

NLC Energy Denmark LLC RNG Production Pathway

September 2021
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I. General Information

EEC MARKET GROUP LLC is owned by a common corporate parent, NLC Energy LLC, which owns and operates the NLC ENERGY DENMARK LLC (previously, NEW ORGANIC DIGESTION LLC) facility ("Facility") which upgrades biogas generated in dairy manure digesters into Renewable Natural Gas (RNG) that will be injected into the ANR pipeline onsite. The Facility (EPA facility ID: 70242) is located in Denmark, Wisconsin and, as of 9/1/2021, digests manure from eight (8) different dairies that truck manure to the site: Rolling Hills I, Rolling Hills II, Leiterman, Barta, Heim's Hillcrest, Branch View, D&D and Habeck. During the analysis period 700 to 800 truckloads of manure per month arrived at the digester. The facility completed constructing in 2010 to originally process high strength waste (HSW). In April of 2020 the facility began accepting manure to dairy dedicated digesters. As of 9/1/2021, the facility has four digesters onsite, two dedicated to dairy manure and two dedicated to HSW.

Neither the facility nor the dairies included have participated in California's Offset Program. Currently the manure (and allocated gas production) from Habeck is not included in the carbon intensity analysis since manure was included for only the last month within the analysis period. Habeck will continue to supply manure and will be included as part of a future application. All baseline manure management practices included here are detailed in the accompanying affidavits of baseline manure management. A summary of the practices is included in the section below, and the Appendix contains process flow diagrams for the baseline and project manure management practices and a table summarizing the values entered into the calculator.

Rolling Hills I

This dairy was originally built before 1990 and has been in its current ownership since 2006. The most recent lagoon construction occurred in 2011.

Rolling Hills Dairy has two sites approximately 4 miles apart. Site I houses the main dairy with approximately 1,500 milking, dry, heifers, and calves.

In the baseline scenario, 100% of the manure is collected in the free-stall barns and sent to the lagoon without solid separation meaning 100% of the volatile solids are sent to the lagoon in the baseline. Prior to sending manure to the digester, the dairy did not perform complete annual cleanouts of the anaerobic storage/ treatment system and as a result, no lagoon cleanouts were modeled, consistent with previously verified practices.

In the project, 100% of the milking dairy cow manure is collected from all but three pens. The other pens, #11, #12, hold 175 cows each, and those cows spend 3 hours each in the milking parlor, which is being captured. Pen 14 holds 60 cows, and they spend 1 hour each day in the milking parlor, which is being captured. All captured manure is trucked to the digester.

All manure from heifers and dry cows is collected and trucked to the digester. For calves (grazing), only 20% of the manure is captured in the pathway, and the remaining 80% uncaptured fraction is managed as "Cattle and Swine deep bedding (>1 month)" – for both the baseline and project scenarios.

The digestate is trucked back on the return trip to the anaerobic storage ponds at the dairy. There are over 220 truckloads per month from Rolling Hills averaging over 7 loads per day.



Exhibit 1. Aerial Map of Rolling Hills I Dairy

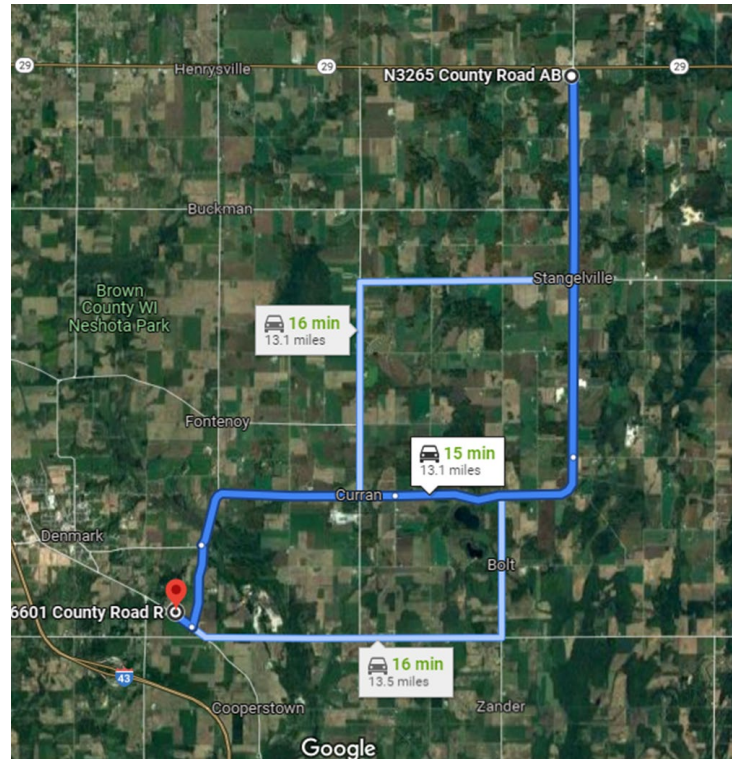


Exhibit 2. Aerial Map of Trucking from Rolling Hills I Dairy to the Digester

Rolling Hills II

This dairy was built prior to 1990 and has been in its current ownership since 2006. The original lagoon, built in 1990, was expanded in 2020.

