



Life-Cycle Assessment of Billings Regional Landfill Gas to Delivered LNG and LCNG in California

November 19th, 2014; Revised September 24, 2015

Submitted to:

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General Information

Montana-Dakota Utilities Co. (MDU) operates a landfill gas (LFG) treatment facility to recover methane from the Billings Regional Landfill in Billings, MT, to recover methane and process landfill gas to pipeline quality natural gas. MDU owns and operates the Billing Regional Landfill, a 800-acre municipal solid waste facility that is currently landfilling a 50-acre area of the permitted facility.

[REDACTED]

The MDU treatment facility purifies raw LFG via a series of processes using specifically designed equipment. Two pressure-swing absorption (PSA) beds remove carbon dioxide and nitrogen. The tail gas from the CO₂ PSA is a lower-BTU stream that is combusted in the enclosed flare (thermal oxidizer). The tail gas stream that is generated by the N₂ PSA unit is a higher-BTU stream that is combusted in the open flare (main flare).

[REDACTED]

No permit limitation exists to the production of product gas at MDU. The maximum production capacity is the facility's equipment processing capacity and was determined through the EPA Registration process.

[REDACTED]

Pipeline grade LFG is transported via pipeline from Montana to California for liquefaction and sale. The following pathway was produced using two (2) years (July 2012 – June 2014) of landfill gas production data¹ and two (2) years (2011-2012) of LNG liquefaction data.²

¹ Please see Annex 2 for MDU Facility Energy Data Analysis
² Please see Annex 7 for CNG Station Electrical Efficiency Data

Process Description

(THIS SECTION CONTAINS CONFIDENTIAL BUSINESS INFORMATION)

The following steps outline the process train for the production of pipeline quality natural gas from MDU³:

- [REDACTED]
 - [REDACTED]
 - [REDACTED]
- [REDACTED]

Data Collection and Process Results

To estimate GHG emissions, the energy and materials necessary for the following processes needs to be determined: LFG Production Plant, Transport of Gas to California (Pipeline), Liquefaction, and Transportation & Distribution.

LFG Production Plant

(THIS SECTION CONTAINS CONFIDENTIAL BUSINESS INFORMATION)

[REDACTED]

The MDU facility imports the necessary electricity to purify the landfill gas and uses an onsite thermal oxidizer and open flares to combust off-gases generated during the regeneration steps and when plant is not operating.

[REDACTED]

³ This information was taken from Annex 3 RSF Control Union Engineering Report

⁴ Annex 3 MDU RSF Control Union Engineering Report, page 39

⁵ Annex 2, Summary tab, cell K27. 82% is the sales gas (10.85 mmbtu/hour) divided by the landfill gas (13.22 mmbtu/hour)

