LCFS Life Cycle Fuel Pathway Report

Method 2B Application: Element Markets Renewable Energy, LLC

LFG collected and processed in Pennsylvania; delivered via pipeline for liquefaction to Boron, CA; used as LNG & L-CNG in 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-Compressed Natural Gas (pathway is hereinafter referred to as LFG-to-L-CNG, since the pathway involves re-vaporization of LNG and subsequent compression to CNG) pathways of Element Markets Renewable Energy, LLC (EMRE).

In our two pathways Landfill Gas is recovered from three Pennsylvania landfills (Southern Alleghenies Landfill, Shade Landfill and Laurel Highlands Landfill) and processed at onsite LFG to high-btu natural gas facilities owned and operated by Johnstown Regional Energy (JRE). EMRE takes title of the processed LFG that is injected into the gas transmission pipelines in Pennsylvania and supplies biomethane for liquefaction to Clean Energy Renewable Fuels, LLC (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 The withdrawn gas is liquefied in Clean Energy's Boron, CA LNG Plant and LNG is transported to California customers using Westport HDPI trucks. The LNG is used by Clean Energy's customers either as LNG or – after re-vaporization and compression – as CNG.

The biomethane EMRE purchases from JRE is commingled with fossil natural gas when it enters the interstate pipeline system. EMRE will be obligated to retain records that demonstrate that the credits it earns under the pathways described in this document correspond directly with the volumes of biomethane purchased from the landfill and subsequently sold to Clean Energy.

In our analysis we divide EMRE'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. Carbon Intensity of the Upstream Phase is identical to the corresponding steps of pathway CNG007.[1]
2. Downstream Phase: This phase begins with natural gas withdrawal at the Boron, CA LNG Plant for liquefaction and contains all following steps. The Carbon Intensity analysis of the Downstream Phase is based on Clean Energy's pathways for Washington LFG-to-CNG (CNG011)[2] and LFG-to-LNG (LNG014)[3].

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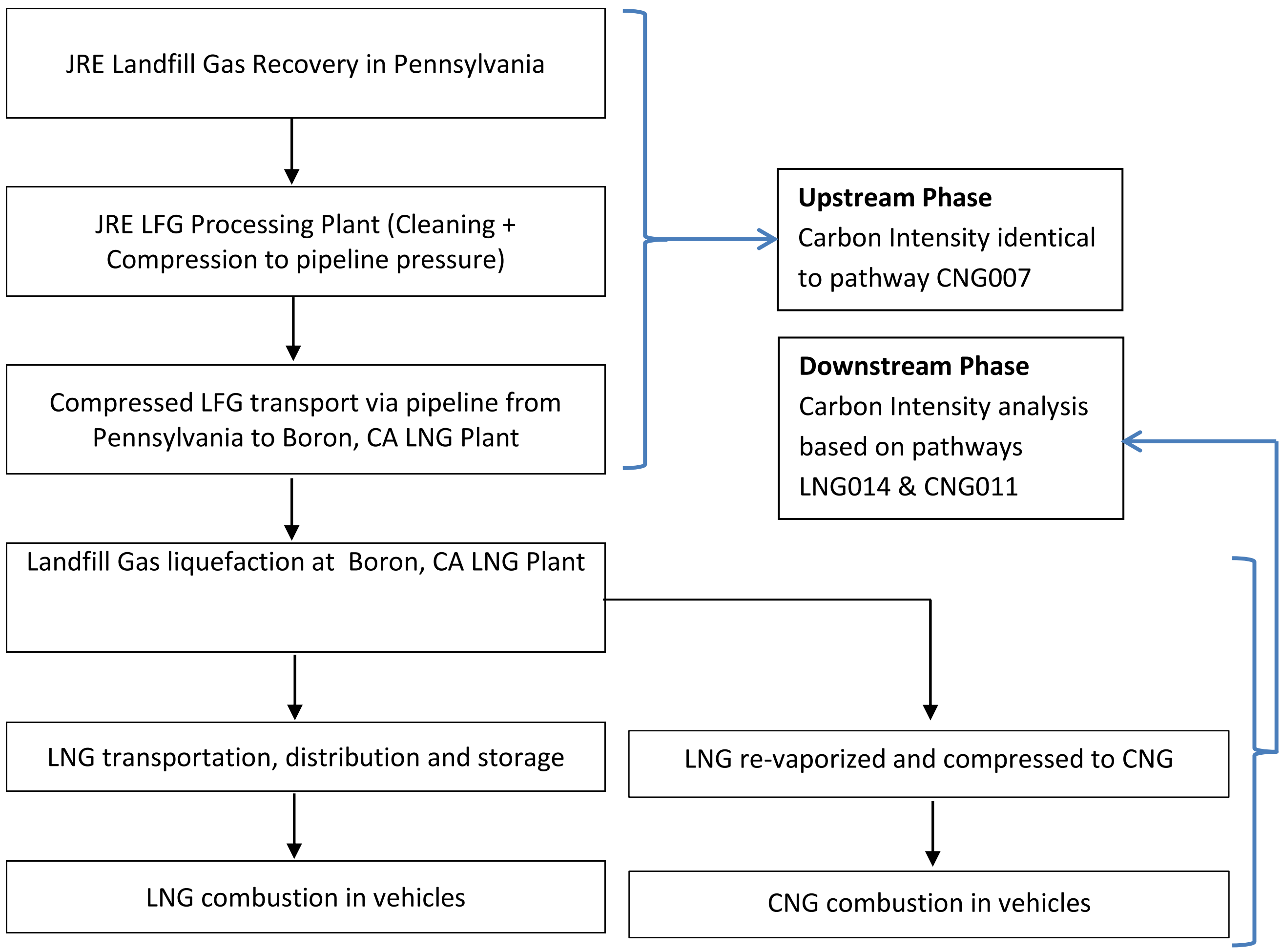
[1] Johnstown Regional Energy LLC – Pennsylvania Landfill Gas to CNG; posted on ARB website on 04/10/2013; http://www.arb.ca.gov/fuels/lcfs/2a2b/apps/jre-040913.pdf