Site II houses approximately 250 heifers. The Heifers have access to Paddock/Range/Pasture, and not all the manure is captured. The manure capture fraction was estimated by the Dairy representative based on the fraction of time the animals spend inside the manure capture area, varying by month. The animals get most of their nutrition from feed instead of the relatively small pasture area, and they are therefore classified as heifers (on feed). The situation is the same for baseline and project scenario.



Exhibit 3. Aerial Map of Rolling Hills II Dairy

Leiterman Dairy

This dairy was started in 1993. The lagoon was constructed in 1999 and expanded in 2006 and 2010.

Leiterman Dairy houses approximately 600 milking cows, dry cows, and calves. Prior to the digester, manure from the cows was collected from the free-stall barns and 100% was transferred to the lagoon, meaning 100% of the volatile solids are sent to the lagoon in the baseline. Prior to sending manure to the digester, the dairy did not perform complete annual cleanouts of the anaerobic storage/ treatment system and as a result, no lagoon cleanouts were modeled, consistent with previously verified practices.

In the project, all milking cow manure is collected and trucked 5.2 miles to the digester. The digestate is trucked back on the return trip to the anaerobic storage ponds at the dairy. There are on average over 80 truckloads per month with 2-3 loads per day.



Exhibit 4. Aerial Map of Leiterman Dairy

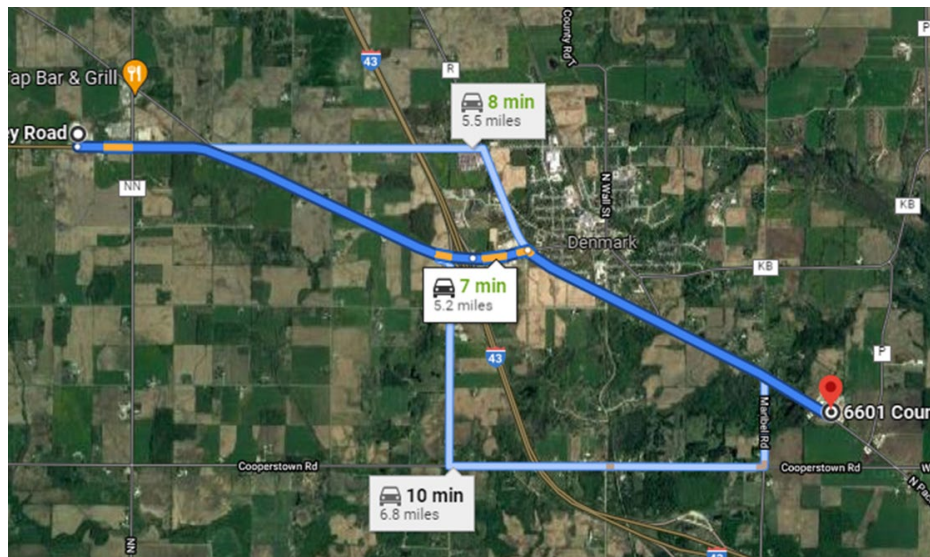


Exhibit 5. Aerial Map of Trucking from Leiterman Dairy to the Digester

Barta Dairy

This dairy was built prior to 1990 and has been in its current ownership since 2008. The current lagoon was first constructed in 2009 and expanded in 2011.

Barta Dairy houses approximately 450 milking and dry cows. Prior to the digester, manure from all but the non-milking dairy cows was collected from the free-stall barns and 100% was transferred to the lagoon. Non-milking dairy cows (on feed) are on deep bedding that is replaced in >1 month intervals and the dairy representative estimates that 50% of that manure is not captured in both the baseline and project scenario. Consequently, less than 100% of the total volatile solids are sent to the lagoon in the baseline. Prior to sending manure to the digester, the

dairy did not perform complete annual cleanouts of the anaerobic storage/ treatment system and as a result, no lagoon cleanouts were modeled, consistent with previously verified practices.

In the project, not all cow manure is collected, as described above, and trucked 13.9 miles to the digester. The digestate is trucked back on the return trip to the anaerobic storage ponds at the dairy. There are on average over 90 truckloads per month with 2-3 loads per day.



