LCFS Life Cycle Fuel Pathway Report

Method 2B Application: Clean Energy Renewable Fuels, LLC

LFG collected and processed in New York; delivered via pipeline for liquefaction to Boron, CA; transported with trucks for use as LNG & L-CNG to CA.

1.) Overview

This document describes the Life Cycle Analysis and Carbon Intensity calculations- based on the CA-GREET model - for the Landfill Gas-to-Liquefied Natural Gas (LFG-to-LNG) and Landfill Gas-to-Liquefied Compressed Natural Gas (LFG-to-L-CNG) pathways of Clean Energy Renewable Fuels, LLC (Clean Energy). Clean Energy is supported in fuel production under this pathway by EM Gas Marketing, LLC (EMGM), who is supplying biomethane connected to Landfill Gas produced at the Fresh Kills landfill.

In our two pathways Landfill Gas is recovered from the Fresh Kills landfill on Staten Island, NY and processed using onsite LFG to high-btu natural gas facilities owned and operated by The City of New York Department of Sanitation (DSNY). Maximal capacity for raw landfill gas (containing approx. [redacted]) extraction at the Fresh Kills Landfill is [redacted], while maximal biomethane ([redacted]) production capacity is [redacted]. An average LFG recovery distance of [redacted] is assumed, the map of the Fresh Kills Landfill and on-site biogas processing plant can be seen below:

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EM Gas Marketing, LLC tracks the processed LFG that is injected into the gas transmission pipelines in New York and supplies biomethane for liquefaction to Clean Energy in California. The withdrawn gas is liquefied in Clean Energy's Boron, CA LNG Plant and LNG is transported to California customers using special LNG trailers. The LNG is used by Clean Energy's customers to fuel heavy-duty trucks either as LNG or – after re-vaporization and compression – as CNG.

The biomethane produced by the Fresh Kills processing plant is commingled with fossil natural gas when it enters the interstate pipeline system. With the support of EMGM, Clean Energy will be obligated to retain records that demonstrate that the credits it earns under the pathways described in this document correspond directly with volumes of biomethane that were produced at the landfill and subsequently sold to Clean Energy.

In our analysis we divide Clean Energy's pathway into two phases:

1. Upstream Phase: Steps from LFG recovery up to NG liquefaction. In this phase, LFG is processed to pipeline quality gas and delivered to Boron, CA for liquefaction. Our analysis is based on technical and production data supplied by DNSY, we used the GREET model published by ARB for pathway LNG021_1 and modified appropriate inputs to reflect the Fresh Kills facility's operations.[1]

