State of Oregon

Department of Environmental Quality — Memorandum

Date: Nov. 2, 2022

To: Environmental Quality Commission

From: Leah Feldon, Interim Director

Subject: Item A: Petition to Promulgate Dairy Air Emissions Regulatory Program (Action)
Nov. 9, 2022, EQC special meeting

Why this is important

The EQC received a petition on Aug. 17, 2022, that requests the promulgation of new rules to quantify and control air pollution from large dairy confined animal feeding operations (dairy CAFOs). The petition contains proposed rule language that would establish a new dairy air emissions program and establish policies to quantify and regulate air emissions from large dairy CAFOs.

According to the statute, EQC must either deny the petition or initiate rulemaking proceedings within 90 days of receiving the petition.

What the petition asserts

According to the petitioners, dairy CAFOs present a direct and serious impact on air quality and pose a direct threat to public health, particularly for the dairy workers and communities near operations that are often environmental justice communities of concern.

The petitioners assert that these operations emit major air pollutants including ammonia, hydrogen sulfide, methane, methanol, volatile organic compounds, nitrogen oxides, particulate matter, and odors; and contribute significantly to climate change in Oregon.

Regulated entities

The petition defines large dairy CAFOs as those permitted to confine 700 or more mature dairy cows that have or will use a liquid manure handling system.

Potential regulated entities of the proposed petition rules would be large dairy CAFO owners and operators. Based on one currently available estimation methodology, at least three dairy CAFOs likely exceed federal permitting thresholds for volatile organic compounds (VOCs). Under the petitioners proposed rules, approximately 44 additional dairy CAFOs would be required to obtained Air Contaminant Discharge Permits.

Public comment

DEQ accepted public comment on the proposed rulemaking from October 3 until 4 p.m. on Oct. 23, 2022. DEQ received 1,649 comments, 21 of these comments were received after the comment deadline. 1,578 comments supported the regulations proposed in the petition, 58 opposed the proposed regulations, and 13 comments were neither supporting nor opposed.

Petition analysis

DEQ's analysis indicates that, overall, the proposed rules would fall within EQC's authority to regulate air emissions from agricultural operations. DEQ has identified areas in the proposed program where additional data needs to be collected and emissions estimation methods finalized before a program would be practically developed and implemented. This additional information includes establishing an appropriate model for conducting Air Impact Analyses and methods to quantify emissions reductions from various best management practices.

DEQ and ODA resources

DEQ's Air Quality Program does not have funding or resources to implement a program that is being suggested by the petitioners. A Dairy Air Emissions Program would require both DEQ regional and headquarters resources as well as ODA resources. The resources needed would depend on how the program is developed and if EPA succeeds in developing a usable tool to estimate emissions.

DEQ has ongoing work related to the goals of the petition that is consistent with currently funded programs. This includes following EPA's work on NAEMS and reporting requirements, examining environmental justice priorities regarding dairy CAFOs, examining potential visibility impacts from dairy CAFOs, and implementing a federally required program that may include the issuance of air quality permits.

DEQ recommendation

DEQ recommends that the Environmental Quality Commission (EQC) deny the Petition to Promulgate Dairy Air Emissions Regulatory Program in writing.

DEQ recommends that implementation of a dairy air program be postponed until EPA finalizes the National Air Emissions Monitoring Study (NAEMS) and additional resources are provided to DEQ and ODA to design and implement such a program. In the event of funding of a dairy air emissions program by the legislature, the report lists actions that would be important components in creating a comprehensive dairy air emissions program.

Report prepared by Heather Kuoppamaki
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State of Oregon Department of Environmental Quality

Oregon Environmental Quality Commission Special Meeting

Nov. 9, 2022

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DEQ Recommendation to the Environmental Quality Commission

DEQ recommends that the Environmental Quality Commission (EQC), per the statutory requirements of ORS 183.390, deny the Petition to Promulgate Dairy Air Emissions Regulatory Program in writing.

Recommended motion language:
"I move that the Oregon Environmental Quality Commission deny the rulemaking petition to promulgate a Dairy Air Emissions Regulatory Program proposed by the Food & Water Watch and 21 co-petitioners on August 17, 2022."

Overview

Summary of Petition

The EQC received a petition on Aug. 17, 2022, that requests the promulgation of new rules to quantify and control air pollution from large dairy confined animal feeding operations (large dairy CAFOs). The petition defines large dairy CAFOs as those permitted to confine 700 or more mature dairy cows that have or will use a liquid manure handling system. The petition contains proposed rule language that would establish a new dairy air emissions program and establish policies to quantify and regulate air emissions from large dairy CAFOs. DEQ finds that the petition contains the minimum elements required by OAR 137-001-0070 to be considered a petition for rulemaking. The petition is included as Appendix A of this report.

New Rules Proposed by the Petition

The petition requests that the Commission promulgate new rules establishing a dairy air emissions program to quantify and regulate air emissions from large dairy CAFOs to comply with federal Clean Air Act requirements (CAA), achieve state greenhouse gas reduction goals, and implement recommendations of the Dairy Air Quality Task Force.

The program proposed in the petition would establish a permitting program, implemented by DEQ, for existing, new, and expanding large dairy CAFOs. The permitting program would have the following main elements:

Regulated Sources - The proposed rules would apply to "Regulated Dairies" which are Grade A dairy operations that:

- Confine and feed or maintain animals for a total of 45 days or within a 12-month period
- Do not sustain crops, vegetation, forage growth, or post-harvest residues in the normal growing season over any portion of the lot or facility
- Are permitted to confine 700 or more mature dairy cows, whether milked or dry; and
- Have or will use a liquid manure handling system.

Air Impact Assessment - Under the proposed rules, Regulated Dairies would be required to submit an Air Impact Assessment (AIA) with a permit application. The AIA would be required to:

- Estimate the baseline as well as mitigated emissions of: Ammonia, Hydrogen Sulfide, Methane, Nitrogen Oxides, Nitrous Oxides, Particulate Matter, and Volatile Organic Compounds.
- Be conducted using a Department-approved model.
- Include an analysis of visibility impacts for Regulated Dairies that exceeded federal CAA permitting thresholds.

2-Tier System - Under the proposed rules, Regulated Dairies would be required to implement BMPs based on a 2-Tiered system. The two tiers would be:

- Tier 1 sources would have the potential to exceed regulated pollutants above the federal CAA permitting thresholds and would be required to obtain a federal permit and implement Tier 1 BMPs. DEQ would promulgate Maximum Achievable Control Technology (MACT) if any regulated dairies require a Title V permit for HAP.
- Tier 2 sources would have the potential to emit regulated pollutants below the federal permitting thresholds and would be required to obtain an air contaminant discharge permit and implement Tier 2 BMPs.

Best Management Practices - Under the proposed rules, DEQ would select BMPs based on those practices identified as capable of achieving quantifiable emissions reductions by:

- EPA and USDA in the "Agricultural Air Quality Conservation Measures: Reference Guide for Poultry and Livestock Production Systems;[1]"
- The University of Idaho College of Agricultural and Life Sciences in "Dairy Ammonia Control Practices;[2]" and the
- San Joaquin Valley Air Pollution Control District in "Phase II Rule 4570 Permit Application Form.[3]"

Background Information on Rulemaking Petitions

Oregon law allows any person to petition an agency to promulgate, amend, or repeal a rule. Oregon Revised Statute 183.390 and administrative rules at OAR 340-011-0046 and 137-001-0070 describe the requirements for the petition and for agency review. A petition to adopt new rules must include the full text of proposed rules and provide facts and arguments supporting the proposal. According to the statute, the agency must either deny the petition or initiate rulemaking proceedings within 90 days of receiving the petition.

Upon its review, the EQC must either:

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[1] United States Department of Agriculture, United Stated Environmental Protection Agency, September 2017 *Agricultural Air Quality Conservation Measures, Reference Guide for Poultry and Livestock Production Systems.*
[2] Ron E. Sheffield and Bruce Louks, Dairy, University of Idaho Extension, April 2007 *Ammonia Control Practices*.
[3] San Joaquin Valley Air Pollution Control District, Phase II Rule 4570 Permit Application Form, Calf Ranch, Heifer Ranch, or Other Cattle (CAF) Mitigation Measures, 7,500 head or more. http://valleyair.org/farmpermits/updates/applications/4570/beef_feedlot_caf_phase_2.doc

1) Deny the petition, or
2) Direct DEQ to initiate rulemaking proceedings.

Background Information on Dairy Air

Federal Dairy Air Regulation History

Below is a summary of federal activities and key reports regarding air emissions from agricultural sources. A more comprehensive timeline is provided in Appendix B.

In August 2001, EPA published a report which contained methodologies for estimating farm-level emissions from animal feeding operations (AFOs) in the beef, dairy, swine, and poultry (broilers, layers, and turkeys) animal sectors.[4] Reports issued by the National Academy of Sciences (NAS) in 2002 and 2003 identified issues with using standard emission factor methods for estimating CAFO emissions and noted that additional data was needed to develop emission estimating methodologies[5,6].

In January 2005, EPA announced the voluntary Air Compliance Agreement with the AFO industry[7]. The goals of the Air Compliance Agreement were to reduce air pollution, monitor AFO emissions, and promote a national consensus on methodologies for estimating emissions from AFOs. Fees assessed from the AFOs participating in the Air Compliance Agreement were used to fund the National Air Emission Monitoring Study (NAEMS).

In 2012, EPA presented draft NAEMS results and proposed methodology for dairy emissions of ammonia, but they were unable to develop a methodology for VOC. The EPA's Science Advisory Board (SAB) reviewed and rejected the 2012 data and methodologies. In 2013 the SAB recommended re-working the data to develop a different methodology.

In September 2017, EPA Office of Inspector General issued a report identifying that EPA's ability to characterize and address AFO air emissions was unchanged since its 2005 Agreement with the AFO industry intended to produce reliable emissions estimation methods[8].