Exhibit 6. Aerial Map of Barta Dairy

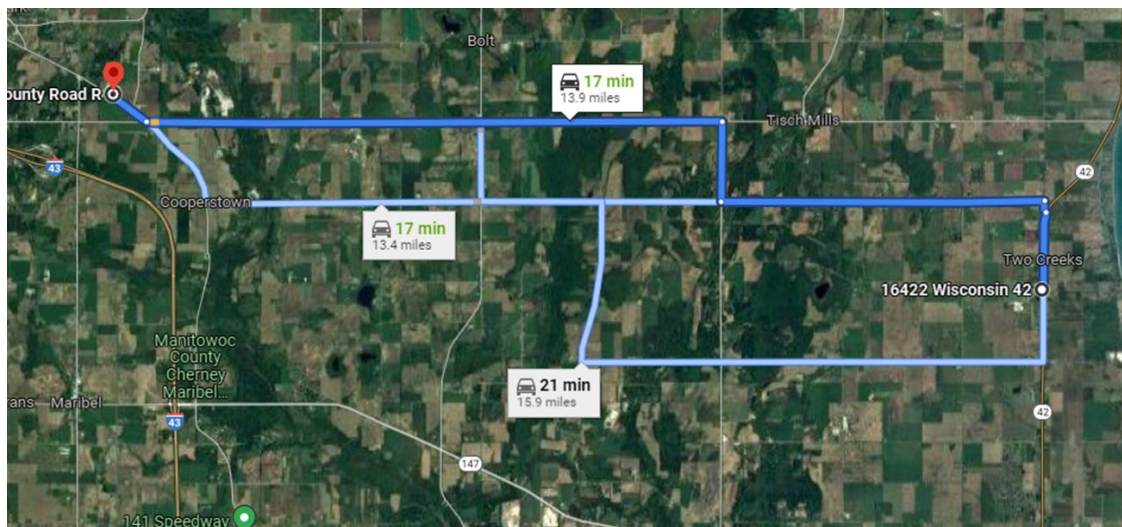


Exhibit 7. Aerial Map of Trucking from Barta Dairy to the Digester

Heim's Hillcrest Dairy

This dairy was started in 1976, with the first lagoon constructed in 1984 and the second in 2009.

Heim's Hillcrest Dairy houses approximately 600 milking and dry cows. Prior to the digester, manure from the cows was collected from the free-stall barns and 100% was transferred to the lagoon, meaning 100% of the volatile solids are sent to the lagoon in the baseline. Prior to sending manure to the digester, the dairy did not perform complete annual cleanouts of the anaerobic storage/ treatment system and as a result, no lagoon cleanouts were modeled, consistent with previously verified practices.

In the project, all cow manure is collected and trucked 25.3 miles to the digester. The digestate is trucked back on the return trip to the anaerobic storage ponds at the dairy. There are on average over 150 truckloads per month with 4-6 loads per day.

