Dairy Digester Emissions Matrix (DRAFT)

DAIRY AND LIVESTOCK SUBGROUP #2: FOSTERING MARKETS FOR DIGESTER PROJECTS

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CALIFORNIA AIR RESOURCES BOARD

Introduction

Goals:

- Identify common or reasonably feasible pathways for transportation uses of methane from dairy digestion
- Identify reasonable assumptions and scenarios
- Emissions using CA-GREET 2.0

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Terminology

***Biomethane*:** methane derived from digestion of organics upgraded to be suitable for pipeline injection

***Biogas*:** digester gas for on-site use that has not been upgraded for pipeline injection

***Local*:** emissions or fuel use occurring on-site plus emissions or fuel use occurring before gas is injected into a pipeline or electricity is placed on the grid

***Remote*:** emissions or fuel use occurring off-site after gas is injected into a pipeline or electricity is placed on the grid. Includes grid electricity used for dairy farm equipment.

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Baseline and Pathways Evaluated

Baseline: Uncovered lagoon

Pathways (from covered lagoon):

1. Biogas to on-site reciprocating engine producing grid electricity for powering electric vehicles (EV)
2. Biomethane injection to pipeline for powering natural gas (NG) vehicles
3. Biomethane injection to pipeline for use in large, combined cycle power plants producing grid electricity for powering EVs
4. Biomethane injection to pipeline for steam methane reformation (SMR) producing hydrogen for powering fuel cell vehicles
5. Biomethane injection to pipeline to supply fuel cells producing grid electricity for powering EVs

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Models and Assumptions

General Methods and Assumptions (all pathways evaluated)

- **Emissions model:** CA-GREET 2.0 Dairy-CNG Template (https://www.arb.ca.gov/fuels/lcfs/ca-greet/ca-greet2-dairycng.xlsm)
- **Tailpipe emissions:** EMFAC2017 (v 1.0.2) https://www.arb.ca.gov/emfac/2017/
- **Source of model inputs:**
  - Air district permits and source testing
  - Manufacturer specifications
  - Dairy Digester Research and Development (DDRDP) Calculator Tool (https://www.arb.ca.gov/cc/capandtrade/auctionproceeds/cdfa_ddrdp_finalcalculator_17-18.xlsx)

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Assumptions (Cont.)

General Methods and Assumptions (all pathways evaluated)

- **Methane 20-year GWP:** 72
- **Methane 100-year GWP:** 25
- **Assumed dairy size:** 5,000 cows
- **Dairy type:** Freestall with flush manure management
- **Open lagoon methane emissions (baseline):** 980 MT/yr
- **Methane to Project:** 980 MT/yr minus 5% leakage from covered lagoon

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Assumptions (Cont.)

Assumption common to baseline and pathways

- Emissions calculated on local and remote basis
- Peripheral equipment uses grid electricity

Assumptions for digester projects

- Baseline solids separation via stationary screen
- Double-lined covered lagoon (no heating or mixing)
- Digester cover leak rate of 5%
- Projects must meet best available control technology

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Assumptions (Cont.)

Off-Site Use Assumptions

- Renewable natural gas
  - Distance from initial pipeline injection to fueling station is 100 miles
- *Renewable hydrogen*
  - Distance from pipeline injection to SMR is 100 miles
  - Distance from SMR to fueling station is 100 miles
- *Stationary fuel cells (solid oxide)*
  - 57% efficiency
- Electricity and hydrogen pathways use medium-duty vehicle
- Grid electricity line loss of 6.5%

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Dairy Digester Emissions Matrix