[2] Clean Energy Fuel Pathway – WA LFG to CA L-CNG; posted on ARB website on 08/30/2013 http://www.arb.ca.gov/fuels/lcfs/2a2b/apps/ce-ch-083013.pdf

[3] Clean Energy Fuel Pathway – WA LFG to CA LNG; posted on ARB website on 08/30/2013 http://www.arb.ca.gov/fuels/lcfs/2a2b/apps/ce-ch-083013.pdf

ELEMENT MARKETS RENEWABLE ENERGY, LLC
3555 Timmons Lane, Suite 900, Houston, Texas 77027
PHONE 281.207.7200 | FAX 281.207.7211

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



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3555 Timmons Lane, Suite 900, Houston, Texas 77027
PHONE 281.207.7200 | FAX 281.207.7211

2.) Pathway Description

2.1) Upstream Phase

As stated above, Carbon Intensity analysis steps of EMRE's pathway from LFG recovery to delivery for liquefaction are identical with those of pathway CNG007.

In the following we provide a summary of the energy usage and Carbon Intensity values for each step of the pathway's Upstream Phase:

	Energy Required (Btu/mmBtu)	GHG Emissions (g CO_2e/MJ)
Landfill Gas Recovery and Transport to Processing	[redacted]	[redacted]
Landfill Gas Processing	[redacted]	[redacted]
Natural Gas Transport	[redacted]	[redacted]
Total	[redacted]	**-42.45**

Please see the Application Package for pathway CNG007 available on ARB's website for additional details.

ELEMENT MARKETS RENEWABLE ENERGY, LLC
3555 Timmons Lane, Suite 900, Houston, Texas 77027
PHONE 281.207.7200 | FAX 281.207.7211

2.2) NG Liquefaction at LNG Plant

(This Section contains Confidential Business Information)

Based on the submitted Confidential Business Information from Clean Energy Fuels for two (2) years (2011-2012), the Boron facility requires [redacted] of LNG for liquefaction[redacted] kWh/gal LNG). Only electricity is required for the process making the fuel shares 100% electricity. For the Boron LNG facility, the feed gas is the same as the product LNG gas. All excess gas that is not converted to LNG is sent to the neighboring natural gas power plant. 1 below shows the calculation from kWh per gallon to process efficiency and the cells that were changed. Table 2 shows the results from cells G163- G169.

