APPENDIX F-3

Greenhouse Gas Emissions Model Methodology and Calculations

GREENHOUSE GAS EMISSIONS QUANTIFICATION: METHODOLOGY AND CALCULATIONS

As set forth in CEQA Guidelines Section 15064.4(c), the lead agency has discretion to select the model or methodology it considers most appropriate to enable decision makers to intelligently take into account the project's incremental contribution to climate change. Where direct quantification of emissions is not possible, they may be described qualitatively.

For the purposes of this Environmental Impact Report, the proposed dairy expansion project estimated calculations include greenhouse gas (GHG) emissions that occur at the project dairy farm, but it does not account for the full production system of the dairy beyond the farm boundaries, nor does it include any soil carbon sequestration in the field. More complicated models are useful for understanding farm processes and their interacting effects on overall greenhouse gas emissions, and they can assist in the development and evaluation of mitigation strategies for reducing emissions and improving overall sustainability of dairy farms[1]. However, in order to provide a more direct estimate for decision support, this assessment uses a simpler method based on emission factors and basic calculator models available to estimate GHG emissions from the animals, manure management, lagoons, energy use at the dairy, vehicle use and trucking, and from cropping activities. These simpler emission methodologies generally result in larger overall GHG emissions since they do not include emission sinks that are used in life cycle assessment methodologies.

The proposed dairy project includes increased solid manure exported offsite to be applied to cropland in the area. This analysis assumes animal wastes used as fertilizer would replace all or a portion of existing synthetic fertilizers used on existing cropland, and no feature of general best practices in the San Joaquin Valley would require the application of greater amounts of fertilizer than those currently used. Therefore, it is assumed that N_2O emissions from offsite agricultural fields would not change dramatically, and the GHG emissions from exported manure applied to offsite fields are not included in this analysis.

Listed below are the GHG emission sources and calculation methodologies used for this analysis.

GHG Emissions from the Dairy: Enteric Emissions, Lagoons, Manure Spreading and Storage

The San Joaquin Valley Air Pollution Control District Dairy Calculator (Rev. January 6, 2020, updated with CARB emission factors from the Year 2021 GHG Inventory) was used to estimate GHG emissions from the existing and proposed herd, including emissions from the lagoon, manure spreading, solid manure storage, and enteric emissions. The calculator uses GHG emission factors by animal type to determine CH_4 and N_2O emissions from these sources, and converting the emissions into carbon dioxide (CO_2) equivalents (see calculations included in this appendix).

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1 Rotz, A. 2018. Modeling greenhouse gas emissions from dairy farms. J. Dairy Sci. 101:6675–6690. July 01, 2018. Accessed on May 4, 2023 at: <https://doi.org/10.3168/jds.2017-13272>

GHG Emissions from Energy Use

Based on annual energy use provided by the project applicant, a factor for energy use per cow per year was developed. This per cow factor was used to calculate estimated energy use for the proposed expanded herd. Because there are energy efficiencies that occur with a larger herd size, this is considered a conservative estimate methodology.

GHG Emissions from Mobile Sources

GHG emissions from vehicle trips (employee trips, milk tanker trucks, commodities transport, solid manure transport, etc.) and off-road equipment sources (feed loading, bedding delivery, manure scraping, manure loading, and feed delivery) were estimated using CalEEMod Version 2020.4.0. Due to the limited amount, estimated GHG emissions from solid waste were included with mobile source emissions.

GHG Emissions from Agricultural Activities

The two major greenhouse gases from field crop agriculture are carbon dioxide (CO_2) and nitrous oxide (N_2O). Carbon dioxide is emitted through fossil fuel use on and off the farm, from activities such as vehicle use and fertilizer production. It can also be emitted or sequestered (stored) in the soil. Whether or not soil carbon sequestration occurs depends on the type of land and the farming practices, for example, soil tillage and plant residue management. Nitrous oxide is a very powerful greenhouse gas and is emitted primarily through soil management activities such as nitrogen fertilizer application. The Michigan State University's US Cropland Greenhouse Gas Calculator accounts for different cropping systems using USDA county-specific data considering crop type, tillage, fertilizer, and environmental variables to calculate greenhouse gas emissions. The dairy existing and proposed crop types and acreage were used to estimate the change in GHG emissions from project site cropland with implementation of the expansion.