In June 2022, EPA published the draft *Development of Emissions Estimating Methodologies for Dairy Operations*. This report contains draft emissions estimating models for NH_3, H_2S, PM, and total suspended particulate (TSP) emissions for various dairy operations. According to EPA's National Air Emissions Monitoring Study website, draft models for VOC emissions from swine,

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[4] U.S. Environmental Protection Agency, August 15, 2001, *Emissions from Animal Feeding Operations – Draft*, Office of Air Quality Planning and Standards, EPA Contract No. 68-C6-0011, Task Order 71

[5] National Research Council 2002. *The Scientific Basis for Estimating Emissions from Animal Feeding Operations – Interim Report.*

[6] National Research Council 2003. *Air Emissions from Animal Feeding Operations: Current Knowledge, Future Needs*. Washington, DC: The National Academies Press. https://doi.org/10.17226/10586.

[7] Animal Feeding Operations Consent Agreement and Final Order, 70 Fed. Reg. 4958 (Jan 31, 2005)

[8] EPA Office of Inspector General, September 19, 2017, *Eleven Years After Agreement, EPA Has Not Developed Reliable Emission Estimation Methods to Determine Whether Animal Feeding Operations Comply with Clean Air Act and Other Statutes*, Report No. 17-P-0396

poultry, and dairy farms were scheduled for release in August 2022. EPA expects to finalize all AFO emission models in late 2023.

Oregon Dairy Air Regulation History

Legislation adopted in 1993, and updated in 1995 and 2001, declares farm and forest practices as critical to the welfare of the Oregon economy and establishes the Farming and Forest Practices Act. This law protects growers from court decisions based on customary noises, smells, dust or other nuisances or trespasses. It also limits local governments and special districts from administratively declaring certain farm and forest products to be nuisances or trespasses (ORS 30.930).

Until 2007, Oregon law generally exempted most agricultural operations from air quality regulations, with the primary exception being for regulation of field burning in the Willamette Valley. On November 1, 2005, several environmental groups filed a petition requesting EPA to determine that Oregon's Title V program does not meet CAA requirements because state law exempts agricultural operations.

The 2007 Oregon Legislature passed Senate Bill 235 (SB 235, the Bill) to allow the EQC to regulate agricultural operations to the extent necessary to implement the CAA. The Bill directed DEQ and ODA to enter into a Memorandum of Understanding to implement the federal CAA requirements for agriculture. Additionally, SB 235 established a Dairy Air Task Force (DATF), legislated its membership, and charged it with studying the emissions from dairy operations, evaluating available alternatives for reducing emissions, and presenting findings and recommendations to the DEQ and ODA. The Bill also allowed the EQC to implement recommendations of the Task Force beyond CAA requirements.

On July 1, 2008, the DATF published the *Final Report to the Department of Environmental Quality & Department of Agriculture* that provided recommendations on the development of an "Oregon Dairy Air Emissions Program" (the Program)[9]. Both ODA and DEQ have submitted requests to the Oregon Legislature for funding to implement the recommendations of the DATF, but no funding has been made available.

EQC Authority

In this section, DEQ analyzes the authority to regulate dairy air emissions in Oregon. As noted in the section on Oregon's history of dairy air regulation, EQC's authority to regulate agricultural emissions is statutorily limited, under ORS 468A.020, to the following two scenarios (with other exceptions not relevant to consideration of this petition for rulemaking):

1. As necessary to implement the federal Clean Air Act, or
2. As necessary to implement a recommendation of the Task Force on Dairy Air Quality.

Federal Clean Air Act

The Clean Air Act could apply to dairies in the following ways:

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[9] Oregon Dairy Air Quality Task Force, July 1, 2008, *Final Report to the Department of Environmental Quality & Department of Agriculture*.

- If dairy air emissions play an important role in violations of the federal National Ambient Air Quality Standard (NAAQS) for any of the criteria pollutants
- If dairy air emissions play an important role in the formation of haze pollution in National Parks and wilderness areas. For example, dairies are noted as sources of ammonia contributing to haze east of the Columbia River Gorge[10],[11],[12]
- If dairy air emissions are of a sufficient quantity to trigger air quality permitting
    - EPA has entered into a Consent Agreement with the animal feeding industry. As part of the agreement, EPA agreed not to sue participating AFOs for certain past and ongoing violations of the CAA, CERCLA, and EPCRA, provided that the AFOs comply with the agreement's conditions. This may limit DEQ's ability enforce CAA requirements as long as any such agreements remain in place.

National Ambient Air Quality Standards
The CAA requires EPA to set NAAQS for six criteria pollutants: carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter, and sulfur dioxide. NAAQS are implemented by states through state implementation plans (SIPs), based on the consideration of a broad range of factors and tools identified by Congress and EPA.

Oregon currently has one area that is in nonattainment of any of the NAAQS. Klamath Falls is in nonattainment for particulate matter. According to ODA data, Klamath Falls County has seven dairies with a maximum of just over 20,000 permitted dairy cows, heifers, and calves.

Regional Haze
In 1999, EPA announced the Regional Haze Rule which calls for state and federal agencies to work together to improve visibility in 156 national parks and wilderness areas, called Class I areas. EPA updated these rules in 2017 to streamline, strengthen, and clarify aspects of the agency's regional haze program. Oregon has 12 designated Class 1 areas and one National Scenic Area (Columbia River Gorge).

In February 2022, EQC adopted the updated federal Regional Haze rules and approved incorporating the rule amendments into the Oregon CAA State Implementation Plan. The 2021 Regional Haze Plan includes the following language on dairy operations[13]:

> *DEQ recognizes that ammonium nitrate from dairy operations is probably a significant contributor to regional haze, particularly in the winter in the Columbia Gorge. In the last two decades, DEQ, the Columbia River Gorge Commission, Southwest Washington Clean Air Agency, the Oregon Department of Agriculture, the Oregon Legislature and others have put resources toward studying visibility impacts from agriculture and refining our understanding of sources, emissions, and best management practices.*

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[10] Oregon Department of Environmental Quality, Southwest Clean Air Agency, September 15, 2011, *Columbia River Gorge Air Study and Strategy*
[11] Desert Research Institute, July 31, 2006, *Causes of Haze in the Gorge*
[12] Memo to Lisa Hanson, ODA, from David Collier, DEQ Air Quality Planning, June 6, 2008, *Subject: Ammonia and Regional Haze*
[13] Oregon Department of Environmental Quality, August 27, 2021, *Oregon Regional Haze State Implementation Plan for the period 2018-2028, submitted to: Public Notice*.

DEQ will continue partnering with ODA and other stakeholders to develop a Dairy Air Quality permitting program based on implementation of best practices. DEQ will also develop and refine the state's ammonia emission inventory and will seek EPA's assistance, as necessary.

Visibility degradation in the Columbia River Gorge Scenic Area, however, is not subject to authorities in the CAA. While the Columbia River Gorge National Scenic Area is not a Class 1 area, it was designated a National Scenic Area by Congress in 1986.

In 2011, at the request of the Columbia River Gorge Commission, Oregon DEQ and Southwest Clean Air Agency, in Washington State, completed the Columbia River Gorge Air Study and Strategy[14]. The Strategy proposed that Gorge visibility be monitored, evaluated, and improved through the framework of the Regional Haze program. The goal for visibility in the Gorge is continued improvement, the same approach used in the federal Regional Haze Program.

Additionally, the Gorge Visibility Study attributed most visibility impairment to regional, rather than local, sources of haze-forming pollutants. The rationale is that visibility improvement in the Gorge can be expected to mirror the visibility improvement in Class 1 areas such as Mt. Hood and Mt. Adams that will be achieved by emission reduction strategies adopted through the regional haze plans. The Gorge Commission approved the Strategy in 2011, and the agencies provide annual reports to the Commission as they implement the Strategy.

Permitting

The CAA establishes several permitting programs designed to carry out the goals of the Act. Major sources (and certain other sources) must obtain an operating permit that contains conditions necessary to assure compliance with all CAA requirements applicable to the source. **Major sources** are defined (in part) as stationary sources. Stationary sources are defined as any "building, structure, facility, or installation that emits or may emit any regulated air pollutant or any pollutant listed under section 112(b) [hazardous air pollutants] of the Act".

When estimating emissions from stationary sources, the emissions can be considered **fugitive or non-fugitive**. EPA defines "fugitive emissions" as "those emissions which could not reasonably pass through a stack, chimney, vent, or other functionally-equivalent opening".

Congress provided EPA with a list of **hazardous air pollutants** and EPA has identified categories of sources for control of these pollutants. Currently, dairies are not one of the identified categories, although methanol emissions may be large enough to require an air quality permit.

Consent Order

Once EPA publishes final emissions estimating methodologies for an AFO's animal sector, that AFO must apply the final methodologies to determine what actions, if any, it must take to comply with all applicable CAA requirements. To date, EPA has not published final emissions estimating methodologies. In June 2022, EPA published draft emissions estimating

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[14] https://www.swcleanair.gov/docs/ColumbiaRiverGorge/ColumbiaGorgeAirStrategyDocument-Final.pdf

methodologies for ammonia, hydrogen sulfide, and particulate matter emissions from dairy farms. EPA is due to release draft models for VOC emissions from dairy farms in 2022 and intends to publish final emission estimating methodologies in late 2023/early 2024.

Dairy Air Task Force Recommendations

The Dairy Air Task Force (DATF) included recommendations for guiding principles, program elements, program resources for the Program and recommended a Dairy Air Advisory Committee (DAAC) be convened to advise and make recommendations about Program implementation details. The final report from the DATF is provided in Appendix C.

The Program proposed by the DATF centered on establishing Best Management Practices based on approaches used in California and Idaho and recommendations from the DAAC. The proposed Program would be rolled out in two phases: Phase I would be voluntary and Phase II would be mandatory for all Grade A dairies in Oregon that have or need a CAFO permit. The Program would include tax credits for voluntary participation during Phase I and exceeding the requirements during Phase II. The Task Force recommendations on structure, staging and funding, as well as the status of the recommendations are provided in Table 1.

