Life-Cycle Assessment of Seneca Landfill Gas to Delivered LNG and L/CNG in California

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General Information

(This Section contains Confidential Business Information)

Seneca Energy II, LLC, is constructing a landfill gas (LFG) refinery located in Waterloo, NY. The refinery will recover methane from the Seneca Meadows solid waste landfill, which is operated by Seneca Meadows Inc, a Progressive Waste Solutions, Ltd. company. Before the refinery, the LFG was previously used as fuel for electricity generation in an adjacent energy park and excess gas was flared. The refinery was in final commission stages and was expected to be completed within the first quarter of 2014.

The refinery will use [redacted] to remove the impurities in the landfill gas and produce commercially saleable natural gas. Seneca will purchase natural gas from Minard Run Oil Company to provide supplemental fuel for the thermal oxidizer. Seneca will purchase electricity from New York State Electric and Gas Corporation (NYSEG) to serve the plant's electrical demand.

The Seneca refinery is currently designed to intake up to [redacted] of landfill gas. Once additional LFG becomes available (currently anticipated in approximately three years), the refinery will be expanded to the full planned capacity of [redacted] Seneca has a permit from the New York State Department of Environmental Conservation for [redacted]. Based on this permitted limit, refined gas would be produced at a rate of [redacted] at 98.5% methane, or [redacted] (LHV). The Btu content at 98.5% methane averages 895 Btu (LHV)/SCF[1]. The US EPA equivalent maximum volume of renewable fuels is [redacted]. However, with the refinery currently designed to handle only half of the permitted capacity, actual peak capacity was calculated using the maximum volume of refined biogas contracted to be sold as transportation fuel. At [redacted] (HHV) – or [redacted]r (LHV) – maximum contract sales, the equivalent volume of renewable fuels from this contracted volume is [redacted]

The following pathway was produced using the designed material balance and electric profile provided by LES and contained in the EPA RFS2 engineering review and two (2) years (2011 – 2012) of liquefaction data.

Process Description

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[redacted]

[1] Methane Lower Heat Value = 909.4 Btu/scf (Source: ASTM D3588 "Standard Practice for Calculating Heat Value, Compressibility Factor, and Relative Density of Gaseous Fuels")

[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), and Liquefaction.

LFG Production Plant

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The Seneca refinery is currently being built to intake up to [redacted] of landfill gas. However, the refinery is permitted by the New York State Department of Environmental Conservation for [redacted]. Based on this permitted limit, refined gas at 98.5% methane would be produced at a rate of [redacted] or [redacted] (LHV). The US EPA equivalent maximum volume of renewable fuels is [redacted] However, with the refinery currently designed to handle only half of the permitted capacity, actual peak capacity was calculated using the maximum heating value of refined biogas contracted to be sold as transportation fuel. At [redacted] (HHV) – or [redacted] (LHV) – maximum contract sales, the equivalent volume of renewable fuels from this contracted volume is [redacted].

Seneca will receive electricity to run electric motors that drive the purification processes. The refinery will use a thermal oxidizer and flares to combust gas not meeting pipeline specifications or unable to be accepted in the pipeline. Seneca does not have process heaters.

The process has a thermal oxidizer that consumes the waste stream LFG ([redacted]) which is [redacted]). The Seneca Plant expected load is [redacted] as shown in the submitted electric profile ([redacted]). The electric profile shows the maximum demand values when the equipment is expected to be used 100% of the time and factors for motor efficiency, power factor, percent (%) of time running, brake Hp, and percent (%) design oversize are multiplied to the full load to determine the expected actual loads. The electric motors operate at [redacted]). This means that operationally, the power draw of the system will be approximately [redacted]. The electric motors consume [redacted] of product pipeline gas for processing.

There are no process heaters, therefore there is no process heaters fuels combusted, only waste streams and LFG as feed and pilot for the thermal oxidizer. The thermal oxidizer operates 100% of the time. The submitted material balances for the TOX show a flow of [redacted] with [redacted]% methane equal to [redacted]. It has a pilot of [redacted]) during the processing stage. This is shown in the submitted material balance ([redacted] which is also part of the EPA RFS2 engineering report.