Michigan State University's US Cropland Greenhouse Gas Calculator. Accessed on March 30, 2023 at <http://carboncalculator.kbs.msu.edu/>

Energy Use at the Silva Dairy

Energy Use	kWh/mo	kWh/d	kWh/yr	cows	kWh/yr/cow
Average			954,797	2,953	323.33
Estimated Proposed			2,360,318	7,300	
kWh/yr/cow				323.33	
Increase			**1,405,521**		

Greenhouse Gas Emission Rates for Electricity Use		
eGrid State	Average Output Emission Rate (lb CO2e/MWh)	Average Output Emission Rate (lb CO2e/kWh)
California	480.5	0.4805
Source: eGRID2021. Released 1/30/2023. Accessed at: <https://www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid>		

GHG Emissions from Energy Consumption

	Herd Count	Average Electricity Use (kWh/yr)	GHG Emission Rate (lbs CO_2e/kWh)	GHG Emissions (lbs CO_2e/yr)	GHG Emissions (metric tons CO_2e/yr)
T.I.D. Electricity Use	2,953	954,797	0.4805	458,780	**208**
Expansion Projection	7,300	2,360,318	0.4805	1,134,133	**514**
Increment of Increase	4,347	1,405,521	-	675,353	**306**

GHG Emissions from the Dairy - Enteric emissions, lagoons, manure spreading and storage

	Existing Total Emissions (metric tons/yr)	Proposed Total Emissions (metric tons/yr)	Increment of Increase
Tons/Year	30,253	47,608	**17,355**

See Appendix F- for GHG Calculation Worksheets

GHG Emissions from Agricultural Activities

3	Acres	Soil	N2O	Fuel	Fertilizer	Total GHG Emissions (metric tons CO_2e/yr)
		Annual Average (Metric Tons CO_2e/Acre/Year)				
Existing Cropping						
Corn/Oats	346	-0.07	0.32	0.04	0.02	107.26
Total						**107.26**
Proposed Cropping						
Corn/Oats	339	-0.07	0.32	0.04	0.02	**105.09**
Change						**-2.17**

The Michigan State University's US Cropland Greenhouse Gas Calculator accounts for different cropping systems using USDA county-specific data considering crop type, tillage, fertilizer, and environmental variables to calculate greenhouse gas emissions. Michigan State University's US Cropland Greenhouse Gas Calculator. Accessed on October 13, 2023 at <http://carboncalculator.kbs.msu.edu/>

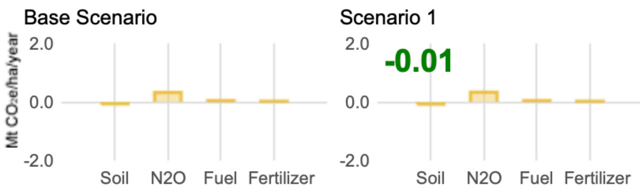
Total Greenhouse Gas Emissions

	Increased Herd (metric tons CO_2e/yr)	Increased Mobile Source* (metric tons CO_2e/yr)	Increased Electricity (metric tons CO_2e/yr)	Increased Farming Emissions (metric tons CO_2e/yr)	GHG Emissions (metric tons CO_2/yr)
Silva Dairy Expansion	17,355	144	306	-2	**17,804**

*GHG emissions from mobile sources were estimated using CalEEMod Version 2020.4.0. Due to the limited amount, estimated solid waste emissions were included with mobile source emissions above.
GHG emissions from the herd were estimated using emissions factors from the CARB. See Appendix F for calculator emissions.

