Oregon Clean Fuels Program

Determining the Carbon Intensity of Biogas to Electricity Pathways

Technical Guidance Document

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Introduction

The Oregon Department of Environmental Quality developed this guidance related to determining the carbon intensity of biogas to electricity pathways within Oregon using the Oregon Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation 4.0 model following the re-classification of those fuel pathways to Tier 2 status. Tier 2 pathways are more complex and are subject to a public comment period. Tier 1 pathways are better understood and have been captured in DEQ's simplified calculator, which the Environmental Quality Commission adopted. This guidance document describes the modifications to the dairy and swine manure to renewable natural gas Tier 1 calculator that DEQ expects applicants taking dairy and swine manure biogas to electricity projects to make.

Application Process and Requirements

The Tier 1 simplified CI calculators are designed to determine the CI of pathways where biomethane is dispensed as compressed natural gas, liquefied natural gas, and liquefied to compressed natural gas for transportation fueling. However, the simplified Tier 1 calculators can be modified to determine the CI of biogas-derived electricity as part of a Tier 2 application.

The current OR-GREET manual for Tier 1 simplified carbon intensity calculators provides instructions on biomethane pathways. This document provides additional guidance for modifications to the Tier 1 simplified calculator for biomethane from anaerobic digester of dairy and swine manure for electricity generation.

Two main topics are covered in this document:

1. The "adjustment factor" accounting for the average efficiency of the generator set used in natural gas- and biogas-derived electricity in Oregon power plants, and
2. Modifications to the biomethane from anaerobic digester of dairy and swine manure simplified calculator for biogas to electricity pathways.

Although this document focuses on modifying the biomethane from anaerobic digester of dairy and swine manure simplified calculator, applicants should consult with Clean Fuels Program staff regarding any additional potentially necessary modifications for other organic material inputs used for biogas to electricity pathways.

The adjustment factor for generator set efficiency

An "adjustment factor" is used to account for the average efficiency of the generator set (or genset) used for biogas-derived electricity because no electrical generation system currently converts 100% of the energy in methane or biomethane (or biogas) to electricity. Therefore, the

Clean Fuels Program considers a 50% efficiency factor in the CI calculation for biogas to electricity pathways.

This adjustment serves to (1) reasonably limit the incentive for negative CI value pathways (i.e., manure pathways that receive a methane emissions avoidance credit) and (2) to maintain the program's overall incentive for the most efficient use of fuels. Because of the methane reduction credit with dairy and swine manure pathways leading to them having negative carbon intensity scores, the adjustment factor avoids creating an incentive to pick an inefficient generator, get an even more negative CI score, and generate a similar number of credits while producing fewer kilowatt-hours.

The Clean Fuels Program also considered that the energy lost as engine heat, depending on the system design, can be recovered heat to the digester, lowering overall operating costs.[1] The recovered heat from the genset is not directly accounted for in the efficiency calculation. However, it is indirectly accounted for as reduced input heat to the digester. Therefore, the total amount of heat available from biogas can be deduced from the higher heating value.

The adjustment factor is applied to the subtotal CI to determine the final CI. This subtotal CI includes net methane from the digester (avoided methane), fugitive methane from biogas cleanup, and net CO_2 (engine emissions and CO_2 diverted from the baseline scenario), emissions from energy use (e.g., grid electricity or utility natural gas) are not adjusted. If the genset operates at a higher than 50% efficiency, the adjustment factor is not applicable.

Calculation:

$$f_{adj} = \frac{\eta_e}{\eta_{reference}} = \frac{kWh_{produced} \times 3{,}412 \frac{Btu}{kWh}}{MMBtu_{(HHV)biogas\ consumed} \times \frac{10^6 Btu}{MMBtu} \times 50\%}$$

Example: $f_{adj} = \frac{\eta_e}{\eta_{reference}} = \frac{23\%}{50\%} = 0.46$

Where, η_e represents the electrical efficiency of the generating unit, if less than 50%, determined using the quantity of biogas (in MMBtu, HHV) supplied to the power generating unit and the quantity of electricity generated over the operational data period. Again, the adjustment factor is not applicable if the system operates at a higher than 50% efficiency.