Table 1: DATF recommended structure, staging and funding for the Program:

Date	Staging and Funding	Current [2022] status
July 2008	Oregon Dairy Air Quality Task Force (With Co-Chairs) report to ODA and DEQ.	Completed [Appendix C]
Sept 2008	Task Force, ODA, and DEQ report (with Co-Chairs) to interim legislative committees.	
Oct/Nov 2008	Possible Task Force reconvening based upon interim legislative committee input.	
Late 2008	ODA and DEQ approve an interim list of recommended air BMPs in collaboration with ODFA, OSU, NRCS, and the stakeholders identified for DAAC.	
Jan 2009	ODA begins outreach to educate industry about the Program and encourages the use of the interim air BMPs.	
Jan-July 2009	**2009 Legislative Session:** • Request initial staffing for the program: 1 ODA and 1 DEQ staff to do outreach and assistance, conduct a baseline survey, develop rules, and implement tax credits • Request $500K for OSU research and development of BMPs that are specific to Oregon's needs • Request tax credits for voluntary BMPs to begin in 2010 and continue through 2014	No funding provided by legislature
Late 2009	1) EQC adopts initial program rules under ORS 468A.020(2)(c) based upon the Dairy Air Quality Task Force recommendations in section IV of this report, including: a) Framework for Program b) Membership and structure of the Dairy Air Advisory Committee (DAAC) c) Tax credits if EQC is authorized by the 2009 legislature 2) DAAC starts. Initial focus is to refine the air BMP list. Subsequent focus is to refine the program structure. 3) ODA conducts baseline survey of air BMPs in use in Oregon.	

Date	Staging and Funding	Current [2022] status
2010	**Phase I Begins:** • ODA/DEQ/OSU Outreach / Education begins to encourage voluntary participation in phase 1 of the Program and assist dairies in the selection of BMPs • DEQ implements the tax credits for dairies that meet the phase 1 targets • DAAC recommends Program revisions, including revisions to the BMP list, targets and program structure	
2011	**2011 Legislative Session:** • Request increased staffing for the program: 2 additional ODA staff to expand outreach implementation, and 1 DHS FTE (parts of three positions) to conduct risk communication. • Request additional funding for BMP research and development if needed. • Request $500K for OSU research and development of BMPs that are specific to Oregon's needs. • DAAC continues to evaluate Program and make recommendations, including mandatory targets to apply in 2015.	
Late 2011 and 2012	• EQC revises rules to incorporate DAAC recommendations. • ODA expands outreach and assistance, conducts follow-up survey of BMP use in Oregon, and issues Annual Program Report. • DEQ continues to implement tax credits for dairies that meet the phase 1 targets. • DAAC continues to evaluate Program; assess EPA's NAEMS preliminary results; make recommendations as needed.	
2013	**2013 Legislative Session:** • Request increased staffing for the program: 2 additional ODA staff to further implementation, monitoring, and compliance. • Request $500 K for OSU research and development of BMPs that are specific to Oregon's needs. • DAAC continues to evaluate Program and make recommendations as needed.	
Late 2013 and 2014	• EQC revises rules to incorporate any further DAAC recommendations. • ODA conducts follow-up survey of BMP use in Oregon, and issues Biennial Program Report. • DEQ continues to implement tax credits for dairies that meet the phase 1 targets. • DAAC continues to evaluate Program; assess EPA's NAEMS results; make recommendations as needed.	
2015	**2015 Legislative Session:** • Request $500 K for OSU research and development of BMPs that are specific to Oregon's needs.	
2015	**Phase II begins:** • Targets become mandatory. • ODA implements the program, ensures compliance, and issues annual Program Report. • DAAC continues to evaluate Program and make recommendations, as needed.	

Dairy CAFOs in Oregon

This section provides an overview of dairy CAFOs in Oregon. This data is provided by ODA from its implementation of the joint ODA-DEQ water quality permitting program, as it applies to CAFOs.

Figure 1 shows the locations of permitted dairy CAFOs across the state as well as Oregon's 12 designated Class I areas and the Columbia River Gorge national scenic area (2021 data). Dairies appear to be congregated in Morrow and Umatilla Counties, Tillamook County, and north Willamette Valley (Benton, Linn, Lane, Marion, Polk, Washington, and Yamhill Counties).

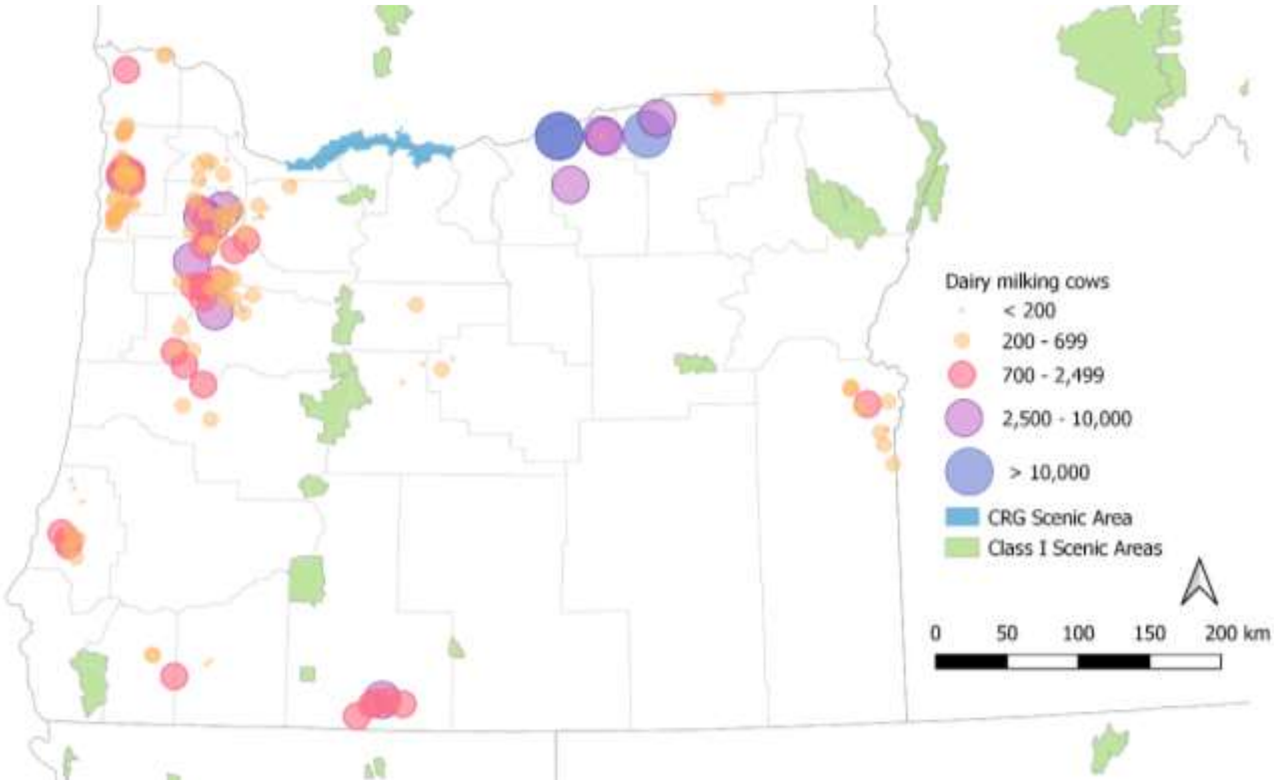

Figure 1: Dairy CAFO locations. Data provided by ODA

Figure 2 provides data on the number of dairy CAFOs and animals housed at dairy CAFOs in 2021. This figure includes the maximum permitted number of mature cows onsite and the total number of CAFOs per county. The highest number of permitted animals are in Morrow, Tillamook, and Marion counties. Morrow county has relatively few dairy CAFOs (5 dairy CAFOs in Morrow County) compared to Tillamook County (96 dairy CAFOs in Tillamook County) which indicates dairy CAFOs in Morrow County have higher permitted number of animals. Additionally, of those 96 dairy CAFOs in Tillamook County, only 10 would trigger permitting requirements in the petitioners proposed program. Dairy CAFOs in north Willamette Valley has 16 percent of the total permitted mature dairy cows and 74 CAFOs. Of these 74 CAFOs in the north Willamette Valley, 18 would trigger permitting requirements in the petitioners proposed program.