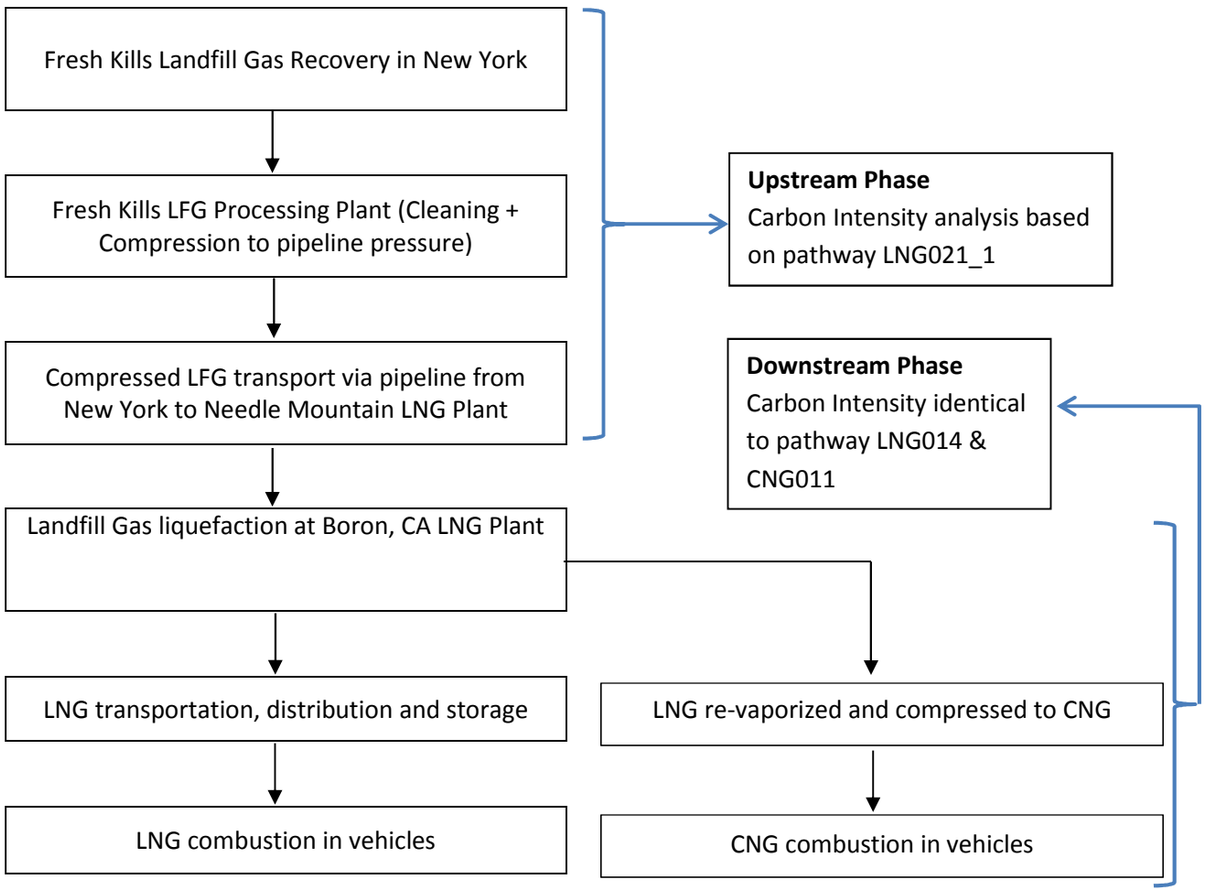
2. Downstream Phase: This phase begins with natural gas withdrawal at the Boron, CA LNG Plant for liquefaction and contains all following steps. LCA for this phase was performed by Clean Energy and approved by ARB as part of the Method 2B application process of pathways LNG014 and CNG011.[2] Carbon

[1] Internal ARB-Developed Fuel Pathway – North American Landfill Gas to Compressed Natural Gas, Liquefied Natural Gas, and Liquefied Compressed Natural Gas; posted on ARB website on 05/28/2015; http://www.arb.ca.gov/fuels/lcfs/2a2b/internal/nalfg-cng-lng-lcng-052815.pdf

[2] Clean Energy LNG014 & CNG011 pathways - Liquefied Natural Gas and Compressed Natural Gas from Cedar Hills Washington Biomethane Landfill Gas; posted on ARB website on 8/30/2013 http://www.arb.ca.gov/fuels/lcfs/2a2b/apps/ce-ch-083013.pdf

Intensity values of the appropriate phases of pathways LNG014 and CNG011 are incorporated in our analysis.

Following figure is intended to summarize the steps of the Upstream and Downstream Phase of Clean Energy's pathways:



2.) Pathway Description

Assumptions have been adjusted to better reflect the facility-specific operating parameters of the Fresh Kills LFG processing plant. As stated above, this document focuses on adjustments made to the LNG021_1 pathway respectively; the assumptions of that pathway are not detailed.

2.1) Landfill Gas Recovery and Transport to Processing

The LFG-to-LNG and LFG-to-L-CNG pathways begin with the collection of raw landfill gas from wells drilled into the Fresh Kills Landfill. Gas is collected and then transported to the on-site processing facility via a negative pressure pipeline system, [redacted]. According to the CA-GREET model, the energy necessary for these steps is approximately [redacted] of landfill gas collected and [redacted] – this results in an LFG recovery efficiency of [redacted]. Total emissions of this step are [redacted].