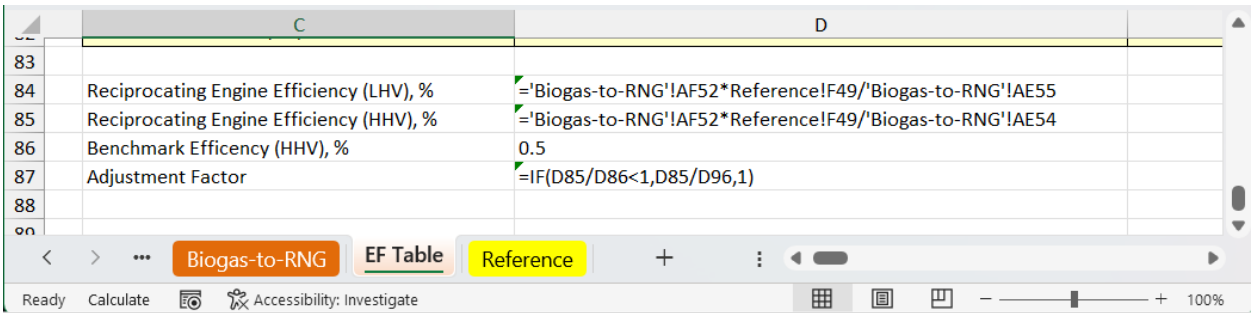
$\eta_{reference}$ represents the genset efficiency of 50%.

How to modify the simplified calculator:

1. Enter all required data for the manure management and digester operations in the "manure-to-biogas (LOP inputs)" tab and the biogas-electricity generation operations in the 'biogas-to-RNG' tab, using the Tier 1 calculator instruction manual as guidance.
2. In the "avoided emissions" tab, alter the following formulas to use cell C45, which references the quantity of biogas supplied to electricity generation rather than the quantity of biomethane pipeline injected in cell C43:
    a. In cell C47, replace the allocation factor formula with C45/C40.
    b. In cell C50, replace C49/C43 with C49/C45.
    c. Similarly, in cell G51 of the same tab, replace G50/C43 with G50/C45

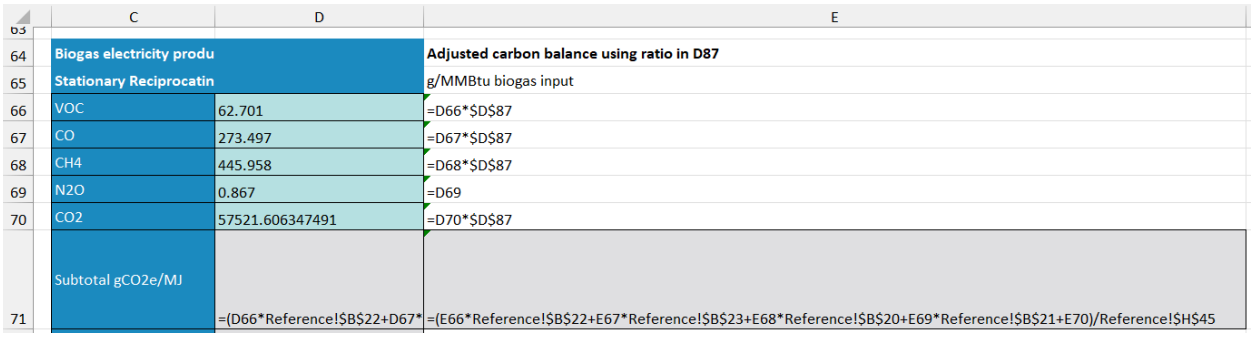
[1] Temperatures range between 86–100° F for mesophillic and 122–140° F for thermophilic anaerobic digesters.