Table 1. Boron LNG Plant Operating Energy

(This Table contains Confidential Business Information)

[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]		
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]

Table 2. Boron LNG Plant Greenhouse Gas Emissions

(This Table contains Confidential Business Information)

Recovery and Processing Emissions	Boron LNG Plant
gVOC/MMBTU	[redacted]

gCO/MMBTU	[redacted]
gCH4/MMBTU	[redacted]
gN2O/MMBTU	[redacted]
gCO2/MMBTU	[redacted]
gCO2e/MMBTU	[redacted]
gCO2e/MJ	[redacted]

2.3) LNG Storage

In addition the CA-GREET default for LNG storage was used. The default values are listed in Table 3 below and yield the results in Table 4 (the results were taken from cells I163-I169 on the "NG" tab.).

Table 3. 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	[redacted]	[redacted]	[redacted]	[redacted]
Duration of Storage or Transit: Days	[redacted]	[redacted]	[redacted]	[redacted]
Recovery Rate for Boil-Off Gas	[redacted]	[redacted]	[redacted]	[redacted]

Table41. LNG Storage Greenhouse Gas Emissions

	LNG Storage
gVOC/MMBTU	-
gCO/MMBTU	-
gCH4/MMBTU	[redacted]
gN2O/MMBTU	-
gCO2/MMBTU	-
gCO2e/MMBTU	[redacted]
gCO2e/MJ	[redacted]

2.4) LNG distribution

In addition the CA-GREET default LNG transport distance of 50 miles was used but the fuel shares were modified to utilize the Westport HPDI trucks consuming 90% LNG and 10% diesel with an EER of 1.0. The numbers were inputted in cells CD95 (% diesel consumption) and CD97 (% LNG consumption) on the "T&D" tab and the results were taken from cells H153-H159 on the "NG" tab.

Table 4. LNG Transport Greenhouse Gas Emissions

(This Table contains Confidential Business Information)

	California LNG Plant –

	50 miles 10% Diesel and 90% LNG
gVOC/MMBTU	[redacted]
gCO/MMBTU	[redacted]
gCH4/MMBTU	[redacted]
gN2O/MMBTU	[redacted]
gCO2/MMBTU	[redacted]
gCO2e/MMBTU	[redacted]
gCO2e/MJ	[redacted]

2.5) LNG Tank to Wheel

According to ARB default LNG and CNG pathways:

- **Total: 58.5**

2.6) Re-vaporization and compression to CNG

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):

- [redacted]
- Total: 2.89 gCO2e/MJ

2.7) CNG Tank to Wheel

According to ARB default LNG and CNG pathways:

- **Total: 57.7**

3.) Results From CA-GREET Model

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

	Energy Required [Btu/MMBtu]	GHG Emissions [gCO2e/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 Storage	[redacted]	[redacted]
LNG Distribution	[redacted]	[redacted]
Dispensing of LNG	[redacted]	[redacted]
LNG Tank to Wheel	1,000,000	58.50
Total	[redacted]	**22.65**

As seen above, EMRE's LFG-to-LNG pathway has a total energy usage of [redacted] **Btu/MMBtu** and a Carbon Intensity of **22.65 gCO2e/MJ.**

LFG-to-L-CNG Pathway

The following table contains the total energy usage and Carbon Intensity of each steps of EMRE's LFG-to-L-CNG 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 Storage	[redacted]	[redacted]
LNG Distribution	[redacted]	[redacted]
Dispensing of LNG	[redacted]	[redacted]
CNG Compression and Dispensing	[redacted]	[redacted]
CNG Tank to Wheel	1,000,000	57.73
Total	[redacted]	**24.74**