⁶ Please see Annex 2, Summary tab, cell E21 for the calculation of this figure

⁷ Please see Annex 2, Summary tab, cell E27 for the calculation of this figure

⁸ Please see Annex 2, Summary tab, cell F27 for the calculation of this figure

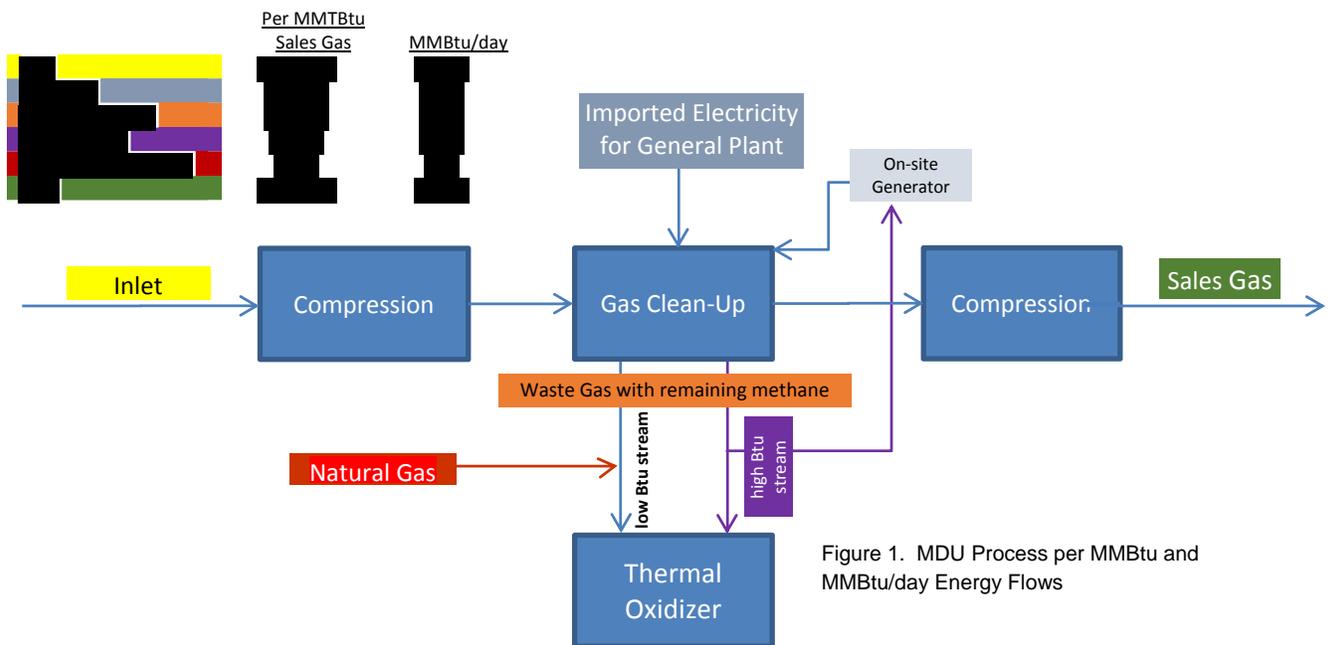


Figure 1. MDU Process per MMBtu and MMBtu/day Energy Flows

The Southeast Asia region on the Regional LT tab was changed to the WECC Northwest (NWPP) Region to represent the 2012 eGRID data for year 2009 where MDU facility is located and this was used for the MDU Pathway. The ARB methodology of converting eGRID electricity mix to marginal mix was employed. This changed the electric mix cells of J83-J88 on the Region LT tab to those shown in [REDACTED]

TABLE 2. NWPP ELECTRICITY GRID MIX

	eGRID CY2009 Grid Mix	Marginal Grid Mix	CA-GREET Cell Regional LT Tab
Residual oil	0.48%	0.48%	J83
Natural gas	15.27%	64.24%	J84
Coal	29.83%	29.83%	J85
Nuclear	2.46%	0.00%	J86
Biomass	1.09%	1.09%	J87
Other (renewables)	50.86% (with hydro)	4.36%	J88

This produced the results for LFG to CNG shown in Table 3 below. These values are taken from the NG Tab of the Modified GREET model which can be found in Annex 2 of the supporting documents submitted in conjunction with this report. Conversion from g/MMBtu to g/MJ was done using the conversion factor of 1055.055 MJ/MMBTU as is done in the CA-GREET model.

The recovery energy and emissions are based on ARB LFG pathway defaults of 4621.25 Btu of electricity/MMBtu of landfill gas.¹³

TABLE 3. MDU LFG PLANT GREENHOUSE GAS EMISSIONS
 (THIS TABLE CONTAINS CONFIDENTIAL BUSINESS INFORMATION)

	Recovery Emissions	MDU LFG Plant	CA-GREET Cell NG Tab
[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]
[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]
[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]
[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]
[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]
[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]
[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]
[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]
[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]
[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]

Transportation to California by Pipeline

[REDACTED] The distances were determined by the using the driving route most similar to the pipeline map. Biomethane from the Billings landfill travels from Montana to California via the MDU, Northern Border, ANR, Transwestern, and Mojave pipelines.¹⁴ Google Maps was used to determine the driving routes most similar to the pipeline map. The emissions were determined by linked cell E148 on the NG tab to cell F479 on the T&D_Flowcharts tab for LFG to CNG, and this same distance will be used for LFG and LNG. The table below shows the pipeline transport emissions from cells H151-H157 on the NG Tab.