3. For the adjustment factor, in the "EF table" tab, starting from cell C84, add the following parameters and formulas to calculate the adjustment factor:



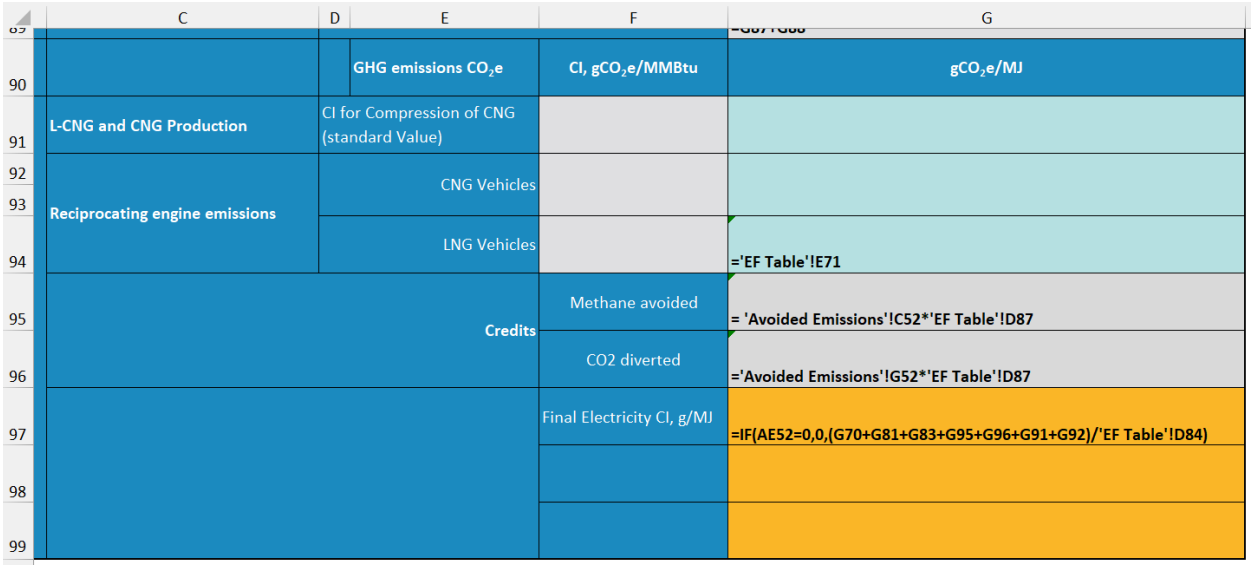
	C	D
83		
84	Reciprocating Engine Efficiency (LHV), %	='Biogas-to-RNG'!AF52*Reference!F49/'Biogas-to-RNG'!AE55
85	Reciprocating Engine Efficiency (HHV), %	='Biogas-to-RNG'!AF52*Reference!F49/'Biogas-to-RNG'!AE54
86	Benchmark Efficency (HHV), %	0.5
87	Adjustment Factor	=IF(D85/D86<1,D85/D96,1)
88		

4. The emission factors for biogas electricity production using a stationary reciprocating engine (in g/MMBtu of biogas input) are built into the "EF table" tab. If another technology is used to produce electricity from biogas, the applicant should modify cells D66 to D72 to reflect the emissions of such technology. Applicants should consult with the CFP staff for assistance deriving appropriate emission factors for technologies other than a stationary reciprocating engine. Then, in the "EF table" tab, starting from cell D64, add the following parameters and formulas to apply the adjustment factor to the combustion emission factors for biogas electricity production using a stationary engine:



	C	D	E
64	**Biogas electricity produ**		**Adjusted carbon balance using ratio in D87**
65	**Stationary Reciprocatin**		g/MMBtu biogas input
66	VOC	62.701	=D66*$D$87
67	CO	273.497	=D67*$D$87
68	CH4	445.958	=D68*$D$87
69	N2O	0.867	=D69
70	CO2	57521.606347491	=D70*$D$87
71	Subtotal gCO2e/MJ	=(D66*Reference!$B$22+D67*	=(E66*Reference!$B$22+E67*Reference!$B$23+E68*Reference!$B$20+E69*Reference!$B$21+E70)/Reference!$H$45