The table below shows the provided data converted to GREET model inputs. The Seneca pathway utilizes the CA-GREET default values for LFG recovery. After the table is a simplified process diagram of the facility. The value of [redacted] in Table 1 below is the amount of designed pipeline quality biogas produced. All supporting data and calculations for Table 1 and Figure 1 below can be found in [redacted] spreadsheet on the "Summary" tab. This spreadsheet includes the data and values shown within the EPA RFS2 engineering review appendices on the "PFD Values" tab. To determine combustion emissions from the consumed natural gas and landfill gas at the landfill gas plant, the GREET default values for natural gas combustion process during natural gas liquefaction (100% natural gas turbine) were chosen since they represent the processes more closely to TOX than natural gas compression (100% natural gas internal combustion engine).

Table 1. Seneca LFG Plant Operating Energy and Flare Credit

(This Table contains Confidential Business Information)

	Hourly Average Modeled Data	Btu/MMBtu of Product Gas	Input Value	Changed Cells – NG Tab
LFG Produced	[redacted] MMBtu	1,000,000		
Imported Electricity	[redacted] kWh	[redacted] [redacted] Btu	[redacted] [redacted]%	AI79 (via C184)
LFG Consumed (TOX)	[redacted] MMBtu	[redacted] [redacted] Btu	[redacted]	AI75 (via C183)
Imported Natural Gas	[redacted] MMBtu	[redacted] [redacted] Btu	[redacted] [redacted]%	AI76 (via C185)
Processing Efficiency	-	[redacted] [redacted]%	[redacted]%	AI66 (via C182)
Flare Credit	-	[redacted] Btu	Calculated w/in GREET	

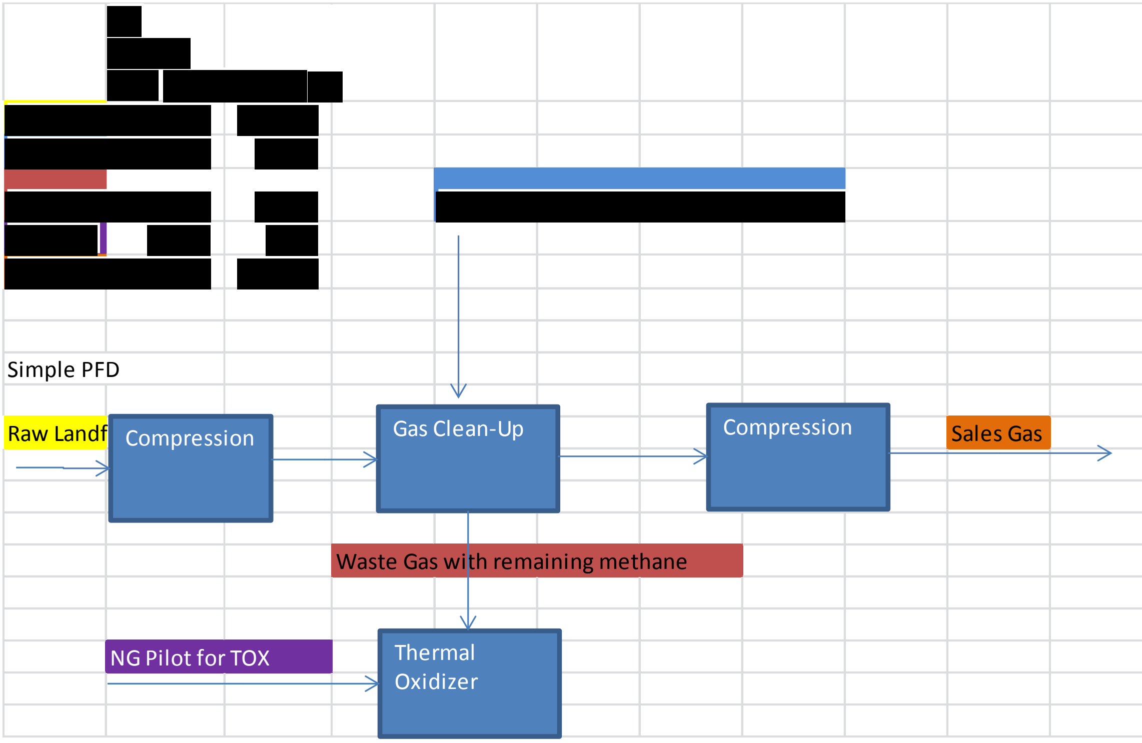

Figure 1. Seneca Process per MMBtu and MMBtu/day Energy Flows

The GREET model LFG pathway was then modified to adjust efficiency gas and process energy shares as listed in Table 1. The Southeast Asia region on the Regional LT tab was changed to the NYUP Region to represent the eGRID (8th Edition[2]) where Seneca Falls is located and this was used for Seneca. The ARB methodology of converting eGRID electricity mix to marginal mix was employed. This changed the electric mix cells of J83-J88 on the Regional LT tab to those shown in Table 2. The remaining values from the Southeast Asia Region (now the NYUP Region) were changed to match the US Average.