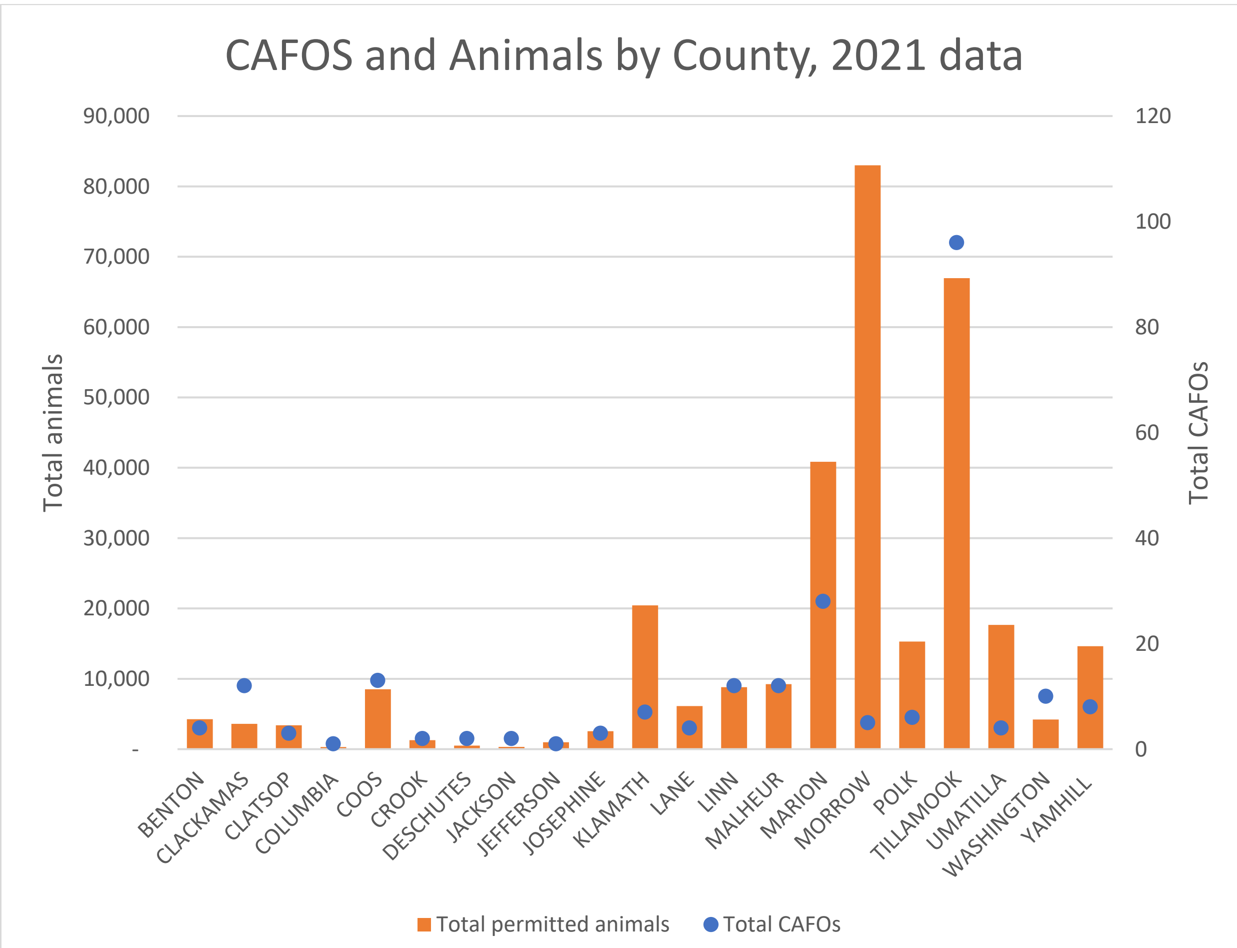

Figure 2: 2021 CAFOs and animals by county in 2021. Data provided by ODA.

Figure 3 provides information on the number of dairy CAFOs permitted, as well as the total number of milking cows, across the state. The total permitted dairies information is provided by ODA while the total milking cows data is survey data from USDA. This figure indicates that the number of dairy CAFOs has gone down slightly while the total number of milking cows has stayed relatively constant, indicating that CAFOs have been consolidating into larger facilities.

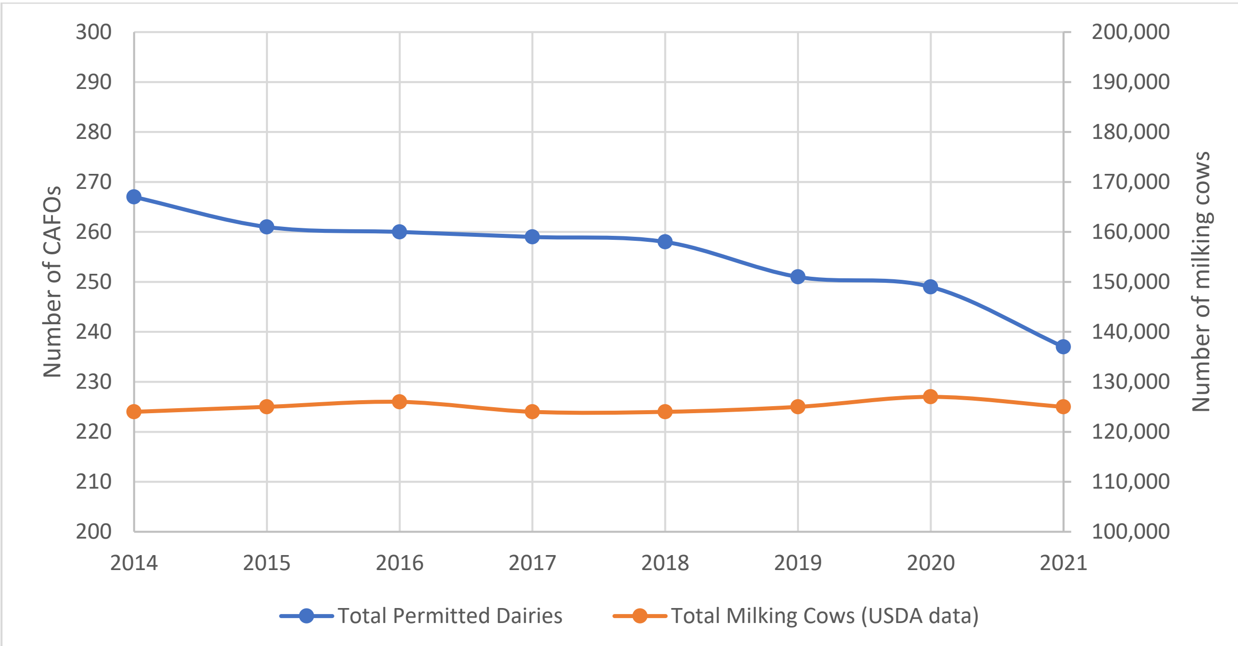

Figure 3: Total permitted CAFOs and milking cows, 2014-2021. Data provided by ODA and USDA.

To look at dairy CAFOs over time in Oregon and neighboring states, DEQ consulted the USDA National Agricultural Statistics Service[15]. Figure 4 provides the milk cow inventories for California, Idaho, Washington, and Oregon going back to 1990. DEQ has added call outs to specific air emission regulations in California, Idaho, and Washington (YRCAA). With the possible exception of California, it does not appear that adoption of air emission regulations or voluntary actions have affected the number of milking cows in these states.

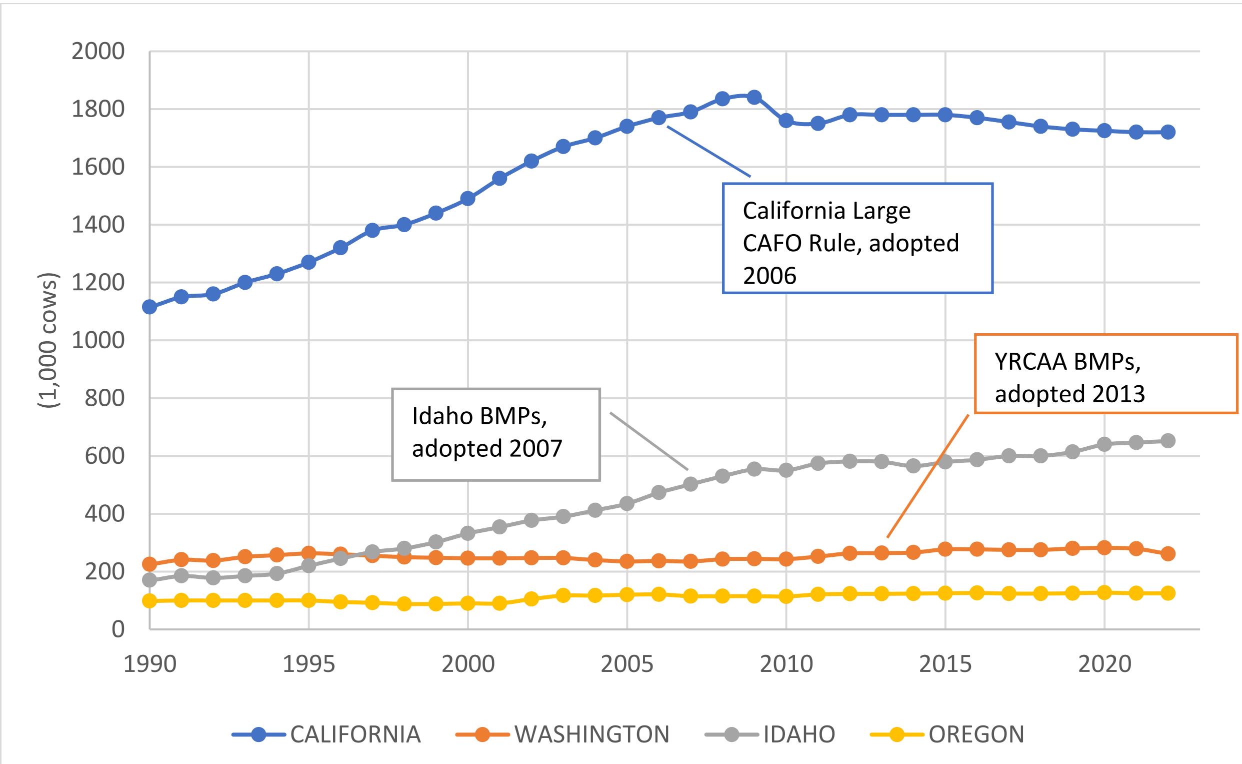

Figure 4: USDA Milk Cow Inventory for California, Idaho, Washington, and Oregon

Emissions Associated with Dairy CAFOs

Emission Sources

Dairy CAFOs can create and emit air pollution, as summarized in **Error! Reference source not found.**. In general, these emissions can come from the following practices:

- animal housing
- manure management
- land application of manure
- vehicles use, including those involved in the off-site transport of manure and in on-site composting operations

[15] United States Department of Agriculture National Agricultural Statistics Service, https://www.nass.usda.gov/

Table 2: Emission sources and health and environmental effects of key pollutants from AFOs

Pollutant	Source Description	Health and air quality effects	CAA
Ammonia (NH3)[1]	Animal housing, manure storage, field applied manure, direct deposits on pasture	• Human health impacts • PM2.5 precursor • Environmental deposition	• Regional Haze • NAAQS (PM)
Volatile organic compounds (VOCs)	Animal feed and waste. Face of an open silo, feed mixer, feed bunk, barn floor, long term manure storage, field application, grazing.	• Human health impacts • Ground-level ozone precursor	• Major source • NAAQs (ozone)
Particulate matter (PM)*	Dry manure, bedding and feed materials, and dirt feed lots.	Human health impacts	• NAAQS • Major source • Regional Haze
Hydrogen Sulfide (H2S)	Decomposition of animal manure stored in anaerobic conditions	• Human health impacts • Contribute to the formation of PM2.5 and acid rain.	• Major source
Carbon Dioxide (CO_2)	Annual flux between CO_2 in feed and CO_2 in land applied manure, animal respiration, barn floor and manure storage	Climate change	
Methane (CH_4)	Enteric fermentation, barn floor, manure storage, feces deposited in pasture	Climate change	
Nitrous oxide (N_2O)	Production of feed on crop and pastureland, manure storage and barn floor.	Climate change	
Methanol[1]	Silage piles, bedding and corrals	Human health impacts	• NAAQS (ozone) • HAP
Nitrogen Oxides (NO_x)	Fertilized crop lands, animal feed, fuel burning	• Haze • atmospheric deposition • smog	• Regional Haze • NAAQS (NO_2) • Major source
Odors[1]	Enteric fermentation, barn floor, manure storage, feces deposited in pasture	Nuisance	

HAP = hazardous air pollutant
NAAQS = National Ambient Air Quality Standard
1 = Dairy Air Task Force recommended to initially focus on ammonia, methanol, and odors.
Source: EPA Office of Inspector General (OIG) analysis and USDA DairyGEM Reference Manual
* PM includes both fine particles (PM2.5,) and coarser particles (PM10).