Assumptions:

- Electricity generation mix parameters for LFG recovery, transportation to facility and processing have been adjusted according to Year 2010 eGRID Subregion Resource Mix – NPCC NYC/Westchester (NYCW) values are used[3].
- [redacted] blowers is metered separately and is [redacted] per mmBtu of LFG inlet to the plant. This results in a [redacted] LFG Recovery Efficiency.

2.2) Landfill Gas Processing

The next step is cleaning the LFG to pipeline quality and pressure, via a compressor system feeding the gas through a treatment process to separate usable methane from the LFG stream. [redacted]

[3] See Appendix A - Year 2010 eGRID Subregion Resource Mix

An overview of Fresh Kill's inputs and outputs can be seen below:

Using the [redacted] efficiency factor and the energy process shares between natural gas and electricity, plus a flaring credit for all energy that is captured, the total energy consumed during the processing stage of the pathway is [redacted] **Btu/mmBtu** of energy captured and the total emissions are [redacted]

Assumptions:

- The gas and electricity usage numbers are based on meter data collected from May 2012 to Aug 2014.
- LFG processing at the Fresh Kills plant is at [redacted] efficiency with processing fuels shares of [redacted]
- [redacted]

2.3) Natural Gas Transport

The third step in the LNG from LFG pathway is transport of the natural gas by pipeline from the LFG processing plant to the natural gas liquefaction plant in Boron, CA. [redacted]

Based on assumptions in the GREET model for pathway LNG021_1, as well as the change in pipeline distance made above, the energy usage in transport and distribution stage is [redacted]

Assumptions

- A pipeline distance of [redacted] from the Fresh Kills Landfill to Boron, CA is used in the calculations.

2.4) Downstream Phase

As stated above, Carbon Intensity analysis steps of Clean Energy's pathway from LFG recovery to delivery for liquefaction are identical with those of pathway LNG014.

Liquefaction

[redacted]

LNG Transport

[redacted]

LNG Storage

[redacted]

L/CNG Conversion

[redacted]

- [redacted]
- [redacted]
- [redacted]

[4] http://www.arb.ca.gov/fuels/lcfs/092309lcfs_lng.pdf
[5] http://www.arb.ca.gov/fuels/lcfs/022709lcfs_cng.pdf

3.) Results From CA-GREET Model

LFG-to-LNG Pathway

The following table contains the total energy usage and Carbon Intensity of each step of Clean's LFG-to-LNG pathway:

	Energy Required [Btu/MMBtu]	GHG Emissions [gCO_2e/MJ]
Landfill Gas Recovery and Transport to Processing	[redacted]	[redacted]
Landfill Gas Processing	[redacted]	[redacted]
Natural Gas Transport	[redacted]	[redacted]
NG Liquefaction at LNG Plant	[redacted]	[redacted]
LNG Transportation and Distribution	[redacted]	[redacted]
LNG Storage	[redacted]	[redacted]
LNG Tank to Wheel	[redacted]	[redacted]
Total	**361,093**	**29.28**

As seen above, Clean's LFG-to-LNG pathway has a total energy usage of **361,093 Btu/MMBtu** and a Carbon Intensity of **29.28 gCO2e/MJ.**

LFG-to-L-CNG Pathway

The following table contains the total energy usage and Carbon Intensity of each steps of Clean's LFG-to-LNG pathway:

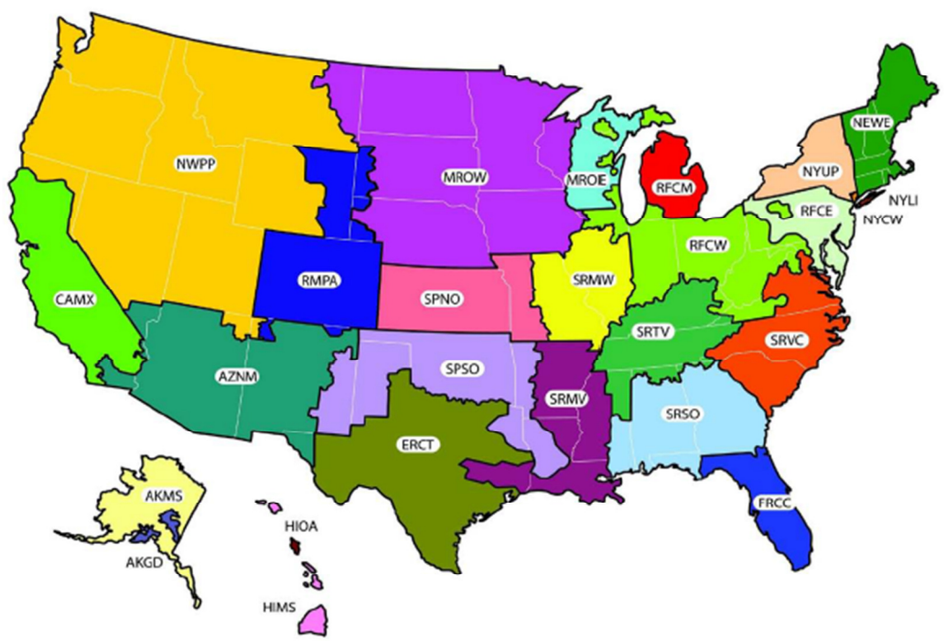
	Energy Required [Btu/MMBtu]	GHG Emissions [gCO_2e/MJ]
Landfill Gas Recovery and Transport to Processing	[redacted]	[redacted]
Landfill Gas Processing	[redacted]	[redacted]
Natural Gas Transport	[redacted]	[redacted]
NG Liquefaction at LNG Plant	[redacted]	[redacted]
LNG Transportation and Distribution	[redacted]	[redacted]
LNG Storage	[redacted]	[redacted]
LCNG Conversion	[redacted]	[redacted]
CNG Tank to Wheel	[redacted]	[redacted]
Total	**361,093**	**31.40**

As seen above, Clean's LFG-to-L-CNG pathway has a total energy usage of **361,093 Btu/MMBtu** and a Carbon Intensity of **31.40 gCO2e/MJ.**

Appendix A - Year 2010 eGRID Subregion Resource Mix

http://www.epa.gov/cleanenergy/documents/egridzips/eGRID_9th_edition_V1-0_year_2010_Summary_Tables.pdf; page 5; downloaded: 11/21/2014