Table 2. NYUP Electricity Grid Mix

	eGRID Grid Mix	Marginal Grid Mix	CA-GREET Cell Regional LT Tab
Residual oil	1.3%	1.3%	J83
Natural gas	18.9%	80.3%	J84
Coal	14.5%	14.5%	J85
Nuclear	30.6%	0%	J86
Biomass	1.6%	1.6%	J87
Other (renewables)	33.1% (w/ hydro)	2.4% (w/o hydro)	J88

[2] eGrid 8th Edition Version 1.0, Year 2009 Summary Tables, created May 2012. www.epa.gov/cleanenergy/documents/egridzips/eGRID_8th_edition_V1-0_year_2009_Summary_Tables.pdf

This produced the results for LFG to biomethane shown in the table below taken from cells on the NG Tab. Conversion from g/MMBtu to g/MJ was done using the conversion factor of 1,055.055 MJ/MMBTU as is done in the CA-GREET model.

The recovery energy and emissions are based on ARB LFG pathway defaults of [redacted] Btu of electricity/MMBtu of landfill gas.[3]

Table 3. Seneca LFG Plant Greenhouse Gas Emissions

(This Table contains Confidential Business Information)

	Recovery Emissions	Seneca LFG Processing	CA-GREET Cell NG Tab
gVOC/MMBTU	[redacted]	[redacted]	B163/C163
gCO/MMBTU	[redacted]	[redacted]	B164/C164
gCH4/MMBTU	[redacted]	[redacted]	B165/C165
gN2O/MMBTU	[redacted]	[redacted]	B166/C166
gCO2/MMBTU	[redacted]	[redacted]	B167/C167
gCO2e/MMBTU	[redacted]	[redacted]	B168/C168
gCO2e/MJ	[redacted]	[redacted]	B169/C169
gCO2e/MJ Flare Credit		[redacted]	D169
Total gCO2e/MJ Recovery + Processing		[redacted]	E169

Transportation to California by Pipeline

The pipeline transport distance was modified to 2,598 miles from Seneca Falls, NY to Boron, CA where the gas will be liquefied. The distance was determined by the using the driving route most similar to the pipeline map. Google Maps was used to determine the driving routes with the I-40 route 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. The table below shows the pipeline transport emissions from cells F163-F169 on the NG Tab.

Table 4. Seneca LFG Transport Greenhouse Gas Emissions

(This Table contains Confidential Business Information)

Transport Emissions	Seneca LFG Transport
gVOC/MMBTU	[redacted]
gCO/MMBTU	[redacted]
gCH4/MMBTU	[redacted]
gN2O/MMBTU	[redacted]
gCO2/MMBTU	[redacted]
gCO2e/MMBTU	[redacted]
gCO2e/MJ	[redacted]

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

Liquefaction

(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] kWh/gal of LNG for liquefaction [redacted] kWh/gal LNG) found in [redacted] The data and efficiency in the excel file have been previously approved in Pathway LNG014. 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. [redacted] Btu is the energy content of one gallon of LNG. All excess gas that is not converted to LNG is sent to the neighboring natural gas power plant. Table 5 below shows the calculation from kWh per gallon to process efficiency and the cells that were changed. Table 6 shows the results from cells G163- G169.

Table 5. Boron LNG Plant Operating Energy

(This Table contains Confidential Business Information)

All Units in Btus per Gal of LNG	Boron LNG Plant	Input Value	Changed Cells – NG Tab
Feed Gas	[redacted]		
Liquefaction Electricity	[redacted] Btu	[redacted]%	AD79
Liquefaction Natural Gas	[redacted]	[redacted]%	AD75
Liquefaction Efficiency	[redacted]%	[redacted]%	AD66

Table 6. 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]

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 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 H163-H169 on the "NG" tab.