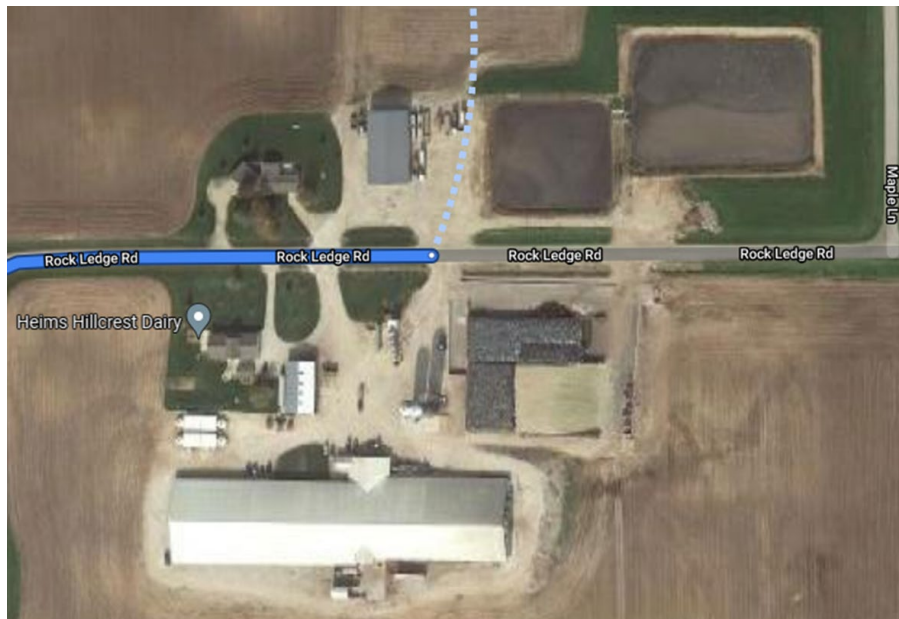


Exhibit 8. Aerial Map of Heim's Hillcrest Dairy

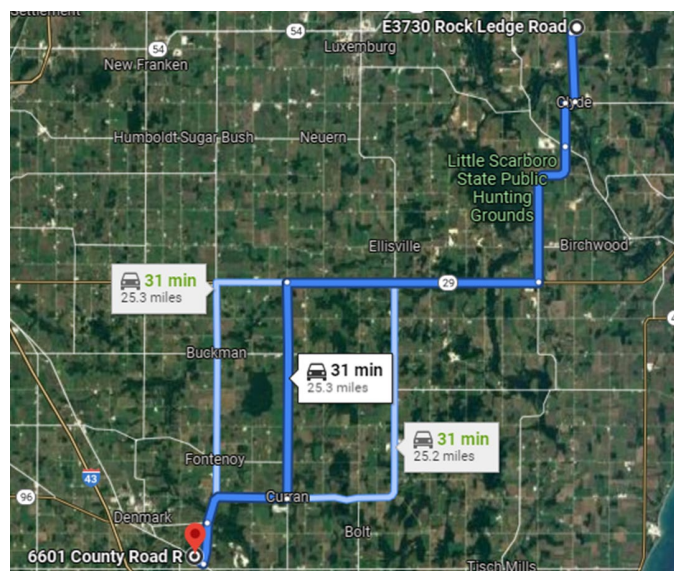


Exhibit 9. Aerial Map of Trucking from Heim's Hillcrest Dairy to the Digester

Branch View Dairy

This dairy was built prior to 1990 and has been in its current ownership since 2018. The first lagoon was built in the 1980s and expanded in the 1990s. Lagoon 2 was constructed in 2004, and lagoon 3 in 2010.

Branch View Dairy houses approximately 700 milking cows. Prior to the digester, manure from the cows was collected from the free-stall barns and 100% was transferred to the lagoon meaning 100% of the volatile solids are sent to the lagoon in the baseline. Prior to sending manure to the digester, the dairy did not perform complete annual cleanouts of the anaerobic storage/ treatment system and as a result, no lagoon cleanouts were modeled, consistent with previously verified practices.

In the project, all cow manure is collected from all but the 50 milking cows in pen 8. The cows in pen 8 spend estimated 65 minutes/day in the milking parlor, during which time their manure is collected. The collected manure is trucked 15.4 miles to the digester. The digestate is trucked back on the return trip to the anaerobic storage ponds at the dairy. There are on average over 90 truckloads per month with 2-3 loads per day.



Exhibit 10. Aerial Map of Branch View Dairy

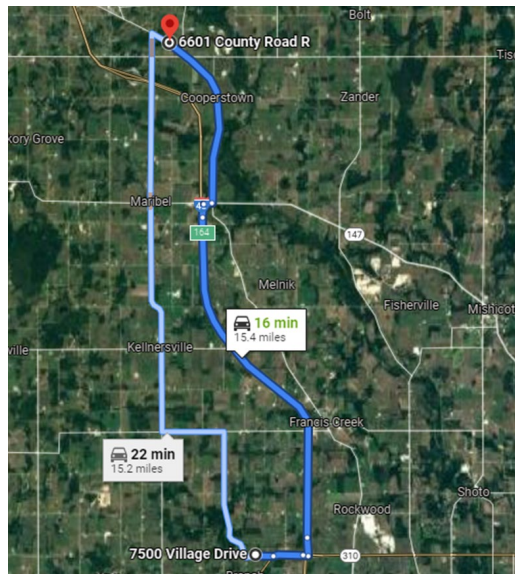


Exhibit 11. Aerial Map of Trucking from Branch View Dairy to the Digester

D&D Dairy

This dairy was started in 1910 and the lagoon was constructed in 1999.

D&D Dairy houses approximately 600 milking cows, heifers and calves. Prior to the digester, 50% of the manure from the heifers (on feed) was land applied from October thru March, and all of the remaining manure from all other cows was transferred to the lagoon, meaning less than 100% of the volatile solids are sent to the lagoon in the baseline. Prior to sending manure to the digester, the dairy did not perform complete annual cleanouts of the anaerobic storage/treatment system and as a result, no lagoon cleanouts were modeled, consistent with previously verified practices.

In the project, all cow manure, including from the heifers, is collected and trucked 16.2 miles to the digester. The digestate is trucked back on the return trip to the anaerobic storage ponds at the dairy. There are on average over 70 truckloads per month with 2-3 loads per day.

