delivery of electricity from Elk River Station Full in order to determine which figure is more appropriate. Annual results are listed in the appendix of this report.

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[3] Great River Energy, *Waste to Energy*, 2017. http://greatriverenergy.com/we-provide-electricity/making-electricity/biomass/ Accessed April 24, 2017.

Appendix

Emission Intensities 2017-2030
grams CO2e / MWh

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
GRE	724,499.0	718,121.8	711,744.6	705,367.3	698,990.1	692,612.9	686,235.7	679,858.5	673,481.2	667,104.0	660,726.8	654,349.6	647,972.4	641,595.2
Xcel	388,939.4	378,099.1	367,258.9	356,418.6	345,578.3	334,738.1	323,897.8	313,057.6	302,217.3	291,377.0	280,536.8	269,696.5	258,856.3	248,016.0
MISO	614,926.1	604,469.9	594,013.7	583,557.4	573,101.2	562,645.0	552,188.7	541,732.5	531,276.3	520,820.0	510,363.8	499,907.6	489,451.3	478,995.1

Annual Avoided Emissions 2018-2030
Metric Tons CO2e

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
GRE	24,416	24,199	23,982	23,766	23,549	23,332	23,115	22,898	22,682	22,465	22,248	22,031	21,814	24,416
Xcel	12,855	12,487	12,118	11,750	11,381	11,013	10,644	10,275	9,907	9,538	9,170	8,801	8,433	12,855
MISO	20,552	20,196	19,841	19,485	19,130	18,774	18,419	18,063	17,708	17,352	16,997	16,641	16,286	20,552

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Sources

Annual emission intensities calculated by Great Plains Institute, April 2017, based on:

Xcel Energy, *Upper Midwest 2016-2030 Resource Plan*, January 2016.
https://www.xcelenergy.com/company/rates_and_regulations/filings/upper_midwest_2016-2030_resource_plan

Great River Energy, *Resource Plan 2015-2029*, October 31, 2014.
http://greatriverenergy.com/wp-content/uploads/2016/02/2014_irp.pdf

Midcontinent Independent System Operator, *Economic Planning Users Group – MTEP17 Resource Expansion and Draft Siting Results*, August 22, 2016. https://www.misoenergy.org/Events/Pages/EPUG20160822.aspx

Coal and Natural Gas Emission Factors: U.S. Department of Energy, Argonne National Laboratory, *GREET Lifecycle Emissions Model*, October, 2016. (GREET emission factors based on EIA and US EPA emissions database). https://greet.es.anl.gov/

Great River Energy, *Waste to Energy*, 2017. http://greatriverenergy.com/we-provide-electricity/making-electricity/biomass/ Accessed April 24, 2017.