eGRID subregion acronym	eGRID subregion name	Nameplate capacity (MW)	Net Generation (MWh)	Generation resource mix (percent)										
				Coal	Oil	Gas	Other fossil	Biomass	Hydro	Nuclear	Wind	Solar	Geo-thermal	Other unknown/ purchased fuel
AKGD	ASCC Alaska Grid	1,522.2	5,332,020.2	11.6362	10.1930	69.3962	0.0000	0.0000	8.7746	0.0000	0.0000	0.0000	0.0000	0.0000
AKMS	ASCC Miscellaneous	713.2	1,415,158.2	0.0000	27.7721	3.5193	0.0000	0.4455	67.3723	0.0000	0.8909	0.0000	0.0000	0.0000
AZNM	WECC Southwest	49,321.6	178,271,415.3	39.4515	0.0661	33.4001	0.0056	0.3422	6.1810	17.5014	0.6862	0.1295	2.2366	0.0000
CAMX	WECC California	75,066.4	212,172,138.5	7.1466	1.1510	50.4490	0.2316	2.6248	15.1942	15.1767	3.0538	0.3564	4.3187	0.2970
ERCT	ERCOT All	100,595.3	345,382,525.6	34.8356	0.7898	44.9525	0.1266	0.1306	0.2040	11.9680	6.8938	0.0024	0.0000	0.0968
FRCC	FRCC All	64,862.9	217,890,866.6	24.3846	4.1835	57.3321	0.6049	1.6658	0.0815	10.9853	0.0000	0.0369	0.0000	0.7254
HIMS	HICC Miscellaneous	895.3	2,952,481.9	1.6723	69.1861	0.0000	7.4198	3.6384	2.3852	0.0000	8.8441	0.0599	6.7941	0.0000
HIOA	HICC Oahu	1,925.6	7,883,554.0	18.9780	76.9519	0.0000	1.9673	2.1028	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
MROE	MRO East	8,897.0	32,293,505.5	69.4580	2.1436	4.0010	0.0783	3.2994	3.3210	15.4528	2.1402	0.0000	0.0000	0.1058
MROW	MRO West	55,325.0	203,656,312.3	65.2593	0.1544	3.1566	0.1293	1.2099	5.8722	14.2313	9.8081	0.0000	0.0000	0.1789
NEWE	NPCC New England	36,485.3	129,920,243.4	10.8375	0.8196	45.2791	1.5167	5.6102	5.9300	29.5263	0.4698	0.0000	0.0000	0.0101
NWPP	WECC Northwest	69,721.0	267,967,318.0	31.3015	0.3279	14.3386	0.1423	1.2372	43.5510	3.4486	4.8371	0.0000	0.6973	0.1179
NYCW	NPCC NYC/Westchester	13,906.9	40,916,871.9	0.0000	1.2934	57.3676	0.4697	0.5234	0.0000	39.8873	0.4585	0.0000	0.0000	0.0000
NYLI	NPCC Long Island	6,000.4	12,148,487.3	0.0000	6.9312	85.4961	3.5635	4.0093	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
NYUP	NPCC Upstate NY	25,067.6	88,551,618.2	15.3388	0.8398	22.2004	0.3017	1.6451	28.1600	28.8520	2.6622	0.0000	0.0000	0.0000
RFCE	RFC East	74,350.1	274,646,405.8	35.2745	0.5476	20.6192	0.6873	1.2794	1.0071	39.9059	0.6687	0.0104	0.0000	0.0000
RFCM	RFC Michigan	29,590.2	91,571,321.5	68.0216	0.3973	13.2495	0.6553	1.8774	0.0000	15.1705	0.6284	0.0000	0.0000	0.0000
RFCW	RFC West	147,391.4	598,607,320.8	68.5984	0.3959	4.1640	0.4478	0.4818	0.6593	23.7740	1.4141	0.0042	0.0000	0.0606
RMPA	WECC Rockies	18,178.1	65,206,132.2	72.9959	0.0427	17.1257	0.0000	0.0923	3.9125	0.0000	5.6469	0.0770	0.0000	0.1070
SPNO	SPP North	21,261.8	69,418,232.2	72.8397	0.2706	7.9546	0.0394	0.0792	0.1460	13.7654	4.9051	0.0000	0.0000	0.0000
SPSO	SPP South	44,883.8	148,456,365.7	52.1508	1.2466	35.9421	0.2062	1.4223	4.4055	0.0000	4.6265	0.0000	0.0000	0.0000
SRMV	SERC Mississippi Valley	50,942.3	176,667,075.4	22.9107	1.1187	46.9265	1.0137	1.8933	1.3544	24.5124	0.0000	0.0000	0.0000	0.2703
SRMW	SERC Midwest	33,454.6	135,896,937.1	80.9052	0.0814	4.0123	0.0576	0.1064	1.0568	12.9569	0.6540	0.0000	0.0000	0.1695
SRSO	SERC South	71,782.9	270,641,138.1	52.3701	0.3031	24.6072	0.1211	2.6539	2.6959	17.2486	0.0000	0.0000	0.0000	0.0000
SRTV	SERC Tennessee Valley	62,065.4	236,050,232.4	58.7899	1.0760	10.4018	0.0144	0.8583	6.5970	22.2454	0.0172	0.0000	0.0000	0.0000
SRVC	SERC Virginia/Carolina	80,849.7	311,931,345.0	45.7303	0.5484	11.7297	0.1706	1.9584	1.4920	38.2454	0.0000	0.0036	0.0000	0.1215
U.S.		1,145,056.0	4,125,847,023.5	44.7748	1.0174	23.9686	0.3498	1.3571	6.1730	19.5589	2.2864	0.0290	0.3689	0.1162



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