State-Wide Emissions

DEQ reviewed National Emissions Inventory (NEI) data to examine the overall impact of dairy emissions state-wide, this data is summarized in Table 3.**Error! Reference source not found.** Appendix D provides this data by county. The NEI estimates emissions from dairy farms using an emission factor based on assumed management practices on the west coast. This method is suitable for estimating state-wide emissions but not detailed enough for estimating farm-level

emissions. DEQ provides this data to analyze the importance of regulating emissions from dairy CAFOs.
This data indicates that ammonia emissions from dairies represents approximately 13% of the state-wide total, excluding exemptional events such as wildfires, and 14% of all Area source emissions. Additionally, dairy ammonia emissions are 6 times greater than all point sources. In Tillamook and Morrow Counties, dairy ammonia emissions are over 50% of the total ammonia emissions. Emissions of particulate matter and VOCs from dairies were all less than 1% of the state-wide total, <1% to 3% of area source emissions, and 3% to 17% of point sources. Hydrogen sulfide, methane, and nitrous oxides, all important dairy CAFO emissions, are not estimated for this activity and thus not included in the NEI.

Table 3: National Emissions Inventory estimated emissions from dairies versus other non-event sources- state total[1]

NEI 2017 Data	NH_3	H_2S	CH_4	NO_x	PM2.5	PM10	VOC	Methanol
	All units in tons/year							
Area (less Dairies)	23,978	not in NEI	not in NEI	50,775	56,417	353,972	957,303	
Dairy (as Area Sources)	4,001	not in NEI	not in NEI	not in NEI	203	977	320	113
Nonroad Mobile	30	not in NEI	1,081	13,886	1,406	1,482	15,635	
On-road Mobile	1,313	not in NEI	1,301	65,196	2,171	4,114	33,896	
Point	635	235,157	39,183	15,341	4,705	5,770	9,383	
Total	29,957	235,157	41,565	145,198	64,902	366,315	1,016,537	122,944
Dairies % of total	**13%**	**na**	**na**	**na**	**0.31%**	**0.27%**	**0.03%**	**0.09%**

1- Event sources include exceptional events such as wildfires that vary significantly year to year.

DEQ examined the variability of modeled state-wide dairy CAFO emissions using four different sources: the South Coast Air Quality Management District (SCAQMD) in California, the San Joaquin Valley Air Pollution Control District in California, draft emission models from EPA's NAEMS, and the NEI. Note that the SJVAPCD estimates do not include VOC emissions from feed. Table 4 Error! Reference source not found. **provides the emission factors from SCAQMD and SJVAPCD used for ammonia, PM10, and VOCs. DEQ estimated state-wide ammonia emissions using the draft emissions estimating models provided by EPA's NAEMS study. The draft NAEMS VOC estimates for dairy CAFOs has not been published. The NAEMS results provided are based on estimates of dairy CAFO management practices across the state. Note, these estimates are for example purposes only and not representative of actual state-wide management practices. Error! Reference source not found.**

Table 5 provides the estimation results. This table shows the wide variation in emission estimation based on emission method used; indicating that an Oregon specific model may be necessary.

Table 4: Emissions Factors from two California Air Districts

Emission Factors	Ammonia, ton/hd-yr	PM10, ton/hd-yr	VOC, ton/hd-yr
	All units in ton/head-year		
SCAQMD estimates no controls	74	3.6	12.8
SCAQMD estimates w/controls	37	2.8	6.4
SJVAMD estimates no controls	74	5.5	20
SJVAMD estimates w/controls	-	-	15.8

Table 5: Estimates of state-wide dairy emissions using various emissions models

Dairy estimates using emission models	NH_3	H_2S	NO_x	PM2.5	PM10	VOC
	All units in tons/year					
SCAQMD estimates no controls	7,650	na	na	na	368	1,323
SCAQMD estimates w/controls	3,825	na	na	na	294	662
SJVAPCD estimates no controls	7,650	na	na	na	564	2,068[a]
SJVAPCD estimates w/controls	na	na	na	na	na	1,633[a]
NAEMS estimates	7,981	68,531	na	na	196	Mid Oct
NEI 2017 Data	4,001	na	na	203	977	320

NAEMS models are draft and not for regulatory purposes. EPA intends to publish draft NAEMS results for VOCs in October.
a. Do not include emissions from feed

Major Source Thresholds

In the absence of federal methods, DEQ reviewed potential emissions using emission factors compiled by the San Joaquin Valley Air Pollution Control District (SJVAPCD), based on available data. The VOC emission factors provided by SJVAPCD do not include feed; however, a technical document on the preparation of these factors includes a potential emission factor for silage. This document recommends that silage emissions be calculated based off area of exposed feed, not a head count of cattle. For purposes of this document, DEQ is using the silage emission factor per head discussed in this paper. Table 6**Error! Reference source not found.** provides a summary of the emission factors used in this analysis.

Based on how the emissions are estimated using the SJVAPCD factors, DEQ estimates that between 3 and 5 Oregon dairies may exceed the federal major source threshold using the SJVAPCD emission factors for VOC emissions and could potentially be required to obtain a federal operating permit[16]. The remaining 42 to 44 Oregon dairies would be considered Tier 2 under the proposed rules. These estimates are based on using standard emission factor estimating methods; the NAS has identified issues with this method. Once EPA publishes final emissions estimating methodologies for dairy CAFOs, the CAFO must determine what actions, if any, it must take to comply with all applicable Clean Air Act requirements.

[16] San Joaquin Valley Unified Air Pollution Control District, February 2012, *San Joaquin Valley Air Pollution Control District Air Pollution Control Officer's Revision of the Dairy VOC Emission Factors.*

Table 6: Range of Potential Emission Factors (lb per head (cow) per year)[1]

Pollutant	SJVAPCD no controls	SJVAPCD with controls	SJVAPCD no controls + silage	SJVAPCD with controls + silage
VOC	20.0[a]	15.8[a]	26.5	22.3
#Head to exceed 100 tons/yr	10,000	12,658	7,547	8,969
# Dairies	3	3	5	3

1 – Data from Dairy Air Task Force Technical Support Document with updates from SJVAPCD and SCAQMD
a – does not include feed

Greenhouse Gas Emissions Estimates

The petition noted that dairy CAFO emissions may be preventing the State from achieving its greenhouse gas reduction targets. The greenhouse gas emissions estimates for Oregon CAFOs, including the emissions from dairy cattle, produced by DEQ are developed utilizing EPA's State Inventory Tool (SIT) model for emissions from agriculture. The SIT Ag Model estimates statewide greenhouse gas emissions from Oregon's agriculture sector including the annual calculation of emissions from livestock. Emissions estimates from livestock include enteric fermentation and methane and nitrous oxide from manure management. The module is typically run with complete Oregon livestock census data from USDA National Agriculture Statistics Service.

In 2014, DEQ staff examined greenhouse gas emissions from the agricultural sector, specifically looking at the dairy sector (Table 7**Error! Reference source not found.**). DEQ estimated that Oregon dairies contribute approximately 1.6 percent of the greenhouse gasses generated in Oregon.

Table 7: Oregon 2014 Greenhouse Gas Emissions

Category	Enteric Fermentation	CH_4 Manure Management	N_2O Manure Management	Total
	All units in tons CO2e			
Oregon statewide GHG emissions				60,410,000
Statewide agriculture emissions				5,171,000
All agriculture animals	2,563,700	474,157	131,361	3,169,217
All permitted CAFOs (2014 ODA data)	713,919	422,414	131,351	1,267,685
All dairies	**522,167**	**394,282**	**47,291**	**963,739**

Conclusions - Emissions Associated with CAFOs

Dairy CAFOs are likely a significant source of ammonia emissions and dairies may be contributing to visibility degradation in the Columbia River Gorge Scenic Area. Further refinement of these estimates should be conducted to determine appropriate actions. Additionally, based on one currently available estimation methodology, at least three dairy CAFOs likely exceed federal permitting thresholds for VOCs.

DEQ Petition Evaluation

In this section, DEQ assesses the completeness of the petition, EQC's authority to implement the petition, and DEQ's ability to implement the proposed program.

The petitioners assert facts and arguments to support their request that the commission regulate dairy air emissions. Petitioners assert that dairy CAFOs present a direct and serious impact on air quality and pose a direct threat to public health, particularly for the dairy workers and communities near operations. Petitioners assert that these communities are often environmental justice communities of concern. They assert that livestock operations emit major air pollutants including ammonia, hydrogen sulfide, methane, methanol, volatile organic compounds, nitrogen oxides, particulate matter, and odors. They also assert that the CAFO sector contributes significantly to climate change in Oregon.

Petition Completeness

DEQ finds that the petition and attachments meet the administrative requirements of ORS 183.390 and administrative rules at OAR 340-011-0046 and 137-001-0070.

DEQ finds that the petition meets the requirements in OAR 137-001-0070 (1) and (1)(a).
As required by OAR 137-001-0070 (1) and (1)(a):

- The petition provides the name and address of the petitioner and others known to the petitioner to be interested in the rule (Appendix A, pages 2-4),
- The petition includes the proposed language in full for the new rules (Appendix A, pages 4-13).