Conversion Factors	
1 megawatt-hour (MWh)	1,000 kilowatt-hour (kWh)
1 short ton	2,000 pounds (lb)
1.10231 short ton	1 metric ton
2.2046 lb	1 kilogram (kg)

Instructions



Base Scenario for Merced County, CA

Greenhouse Gas Costs
CO2 equivalents (Mt/ac/year)

Year	Crop	Yield		Tillage	Fertilizer		Soil	N20	Fuel	Fertilizer	Total	
1	corn	148.3	bu/ac	reduced	142.0	lb N/ac	-0.29	0.50	0.04	0.03	0.28	
2	oats	58.0	bu/ac	reduced	66.1	lb N/ac	0.15	0.14	0.04	0.01	0.34	Remove
					Annual Average:		**-0.07**	**0.32**	**0.04**	**0.02**	**0.31**	

Add another year to the rotation | Remove last year | Recalculate | Reset

Scenario 1 for Merced County, CA Delete

Greenhouse Gas Costs
CO2 equivalents (Mt/ac/year)

Year	Crop	Yield		Tillage	Fertilizer		Soil	N20	Fuel	Fertilizer	Total	
1	corn	148.3	bu/ac	reduced	142.0	lb N/ac	-0.29	0.50	0.04	0.03	0.28	
2	oats	58.0	bu/ac	reduced	66.1	lb N/ac	0.15	0.14	0.04	0.01	0.34	Remove
3	silage	14.7	t/ac	reduced	142.0	lb N/ac	-0.11	0.33	0.04	0.01	0.27	Remove
					Annual Average:		**-0.08**	**0.33**	**0.04**	**0.02**	**0.30**	

Add another year to the rotation | Remove last year | Recalculate | Reset

Environmental Conditions

Air Temperature 47.9 to 74.8 F
Precipitation 12.16 in

Percent Clay 22 %

Bulk Density 1.5 g/cm^3
Initial Soil Carbon 0.5 %

Uncontrolled GHG Emissions Factors (lbs/hd-yr)						
Animal Type	CH4 (Anaerobic Digester Lagoon)	CH4 (Lagoon)	CH4 (Manure Spreading)	CH4 (Solid Manure Storage)	CH4 (Enteric)	CO2 Equivalent Multiplier for CH4
Milk Cows	180.93	322.94	4.99	39.95	318.14	25
Dry Cows	180.93	322.94	4.99	39.95	318.14	25
Support Stock*	54.87	97.94	1.55	--	144.56	25
Large Heifers	54.87	97.94	1.55	--	144.56	25
Medium Heifers	54.87	97.94	1.55	--	95.76	25
Small Heifers	54.87	97.94	1.55	--	95.76	25
Calves	--	--	--	--	25.59	25
Bulls*	54.87	97.94	1.55	--	144.56	25

Uncontrolled GHG Emissions Factors (lbs/hd-yr)						
Animal Type	N2O (Anaerobic Digester Lagoon)	N2O (Lagoon)	N2O (Manure Spreading)	N2O (Solid Manure Storage)	N2O (Enteric)	CO2 Equivalent Multiplier for N2O
Milk Cows	2.3914	4.20	0.55	4.22	0	298
Dry Cows	2.3914	4.20	0.55	4.22	0	298
Support Stock*	1.01	1.78	0.24	--	0	298
Large Heifers	1.01	1.78	0.24	--	0	298
Medium Heifers	1.01	1.78	0.24	--	0	298
Small Heifers	1.01	1.78	0.24	--	0	298
Calves	--	--	--	--	0	298
Bulls*	1.01	1.78	0.24	--	0	298

*Emission factors for Support Stock and Bulls assumed to be the same as Large Heifers. Where there are no emission factor provided beyond dairy cows by the GHG Inventory, none are used. For anaerobic digester lagoons, emission factors for support stock are scaled from the dairy cow emission factor.