			A	B	C	D	E	F	G	H
			CO_2e (20-yr GWP)	CO_2e (100-yr GWP)	NOx	PM_{10}	$PM_{2.5}$	CO	SOx	VOCs
1	**Uncovered Lagoon**	**Baseline Totals** (Local + Remote)	**70,581**	**24,519**	**<0.1**	**<0.1**	**<0.1**	**<0.1**	**<0.1**	**3.0**
2	**Onsite Reciprocating Engine to Grid and EVs**	Local	17,491	7,474	0.5	0.2	0.2	8.5	<0.1	0.6
3		Remote	765	318	0.1	<0.1	<0.1	0.1	0.1	<0.1
4		**Subtotal** (Row 2 + Row 3)	**18,256**	**7,792**	**0.6**	**0.2**	**0.2**	**8.6**	**0.1**	**0.6**
5		Diesel Displaced	8,609	7,629	5.5	1.1	0.6	5.4	2.4	1.0
6		**Pathway Emissions** (Row 4 - Row 5)	**9,647**	**163**	**-4.9**	**-0.9**	**-0.4**	**3.2**	**-2.3**	**-0.4**
7		**Net Benefit** *vs. uncovered lagoon* (Row 6 – Row 1)	**-60,934**	**-24,356**	**-4.9**	**-0.9**	**-0.4**	**3.2**	**-2.3**	**-3.4**
8	**Pipeline Injection to NG Vehicles**	Local	15,448	5,268	0.1	<0.1	<0.1	1.2	<0.1	0.3
9		Remote	4,839	3,568	4.6	0.2	0.2	52.5	0.2	0.6
10		**Subtotal** (Row 8 + Row 9)	**20,287**	**8,837**	**4.7**	**0.2**	**0.2**	**53.7**	**0.2**	**0.9**
11		Diesel Displaced	4,197	3,720	8.8	0.4	0.2	1.6	1.2	12.0
12		**Pathway Emissions** (Row 10 - Row 11)	**16,090**	**5,117**	**-4.1**	**-0.2**	**<0.1**	**52.1**	**-1.0**	**-11.1**
13		**Net Benefit** *vs. uncovered lagoon* (Row 12 – Row 1)	**-54,491**	**-19,402**	**-4.1**	**-0.2**	**<0.1**	**52.1**	**-1.0**	**-14.1**

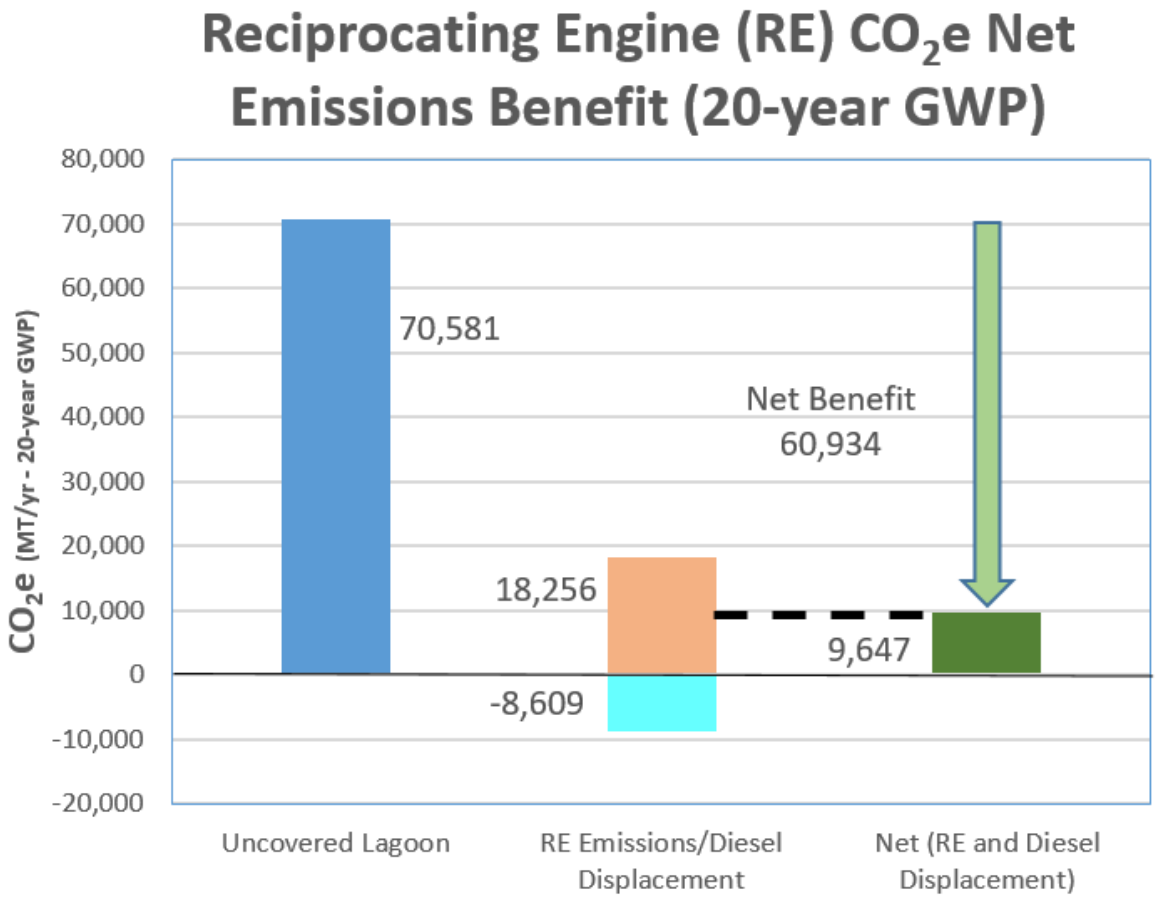
Dairy Digester Emissions Matrix (Cont.)

