

Staff Summary
ARB Internal LCFS Pathway
Production of Biomethane from the
Mesophilic Anaerobic Digestion of Wastewater Sludge at a
Publicly-Owned Treatment Works (POTW)

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Pathway Summary

Staff has developed two Low Carbon Fuel Standard (LCFS) pathways for the production of biomethane from the mesophilic anaerobic digestion of wastewater sludge at a wastewater treatment plant (WWTP) located at a publicly-owned treatment works (POTW). The biomethane produced would be used as transportation fuel and could be dispensed on-site through a compressed gas vehicle fueling station, or may be injected into the natural gas pipeline system (“common carrier pipeline”) for dispensing at an off-site compressed gas vehicle fueling station.

Wastewater sludge is generated from the primary and secondary treatment processes designed for the municipal wastewater that flows into the WWTP. Since the wastewater sludge content is primarily organic material, California State and local laws require further treatment of the wastewater sludge prior to discharge of the material as an effluent, or disposal in a landfill or in a land application site. One of the most common processes for the treatment of wastewater sludge at a POTW is the anaerobic digestion of the sludge under mesophilic operating conditions (35 degrees Celsius). Anaerobically digesting the wastewater sludge destroys part of the organic matter and produces biogas, a mixture comprised of methane (CH₄) and carbon dioxide (CO₂), along with some trace impurities such as hydrogen sulfide, siloxanes, and vinyl chloride. Since both major components of biogas are greenhouse gases (GHG), the biogas produced is further destroyed by flaring (methane capture and destruction), or used in a device that generates electricity from the combustion of the biogas.

An alternative fate for the biogas, which is comprised of approximately 58 percent methane by volume, is to further refine the biogas to remove the carbon dioxide and other trace impurities to produce near-pure biomethane (greater than 99 percent CH₄). This biomethane could then be compressed and sold as a vehicle fuel either on-site, or injected into the common carrier pipeline for fueling at an off-site location. Some POTWs may continue to use part of the biogas or biomethane in compliant energy-producing devices for the production of renewable power and only allocate a fraction of their biogas produced toward transportation fuel uses. These alternate fates for the biogas produced from the mesophilic anaerobic digestion of the wastewater sludge at a POTW are the basis of the LCFS fuel pathways below.

In order to estimate the GHG impacts of these pathways, staff utilized two versions of the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation life cycle analysis models: CA-GREET and GREET1.¹ For wastewater sludge treatment processes that include anaerobic digestion, digestate and supernatant management, biogas cleaning, refining, compression, dispensing and distribution, staff found that worksheets available in the GREET1 Model closely estimated the energy use and material flow rates, and therefore the GREET1 Model was used as a basis to estimate the proposed carbon intensity (CI) for biomethane in CA-GREET.

Based on a survey conducted by the California Association of Sanitation Agencies (CASA, 2013)² of wastewater sludge management practices at over 250 POTWs in California, staff determined that approximately three-fifths of the POTWs operate anaerobic digesters to destroy part of the organic component of wastewater sludge. Of those found to be digesting wastewater organics, the majority of them (more than 90 percent) were found to be operating at mesophilic temperatures. Approximately 90 percent of those facilities digesting wastewater sludge were also using the produced biogas to provide renewable power for plant consumption or for export to the public grid, or both, and half of those POTWs producing power were doing so by use of internal combustion engines (ICE) and generators. The ICEs have come under increasing regulatory scrutiny, subject to more stringent emissions standards for stationary sources by local air districts in order to attain air quality standards. The production of a transportation fuel, however, presents a viable solution to the regulatory constraints facing the POTWs.

Staff has estimated the CIs for biomethane produced under two alternative scenarios. The first is an estimate for biomethane produced at a Small-to-Medium POTW with wastewater inflows of 5-20 million gallons per day (MGD). In this model, only a small parasitic load on the biogas produced is used to heat the digesters. Grid-based electricity, using the California-Marginal mix of electrical generating assets, is assumed to power the wastewater sludge treatment, and biogas cleaning, compression, and fuel dispensing processes. The second is an estimate for a Medium-to-Large POTW with wastewater inflows of 21-100 MGD. In this model, the majority of the biogas is allocated to the production of renewable power using a compliant device (such as a gas-fired turbine with an exhaust heat recovery system). The balance of the biogas produced in the digesters is allocated to on-site vehicle fueling, or compression and distribution through the natural gas grid for purposes of off-site vehicle fueling. Heat recovered from the exhaust of the combustion gases produced by the compliant device is adequate to sustain the mesophilic thermal requirements of the anaerobic digesters. The electrical demand for the wastewater sludge treatment and biogas cleaning, compression, and dispensing processes is provided by the renewable power

¹ The CA-GREET model (Version 1.80b, December 2009) and the GREET1 Model (Revision 2, December 2012) were developed by Argonne National Laboratory (ANL). The CA-GREET model has been adapted for use in California (Life Cycle Associates and ARB Staff). Some emission factors listed in GREET1 and not available in CA-GREET were incorporated by reference.

² California Association of Sanitation Agencies (CASA), 2013. Survey of Publicly-Owned Treatment Work (POTW) Facilities in the State of California, February 2013.

generated on-site by the compliant device. This alternative scenario also predicts that surplus electrical power³ will be generated, and that this power will be exported, displacing California Marginal electricity on the electrical grid. Therefore, this model accrues an additional LCFS credit for lowering the GHG impacts of grid-based California Marginal electrical generation.