1 short ton = 0.9072 metric ton

Global warming potential of CH4 = 25
Global warming potential of N2O = 298

CO2e from CH4 = [CH4 lagoon + CH4 manure spreading + CH4 solid manure storage + CH4 enteric] x 25 x 0.9072 metric tons/short tons ÷ 2000 lb/ton

CO2e from N2O = [N2O lagoon + N2O manure spreading + N2O solid manure storage + N2O enteric] x 298 x 0.9072 metric tons/short tons ÷ 2000 lb/ton

Note: CO2 equivalent emissions are calculated using Global Warming Potential values from the Fourth Assessment Report of the IPCC consistent with that used in the California's Greenhouse Gas Inventory (2023 Edition).

Emission factors obtained from Documentation of California's 2000-2021 GHG Inventory. Year 2021. https://ww2.arb.ca.gov/applications/california-ghg-inventory-documentation.

Pre-Project CO2e Emissions

Pre-Project Lagoon CO2e Emissions from CH4 (metric tons/yr)				
Animal Type	Number of Cows	CH4 (Lagoon) (lb/hd-yr)	CO2e Multiplier	CO2e Lagoons (metric tons/yr)
Milk Cows	1,420	322.94	25	5,200
Dry Cows	185	322.94	25	677
Support Stock	952	97.94	25	1,057
Large Heifers	0	97.94	25	-
Medium Heifers	0	97.94	25	-
Small Heifers	0	97.94	25	-
Calves	396	--	25	
Bulls	0	97.94	25	-

Pre-Project Non-Lagoon CO2e Emissions from CH4 (metric tons/yr)						
Animal Type	Number of Cows	CH4 (Manure Spreading) (lb/hd-yr)	CH4 (Solid Manure Storage) (lb/hd-yr)	CH4 (Enteric) (lb/hd-yr)	CO2e Multiplier	CO2e Non-Lagoons (metric tons/yr)
Milk Cows	1,420	4.99	39.95	318.14	25	5,847
Dry Cows	185	4.99	39.95	318.14	25	762
Support Stock	952	1.55	--	144.56	25	1,577
Large Heifers	0	1.55	--	144.56	25	-
Medium Heifers	0	1.55	--	95.76	25	-
Small Heifers	0	1.55	--	95.76	25	-
Calves	396	--	--	25.59	25	115
Bulls	0	1.55	--	144.56	25	-

Pre-Project Lagoon CO2e Emissions from N2O (metric tons/yr)				
Animal Type	Number of Cows	N2O (Lagoon) (lb/hd-yr)	CO2e Multiplier	CO2e Lagoons (metric tons/yr)
Milk Cows	1,420	4.20	298	806
Dry Cows	185	4.20	298	105
Support Stock	952	1.78	298	229
Large Heifers	0	1.78	298	-
Medium Heifers	0	1.78	298	-
Small Heifers	0	1.78	298	-
Calves	396	--	298	
Bulls	0	1.78	298	-

Pre-Project Non-Lagoon CO2e Emissions from N2O (metric tons/yr)						
Animal Type	Number of Cows	N2O (Manure Spreading) (lb/hd-yr)	N2O (Solid Manure Storage) (lb/hd-yr)	N2O (Enteric) (lb/hd-yr)	CO2e Multiplier	CO2e Non-Lagoons (metric tons/yr)
Milk Cows	1,420	0.55	4.22	0	298	916
Dry Cows	185	0.55	4.22	0	298	119
Support Stock	952	0.24	--	0	298	31
Large Heifers	0	0.24	--	0	298	-
Medium Heifers	0	0.24	--	0	298	-
Small Heifers	0	0.24	--	0	298	-
Calves	396	--	--	0	298	-
Bulls	0	0.24	--	0	298	-

Total Pre-Project CO2e Emissions (metric tons/yr)			
Animal Type	CO2e from CH4	CO2e from N2O	Total
Milk Cows	11,047	1,722	12,769
Dry Cows	1,439	224	1,664
Support Stock	2,635	260	2,895
Large Heifers	0	-	-
Medium Heifers	0	-	-
Small Heifers	0	-	-
Calves	115	-	115
Bulls	0	-	-
Total			**17,442**

