LCFS Life Cycle Fuel Pathway Report

Method 2B Application: Applied Natural Gas Fuels, Inc.

LFG collected and processed in New York; delivered via pipeline for liquefaction to Topock, AZ; 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 Applied Natural Gas Fuels, Inc. (ANGF). ANGF 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 (minimum [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 Applied Natural Gas Fuels in Arizona. The withdrawn gas is liquefied in ANGF's Needle Mountain LNG Plant and LNG is transported to California customers using special LNG trailers pulled by diesel tractors. The LNG is used by ANGF'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, ANGF 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 ANGF.

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

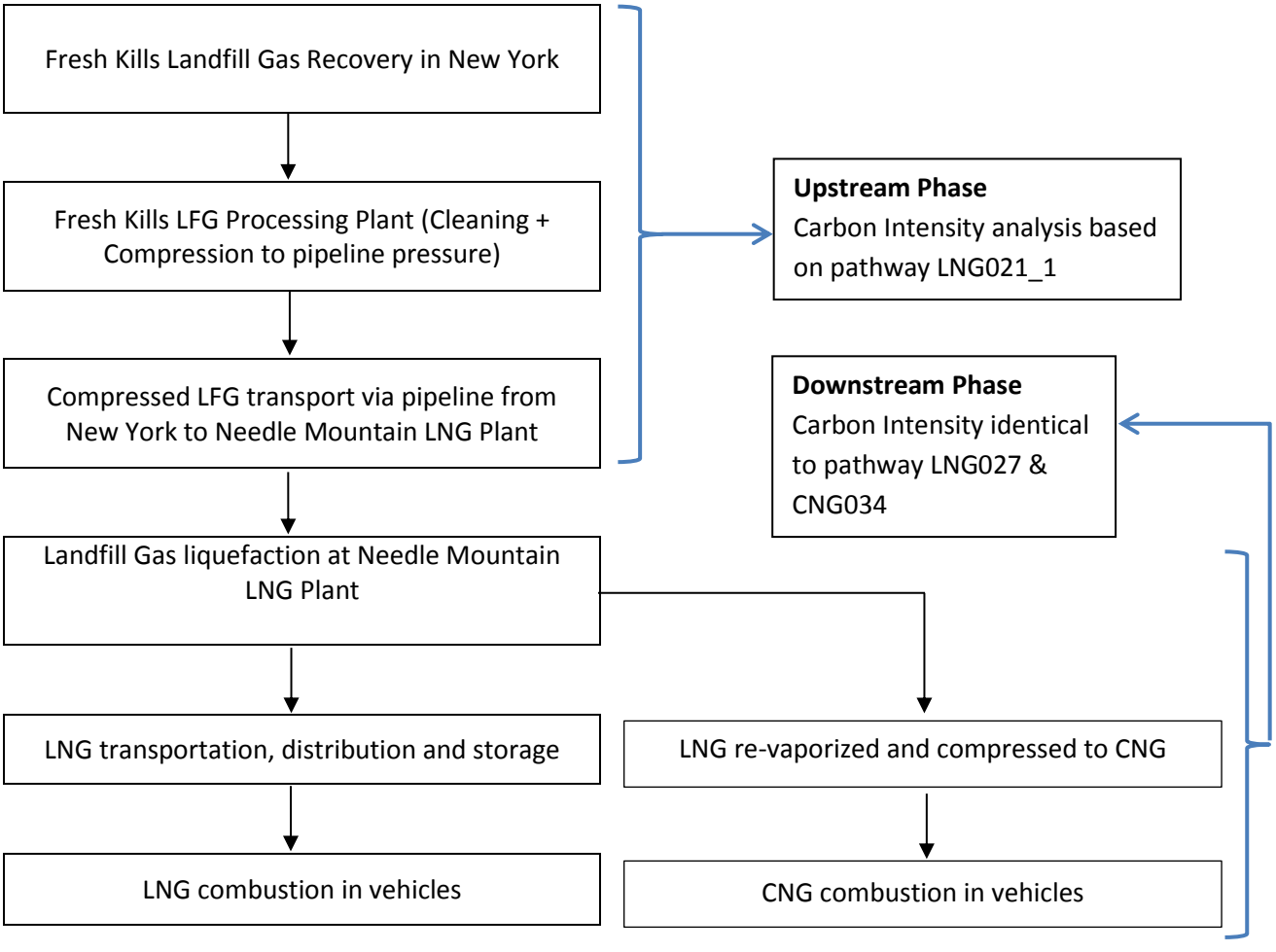
1. Upstream Phase: Steps from LFG recovery up to NG liquefaction. In this phase, LFG is processed to pipeline quality gas and delivered to Topock, AZ for liquefaction. Our analysis is based on technical and production data supplied by DNSY, we used the GREET model published by ARB for pathway LNG021_1 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 Needle Mountain LNG Plant for liquefaction and contains all following steps. LCA for this phase was performed by Element Markets Renewable Energy and approved by ARB as part of the Method 2B application process of pathways LNG027

[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

and CNG034.[2] Carbon Intensity values of the appropriate phases of pathways LNG027 and CNG034 are incorporated in our analysis.