			A	B	C	D	E	F	G	H
			CO_2e (20-yr GWP)	CO_2e (100-yr GWP)	NOx	PM_{10}	$PM_{2.5}$	CO	SOx	VOCs
1	**Uncovered Lagoon**	**Baseline Totals** (Local + Remote)	**70,581**	**24,519**	**<0.1**	**<0.1**	**<0.1**	**<0.1**	**<0.1**	**3.0**
14	**Pipeline Injection to Power Plant, Grid and EVs**	Local	15,448	5,268	0.1	<0.1	<0.1	1.2	<0.1	0.3
15		Remote	3,860	2,957	0.4	0.1	0.1	0.4	0.2	0.1
16		**Subtotal** (Row 12 + Row 13)	**19,307**	**8,226**	**0.5**	**0.1**	**0.1**	**1.6**	**0.2**	**0.4**
17		Diesel Displaced	11,916	10,560	7.6	1.6	0.9	7.4	3.3	1.4
18		**Pathway Emissions** (Row 16 - Row 17)	**7,391**	**-2,334**	**-7.1**	**-1.5**	**-0.8**	**-5.8**	**-3.1**	**-1.0**
19		**Net Benefit** vs. uncovered lagoon (Row 18 – Row 1)	**-63,190**	**-26,853**	**-7.1**	**-1.5**	**-0.8**	**-5.8**	**-3.1**	**-4.0**
17	**Pipeline Injection to Hydrogen Vehicles** (H_2 from SMR)	Local	15,448	5,268	0.1	<0.1	<0.1	1.2	<0.1	0.3
18		Remote	6,140	5,017	3.5	0.6	0.6	1.9	2.4	0.4
19		**Subtotal** (Row 17 + Row 18)	**21,588**	**10,285**	**3.6**	**0.6**	**0.6**	**3.1**	**2.4**	**0.7**
20		Diesel Displaced	7,709	6,832	4.9	1.0	0.6	4.8	2.1	0.9
21		**Pathway Emissions** (Row 19 - Row 20)	**13,879**	**3,453**	**-1.3**	**-0.4**	**<0.1**	**-1.7**	**0.3**	**-0.2**
22		**Net Benefit** *vs. uncovered lagoon* (Row 21 – Row 1)	**-56,702**	**-21,066**	**-1.3**	**-0.4**	**<0.1**	**-1.7**	**0.3**	**-3.2**

Dairy Digester Emissions Matrix (Cont.)

			A	B	C	D	E	F	G	H
			CO_2e (20-yr GWP)	CO_2e (100-yr GWP)	NOx	PM_{10}	$PM_{2.5}$	CO	SOx	VOCs
1	**Uncovered Lagoon**	**Baseline Totals** (Local + Remote)	**70,581**	**24,519**	**<0.1**	**<0.1**	**<0.1**	**<0.1**	**<0.1**	**3.0**
23	**Pipeline Injection to Fuel Cell, Grid and EVs (Solid Oxide Fuel Cell)**	Local	15,448	5,268	0.1	<0.1	<0.1	1.2	<0.1	0.3
24		Remote	3,860	2,957	0.6	<0.1	<0.1	0.5	0.1	0.1
25		**Subtotal** (Row 23 + Row 24)	**19,308**	**8,225**	**0.7**	**0.1**	**0.1**	**1.7**	**0.1**	**0.3**
26		Diesel Displaced	13,292	11,779	8.5	1.8	1.0	8.3	3.7	1.5
27		**Pathway Emissions** (Row 25 - Row 26)	**6,016**	**-3,554**	**-7.8**	**-1.7**	**-0.9**	**-6.6**	**-3.6**	**-1.2**
28		**Net Benefit** *vs. uncovered lagoon* (Row 27 – Row 1)	**-64,565**	**-28,073**	**-7.8**	**-1.7**	**-0.9**	**-6.6**	**-3.6**	**-4.2**