Post-Project CO2e Emissions

Post-Project Lagoon CO2e Emissions from CH4 (metric tons/yr)				
Animal Type	Number of Cows	CH4 (Lagoon) (lb/hd-yr)	CO2e Multiplier	CO2e Lagoons (metric tons/yr)
Milk Cows	4,000	322.94	25	14,649
Dry Cows	500	322.94	25	1,831
Support Stock	2,200	97.94	25	2,444
Large Heifers	0	97.94	25	-
Medium Heifers	0	97.94	25	-
Small Heifers	0	97.94	25	-
Calves	400	--	25	
Bulls	0	97.94	25	-

Post-Project Non-Lagoon CO2e Emissions from CH4 (metric tons/yr)						
Animal Type	Number of Cows	CH4 (Manure Spreading) (lb/hd-yr)	CH4 (Solid Manure Storage) (lb/hd-yr)	CH4 (Enteric) (lb/hd-yr)	CO2e Multiplier	CO2e Non-Lagoons (metric tons/yr)
Milk Cows	4,000	4.99	39.95	318.14	25	16,469
Dry Cows	500	4.99	39.95	318.14	25	2,059
Support Stock	2,400	1.55	--	144.56	25	3,976
Large Heifers	0	1.55	--	144.56	25	-
Medium Heifers	0	1.55	--	95.76	25	-
Small Heifers	0	1.55	--	95.76	25	-
Calves	400	--	--	25.59	25	116
Bulls	0	1.55	--	144.56	25	-

Post-Project Lagoon CO2e Emissions from N2O (metric tons/yr)				
Animal Type	Number of Cows	N2O (Lagoon) (lb/hd-yr)	CO2e Multiplier	CO2e Lagoons (metric tons/yr)
Milk Cows	4,000	4.20	298	2,271
Dry Cows	500	4.20	298	284
Support Stock	2,200	1.78	298	530
Large Heifers	0	1.78	298	-
Medium Heifers	0	1.78	298	-
Small Heifers	0	1.78	298	-
Calves	400	--	298	
Bulls	0	1.78	298	-

Post-Project Non-Lagoon CO2e Emissions from N2O (metric tons/yr)						
Animal Type	Number of Cows	N2O (Manure Spreading) (lb/hd-yr)	N2O (Solid Manure Storage) (lb/hd-yr)	N2O (Enteric) (lb/hd-yr)	CO2e Multiplier	CO2e Non-Lagoons (metric tons/yr)
Milk Cows	4,000	0.55	4.22	0	298	2,580
Dry Cows	500	0.55	4.22	0	298	323
Support Stock	2,400	0.24	--	0	298	77
Large Heifers	0	0.24	--	0	298	-
Medium Heifers	0	0.24	--	0	298	-
Small Heifers	0	0.24	--	0	298	-
Calves	400	--	--	0	298	-
Bulls	0	0.24	--	0	298	-

Total Post-Project CO2e Emissions (metric tons/yr)			
Animal Type	CO2e from CH4	CO2e from N2O	Total
Milk Cows	31,118	4,851	35,969
Dry Cows	3,890	606	4,496
Support Stock	6,420	607	7,027
Large Heifers	0	-	-
Medium Heifers	0	-	-
Small Heifers	0	-	-
Calves	116	-	116
Bulls	0	-	-
Total			**47,608**

Change in CO2e Emissions

Change in CO2e Emissions (metric tons/yr)			
Animal Type	Pre-Project CO2e	Post-Project CO2e	Change
Milk Cows	12,769	35,969	23,200
Dry Cows	1,664	4,496	2,833
Support Stock	2,895	7,027	4,132
Large Heifers	0	-	-
Medium Heifers	0	-	-
Small Heifers	0	-	-
Calves	115	116	1
Bulls	0	-	-
Total			**30,166**