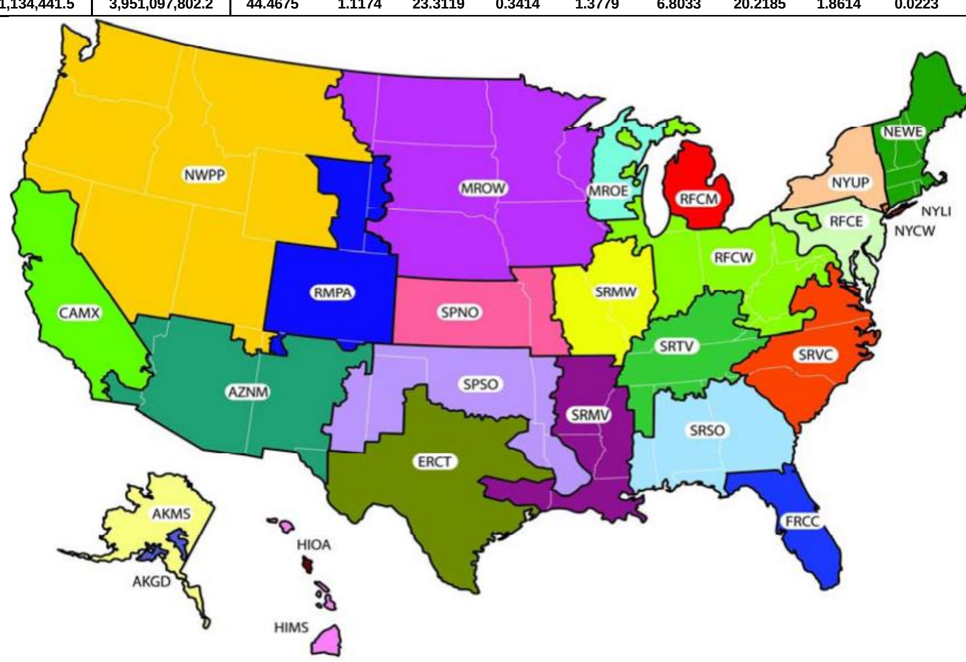
As seen above, EMRE's LFG-to-L-CNG pathway has a total energy usage of [redacted] **Btu/MMBtu** and a Carbon Intensity of **24.74 gCO2e/MJ**

ELEMENT MARKETS RENEWABLE ENERGY, LLC
3555 Timmons Lane, Suite 900, Houston, Texas 77027
PHONE 281.207.7200 | FAX 281.207.7211

Appendix A - Year 2009 eGRID Subregion Resource Mix

http://www.epa.gov/cleanenergy/documents/egridzips/eGRID2012V1_0_year09_SummaryTables.pdf; page 5; downloaded: 08/10/2013