GHG Benefits for Recip. Engine



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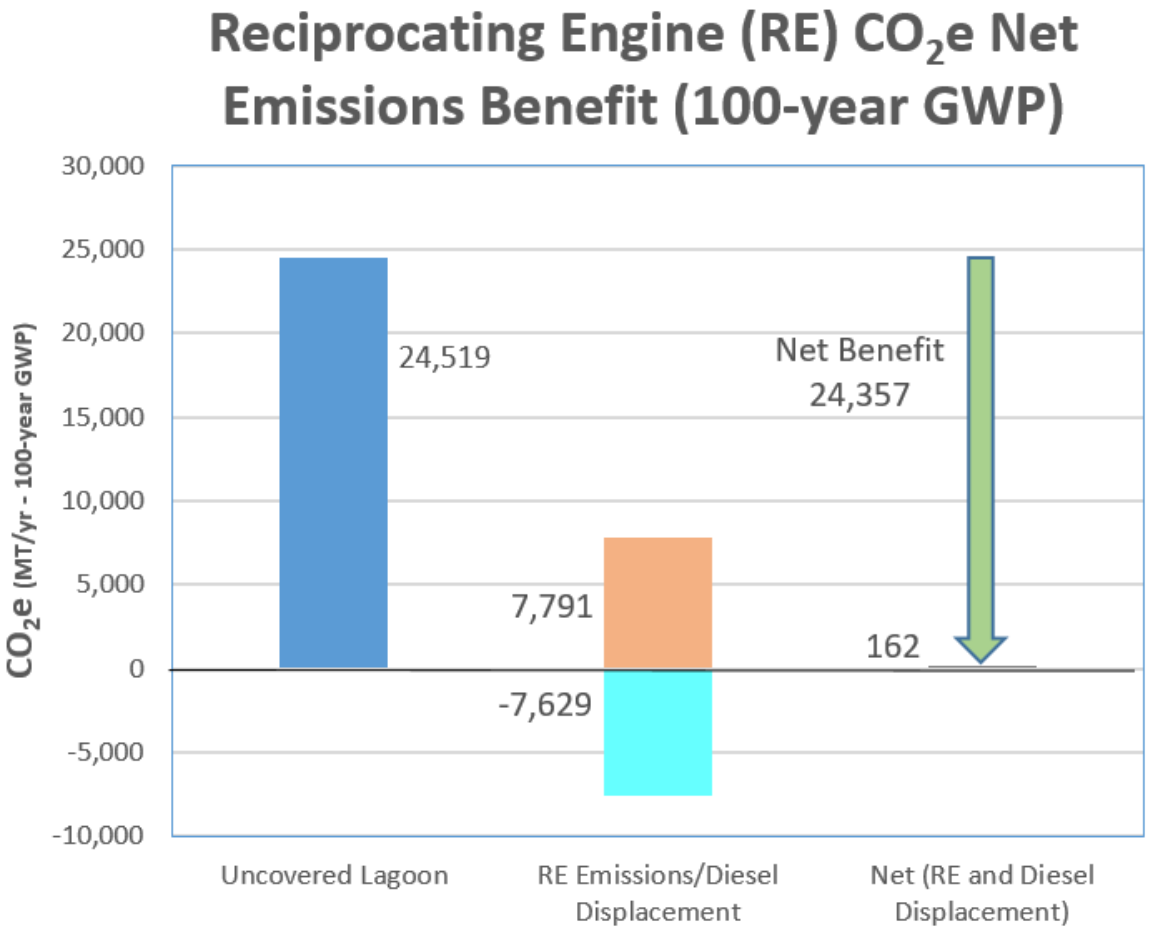
GHG Benefits for Recip. Engine (Cont.)