DEQ finds that the petition meets the requirements in OAR 137-001-0070 (1) (b) and (c).
As required by OAR 137-001-0070 (1)(b), the petition includes facts and arguments in sufficient detail to show the reasons for and effects of adoption of the proposed rule (Appendix A, pages 13-24). The petition includes the following arguments, with supporting facts:

1. Failing to Immediately Regulate Dairy CAFO Air Emissions Threatens Public Health
2. Failing to Immediately Regulate Dairy CAFO Air Emissions Exacerbates Environmental Injustices Across the State
3. Failing to Immediately Regulate Dairy CAFO Air Emissions Poses a Direct and Serious Threat to Oregon's Environment
4. Failing to Immediately Regulate Dairy CAFO Air Emissions Exacerbates Inhumane Living Conditions for Farmed Animals
5. Failing to Immediately Regulate Dairy CAFO Air Emissions Jeopardizes the Economic

Livelihoods of Oregon's Few Remaining Small and Mid-sized Dairy Farms

As required by OAR 137-001-0070 (1)(c), the petition contains a statement of the propositions of law asserted by the petitioner (Appendix A, pages 24-37). The petition includes the following propositions of law:

1. EQC has Broad Authority to Regulate State Air Quality.
2. EQC Has Express Authority to Adopt Air Quality Rules Applicable to Agricultural
   a EQC Must Regulate Dairy CAFO Emissions that Trigger CAA Permitting Requirements. These air pollutants include Hydrogen Sulfide, Nitrogen Oxides, Particulate Matter, and VOCs (collectively, "CAA pollutants")
      i *A Dairy CAFO is a "stationary source" within the meaning of the Clean Air Act*
      ii *Large Dairy CAFOs must be permitted under the Title I Prevention of Significant Deterioration Program*
      iii *Very large Dairy CAFOs also require Title V Operating Permits*
      iv *Dairy CAFOs subject to Title I or Title V permitting are also subject to regulation for Greenhouse Gas Emissions*
   b EQC Should Regulate Dairy CAFO Emissions Beyond Federal Requirements Per Dairy Task Force Recommendations, and Must Do So with Regard to GHG Emissions

The petition also cites applicable federal law and state rule and statutes.

Petition Program Analysis

In this section, DEQ provides an analysis of implementation of the petition proposed rules, including a review of EQC's current authority to regulate emissions from agricultural operations and program elements that DEQ is currently unable to implement.

EQC Authority

As discussed above, EQC's authority to regulate dairy CAFOs is limited (1) as necessary to implement the federal CAA, or (2) in the Commission's discretion, to implement a recommendation of the Task Force on Dairy Air Quality. DEQ's analysis indicates, overall, that the proposed rules would fall under EQC's authority to regulate air emissions from agricultural operations either to implement the federal CAA or to implement a recommendation of the DATF.

Potential Applicability to Regulated Entities

Potential regulated entities of the proposed petition rules would be dairy CAFO owners and operators. This section of the staff report describes how various aspects of the petition's proposed regulations, as well as other options available to EQC, may apply to existing dairy CAFOs. DEQ examined three potential permitting scenarios: (1) permit only sources that exceed the major source threshold, (2) implement the petitioner recommended program, or (3) implement the full DATF program. Since each of these scenarios applies to different size dairy CAFOs, the number of potentially regulated entities varies (Table 8**Error! Reference source not found.**).

Table 8: Estimated Regulated Entities and Air Permits

Scenario Description	Head of cattle	Dairies	Title V permits	ACDPs
Petitioner recommendation	700	47	3	44
Task Force Recommendation	all*	236	3	233
Regulate dairy CAFOs that exceed federal permitting threshold**	10,000	3	3	0

* All existing dairy CAFOs that have or need a water quality CAFO permit.
** Estimated using San Joaquin Valley Air Pollution Control District Emission Factors.

Program insufficiencies

DEQ has identified areas in the proposed program where additional research and collaboration is needed before a program should be developed. The proposed rules would require that Regulated Dairies include an Air Impact Analysis that quantifies baseline and mitigated emissions using a DEQ-approved model. The proposed rules would also require that sources implement all BMPs based on their tier. Both program areas require collaboration between DEQ and ODA for further research and assessment of program design and implementation, which is not currently resourced. Below is a summary of DEQ's review of emission methodologies, BMPs, and resource implications. A more detailed analysis of DEQ's review may be found in Appendix E.

Air Impact Analysis

The program proposed by the petitioners would require DEQ to determine what emission models to use for determining what permitting requirements would apply to a dairy. To evaluate the readiness of existing emission models, their applicability to Oregon, and the resource needs for setting up and implementing these models, DEQ reviewed emission estimation methodologies for dairies used by programs implemented by air quality programs outside of Oregon.

- The petitioners propose use of the DairyGEM, which is a part of the Integrated Farm System Model prepared by USDA. Based on DEQ's research of the model, DEQ agrees that the DairyGEM model is robust with relative accuracy and the ability to accept refined site-specific inputs. DEQ and ODA would need to provide significant technical support and resourcing to dairies in order to collect the information necessary to use the DairyGEM model in the capacity proposed by the petitioners. DEQ and ODA are not resourced to provide the level of technical assistance necessary to support dairies in the collection of the information necessary to complete a DairyGEM analysis.
- EPA has not established methodologies for estimating emissions from dairy CAFOs. EPA's NAEMS, which intends to close this gap, is ongoing and has the goal of establishing emission models. Once this is finalized, dairy CAFOs, and other agricultural operations, will be required to determine compliance with federal permitting requirements. One of the goals of the NAEMS emission models is to reduce the amount of data that needs to be collected by a dairy to complete an emissions estimation and ensure that the models have gone through a rigorous regulatory analysis and can be used throughout the nation. DEQ has been monitoring the NAEMS work and is resourced to continue to follow the development of these emissions models.

Best Management Practices

The DATF, however, recommends flexibility regarding BMPs. The BMP sources proposed in the petition are well researched and shown to reduce emissions, however, additional research would be required to determine *quantifiable emissions reductions* for each BMP in various meteorological conditions. Additionally, DEQ recommends additional research to identify BMPs that have both water quality and air quality benefits. DEQ reviewed various established BMPs and emissions estimating protocol, below.

Resource Implications
A Dairy Air Emissions Program would require both DEQ regional and Air Quality Division staff resources as well as ODA resources. The resources needed would depend on how the program is developed and if EPA succeeds in developing a usable tool to estimate emissions. Previous Policy Option Packages requested one FTE for DEQ and one for ODA to develop this program. Resources to implement a program have not yet been evaluated.

Other Policy Considerations and Technical Issues

Environmental Justice Concerns

The petition correctly points out that CAFOs, including dairy CAFOs, tend to be disproportionately located in poor, rural areas. Emissions from these CAFOs can further exacerbate impacts in these poor, rural communities from existing pollution burdens arising from water pollution, emissions of HAP, and the proximity of hazardous waste management sites. Morrow County (the Oregon county with the largest number of dairy cows, ~77,000) lies in the 80-95th percentile for EJScreen indicators of environmental burden (see Appendix F).

HB 4077, the Environmental Justice for All bill which passed in 2022, updates ORS 182.545 to better define "environmental burden" as well as "environmental justice communities" and dedicates resources for the development of an Oregon-specific Environmental Justice Mapping Tool. The development of the mapping tool and guidance is expected to be completed in about two years.

Memorandum of Understanding

ORS 468A.790 states the DEQ and ODA shall enter into a memorandum of understanding (MOU) for administration and enforcement of air quality laws regarding agricultural operations and equipment. Once funding to implement this program is obtained by DEQ and ODA, the two agencies should enter into a MOU that meets the intent of this statute.

> *(1) The Environmental Quality Commission and the State Department of Agriculture shall enter into a memorandum of understanding that addresses the administration and enforcement of air quality laws contained in this chapter that apply to agricultural operations and equipment. The terms of the memorandum of understanding must be consistent with the obligations of this state under the federal Clean Air Act (P.L. 88-206 as amended) and the purposes described in ORS 468A.305. Subject to the terms of the memorandum of understanding and to oversight by the Department of Environmental*

Quality, the State Department of Agriculture may perform any function of the Department of Environmental Quality under this chapter that relates to air quality, including but not limited to the issuance of permits, establishment of fees, entry and inspection of premises and the assessment of civil penalties.
(2) The Environmental Quality Commission and the State Department of Agriculture shall consider the following when entering into a memorandum of understanding under subsection (1) of this section:

> *(a) Cooperation with private and public entities associated with agriculture in program research, development and implementation.*
> *(b) Program flexibility.*
> *(c) The use of voluntary measures, including education, demonstration projects and incentives, if practicable and reasonably expected to be effective in helping to carry out regulatory requirements.*
> *(d) The diverse nature of agricultural operations and the importance of, and public interest in, the agricultural production of food, fiber and other products.*
> *(e) The desirability of having the State Department of Agriculture serve as the lead agency responsible for the administration of programs relating to agriculture.*
> *(f) The importance of, and public interest in, the protection of human health and the environment, including the protection of natural resources in special areas of the state designated for their outstanding scenery and historical and cultural importance.*

(3) In adopting rules subject to the memorandum of understanding required by subsection (1) of this section, the Environmental Quality Commission and the State Department of Agriculture shall consult with each other. [2007 c.799 §2]

Public Engagement

DEQ created a petition-specific webpage page on the agency's rulemaking webpage. There, DEQ posted the petition, a summary of the petition and instructions for submitting public comment. DEQ held a 20-day public comment period about the regulations proposed in the petition.

Summary of Public Comments

DEQ accepted public comment on the proposed rulemaking from October 3 until 4 p.m. on Oct. 23, 2022, and reviewed all comments submitted before the deadline. Because this comment period was not associated with a formal rulemaking, and because DEQ did not want to exclude relevant comments, DEQ also reviewed comments received after 4 p.m. Oct. 23, 2022, through Monday, Oct. 24, 2022, at 8 a.m. All original comments are on file with DEQ and have been posted to the Dairy Air Emissions Petition page on the agency's rulemaking webpage.

DEQ received 1,649 comments, 21 of these comments were received after the comment deadline. 1,578 comments supported the regulations proposed in the petition, 58 opposed the proposed regulations, and 13 comments were neither supporting nor opposed. DEQ considered all comments, but unlike a formal rulemaking process, DEQ is not required to write a response to comments on the petition. DEQ has summarized the themes covered in the comments and listed the organizations commenting in support and opposition in

Table 9.