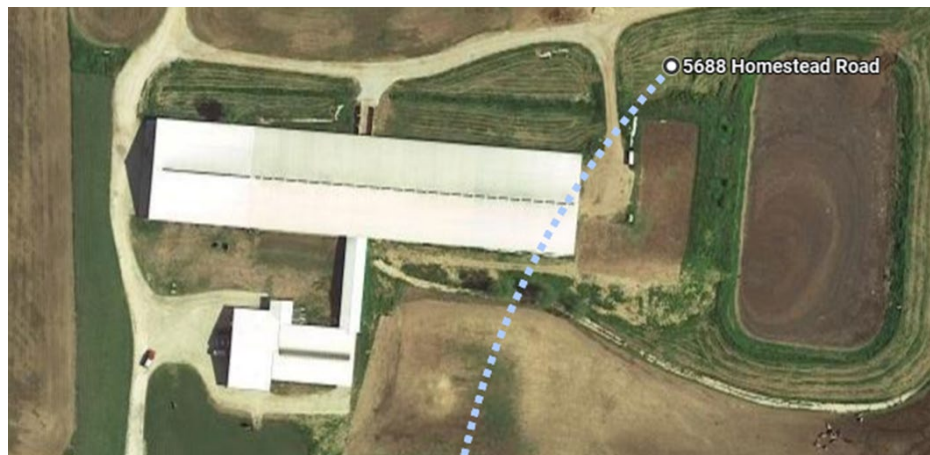


Exhibit 12. Aerial Map of D&D Dairy

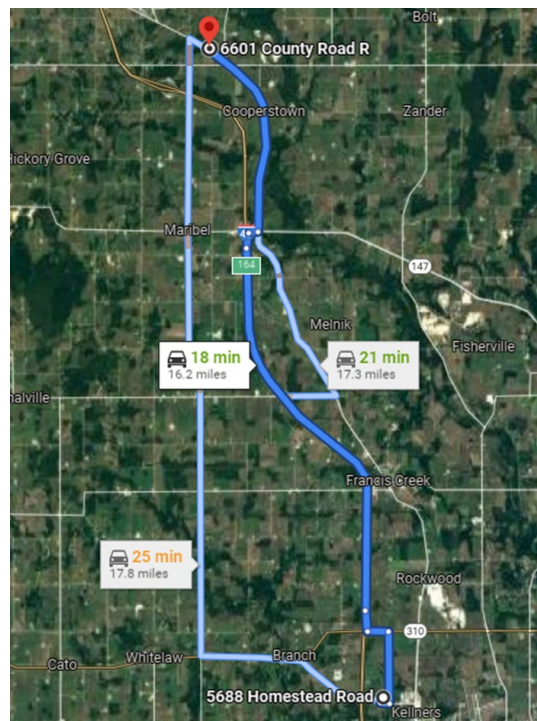


Exhibit 13. Aerial Map of Trucking from D&D Dairy to the Digester

The Facility receives biogas from the four digesters (). Digesters 2B and 3 process trucked dairy manure and digesters 1 and 2A process trucked-in high strength waste (HSW). The gas from each set of digesters is separately metered prior to the biogas upgrading system, which consists of three identical skids. One or more may be employed to meet demands.



The diagram illustrates a biogas processing system. Biogas from digesters enters a blower, then a gas washer, and an AKF filter. It then passes through a biogas compressor and a membrane unit. The system is divided into three main sections: Biogas Processing, CO2 Recycling, and Vented CO2. The CO2 Recycling section includes a CO2-Recovery plant, a CO2 compressor, and an AKF / Drier Filter. The Vented CO2 section includes a Stripper-Reboiler and a storage tank. The final products are Biomethane to Pipeline and Liquid CO2 for commercial use.

The raw biogas is fed through a gas washer and activated carbon filter to remove VOCs and H₂S contamination. The skids use multi-stage membrane technology to separate the methane from the CO₂. Membrane technology enables smaller CO₂ molecules to pass through the

membranes while rejecting the larger CH₄ molecules, which are RNG. The product gas from the upgrading skid outlet is allocated based on the dairy and HSW methane energy at the skid inlet. The methane is compressed and injected into an interstate pipeline located approximately 3 miles away. Any methane that does not meet pipeline quality specification is flared. There is no blending or adding of conventional natural gas at any point in the process. CO₂ is compressed, cleaned, dried, and cooled to the point where it is liquified and sold for commercial or industrial use.

There is also an injection point for trucked RNG at the facility, meaning the pipeline invoice needs to be allocated between dairy RNG, HSW RNG and trucked RNG.

Some of the effluent from digester is screw pressed, where the solids and liquids are separated for eventual land application. All the Cellulosic waste, solid or liquid, that has gone through the cellulosic digesters, is loaded on trucks and returned to the dairy. The diesel fuel consumption for both the transport of manure to the digester and digestate back to the farm is included in the calculator.



Exhibit 16. Aerial Map of the Facility

For this pathway, a well-to-wheel life cycle assessment (LCA) was conducted using the Tier 1 calculator to estimate the CI of CNG used in the California CNG stations. The system boundary of the LCA is shown in Exhibit 17.

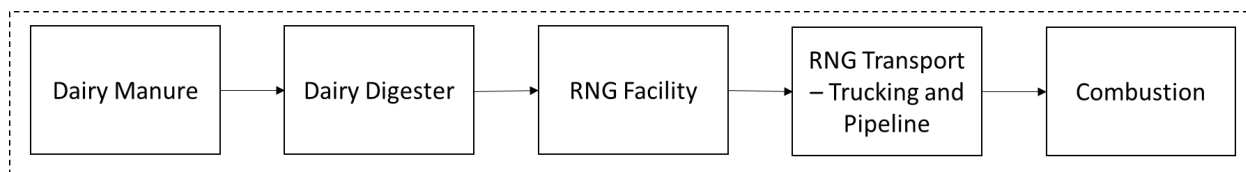


Exhibit 17. System Boundary of Manure Biogas to CNG

II. Data Collection

To calculate the baseline methane emissions, EEC provided historic cow data. A separate calculator using the September 2019 – August 2020 data was used to quantify the VS carryover to go into the first month in the actual CI calculator (September 2020). EEC provided 3 months of digester operating data for the CI calculation. Since the manure management practices of the participating 7 dairies are not the same, the cow counts and related capture fractions had to be calculated as described further below.

