Johnstown Regional Energy

# Method 2A/2B application

Landfill Gas to Compressed Natural Gas

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# 1 Summary

**Johnstown Regional Energy Pathway Description**

A Well-To-Tank (WTT) life cycle analysis of the Johnstown Regional Energy's (JRE) Landfill Gas (LFG) to Compressed Natural Gas (CNG) pathway considers all fuel production steps from feedstock recovery to finished fuel. Tank-to-Wheel (TTW) analysis includes actual combustion of CNG as a transportation fuel in a motor vehicle. Together, WTT and TTW analysis are combined to provide a total Well-to-Wheel (WTW) analysis.

A Life Cycle Analysis Model called the **G**reenhouse gases, **R**egulated **E**missions, and **E**nergy use in **T**ransportation (GREET) developed by Argonne National Laboratory forms the core basis of the method used in this document. LFG to CNG pathway is not available in the original Argonne GREET model but has been coded into the California modified GREET model (v1.8b, released December 2009) namely, CA-GREET. CA-GREET pathway[1] for CNG from Landfill gas forms the basis of this document and has been used to calculate the energy use and Greenhouse Gas (GHG) emissions generated during the process of producing and using compressed natural gas (CNG) from Landfill gas in an internal combustion. Changes specific to our pathway were restricted mostly to input factors (process efficiencies, power consumptions, emission factors from a different generation mix, transportation distances, etc.) with no substantial changes in methodology inherent in the original CA-GREET model.

The three JRE Landfill gas processing facilities namely, Southern Alleghenies Landfill, Shade Landfill and Raeger Mtn Landfill, all located in Pennsylvania, use landfill gas coming in from attached landfills and filter the gas to pipeline quality gas. This purified landfill gas is then transported to California refueling stations via a pipeline.

The pathway described here combines recovery of landfill gas, filtration of inlet gas to pipeline quality gas and final compression to pipeline pressures for all the three processing facilities. The "natural gas" obtained from the 3 facilities is then transported by pipeline to a CNG refueling station in California, where it is compressed and provided to internal combustion vehicles. Pathway for compression of landfill gas to CNG at a refueling station in California, and vehicular emission from combusting CNG is mostly unchanged from that provided by ARB.

[1] ARB (2009) Detailed California-Modified GREET Pathways for Compressed Natural Gas (CNG) from Landfill Gas: Version 2.1, California EPA Air Resources Board, Stationary Source Division, February 28, 2009. http://www.arb.ca.gov/fuels/lcfs/022709lcfs_lfg.pdf

Figure 1 below shows the discrete components that form the Landfill gas to CNG pathway.