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



[2] Applied Natural Gas Fuels LNG027 & CNG034 pathways - McCarty Landfill (Houston, Texas) to Liquefied Natural Gas, and Liquefied-Compressed Natural Gas Delivered in California; posted on ARB website on 5/28/2015 http://www.arb.ca.gov/fuels/lcfs/2a2b/apps/angf-mct-052815.pdf

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] 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] mmBtu of LFG inlet to the plant. This results in a [redacted] 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 [redacted], plus a flaring credit for all energy that is captured, the total energy consumed during the processing stage of the pathway is [redacted] 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 Topock, AZ. The Needle Mountain LNG Plant is located [redacted] from the LFG processing plant.

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] with emissions of [redacted]

Assumptions

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

2.4) NG Liquefaction at LNG Plant

As stated above, Carbon Intensity analysis steps of ANGF's pathway Downstream Phase from liquefaction to delivery and usage of LNG are identical to those of pathway LNG027.

Assumptions have been adjusted to better reflect the facility-specific operating parameters of the Needle Mountain LNG Plant. As stated above, this document focuses on adjustments made to the LNG006 pathway; the assumptions of that pathway are not detailed.

Natural gas delivered to the Needle Mountain LNG Plant in Topock, AZ is stripped of impurities until it is over 98% methane (CH4). CO_2, H_2S, other Sulfur components, moisture, mercury, and particles are stripped via acid gas removal and disposal, gas dehydration, mercury removal, and particle filtration. Stripping is powered by a natural gas-fueled turbine. Stripping prevents corrosion in the pipeline and crystallization of CO_2 during cryogenic processes. The emissions associated with these processes include CO, VOC, SOx, NOx, H_2S, particulates, and many toxic organic compounds. The purified quality NG then is cooled down to a -260^{o}F liquid in a heat exchanger that uses mixed refrigerant gas technology.

Total LNG production efficiency is: [redacted]

Accordingly, total GHG Emissions of NG Liquefaction [redacted]

Assumptions:

- LNG liquefaction and LNG transported data collected from Jan 2013 to Dec 2014
- Electricity generation mix parameters for NG liquefaction have been adjusted according to Year 2009 eGRID Subregion Resource Mix – WECC Southwest (AZNM) values are used.[4]
- Zero fugitive methane emissions are assumed, since the LNG plant is equipped with a recovery system.

2.5) LNG Storage

Fugitive methane emissions occur during LNG storage. The net emissions are a function of the methane boil-off and recovery rates.

Since [redacted] was assumed. Fugitive methane emissions from LNG storage are [redacted]

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

2.6) LNG distribution

The finished LNG is offloaded into special LNG trailers and transported to wholesale customer tanks in CA and to the Ontario and Barstow refueling stations. Some methane boil-off occurs during transportation of the LNG, which is taken into account using the assumptions made in pathway LNG006.

In our LCA we calibrated the GREET model based on the amount of gallons delivered to each CA customer and the respective trip distance. Using this weighted average and taking into account the fugitive methane emissions, total energy usage of LNG distribution is [redacted], while emissions are [redacted]

Assumptions:

- The weighted average of the round-trip transportation distance to CA clients is [redacted]

2.7) Dispensing of LNG

ANGF also operates two vehicle refueling stations in Barstow and Ontario, California. These two stations dispense LNG and L-CNG to NG-powered vehicles.

Total energy used for the dispensing of LNG is [redacted] while emissions are [redacted]

2.8) LNG Tank to Wheel

Tank to Wheel emissions for EMRE's LFG-to-LNG pathway are adapted without changes from ARB pathway LNG006.

Accordingly, Tank to Wheel energy usage is **1,000,000 Btu/MMBtu** and emissions are **58.5 gCO_2e/MJ**.

2.9) Re-vaporization and compression to CNG

Some of the LFG supplied by EMRE is re-vaporized and compressed to CNG before use as transportation fuel in heavy-duty vehicles.

Energy usage of this step is [redacted] and emissions are [redacted]

2.10) CNG Tank to Wheel

Tank to Wheel emissions for EMRE's LFG-to-L-CNG pathway are adapted without changes from ARB pathway CNG006[5].

Accordingly, Tank to Wheel energy usage is **1,000,000 Btu/MMBtu** and emissions are **57.73 gCO_2e/MJ**.

[5] Internal ARB-Developed Fuel Pathway - North American Landfill Gas to Compressed Natural Gas; posted on ARB website on 03/19/2013 - http://www.arb.ca.gov/fuels/lcfs/2a2b/internal/nalfg-cng-031513.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 ANGF's LFG-to-LNG pathway:

	GHG Emissions [gCO_2e/MJ]
Landfill Gas Recovery and Transport to Processing	[redacted]
Landfill Gas Processing	
Natural Gas Transport	
NG Liquefaction at LNG Plant	
LNG Storage	
LNG distribution	
Dispensing of LNG	
LNG Tank to Wheel	58.50
Total	**31.84**

As seen above, EMGM's LFG-to-LNG pathway has a total energy usage of and a Carbon Intensity of **31.84 gCO2e/MJ.**

LFG-to-L-CNG Pathway

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

	GHG Emissions [gCO_2e/MJ]
Landfill Gas Recovery and Transport to Processing	[redacted]
Landfill Gas Processing	
Natural Gas Transport	
NG Liquefaction at LNG Plant	
LNG Storage	
LNG distribution	
Dispensing of LNG	
CNG Compression and Dispensing	
CNG Tank to Wheel	57.73
Total	**32.24**

As seen above, EMGM's LFG-to-L-CNG pathway has a total energy usage of and a Carbon Intensity of **32.24 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**