

## Dairy Emissions Matrix Assumptions

### Terminology:

- ***Biomethane***: methane derived from the digestion of organic material that has been upgraded to a level suitable for pipeline injection and applications that can include equipment or vehicular use
- ***Biogas***: digester gas for onsite use that has not been upgraded for pipeline injection
- ***On-site***: emissions or fuel use occurring *on* the dairy farm<sup>1</sup>
- ***Off-site***: emissions or fuel use occurring *off* the dairy farm
- ***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 after gas is injected into a pipeline or electricity is placed on the grid, including grid electricity use impacts for on-site equipment power

### General Methods and Assumptions (Applies to All Scenarios):

- Emissions model: CA GREET 2.0
- Source of values for entry into model: air quality district emission values, manufacturer specifications, Cap-and-Trade Program Livestock Offset Protocol
- Methane 20-year global warming potential: 72<sup>2,3</sup>
- Assumed dairy size: 5,000 cows<sup>4</sup>
- Dairy type: freestall with flush manure management
- Open lagoon methane emissions (baseline): TBD<sup>5</sup>

### Biogas Producing Covered Digester Scenario/Assumptions:

- Emissions calculated on local and remote basis
- Solid-liquid manure separation implemented
- Digester type: double-lined<sup>6</sup> covered lagoon (no heating or mixing)
- Digester cover leak rate: 5%<sup>7</sup>
- Effluent pond, digester maintenance, and unplanned venting emissions: TBD<sup>5</sup>
- Projects must meet applicable air district's best available control technology (BACT) emission standards
- Peripheral operations use grid electricity<sup>8</sup>

<sup>1</sup> Includes dairies participating in cluster projects

<sup>2</sup> Intergovernmental Panel on Climate Change Fourth Assessment Report: Climate Change 2007

<sup>3</sup> Same 20-year methane global warming potential as used in the Short-Living Climate Pollutant Reduction Strategy, [https://www.arb.ca.gov/cc/shortlived/meetings/03142017/final\\_slcp\\_report.pdf](https://www.arb.ca.gov/cc/shortlived/meetings/03142017/final_slcp_report.pdf)

<sup>4</sup> For comparison, average size of Kern County dairy farm in 2017 was 3,253 head. [https://www.cdfa.ca.gov/dairy/pdf/Annual/2017/2017\\_Statistics\\_Annual.pdf](https://www.cdfa.ca.gov/dairy/pdf/Annual/2017/2017_Statistics_Annual.pdf)

<sup>5</sup> CARB will determine value based off information from the Livestock Offset Protocol, localized research, industry-provided data, or other publicly available sources.

<sup>6</sup> Adopted order of California Regional Water Quality Control Board, [https://www.waterboards.ca.gov/rwqcb5/board\\_decisions/adopted\\_orders/general\\_orders/r5-2013-0122.pdf](https://www.waterboards.ca.gov/rwqcb5/board_decisions/adopted_orders/general_orders/r5-2013-0122.pdf)

<sup>7</sup> CARB Livestock Offset Protocol and U.S. EPA determined leak rate for covered lagoons

<sup>8</sup> CA grid electricity emission factor is 105.15 g/MJ (as utilized in CA GREET model)

**On-Site Use Scenario/Assumptions:**

- *Reciprocating engines*
  - Biogas is upgraded to air district and manufacturer's requirements (not pipeline-quality)
  - Efficiency – 32.8%<sup>9</sup>

**Off-Site Use Scenario/Assumptions**

- All off-site use of fuel will be from pipeline-quality biomethane processed from an on-site upgrading unit<sup>10</sup>
- *Renewable natural gas* – for fueling
  - Distance from initial pipeline injection to fueling station: 100 miles
- *Power plant generation* – producing electricity fed to grid
  - Facility is a large combined cycle power plant<sup>11</sup>
- *Renewable hydrogen*<sup>12</sup> – for fueling
  - Produced from pipeline biomethane using steam methane reformation
  - Distance from biomethane injection point to reforming facility: TBD<sup>13</sup>
  - Distance hydrogen trucked/pipelined from reforming facility to fueling station: TBD<sup>13</sup>
- *Microturbine* – producing electricity fed to the grid
  - Efficiency – 29%<sup>14,15</sup>
- *Fuel cells (solid oxide)*<sup>16</sup> – producing electricity fed to the grid
  - Efficiency – 57%<sup>17</sup>
- Transportation emissions comparison baseline (for all pathway options intended for transportation fuel use): heavy-duty diesel trucks<sup>18</sup>

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<sup>9</sup> CA GREET 2.0 value

<sup>10</sup> Total upgrading efficiency is a user input value for CA GREET 2.0 and 80% is a common calculated value

<sup>11</sup> Large combined cycle power plant is identified as 400MW capacity in CA GREET 2.0

<sup>12</sup> No current pathways available for renewable hydrogen from biomethane

<sup>13</sup> Centralized upgrading facility location will be mapped to determine distances

<sup>14</sup> Capstone Turbine Corporation, <https://www.capstoneturbine.com/products/c65>

<sup>15</sup> FlexEnergy (EnerCom, Inc.), [https://flexenergy.com/wp-content/uploads/2016/07/71000066\\_Flex\\_Turbine\\_GT250S\\_Spec\\_Sheet.pdf](https://flexenergy.com/wp-content/uploads/2016/07/71000066_Flex_Turbine_GT250S_Spec_Sheet.pdf)

<sup>16</sup> Expanding the Use of Biogas with Fuel Cell Technologies, June 11, 2012, [https://www.energy.gov/sites/prod/files/2014/03/f11/june2012\\_biogas\\_workshop\\_satyapal.pdf](https://www.energy.gov/sites/prod/files/2014/03/f11/june2012_biogas_workshop_satyapal.pdf)

<sup>17</sup> Higher Heating Value efficiency number from DG scenario, National Energy Technology Laboratory (Department of Energy), <https://www.netl.doe.gov/File%20Library/research/coal/energy%20systems/fuel%20cells/Natural-Gas-DG-FC-paper-update-090330a.pdf>

<sup>18</sup> Engine size TBD with consultation of subgroup members and CARB transportation/fuel staff