5. Finally, convert the CI result to per MJ of electricity: Several modifications in the "Biogas-to-RNG" tab appropriately incorporate the emissions from electricity generation and the adjustment factor from previous steps and calculate the final CI of the biogas electricity:
    a. In "Section 4. CI calculation details," modify each formula from cell F64 to cell F80 by replacing $AH$58 with $AE$55. This modification changes the functional unit of the CI from "per MMBtu biomethane injected into the pipeline" to "per MMBtu biogas used for electricity production."
    b. In cell G67, G68, G73, G74, G75, G79, and G80, replace Reference!$H$45 with Reference!$H$45*'EF Table'!D87. This modification adjusts emissions that are associated with biogas combustion and fugitive emissions.
    c. Delete original content in cells B82:G89 because the pipeline transmission, compression, liquefaction, and transportation of CNG and LNG are not relevant in this pathway.
    d. From cell B90 to cell G99, modify according to the following table. Note: All blank cells in the following table do not contain values. The applicant should delete the original content in these cells—within the simplified calculator.



	C	D	E	F	G
90			GHG emissions CO_2e	CI, gCO_2e/MMBtu	gCO_2e/MJ
91	L-CNG and CNG Production	CI for Compression of CNG (standard Value)			
92	Reciprocating engine emissions		CNG Vehicles		
93					
94			LNG Vehicles		='EF Table'!E71
95	Credits			Methane avoided	= 'Avoided Emissions'!C52*'EF Table'!D87
96				CO2 diverted	='Avoided Emissions'!G52*'EF Table'!D87
97				Final Electricity CI, g/MJ	=IF(AE52=0,0,(G70+G81+G83+G95+G96+G91+G92)/'EF Table'!D84)
98					
99					

Points considered in the evaluation of efficiency-related factors include the following:

1. Field operating efficiency is typically lower than a manufacturer's specified efficiency, depending on various factors (e.g., system scale, location, and ambient weather conditions).
2. Tradeoffs between criteria pollutants and electricity efficiency exist, and managing a genset for criteria pollutant emissions (e.g., carbon monoxide, sulfur dioxide, nitrous oxides) influences its electricity efficiency.[2,3]

Applicants should also consider the following:

1. Renewable Energy Certificates generated by biogas generators and used for reporting in the Clean Fuels Program must meet the new date and other requirements of the Green-e Standard under OAR 340-253-0470(5)(b).
2. Please be sure to follow all pertinent local operating guidelines and regulations such as the biogas or biomethane from composting (e.g., in landfills or other facilities) operating guidelines in OAR 340-096-0090.[4]

Reporting Requirements

To maintain an active pathway eligible to generate credits, the applicant must file the annual fuel pathway report and seek third-party verification if required.

Third-Party Validation and Verification Requirements

The Clean Fuels Program staff will review the application and identify any site-specific inputs during the certification process.

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[2] Itodo, I. N., Yakubu, D. K., & Kaankuka, T. K. (2019). The Effects of Biogas Fuel in an Electric Generator on Greenhouse Gas Emissions, Power Output, and Fuel Consumption. *Transactions of the ASABE*, *62*(4), 951-958.
[3] Souza, S. N. D., Lenz, A. M., Werncke, I., Nogueira, C. E., Antonelli, J., & Souza, J. D. (2016). Gas emission and efficiency of an engine-generator set running on biogas. *Engenharia Agrícola*, *36*(4), 613-621.
[4] OAR 340-096-0090 Special Rules Relating to Composting: Operations Plan Approval.

Contact

If you have any questions about how to implement this guidance, please contact the Clean Fuels Program at OregonCleanFuels@deq.state.or.us.

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