Below are the main files containing the source data for this pathway.

- 1) Cow Counts
 - a. Includes affidavits of cow counts. The data are tracked by dairy, livestock category, and pen number, as applicable, in a separate spreadsheet “NLC_LivestockTracking.xlsx”. The information from that spreadsheet is pulled into the DSM calculator tab “Herd Count” via external data connection, where further aggregation takes place.
- 2) Biogas data
 - a. All raw 15-minute data for raw biogas, upgrading, flaring, and decanting are compiled in one workbook, “Biogas Flow and Quality Report...”. This workbook contains all data substitution calculations and aggregations into monthly data used as inputs in the DSM calculator.
- 3) Pipeline Injection Statements
 - a. ANR pipeline injection statements
- 4) Utility invoices
 - a. Utility data are compiled in a separate spreadsheet and the tab “tblElectricityConsumption” in the DSM calculator links to those source data via external data connection.
- 5) Manure Trucking data
 - a. All truck scale transactions are automatically recorded in a Fairbanks Scale proprietary database system called “Matrex.” Matrex scale transaction records include material type and source/destination of each load. All scale transactions are extracted automatically into an intermediate PostgreSQL database and into a Microsoft Power BI dataset for further analysis. Within Power BI, additional metrics are calculated on an aggregate basis (i.e. total manure mass per month per dairy), or on an individual transaction basis (i.e. Diesel fuel consumption per load, taking into account the driving distance).
 - b. Diesel consumption data are compiled in the DSM calculator tab “Manure Trucking” via external data connection to the Power BI dataset.

- 6) Manure Management Affidavits
 - a. Includes affidavits for the manure management practices for each of the dairies.
- 7) GREET Models
 - a. Tier 1 calculator to estimate the CI of RNG
 - b. Tier 1 calculator to estimate the VS carryover for the first month.

The following table shows the dairy livestock input data, and RNG production input data. The data provided below was supplied by EEC.

Exhibit 18. Dairy Livestock Input Data for Denmark

Data/Parameters	Data Source Location	Model Location
Cow Populations	Variable by month and cow type; see "Cow Count Summary" file in the Cow Counts folder	"Manure to Biogas (LOP Inputs)" tab, section L.1.{1...4}.6
Fraction of VS sent to the lagoon in the baseline	See LCA Appendix for PFD and values from manure management affidavits	"Manure to Biogas (LOP Inputs)" tab, section L.1.{1...4}.11
Baseline Methane Emissions from Non-Anaerobic Storage/Treatment	See LCA Appendix for PFD and values from manure management affidavits	"Manure to Biogas (LOP Inputs)" tab, section L.2.1 and L.2.3
Fraction of VS sent to the BCS system in the project case	See LCA Appendix for PFD and values from manure management affidavits	"Manure to Biogas (LOP Inputs)" tab, section L.4.5
Manure managed in non-BCS system in the project case	See LCA Appendix for PFD and values from manure management affidavits	"Manure to Biogas (LOP Inputs)" tab, section L.5.1.b and L.5.3

The total amount of biogas produced in each month, biogas methane content, monthly RNG production as well as energy (electricity, natural gas, diesel) consumption were extracted from the data sources and shown in Exhibit 19.

Because Facility also receives manure from sources outside of this pathway, the produced biogas amount is allocated to this pathway per the following formula:

$$\text{Allocated Input} = \left(\frac{\text{Livestock Population of Fuel Pathway Manure Sources}}{\text{Livestock Population for All Manure Sources}} \right) \times (\text{Unallocated Input Value})$$

Exhibit 19. Biogas Production Input Data

Data/Parameters	Data Source Location	Model Location
Raw biogas production and methane content	Variable by month; see the tab "For DSM Calculator" in the Biogas Flow and Quality Report and the Allocation Tab in the calculator	"Biogas-to-RNG" tab, section 2.4,2.5
Raw biogas feedstock and methane content	Variable by month; see the tab "For DSM Calculator" in the Biogas Flow and Quality Report	"Biogas-to-RNG" tab, section 2.6,2.7
Digester natural gas use	Variable by month; see the invoices located in the Utilities Folder and the Allocation Tab in the calculator	"Biogas-to-RNG" tab, section 2.13
Gas processing electricity use	Variable by month; see the invoices located in the Utilities Folder and the ElectricityConsumption Tab in the calculator	"Biogas-to-RNG" tab, section 2.18
Flared gas and its biomethane content	Variable by month; see the tab "For DSM Calculator" in the Biogas Flow and Quality Report and the Allocation Tab in the calculator	"Biogas-to-RNG" tab, section 2.21, 2.22
Diesel for Trucking Manure	See the Manure Trucking Tab in the Calculator	"Biogas-to-RNG" tab, section 2.14
Biomethane injected into pipeline	See the Pipeline Injection Statements Folder and the Allocation tab in the calculator	"Biogas-to-RNG" tab, section 2.23

Model wide assumptions and inputs include: MROE electricity grid mix (Section 2.1); enclosed vessel digester type (Section P1.1), annual average temperature of <10° Celsius (Section 1.10) and 2,139 miles of transport distance from the Facility to Bakersfield, CA (Section 2.27.a).