TABLE 4. MDU LFG TRANSPORT GREENHOUSE GAS EMISSIONS
 (THIS TABLE CONTAINS CONFIDENTIAL BUSINESS INFORMATION)

Transport Emissions	MDU LFG Transport
[REDACTED]	[REDACTED]

¹³ http://www.arb.ca.gov/fuels/lcfs/022709lcfs_lfg.pdf; page 9.

¹⁴ Please see Annex 3 page 230 for pipeline map

Liquefaction

(THIS SECTION CONTAINS CONFIDENTIAL BUSINESS INFORMATION)

[REDACTED]

[REDACTED]

[REDACTED]

TABLE 5. BORON LNG PLANT OPERATING EFFICIENCY¹⁵
 (THIS TABLE CONTAINS CONFIDENTIAL BUSINESS INFORMATION)

All Units in Btus per Gal of LNG	Boron LNG Plant	Input Value	Changed Cells – NG Tab
[REDACTED]	[REDACTED]		
[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]
[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]
[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]

TABLE 6. BORON LNG PLANT GREENHOUSE GAS EMISSIONS
 (THIS TABLE CONTAINS CONFIDENTIAL BUSINESS INFORMATION)

Recovery & Processing Emissions	Boron LNG Plant - Liquefaction
[REDACTED]	[REDACTED]

LNG Transport to Refueling Station

In addition the CA-GREET default LNG transport distance of 50 miles was used but the fuel shares were modified to utilize the [REDACTED]

[REDACTED]

¹⁵ Please see Annex 7 – Boron LNG Electricity Consumption Data for the calculations of the figures presented in this table

TABLE 7. LNG TRANSPORT GREENHOUSE GAS EMISSIONS

(THIS TABLE CONTAINS CONFIDENTIAL BUSINESS INFORMATION)

Recovery & Processing Emissions	Boron LNG Plant – Transport
[REDACTED]	[REDACTED]

LNG Storage

In addition the CA-GREET default for LNG storage was used. The default values are listed in Table 8 below (the results were taken from cells K163-K169 on the “NG” tab).

TABLE 8. LNG STORAGE CA-GREET DEFAULT VALUES

	Bulk Terminal Storage	CA-GREET Cells Inputs Tab	Distribution	CA-GREET Cells Inputs Tab
Boil-Off Rate: % per Day	0.05	E171	0.1	F171
Duration of Storage or Transit: Days	5	E174	0.1	F174
Recovery Rate for Boil-Off Gas	80%	E179	80%	F179

TABLE 9. LNG STORAGE GREENHOUSE GAS EMISSIONS

	LNG Storage
gVOC/MMBTU	
gCO/MMBTU	
gCH4/MMBTU	11.10
gN2O/MMBTU	
gCO2/MMBTU	
gCO2e/MMBTU	277.47
gCO2e/MJ	0.26

L/CNG Conversion

To convert from LNG to CNG, LNG is re-vaporized and then compressed to cylinder pressure (at about 3000psi). According to ARB default LNG and CNG pathways (as sent to Clean Energy and ICF by ARB Staff):

- Re-gasified to LNG: + 0.75 gCO2e/MJ¹⁶
- Compressed to CNG: +2.14 gCO2e/MJ¹⁷

¹⁶ http://www.arb.ca.gov/fuels/lcfs/092309lcfs_lng.pdf

¹⁷ http://www.arb.ca.gov/fuels/lcfs/022709lcfs_cng.pdf

[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]
[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]
[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]
[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]
[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]
[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]
[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]

Appendix B: List of Supporting Annexes

MDU Pathways Annex 2 - Facility Energy Data & Analysis

MDU Pathways Annex 3 - RSF Control Union Engineering Report

MDU Pathways Annex 5 - Electric Invoices – July 2012 to June 2014

MDU Pathways Annex 6 - Gas Sales – July 2012 to June 2014

MDU Pathways Annex 7- Boron LNG Electricity Consumption Data

MDU Pathways Annex 8- Natural Gas Flows

MDU Pathways Annex 9 - Modified GREET model_LFG to LNG and LCNG