Table 7. 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]

LNG Storage

In addition the CA-GREET default for LNG storage was used. The default values are listed in Table 8 below and yield the results in Table 9 (the results were taken from cells I163-I169 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
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/MJ[4]
- Compressed to CNG: +2.14 gCO2e/MJ[5]
- Total: 2.89 gCO2e/MJ

Seneca Fuel Pathway Results

When the CA-GREET model is run completely with the modifications listed above, the table below shows the complete pathway results. The WTT pathway gCO2e/MJ results were taken from cell J170 which is the sum of cells E170 – I170 on the "NG" tab for LNG. The TTW gCO2e/MJ was taken from the Detailed California-Modified GREET Pathway for Liquefied Natural Gas (LNG) from Landfill Gas[6].

Table 10 - Pathway Results

GHG Emissions (gCO2e/MJ)	Seneca LFG Plant to LNG	Seneca LFG Plant to L/CNG
Landfill Gas Recovery	[redacted]	[redacted]
Landfill Gas Processing	[redacted]	[redacted]
Flare Credit	[redacted]	[redacted]
Landfill Gas Transport	[redacted]	[redacted]
Liquefaction	[redacted]	[redacted]
LNG Transport	[redacted]	[redacted]
LNG Storage	[redacted]	[redacted]
L/CNG Conversion		[redacted]
gCO2e/MJ WTT	[redacted]	[redacted]
Carbon in Fuel	[redacted]	[redacted]
Vehicle CH4 and N2O	[redacted]	[redacted]
gCO2e/MJ TTW	[redacted]	[redacted]
gCO2e/MJ WTW	32.03	34.15

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

Appendix A: Summary of CA-GREET Inputs

Parameter	Unit	Value	CA-GREET Cell Changed
LFG Recovery and Transport			
Thermal	Btu/MMBtu	[redacted]	CA-GREET Default (L85)
Electricity	Btu/MMBtu	[redacted]	CA-GREET Default[7] (L91)
Total Energy	Btu/MMBtu	[redacted]	N/A
LFG Plant			NG Tab
LFG Processing Efficiency	%	[redacted]	AI66 (via C182)
Electricity Fuel Share	%	[redacted]	AI79 (via C184)
LFG Fuel Share	%	[redacted]	AI75 (via C183)
Natural Gas Fuel Share	%	[redacted]	AI76 (via C185)
Electricity	kWh/MMBtu	[redacted]	N/A
Electricity	Btu/MMBtu	[redacted]	Calculated in CA-GREET (AI91)
Natural Gas	Btu/MMBtu	[redacted]	Calculated in CA-GREET (AI85)
LFG	Btu/MMBtu	[redacted]	Calculated in CA-GREET (AI87)
Credit for Not Flaring	Btu/MMBtu	[redacted]	Calculated in CA-GREET (AJ88)
Total Energy	Btu/MMBtu	[redacted]	N/A
Electricity Grid Mix			Regional LT Tab
Residual oil	%	1.3	J83
Natural gas	%	80.3	J84
Coal	%	14.5	J85
Nuclear	%	0	J86
Biomass	%	1.6	J87
Other (renewables)	%	2.4	J88
Natural Gas Transport			T&D Flowcharts Tab (via NG Tab)
Pipeline Distance	mi	2,598	F479 (via E148)
Liquefaction			NG Tab
Electricity	kWh/Gallon	[redacted]	N/A
Liquefaction Efficiency	%	[redacted]	AD66
Electricity Fuel Share	%	[redacted]	AD79
Natural Gas Fuel Share	%	[redacted]	AD75
Electricity	Btu/MMBtu	[redacted]	Calculated in CA-GREET (AD91)

[7] http://www.arb.ca.gov/fuels/lcfs/022709lcfs_lfg.pdf, pages 9-10.

LNG Transport			T&D Tab
Truck LNG Fuel Share	%	90	CD97
Truck Diesel Fuel Share	%	10	CD95
LNG Storage			Inputs Tab
Boil-Off Rate: % per Day	%/day	0.05 / 0.1	E171 / F171
Duration of Storage or Transit: Days	Days	5 / 0.1	E174 / F174
Recovery Rate for Boil-Off Gas	%	80% / 80%	E179 / F179
L/CNG			NG Tab
L/CNG Conversion	gCO2e/MJ	2.89	J171