In Tier 1 calculator, section L1.{1...4}.14, the carryover VS from the previous month is defined as the difference between the VS available for degradation and the VS degraded from the previous month. VS carryover in month 1 (September 2020) was quantified in the VS Carryover GREET model.

Additional model modifications applied to the Tier 1 calculator are included in Exhibit 20.

Exhibit 20. List of Modifications Made to the Dairy Manure Tier1 Calculator

Cell Location	Default Value	Modified Value
"EF Table" tab, Cell E86	2.00%	=IF(2.00%>F86,2.00%,F86)
"EF Table" tab, Cell F86	-	=('Biogas-to-RNG'!F55-'Biogas-to-RNG'!U55-'Biogas-to-RNG'!V55)/'Biogas-to-RNG'!F55
"Biogas-to-RNG" tab, Cell D52	=IFERROR(AVERAGE(D28:D51),0)	=IFERROR(SUMPRODUCT(D28:D51,C28:C51)/C52,0)
"Biogas-to-RNG" tab, Cell F52	=IFERROR(AVERAGE(F28:F51),0)	=IFERROR(SUMPRODUCT(F28:F51,E28:E51)/E52,0)
"Biogas-to-RNG" tab, Cell U52	=IFERROR(AVERAGE(U28:U51),0)	=IFERROR(SUMPRODUCT(U28:U51,T28:T51)/T52,0)

III. GREET Results

Exhibit 21 shows the extracted results from a table created on the “Biogas to RNG” tab for the dairy manure in Section 4 of the Tier 1 calculator.

Exhibit 21. Total Carbon Intensity for RNG

Process Stage	Carbon Intensity (gCO ₂ e/MJ)
Raw Biogas Production-Digester	
Biogas Upgrading	
NG Transmission	
RNG Compression	3.50
Combustion	60.73
Methane Credit	
CO ₂ Diverted	
Total – (gCO ₂ e/MJ)	-284.21

IV. Appendix

1. Site-Specific Inputs

Since not all dairies have the same manure management practices, additional calculations are necessary to determine the appropriate input values across all dairies for fields L1.X.11, L2.3, L4.5, and L5.3. Generally, the related fractions and factors are calculated for the time frame June-August 2021. They are aggregated across dairies based on headcount-weighted averages within each livestock category. The data for individual dairies, livestock categories, pens (if applicable), and months are obtained from the centralized Livestock Tracking spreadsheet which contains the necessary detailed information based on the affidavits provided by the dairies.

The involved calculations are described in further detail below.

- Section L1 – fields L1.*.11
 - The overall fraction of Volatile Solids that was handled in an uncovered anaerobic lagoon in the baseline scenario $MS_{AS,L}$ (BaselineManureCaptureFraction [%]) is obtained from a pivot table, which is linked from a Power BI dataset where the headcount-weighted average manure capture fraction is calculated across the selected dairies for a given month and livestock category, as shown by the DAX expression below:
 - `[BaselineManureCaptureFraction [%]] = divide(sumx(tblLivestockTracking, tblLivestockTracking[Baseline % of Manure to Lagoon] * tblLivestockTracking[Livestock Count] ), sum(tblLivestockTracking[Livestock Count]))`
- Section L2 – field L2.1
 - The overall fraction of Volatile Solids that was handled in any non-anaerobic storage/treatment system $MS_{L,nAS}$ in the baseline scenario is calculated as follows for each livestock category across the dairies and reporting months, using the information from two separate pivot tables which are linked to the Power BI dataset containing the detailed Livestock Tracking information:
 - $MS_{L,nAS} = \frac{BaselineUncapturedEquivHeadCount}{HeadCount}$, where the numerator refers to the uncaptured headcount in the baseline scenario, and the denominator is the raw headcount in the project scenario (which is the same value as the baseline scenario headcount), and
 - `BaselineUncapturedEquivHeadCount = sum(tblLivestockTracking[Baseline Equiv. Uncapt'd Headcount])`
 - Where `Baseline Equiv. Uncapt'd Headcount`=(1-[@[Baseline % of Manure to Lagoon]])*[@[Livestock Count]]]; which is calculated within the Livestock Tracking table. This headcount represents the equivalent number of animals (not necessarily a whole number) from the baseline scenario, of which the manure was sent to the respective alternate non-anaerobic storage/treatment systems.
 - `HeadCount = sum(tblLivestockTracking[Livestock Count] )`