DEQ found that the comments reflected common themes. Commenters that supported the regulations proposed in the petition mentioned concerns such as:

- Harm being done by mega-dairies
- Climate change
- Expand the program to include all livestock operations as well as smaller operations
- Impacts to vulnerable communities
- Impacts to small dairy farms
- Air emissions from dairies

Commenters that opposed the regulations proposed in the petition mentioned concerns such as:

- Regulations will impact dairy prices
- Financial impacts to farms
- No legislative budget or position authority to implement the program
- Need to wait for EPA to complete the emissions monitoring study
- Need to collaborate with ODA
- Other air quality issues are a higher priority
- Petition is inconsistent with the DATF recommendations
- No statutory authority due to Right to Farm act

Table 9: Organizations and legislative members commenting on the Dairy Air Emissions Petition

Supporting	Opposing
Representative Rob Nosse	Representative David Gomberg
Senator Michael Dembrow	Senator Dick Anderson
Representative Zach Hudson	Senator Lynn Findley
Representative Khanh Pham	Senator Bill Hansell
Representative Maxine Dexter	Senator Janeen Sollman
Senator Jeff Golden	Senator Elizabeth Steiner Hayward
Senator Chris Gorsek	Representative Shelly Boshart Davis
Representative Wlnsvey Campos	Representative Vikki Breese Iverson
Senator Deb Patterson	Representative David Brock Smith
Socially Responsible Agriculture Project	Representative Jami Cate
Friends of the Columbia Gorge	Representative Jessica George
Climate Energy Environment Team of the Consolidated Oregon Indivisible Network	Representative Bobby Levy
Food & Water Watch	Representative Rick Lewis
Animal Legal Defense Fund	Representative Susan McLain
Beyond Toxics	Representative Raquel Moore-Green
Center for Biological Diversity	Representative Lily Morgan
Center for Food Safety	Representative Mark Owens
Columbia Riverkeeper	Representative E. Werner Reshke

Supporting	Opposing
Human Voters Oregon	Representative Anna Scharf
Mercy for Animals	Representative Suzanne Weber
Northwest Environmental Defense Center	Oregon Farm Bureau
World Animal Protection	Tillamook Creamery Association
	Tillamook County Soil & Water Conservation District
	Oregon Dairy Farmers Association

Recommendations

Petition Action

Per the statutory requirements of ORS 183.390, DEQ recommends that the commission deny the Dairy Emissions Rule Petition in writing.

DEQ finds that while the petition does provide an outline for a potential dairy CAFO permitting program, DEQ cannot recommend approving the petition for the following reasons:

1) DEQ and ODA would both require additional resources to implement a proposed dairy CAFO emissions permitting program.
2) The petition rules include a requirement for an Air Impact Assessment to be completed by the permittees using a DEQ-approved model to calculate estimated baseline and mitigation emissions associated with the project. DairyGEM and NAEMS (not finalized) may both be appropriate models; however, DEQ would need additional research into the use of these models for this purpose. DEQ also recommends waiting for NAEMS to be finalized.
3) The petition rules include requirements for permittees to implement Best Management Practices to achieve quantifiable emissions reductions. DEQ reviewed the Best Management Practices identified in the petition rules as well as additional Best Management Practices and finds that most provide an estimated range of potential emission reductions but do not provide for *quantifiable* emissions reductions. DEQ will need additional research support to develop such quantification methodology.

DEQ identified elements of the program proposed by the petitioners that require research and collaboration by DEQ and ODA. Both agencies are not resourced to complete the work necessary to stand-up or implement the program proposed by the petitioners.

DEQ has ongoing work related to the goals of the petition that is consistent with currently funded programs. DEQ proposes taking the following actions within current resource levels:

1. Follow EPA's National Air Emissions Monitoring Study (NAEMS) work to ensure we are prepared to implement a federally required program that may include the issuance of

air quality permits.
Once NAEMS is completed, and in collaboration with ODA, initiate implementation, including a resource plan, of an Oregon program including required permitting of sources that exceed federal regulatory thresholds.

2. Follow EPA's work on confined (also called concentrated) animal feeding operations (CAFO) emission reporting under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Emergency Planning and Community Right-to-Know Act (EPCRA).
3. Examine Environmental Justice priorities regarding dairy CAFOs as part of DEQ's mission to ensure that the agency's actions address the interests of Oregon communities.
4. Continue to examine the potential impact of dairy CAFOs on Regional Haze, especially in the Columbia River Gorge National Scenic Area as part of DEQ's Regional Haze State Implementation Plan.

In the event of funding of a dairy air emissions program by the legislature, the following actions would be important components in creating a comprehensive dairy air emissions program:

1. Collaborate with ODA on a CAFO Air Quality MOU between DEQ and ODA.
2. Collaborate with ODA to gather farm information needed for permitting; to provide information to dairy CAFOs on potential best management practices; and to provide information to dairy CAFOs on funding opportunities.
3. Work with OSU/PNW Universities to research the expected emissions reductions from permitting sources below federal permitting thresholds as well as prioritizing and quantifying the emissions reduction of potential BMPs

Accessibility Information

You may review copies of all documents referenced in this staff report at:
Oregon Department of Environmental Quality
700 NE Multnomah St., Ste. 600
Portland, OR, 97232

To schedule a review of all websites and documents referenced in this staff report, contact Heather Kuoppamaki, DEQ Air Quality Division, (503) 407-7596 or at heather.kuoppamaki@deq.oregon.gov.

DEQ can provide documents in an alternate format or in a language other than English upon request. Call DEQ at 800-452-4011 or email deqinfo@deq.state.or.us.

El DEQ puede proporcionar los documentos en un formato alternativo o en un idioma distinto al inglés si así lo solicita. Llame al DEQ al 800-452-4011 o envíe un correo electrónico a deqinfo@deq.oregon.gov.

DEQ 可以根據要求提供另一種格式的文件或英語和西班牙語以外的語言。請致電 DEQ：800-452-4011 或發送電=子 郵件至 ： deqinfo@deq.oregon.gov.

ДЭК может предоставить документы в другом формате или на другом языке, помимо английского и испанского, по запросу. Позвоните в ДЭК по телефону 800-452-4011 или свяжитесь по электронной почте deqinfo@deq.oregon.gov.

Tùy theo yêu cầu, cơ quan DEQ có thể cung cấp các tài liệu ở định dạng thay thế hoặc bằng ngôn ngữ khác ngoài tiếng Anh và tiếng Tây Ban Nha. Liên hệ với DEQ theo số 800-452-4011 hoặc gửi email đến deqinfo@deq.oregon.gov.

Appendix A
Petition

August 17, 2022

Kathleen George, Chair
Oregon Environmental Quality Commission
700 NE Multnomah St, Suite 600
Portland, Oregon 97232

Re: Petition to Promulgate Dairy Air Emissions Regulatory Program

Dear Chair George:

Air pollution from the State's growing number of exceedingly large mega-dairies threatens the public health and safety of Oregonians, as well as the environment. Yet the Oregon Department of Environmental Quality ("DEQ") neither monitors nor regulates this air pollution through its current Air Contaminant Discharge Permit ("ACDP") program. It is past time for Oregon to address air pollution from large dairy concentrated animal feeding operations ("CAFOs"). Pursuant to ORS § 183.390, OAR 137-001-0070, and OAR 340-011-0046, and on behalf of twenty-two advocacy organizations, we hereby submit this Petition to the Environmental Quality Commission ("EQC" or "Commission") to adopt a dairy air emissions program to quantify and regulate air emissions from large dairy CAFOs.

Led by members of the Stand Up to Factory Farms coalition, Petitioners represent a diverse array of environmental, public health, family farm, environmental justice, animal welfare, and community-based organizations concerned about the adverse impacts of mega-dairies and their air pollution. Collectively, Petitioners represent hundreds of thousands of members throughout the State.

As required by ORS § 183.390 and OAR 137-001-0070, accompanying this letter are a list of the names and addresses of Petitioners, the rule Petitioners request the Commission adopt, and the facts, arguments, and propositions of law in support of the proposed rule. Additionally, the sources cited throughout the petition are accessible through this Google Drive link.

We deeply appreciate you considering this request, and the gravity of the situation.

Sincerely,

Emily Miller

Emily Miller
Staff Attorney
Food & Water Watch
eamiller@fwwatch.org
On Behalf of Petitioners

BEFORE THE OREGON ENVIRONMENTAL QUALITY COMMISSION
Petition to Adopt a Dairy Air Emissions Program to Quantify and Regulate Large Dairy CAFO Air Emissions

August 17, 2022

Pursuant to ORS 183.390, OAR 137-001-0070, and OAR 340-011-0046, and the following supporting facts and arguments, we petition the Oregon Environmental Quality Commission ("EQC" or "Commission") to promulgate a new rule quantifying and regulating air emissions from large dairy concentrated animal feeding operations ("CAFOs"). Petitioner Food & Water Watch has signed on behalf of all co-petitioners.

As per OAR 137-001-0070(1), petitioners are:

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I. PROPOSED RULE LANGUAGE

As required by OAR 137-001-0070(1)(a), petitioners request that EQC adopt the proposed rule language below.[1]

Section 1. Policy and Purpose

The Commission finds and declares Regulated Dairies to be air contamination sources as defined in ORS 468A.005. The Commission further finds and declares the regulation of dairy operations is necessary to comply with federal Clean Air Act requirements, achieve state greenhouse gas reduction goals, and implement the recommendations of the Dairy Air Quality Task Force.

Section 2. Jurisdiction

Nothing in this rule shall preclude a city, county, Regional Authority, or other political subdivision of this state from establishing additional permit conditions or requirements for Dairy Air Emission Permit applicants or permittees within its jurisdiction, so long as such permit conditions or requirements are no less stringent than those established in this rule.

Section 3. Definitions

(1) "Air contaminant" or "air pollutant" has the same meaning as in OAR 340-200-0020(8), and means a dust, fume, gas, mist, odor, smoke, vapor, soot, carbon, acid, particulate matter, compound, regulated pollutant, or any combination thereof, which is emitted into or otherwise enters the ambient air.

