



Life-Cycle Assessment of Cedar Hills Landfill Gas to Delivered CNG at Trillium CNG Station

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BP Natural Gas and Power

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General Information

(This Section contains Confidential Business Information)

The Cedar Hills LFG Plant is located in Maple Valley, WA, 30 miles Southwest of Seattle. It is owned and operated by Bio-Energy Washington. The Cedar Hills Plant will be processing, cleaning and pressurizing LFG from the Cedar Hills Landfill to be introduced into the pipeline. The plant has a capacity of [REDACTED] MMBtu/day of product gas. The production capacity equals [REDACTED] scfm using the average Btu content of [REDACTED] Btu (LHV)/SCF¹. Puget Sound Energy (PSE) has the rights to purchase up to [REDACTED] MMBtu/day should BEW's production increase to that level. The actual peak capacity of the BEW facility is [REDACTED] renewable fuel gallon equivalents of purified biogas production per year.

The BEW facility commenced construction in May 2008 and completed construction in May 2009. Plant technology was provided by Merichem Corp. and INGENCO. [REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

¹ Values of [REDACTED] Btu/scf (HHV) and [REDACTED] Btu/scf LHV were used in the calculations, average of [REDACTED] methane.

(This Section contains Confidential Business Information)

[Redacted]

[Redacted]

[Redacted]

[Redacted]

[Redacted]

(This figure contains Confidential Business Information)



Figure 2. Cedar Hills LFG Plant Process Flow Diagram (This figure is Confidential Business Information)

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 Compression.

LFG Production Plant

(This Section contains Confidential Business Information)

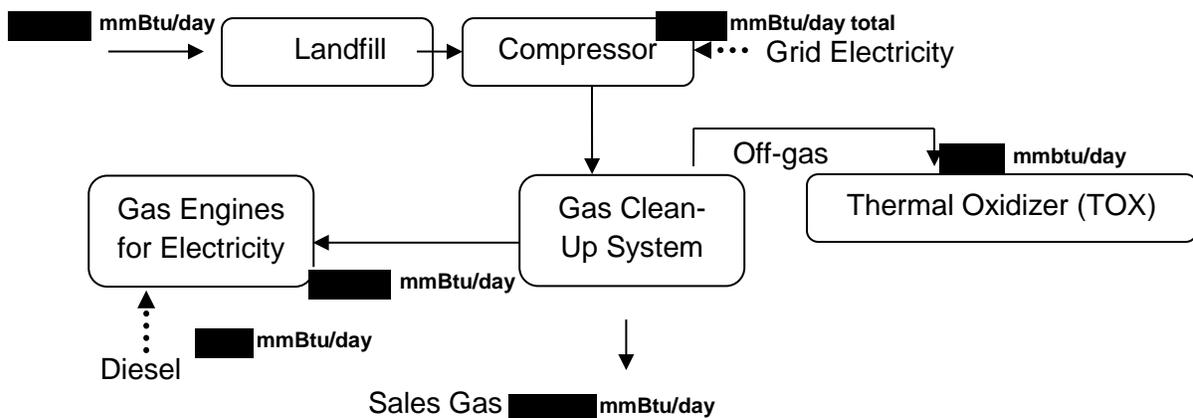
[Redacted]

[Redacted]

Table 1. CedarHill LFG Plant Operating Energy and Flare Credit

(This Table contains Confidential Business Information)

	Jan – Mar 2013 Data	Btu/MMBtu of Product Gas	Input Value	Changed Cells – NG Tab
LFG Produced	██████████	██████████		
Imported Electricity	██████████	██████████	██████████	████
LFG Consumed (Engines+TOX)	██████████	██████████	██████████	████
Diesel	██████████	██████████	██████████	████
Processing Efficiency	-	██████████	██████████	████
Flare Credit	-	██████████	██████████	



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 Washington State and this was used for Cedar Hills. After discussions with ARB, the eGRID 2012 (2009 data) for NWPP-WECC Northwest Sub region average electricity mix was used. This changed the electric mix cells of J83-J88 on the Region LT tab to those shown in Table 2. The remaining values from the Southeast Asia Region (not the Washington State Region) were changed to match the US Average.

Table 2. Washington Electricity Grid Mix

	eGRID Mix	CA-GREET Cell Regional LT Tab
Residual oil	████	████
Natural gas	████	████
Coal	████	████
Nuclear	████	████
Biomass	████	████
Other (renewables)	████	████

This produced the results for LFG to LNG 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 1055.055 MJ/MMBTU as is done in the CA-GREET model.