eGRID subregion acronym	eGRID subregion name	Nameplate capacity (MW)	Net Generatio	Generation resource mix (percent)										
				Coal	Oil	Gas	Other fossil	Biomass	Hydro	Nuclear	Wind	Solar	Geo-thermal	Other unknown/ purchased fuel
AKGD	ASCC Alaska Grid	1,514.9	5,337,982.5	11.8133	13.6743	66.0333	0.0000	0.0000	8.4791	0.0000	0.0000	0.0000	0.0000	0.0000
AKMS	ASCC Miscellaneous	701.1	1,364,176.9	0.0000	31.2972	3.8526	0.0000	0.4773	63.8578	0.0000	0.5151	0.0000	0.0000	0.0000
AZNM	**WECC Southwest**	**48,647.5**	**186,138,763.9**	**38.5979**	**0.0598**	**35.6808**	**0.0013**	**0.3166**	**6.0901**	**16.4726**	**0.5008**	**0.1012**	**2.1789**	**0.0000**
CAMX	WECC California	73,662.1	212,768,947.3	7.3284	1.3637	53.0498	0.2087	2.7167	12.7172	14.9288	2.7635	0.3003	4.3676	0.2553
ERCT	ERCOT All	101,910.6	337,031,899.7	32.9816	1.0518	47.8308	0.1257	0.1215	0.1539	12.3127	5.3314	0.0000	0.0000	0.0906
FRCC	FRCC All	65,716.1	208,123,783.6	23.6531	4.4222	54.8319	0.6348	1.7398	0.0099	13.9907	0.0000	0.0046	0.0000	0.7130
HIMS	HICC Miscellaneous	881.5	3,019,123.5	1.9907	69.8707	0.0000	7.1345	3.3481	3.7312	0.0000	8.3278	0.0460	5.5510	0.0000
HIOA	HICC Oahu	1,925.6	7,991,409.4	18.0201	77.6079	0.0000	2.2104	2.1615	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
MROE	MRO East	8,881.2	29,587,725.5	68.9039	2.3652	4.9759	0.1206	3.2381	2.7096	15.2608	2.3228	0.0000	0.0000	0.1030
MROW	MRO West	53,894.9	190,640,178.1	69.0860	0.1515	2.3997	0.1600	1.1844	4.3578	13.9045	8.6647	0.0000	0.0000	0.0914
NEWE	NPCC New England	36,906.5	121,742,618.3	11.8606	1.5048	41.9731	1.6223	5.9158	7.0413	29.7601	0.3110	0.0000	0.0000	0.0109
NWPP	WECC Northwest	68,188.2	269,325,957.1	29.8340	0.3352	15.1503	0.1462	1.0927	46.5021	2.4632	3.8023	0.0000	0.5541	0.1199
NYCW	NPCC NYC/Westchester	13,914.0	40,501,288.1	0.0000	1.7869	55.8586	0.4808	0.5357	0.0185	40.8410	0.4784	0.0000	0.0000	0.0000
NYLI	NPCC Long Island	6,002.5	9,431,561.8	0.0000	12.9940	77.3406	4.5546	5.1108	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
NYUP	NPCC Upstate NY	24,408.3	88,081,534.5	14.4853	0.9024	18.9282	0.3570	1.5950	30.7898	30.5892	2.3530	0.0000	0.0000	0.0000
RFCE	RFC East	73,537.6	261,151,661.8	35.3677	0.7271	17.1304	0.8437	1.3211	1.2358	42.9614	0.4050	0.0055	0.0000	0.0023
RFCM	RFC Michigan	29,501.5	88,251,703.2	71.9861	0.4093	9.5071	0.5982	1.8820	0.0000	15.2782	0.3391	0.0000	0.0000	0.0000
RFCW	RFC West	146,174.7	561,623,124.7	69.8826	0.4022	3.5051	0.3533	0.5057	0.7949	23.5563	0.9355	0.0000	0.0000	0.0644
RMPA	WECC Rockies	17,516.6	62,070,098.9	67.7689	0.0435	22.5989	0.0000	0.0911	4.3045	0.0000	5.0659	0.0412	0.0000	0.0860
SPNO	SPP North	21,159.4	65,008,815.6	73.8392	0.2559	7.8088	0.0368	0.0289	0.1377	13.4882	4.4044	0.0000	0.0000	0.0000
SPSO	SPP South	43,413.8	140,443,029.2	55.2342	0.1667	33.8651	0.2189	1.2052	5.5274	0.0000	3.7798	0.0000	0.0000	0.0027
SRMV	SERC Mississippi Valley	50,443.7	165,358,644.7	22.7319	1.4534	45.0929	0.8605	1.9253	1.7270	25.9742	0.0000	0.0000	0.0000	0.2347
SRMW	SERC Midwest	27,319.6	112,061,747.1	79.7879	0.0884	1.0399	0.0122	0.1270	1.7552	17.0754	0.1140	0.0000	0.0000	0.0000
SRSO	SERC South	70,962.7	252,713,667.3	52.1843	0.3499	22.3083	0.0748	2.9228	4.0925	18.0664	0.0000	0.0000	0.0000	0.0010
SRTV	SERC Tennessee Valley	67,069.4	238,173,939.7	58.8034	0.9387	8.6065	0.0087	0.7817	8.5808	22.1286	0.1516	0.0000	0.0000	0.0000
SRVC	SERC Virginia/Carolina	80,187.5	293,154,419.6	45.1039	0.6421	8.9501	0.1921	2.0466	1.6491	41.3467	0.0000	0.0016	0.0000	0.0678
U.S.		**1,134,441.5**	**3,951,097,802.2**	**44.4675**	**1.1174**	**23.3119**	**0.3414**	**1.3779**	**6.8033**	**20.2185**	**1.8614**	**0.0223**	**0.3799**	**0.0984**



This is a representational map; many of the boundaries shown on this map are approximate because they are based on companies, not on strictly geographical boundaries.
USEPA eGRID2012 Version 1.0 p. 5

ELEMENT MARKETS RENEWABLE ENERGY, LLC
3555 Timmons Lane, Suite 900, Houston, Texas 77027
PHONE 281.207.7200 | FAX 281.207.7211