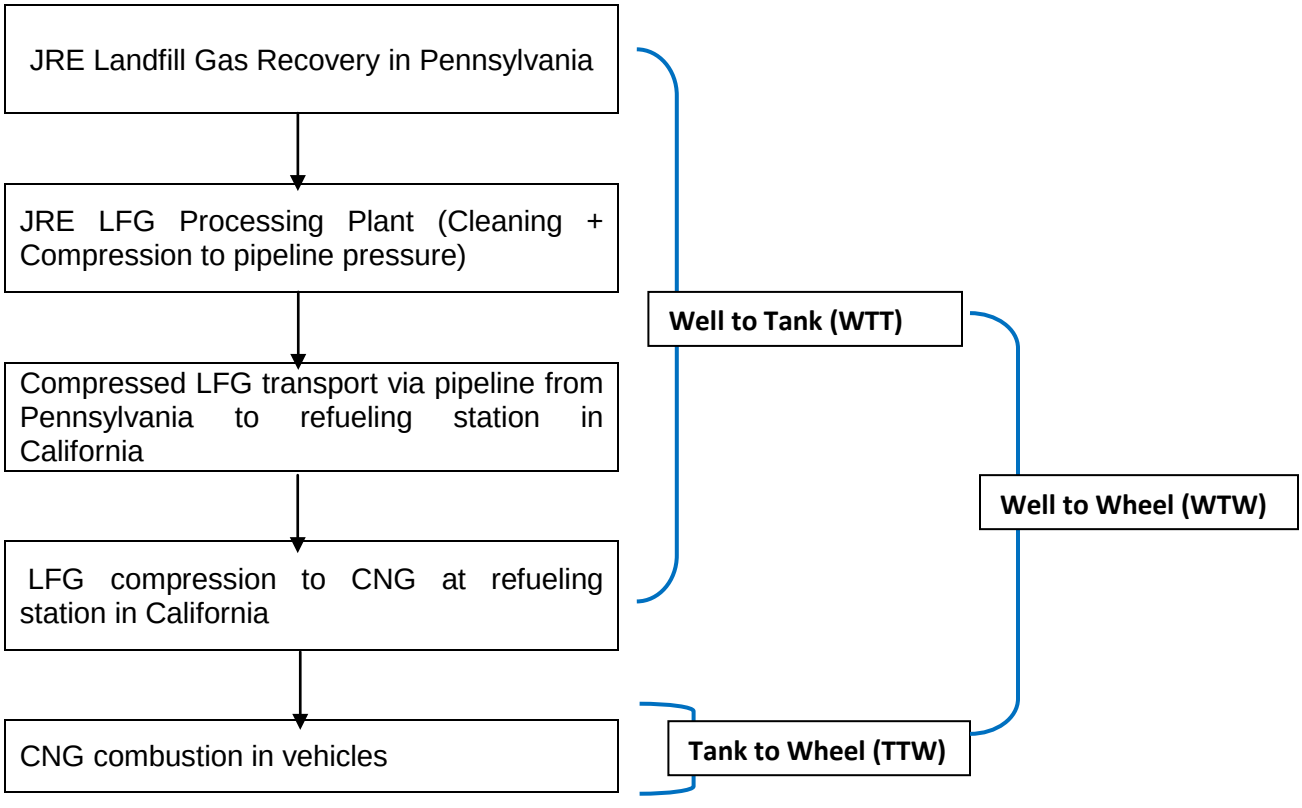


**Figure 1.** Discrete Components of the Landfill gas to CNG Pathway

The WTW analysis shows that **227,371** Btu of energy is required to produce 1 (one) mmBtu of available fuel energy. From a GHG perspective, **17.41** g $CO_2$ e/MJ of GHG emissions are generated during the production and use of CNG in a passenger vehicle.

# APPENDIX A

# SECTION 1. LANDFILL GAS RECOVERY

## 1.1 Energy Use for Landfill Gas Recovery and Transport to Processing

The first step in the CNG from LFG pathway is LFG recovery and transport to the point of processing. Because the location of our processing facility is practically attached to the landfill, the energy consumed in this transport is assumed to be negligible. Hence for this stage, we only calculate the energy required to recover the landfill gas.

### 1.1.1 Energy Use for Landfill Gas Recovery

There are three key inputs that were modified to calculate direct energy consumption for landfill gas recovery:

· Direct Energy Required
· Electricity Generation Mix (The electricity generation mix for JRE facilities was assumed to be same as that provided on EPA's eGRID database for state of Pennsylvania which falls under RFC East region.
· Leak Rate (0%, Standard industry practice since many years is to use hermetically sealed blowers to transfer landfill and digester gases)

## 1.2 GHG Emissions from Landfill Gas Recovery

First the direct emissions are calculated and then the upstream emissions (due to recovery and processing of each direct fuel used) are added. Emissions of $CO_2$, $N_2O$ and methane due to combustion are quantified. In addition, emissions of VOC and CO are quantified and assumed to convert to $CO_2$ in the atmosphere. The conversions are calculated as follows:

CO (g/MMBtu) * 44 g $CO_2$/gmole / 28 gCO/gmole

VOC (g/MMBtu) * 44 g $CO_2$/gmole / 12 gC/gmole * 0.85 gC/ gVOC

For LFG recovery, only electric blowers are utilized. Therefore, there are no direct emissions, only upstream emissions from electricity production.

# SECTION 2. LANDFILL GAS PROCESSING

## 2.1 Energy Use for Landfill Gas Processing

The next step in the LFG to CNG pathway is cleaning the LFG to pipeline quality and compressing it to natural gas distribution pipeline pressures. The three JRE facilities together draw xxx mmBtu/day of LFG from the landfill and require xxx hp of grid electricity. The compressors are needed to compress the gas before the membrane filters as well as to compress the gas to pipeline pressures after it has been filtered. All the facilities use the Air Liquide MEDAL membrane that can achieve >90% removal efficiency. The remaining gas is combusted in a thermal oxidizer (TOX) to minimize emissions.