Table 3. Cedar Hills LFG Plant Greenhouse Gas Emissions

(This Table contains Confidential Business Information)

	Recovery Emissions	Cedar Hills LFG Plant	CA-GREET Cell NG Tab
gVOC/MMBTU	████	████	████
gCO/MMBTU	████	████	████
gCH4/MMBTU	████	████	████
gN2O/MMBTU	████	████	████
gCO2/MMBTU	████	████	████
gCO2e/MMBTU	████	████	████
gCO2e/MJ	████	████	████
gCO2e/MJ Flare Credit		████	████
Total gCO2e/MJ Recovery + Processing		████	████

Transportation to California by Pipeline

The pipeline transport distance was modified to 1,160 miles from Maple Valley, WA to Anaheim, CA. 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-5 route most similar to the pipeline map. Anaheim was conservatively chosen as the transport location since it is the station farthest from biogas production location. The emissions were determined by linked cell E148 on the NG tab to cell F487 on the T&D_Flowcharts tab for LFG to CNG, and this same distance will be used for LNG and CNG. The table below shows the pipeline transport emissions from cells F151-F157 on the NG Tab.

Table 4. Cedar Hills LFG Transport Greenhouse Gas Emissions

(This Table contains Confidential Business Information)

Transport Emissions	Cedar Hills LFG Transport
gVOC/MMBTU	████
gCO/MMBTU	████
gCH4/MMBTU	████
gN2O/MMBTU	████
gCO2/MMBTU	████
gCO2e/MMBTU	████
gCO2e/MJ	████

Compression

(This Section contains Confidential Business Information)

Based on the submitted Confidential Business Information from Trillium, Trillium will be submitting for one pathway for their CNG Stations based on 15-19 months of data, depending on the station. The weighted average energy consumption is [REDACTED] kWh/GGE. The tables below show the calculation from kWh/GGE to process efficiency and the cells that were changed and the results from cells G151- G157.

Table 5. CNG Station Plant Operating Efficiency

(This Table contains Confidential Business Information)

All Units in Btus per GGE	Compression	Input Value	Changed Cells – NG Tab
CNG Produced	[REDACTED]	[REDACTED]	
Compression Electricity	[REDACTED]	[REDACTED]	[REDACTED]
Compression Natural Gas	[REDACTED]	[REDACTED]	[REDACTED]
Compression Efficiency	[REDACTED]	[REDACTED]	[REDACTED]

Table 6. CNG Compression Greenhouse Gas Emissions

(This Table contains Confidential Business Information)

Recovery and Processing Emissions	Compression
gVOC/MMBTU	[REDACTED]
gCO/MMBTU	[REDACTED]
gCH4/MMBTU	[REDACTED]
gN2O/MMBTU	[REDACTED]
gCO2/MMBTU	[REDACTED]
gCO2e/MMBTU	[REDACTED]
gCO2e/MJ	[REDACTED]

² [REDACTED] Btu/GGE default CA-GREET value

Cedar Hills 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 H158 which is the sum of cells E158 – G158 on the “NG” tab for LNG. The TTW gCO₂e/MJ was taken from the Detailed California-Modified GREET Pathway for Compressed Natural Gas (CNG) from Landfill Gas³.

Table 7 - Pathway Results

GHG Emissions (gCO ₂ e/MJ)	Cedar Hills LFG Plant to CNG
Landfill Gas Recovery	
Landfill Gas Processing	
Flare Credit	
Landfill Gas Transport	
Compression	
gCO ₂ e/MJ WTT	
Carbon in Fuel +CH ₄ +N ₂ O	
Vehicle CH ₄ and N ₂ O	
gCO ₂ e/MJ TTW	
gCO ₂ e/MJ WTW	13.86

³ http://www.arb.ca.gov/fuels/lcfs/022709lcfs_lfg.pdf

Appendix A

Trillium Stations for Cedar Hills Pathway

Name	Address
1919 State College	1919 S State College Blvd Anaheim, CA 92806
2999 E LA Holla	2999 E La Holla St Anaheim, CA 92806
Berkeley	1101 2 nd St Berkeley, CA 94710
Concord	2352 Bisso Ln Concord, CA 94520
Fresno	1825 W McKinley Ave Fresno, CA 93728
Los Angeles	1800 N Main St Los Angeles, CA 90031
San Jose	2230 Unified Way San Jose, CA 95125
San Ramon	4500 Norris Canyon, Rd San Ramon, CA 94583
Santa Clara	3351 Thomas Rd Santa Clara, CA 95054
SFO	R-2 500 North of Millbrae Airport View Lot Millbrae, CA 94128
West Sacramento	1300 Shores St West Sacramento, CA 95691