Common to both models is a credit for avoided flaring emissions. Staff assumes that due to regulatory and air quality non-attainment considerations, flaring of the biogas to achieve near complete destruction of the volatile components in the biogas with high global warming potentials is the only available option for the reference case. Therefore, any productive use of the biogas, such as for vehicle fuel or for the production of renewable electrical power, avoids the emissions and energy loss caused by flaring of the biogas. The avoided flaring emissions accrue as an LCFS credit in the pathway CI analyses.

The modeled CI results, along with the applicable avoided flaring emissions credit, and the credit for displaced grid-based electrical generation are presented in Table 1 below. The CI estimate for each alternative case presented is obtained by first estimating the total well-to-tank (WTT) GHG impacts, which arise from the anaerobic digestion, digestate management and transport, biogas conditioning and refining, renewable power production, and biomethane compression, distribution, and dispensing. To this estimate is added the tank-to-wheels (TTW) GHG impacts, which arise when the finished fuel is combusted in a vehicle to derive motive power. This results in the total well-to-wheels (WTW) GHG emissions impacts, which, when expressed per unit of transportation fuel energy produced, represents the CI of the fuel.

As shown in Table 1, the resulting CIs are 10.86 g CO₂e/MJ and -65.27 g CO₂e/MJ for the two alternative scenarios presented. In both cases, staff estimated the CI for compressing biomethane for on-site, high-speed vehicle fueling. The CIs are also applicable to biomethane produced for injection into the common carrier pipeline.⁴

³ The GREET1 Model estimates that electrical power surplus to the system boundary defined for the life cycle analysis of the scenario (Alternative Case 2) will be available for export. This amount of power is then considered to displace grid-based electrical generation.

⁴ In most cases, the compression pressure required for pipeline injection (600-800 psig) is lower than the compression pressure required for high-speed vehicle fueling (3,600 psig).

Table 1: Summary of Life Cycle GHG Impacts and CIs for Biomethane Derived from Anaerobic Digestion of Wastewater Sludge

Parameter	Small-to-Medium POTW (Using Grid-based Electricity)	Medium-to-Large POTW (With Electricity Co- Product Export Credit)
Total WTT GHG Emissions Impacts (g CO ₂ e/day)	(5,051,355.72)	(101,477,229.25)
Total TTW GHG Emissions Impacts (g CO ₂ e/day)	7,748,625.74	20,403,793.71
Total WTW (WTT + TTW) GHG Emissions Impacts (g CO ₂ e/day) (A)	2,697,270.02	(81,073,435.54)
Allocation of Biomethane for Vehicle Fueling (m ³ /day)	6,931.35	34,656.77
Allocation of Biomethane for Vehicle Fueling (scf/day)	133,366.58	351,182.80
Biomethane LHV (Btu/scf)	962.00	962.00
Biomethane Energy Value (MJ/day) (B)	248,414.33	1,242,071.63
Proposed Biomethane CI (g CO₂e/MJ) (A/B)	10.86	- 65.27

The proposed Lookup Table entries for the wastewater sludge-to-biomethane pathways are presented in Table 2 below:

Table 2: Proposed Lookup Table Entry for Fuel/Feedstock

Fuel	Pathway Identifier	Pathway Description	Carbon Intensity Value (g CO ₂ e/MJ)		
			Direct Emissions	Land Use or Other Indirect Emissions	Total Emissions
Compressed Natural Gas	CNG020	Biomethane produced from the mesophilic anaerobic digestion of wastewater sludge at a publicly-owned treatment works; capable of on-site, high speed vehicle fueling, or meets standards for pipeline quality biomethane; co-product credit for export of surplus cogenerated electricity.	-65.27	0.00	-65.27
Compressed Natural Gas	CNG021	Biomethane produced from the mesophilic anaerobic digestion of wastewater sludge at a publicly-owned treatment works; capable of on-site, high speed vehicle fueling, or meets standards for pipeline quality biomethane. Use of grid-based electricity generated from a marginal energy mix with a CI at or below the CI associated with 78.7 percent natural gas and 21.3 percent renewables.	10.86	0.00	10.86

Applicable Operating Conditions

The proposed pathway CIs are contingent upon the production of biomethane under the following operating conditions:

1. The biomethane is derived from the anaerobic digestion of municipal wastewater sludge in a low-solids (wet fermentation) process under mesophilic operating conditions.
2. The CI of 10.86 g CO₂e/MJ is applicable to the biomethane produced when process thermal energy use (for digester heating purposes) is provided by a draw on the biogas produced in the digesters (parasitic thermal load), and process electrical energy is provided by the grid-based electricity with a

marginal energy mix CI at or below the CI associated with 78.7 percent natural gas and 21.3 percent renewables.

3. The CI of -65.27 g CO₂e/MJ is applicable to the biomethane produced when process thermal energy use (for digester heating purposes) is provided by the heat recovered from the exhaust gases that emit from a compliant, energy-producing device, and process electrical energy is also generated by the compliant, energy-producing device.
4. Both CIs are applicable to the biomethane produced after it is compressed and then dispensed either on-site through a high-speed vehicle fueling station, or is compressed for injection into the common carrier pipeline for fueling at an off-site location.

Staff Analysis and Recommendations

Staff has proposed pathways for certification of biomethane derived from wastewater sludge digested under mesophilic operating conditions and finds the following:

- Using the material and energy balances for the processes modeled in GREET1, staff has determined with reasonable accuracy the CA-GREET GHG lifecycle emissions and the available biomethane energy upon which the CI values described above are based.
- The pathway well-to-wheels GHG emissions analysis reflects a credit for avoided flaring of biogas and correspondingly accounts for combustion of biomethane in a vehicle to derive motive power.

ARB staff therefore recommends that the LCFS pathways proposed in Table 2 above be approved.