Figure 2 below depicts the process flow diagram where all the facilities are combined into single flow diagram

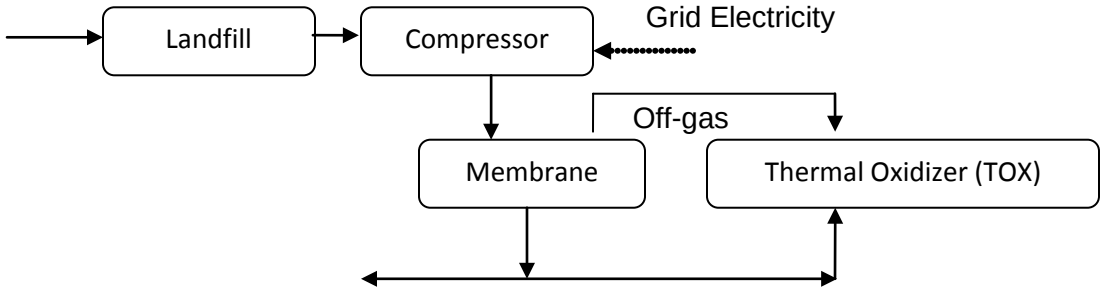


**Figure 2.** Process (Energy) Flow Diagram (combined description of all three facilities)

## 2.2 GHG Emissions from LFG Processing

The only fuel directly combusted is LFG in the TOX. An industrial boiler has been used as a surrogate for the thermal oxidizer in GREET when calculating emissions. Because the LFG would otherwise have been flared, a credit is applied for the flare emissions.

These emission factors are combined with direct energy consumption to yield direct emissions. Similar to total energy, the total emissions include direct emissions plus the emissions associated with recovery and processing/refining the fuels used to process landfill gas.

# SECTION 3. NATURAL GAS TRANSPORT & DISTRIBUTION

## 3.1 Energy Use for NG Transport and Distribution

The fourth step in the CNG from LFG pathway is transport and distribution of the natural gas by pipeline from the processing plant to the CNG refueling station. Since processed landfill gas is to be transported to refueling stations in California, the no. of miles covered by gas in the pipeline has been modified in the GREET model to represent the appropriate distance. The energy consumption for T&D consists of:

- T&D Feedstock Loss
- T&D Pipeline Transport Energy Consumption

The feedstock loss factor is based on the specification of a leak rate along the transmission & distribution pipelines. The feedstock loss factor value is assumed to be 0.08%, same as that used for LFG to CNG pathway provided by ARB.
Because almost all of this loss occurs in the distribution system, the leak rate does not vary with distance.

The pipeline energy consumption is the energy associated with moving the natural gas through the pipeline. The main assumptions are:

- Fuel Shares: % natural gas, % electricity (Pennsylvania Electricity)
- Energy Intensity in Btu/ton-mile
- Distance: approximate distance between Pennsylvania and California
- Lower Heating Value (LHV) of the landfill gas
- Density for average pipeline gas quality natural gas

## 3.2 GHG Emissions from Natural Gas Transport to the Refueling Station

The pipeline transport emissions are composed of methane leaks and emissions associated with moving the natural gas through the pipeline. The pipeline combustion emissions are calculated using the energy intensity and the assumed transport distance.

# SECTION 4. NATURAL GAS COMPRESSION TO CNG

## 4.1 CNG Compression Energy Use

The final step in CNG production is compression at the refueling station. The three assumptions for this part of the analysis are:

- Compression Efficiency (98%, same as ARB pathway)
- Compression Fuel (electric)
- Electricity mix is marginal California mix (NG + renewables)

## 4.2 GHG Emissions from Natural Gas Compression to CNG

As stated above, this pathway assumes that only electric compressors are used to compress the natural gas. There are no direct emissions from electricity, only upstream emissions.

# SECTION 5. GHG EMISSIONS FROM VEHICLE

## 5.1 GHG Emissions from Vehicles

The main assumptions used in the calculating emissions from CNG combustion in a motor vehicle are the same as that provided by ARB pathway document.
The vehicle GHG emissions consist of:

- Tailpipe $CO_2$ (100% of carbon in fuel goes to $CO_2$)
- Tailpipe $N_2O$ (combustion product)
- Tailpipe $CH_4$ (product of incomplete combustion, evaporative losses)

The $CO_2$ may be directly calculated from finished fuel properties

Similar to the ARB pathway calculations, we use California Climate Action Registry (CCAR)[5] g/mile values for calculating $CH_4$ and $N_2O$ emissions. The CCAR emission factors for $CH_4$ and $N_2O$ for CNG vehicles are both set at 0.0375 g/mi.