- Where *Livestock Count* is the full livestock headcount for the respective livestock categories for a given month, dairy, and pen number (if applicable).
- Section L4 – field L4.5
 - The overall fraction of Volatile Solids that are sent to the BCS, $MS_{L,BCS}$, in the project scenario is calculated as follows for each livestock category across the dairies and reporting months, using the information from two separate pivot tables which are linked to a Power BI dataset containing the detailed Livestock Tracking information:
 - $MS_{L,BCS} = 1 - \frac{ActualUncapturedEquivHeadCount}{HeadCount}$, where the numerator refers to the actual uncaptured headcount in the project scenario, and the denominator is the headcount in the project scenario, and
 - `ActualUncapturedEquivHeadCount = sum(tblLivestockTracking[ActualUncapt'd Headcount] )`
 - Where `Actual Uncapt'd Headcount` is the equivalent headcount (not necessarily a whole number) representing the number of animals from the project scenario, of which the manure was captured.
 - *Headcount* is defined the same way as above.
- Section L5 – field L5.3
 - The overall fraction of Volatile Solids that was handled in a non-anaerobic storage/treatment system $MS_{L,S}$ in the project scenario is calculated as follows for each livestock category and treatment system across the dairies and reporting months, using the information from two separate pivot tables which are linked to a Power BI dataset containing the detailed Livestock Tracking information:
 - $MS_{L,S} = \frac{ActualUncapturedEquivHeadCount}{HeadCount}$, where the numerator refers to the actual uncaptured headcount in the project scenario and the denominator is the headcount in the project scenario, and
 - `ActualUncapturedEquivHeadCount = sum(tblLivestockTracking[ActualUncapt'd Headcount] )`
 - Where `Actual Uncapt'd Headcount` is the equivalent headcount (not necessarily a whole number) representing the number of animals from the project scenario, of which the manure was captured.
 - *Headcount* is defined the same way as above.

Summing the respective underlying values across dairies and months results in the correctly calculated overall fractions. There is also a checking calculation to ensure that the sum of the headcount-weighted average fractions of L1*.11 and L2 add up to exactly 1 for each livestock category. A similar checking calculation is implemented for L4+L5.

2. Manure Management Flowcharts

Manure management practices vary by dairy. Below flowcharts show the manure management practices before and after the project beginning, and they are grouped by dairies with similar practices.

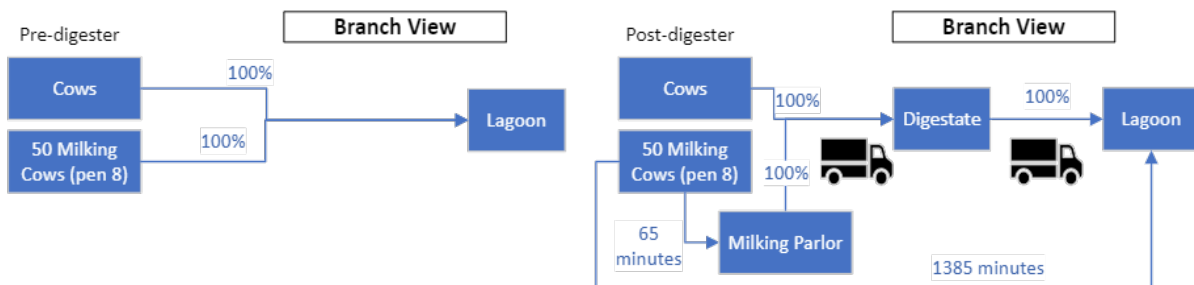
2.1 100% manure collection pre- and post-digester

This applies to dairies Leiterman and Heim's Hillcrest.



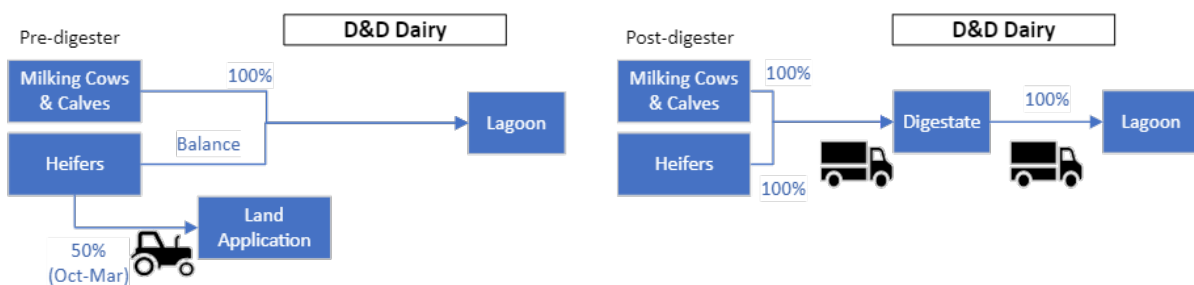
2.2 100% manure collection pre-digester and partial manure collection post-digester

This applies to Branch View dairy.



2.3 Partial manure collection pre-digester and 100% collection post-digester

This applies to D&D dairy.



2.4 Partial manure collection pre- and post-digester

This applies to dairies Barta, Rolling Hills I, and Rolling Hills II