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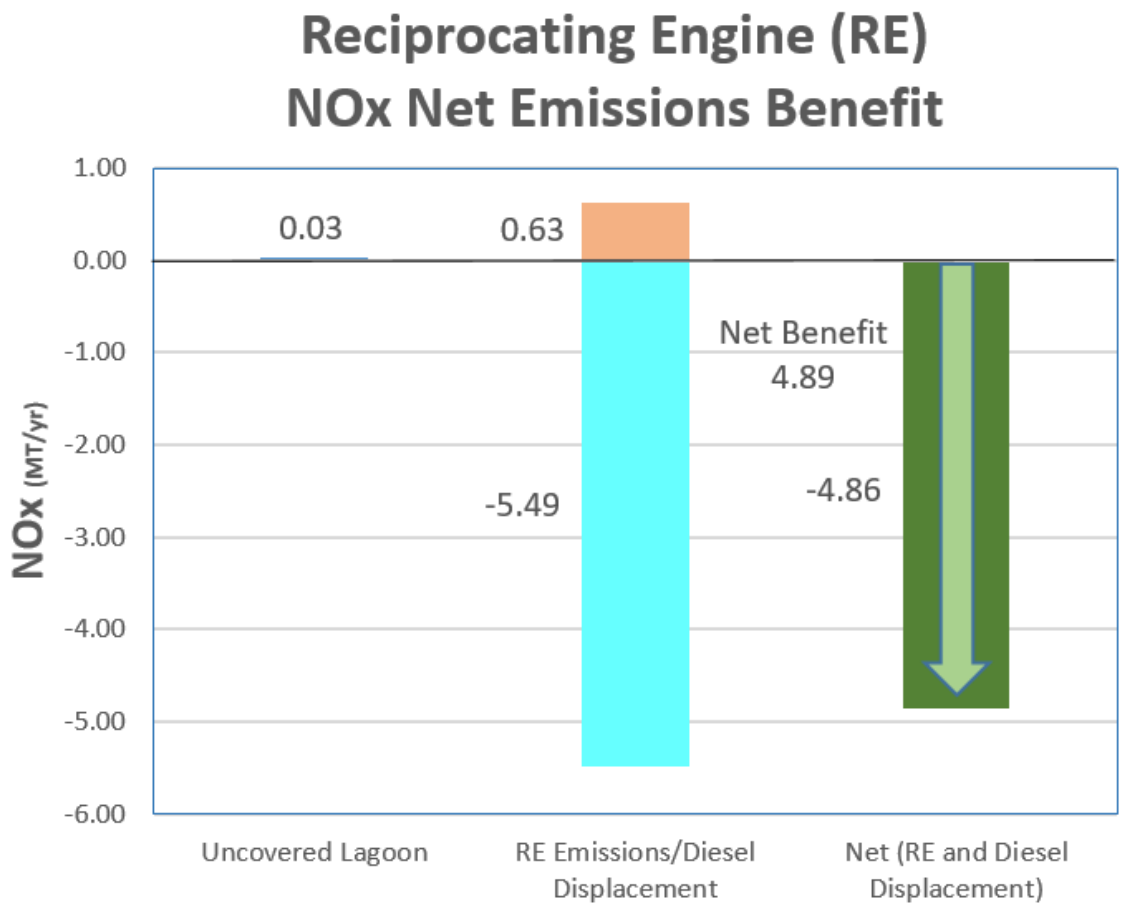
NOx Benefits for Recip. Engine (Cont.)



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Qualitative Environmental Impacts

Pathways	H_2S	NH_3	N_2O	WQ
Onsite reciprocating engine to grid and EV	↓	↓	↓	↓
Pipeline injection to NG vehicle	↓	↓	↓	↓
Pipeline injection to powerplant, grid, and EVs	↓	↓	↓	↓
Pipeline injection to hydrogen fuel cell vehicles	↓	↓	↓	↓
Pipeline injection to fuel cell, grid, to EVs	↓	↓	↓	↓

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Summary

- GHG emissions are lower in all pathways evaluated
- Most pathways show a net benefit in co-pollutants
- There is no “silver bullet” pathway – all pathways evaluated have reasonable applications
- Qualitative analyses suggest improvements in other environmental metrics

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Contact Information

Questions and comments can be directed to the Subgroup #2 comment docket accessible from the Dairy and Livestock Working Group website at:

https://www.arb.ca.gov/cc/dairy/dsg2/dsg2.htm

Additional Contact Information:

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