[1] Petitioners request the Commission adopt the language of the rule as proposed. However, if the Commission has any concerns about the rule language as proposed herein, the Oregon Attorney General has instructed that it may nevertheless grant the petition, begin rulemaking, and amend the proposed rule during the course of rulemaking. *See* Hardy Myers, *Oregon Attorney General's Administrative Law Manual and Uniform and Model Rules of Procedure under the Administrative Procedure Act*, OR. DEP'T JUST. 54 (Jan. 1, 2008).

(2) "Air Impact Assessment" (AIA) means the calculation of emissions generated by the project and the emission reductions required by the provisions set forth in this rule. The AIA must be based solely on the information provided to the Department or Regional Authority having jurisdiction in the permit application, and must include all information listed in section 5(3) of this rule.

(3) "Animal unit" has the same meaning as in OAR 141-110-0005, and means one mature cow of approximately 1,000 pounds and a calf up to weaning, usually 6 months of age, or their equivalent as determined by the Department. For example: one yearling is 0.7 of an animal unit; one bull is 1.35 of an animal unit; and one dry cow is 0.92 of an animal unit.

(4) "Applicant" means an applicant for a Dairy Air Emissions Permit.

(5) "Baseline emissions" means the unmitigated aggregate emissions of any regulated air pollutant, as calculated by the Department-approved model, produced by or projected to be produced by the activity and operations of a Regulated Dairy, including but not limited to emissions from animal housing, feed storage and handling, manure storage, handling and treatment, land application, and combustion-powered equipment.

(6) "Best Management Practice" or "BMP" means a method, practice, activity, technology, or any combination thereof that is determined by the Department to be an effective means of preventing or reducing emissions of any regulated air pollutant.

(7) "Clean Air Act permitting thresholds" means the annual emission rates triggering permitting requirements under the federal Title I Prevention of Significant Deterioration ("PSD") and New Source Review ("NSR") programs, as well as emission rates triggering permitting requirements under the Title V Operating Permit program.

(8) "Certifying individual" has the same meaning as in OAR 340-200-0020(24), and means the responsible person or official authorized by the owner or operator of a Regulated Dairy who certifies the accuracy of the emission statement.

(9) "Construction" means any physical change including, but not limited to, fabrication, erection, installation, demolition, or modification of a physical structure, including wastewater retention structures.

(10) "Dairy Air Emissions Permit" means a written permit issued by the Department or Regional Authority having jurisdiction, which authorizes the permittee to commence construction, and/or commence or continue operations of a Regulated Dairy under conditions and schedules as specified in the permit.

(11) "Department" means the Department of Environmental Quality.

(12) "Department-approved model" means any process-based or statistical model that estimates emissions of any regulated air pollutant resulting from the activity and operations associated with a Regulated Dairy, using the most recent Department or United States Environmental Protection Agency ("EPA")-approved version of relevant emissions models and emission factors. Department-approved models include the Dairy Gas Emission Model and the Integrated Farm Service Model developed and utilized by the

United States Department of Agriculture ("USDA"), as well as emission factors developed and utilized by the San Joaquin Valley Air Pollution Control District.

(13) "Emission" has the same meaning as in OAR 340-200-0020(51), and means a release into the atmosphere of any regulated pollutant or any air contaminant.

(14) "Fugitive Emission" has the same meaning as in 40 C.F.R. § 51.165(1)(1)(ix), and means those emissions which could not reasonably pass through a stack, chimney, vent, or other functionally equivalent opening. For Regulated Dairies, emissions from land application activities are considered fugitive.

(15) "Hazardous Air Pollutant" or "HAP" has the same meaning as in OAR-340-200-0020(76), and means an air contaminant listed by EPA under section 112(b) of the federal Clean Air Act or determined by the Department to cause, or reasonably be anticipated to cause, adverse effects to human health or the environment.

(16) "Liquid manure handling system" means a form of manure management in which water is used to flush manure from confinement buildings to a lagoon, pond, or some other liquid storage structure.

(17) "Monitoring" means any form of collecting data on a routine basis to determine or otherwise assess compliance with emission limitations or standards. Monitoring may include record keeping if the records are used to determine or assess compliance with an emission limitation or standard such as records documenting compliance with best management practice requirements. Monitoring may also include one or more of the data collection techniques listed under OAR 340-200-0020(94).

(18) "Non-fugitive emissions" means those emissions that could reasonably pass through a stack, chimney, vent, or other functionally equivalent opening. For Regulated Dairies, non-fugitive emissions include but are not limited to emissions from animal housing, milking parlors, feed storage and handling structures, and manure storage and treatment structures.

(19) "Potential to emit" means the maximum capacity of a Regulated Dairy source to emit a pollutant under its physical and operational design. Any physical or operational limitation on the capacity of the source to emit a pollutant, including air pollution control equipment and restrictions on hours of operation or on the type or amount of material combusted, stored, or processed, shall be treated as part of its design if the limitation or the effect it would have on emissions is federally enforceable.

(20) "Regional Authority" means a regional air quality control authority established under the provisions of ORS 468A.105.

(21) "Regulated air pollutant" or "regulated pollutant" means:

- **a.** Any criteria pollutant for which there is a National Ambient Air Quality Standard or any air contaminant for which an ambient air quality standard has been promulgated, including any precursors to such pollutants; and

b. Any air contaminant, which the Department or EPA determined may reasonably be anticipated to endanger the public health or welfare of current or future generations, including hazardous air pollutants and greenhouse gases.

c. Air contaminants subject to regulation under this rule include but are not limited to ammonia, hydrogen sulfide, methane, methanol, nitrogen oxides, nitrous oxide, particulate matter ($PM_{2.5}$ and PM_{10}), and volatile organic compounds.

(22) "Regulated Dairy" means a Grade A dairy operation that (1) confines and feeds or maintains animals for a total of 45 days or more within a 12-month period; (2) does not sustain crops, vegetation, forage growth, or post-harvest residues in the normal growing season over any portion of the lot or facility; (3) is permitted to confine 700 or more mature dairy cows, whether milked or dry; and (4) has or will use a liquid manure handling system.[2]

Section 4. Sources Required to Have Dairy Air Emission Permits

This rule shall apply to all new and existing Grade A dairies that meet the definition of a Regulated Dairy, as defined in Section 3, subsection 22 of this rule.

(1) Existing Sources. Existing Regulated Dairies to which this section is applicable shall apply for a Dairy Air Emission Permit within 365 days of the effective date of this rule.

(2) New or Expanding Sources. New Regulated Dairies to which this section is applicable shall apply for and receive a Dairy Air Emission Permit prior to construction and/or operation of the facility. Existing facilities proposing to expand or modify operations such that they become Regulated Dairies must apply for and receive a Dairy Air Emission Permit reflecting the expected increase in air emissions before such expanded operations may begin.

Section 5. Dairy Air Emission Permit Application Process

(1) Fees. Persons applying for a Dairy Air Emissions Permit shall at the time of application pay a permit fee established by the Commission.

(2) Application requirements. An applicant for a Dairy Air Emissions Permit shall submit the following to the Department:

a. A completed Short Form Application;

b. A map showing the location and size of the site;

c. A description of the current, proposed, and/or prior use of the site, including number and type of animals and animal units;

d. A detailed description of current or expected air contaminant source activity at the site, including the location, number, size and type of manure and process wastewater storage lagoons, and the location, number, acreage, and irrigation methods for land application fields;

[2] This definition is based on the federal definition of a large concentrated animal feeding operation, as defined in 40 C.F.R. § 122.23.

e. A completed air impact assessment, as specified in Section 5, subsection (3) of this rule.

f. A completed list of emissions best management practices to be implemented, as specified in Section 5, subsection (4) of this rule;

g. A completed Monitoring and Reporting Schedule, as specified in Section 5, subsection (5) of this rule;

h. Such additional information as may be required when there is reasonable basis for concluding:

- **i.** The Regulated Dairy may cause or contribute to a violation of the Clean Air Act Implementation Plan for Oregon;
- **ii.** The Regulated Dairy may cause or contribute to a delay in the attainment of or a violation of any applicable ambient air quality standard, or may cause or contribute to the violation of any applicable increment; or
- **iii.** The information is necessary to determine whether the Regulated Dairy may cause or contribute to any such delay or violation. The Department shall base such conclusion on any reliable information, including but not limited to application of a Department-approved model quantifying the Regulated Dairy's emissions, as well as ambient air monitoring, Regulated Dairy size, site design, or air quality projections based thereon.

(3) Air Impact Assessment. An applicant for a Dairy Air Emissions Permit must submit an Air Impact Assessment (AIA) with its Dairy Air Emissions Permit application. The AIA shall meet the following requirements:

a. The applicant shall estimate and quantify all operational emissions of the following air pollutants: Ammonia (NH_3), Hydrogen Sulfide (H_2S), Methane (CH_4), Methanol, Nitrogen Oxides (NO_x), Nitrous Oxides (N_20), Particulate Matter ($PM_{2.5}$ and PM_{10}), and Volatile Organic Compounds (VOCs). The applicant's AIA shall include:

- **i.** The estimated baseline emissions of every regulated pollutant that may reasonably be produced from operation of the Regulated Dairy; and
- **ii.** The mitigated emissions of every regulated pollutant upon implementation of selected best management practices.

b. Based on the results of the emissions analysis required by Section 5, subsection (3)(a), if the Regulated Dairy will be considered a federal major source, the AIA must also include an analysis of the visibility impacts of the source, including meteorological and topographical data, specific details of models used, and other information necessary to estimate air quality impacts.

c. The AIA analysis required by Section 5, subsections (3)(a) and (3)(b) of this rule shall use a Department-approved model to calculate the estimated baseline emissions and mitigated emissions associated with the project.

d. The applicant shall include in its application any other information and documentation that supports the baseline and mitigated emissions calculations specified in the AIA.

(4) Certification. An applicant for a Dairy Air Emissions Permit shall sign and certify under penalty of perjury in its Dairy Air Emissions Permit application that the information contained therein is true and accurate. The certifying individual shall also attest that the source's reported baseline emissions and mitigated emissions are the true and accurate results of the Department-approved emissions modeling process.

(5) Timing.

a. An applicant proposing to construct a Regulated Dairy, or modify or expand an existing dairy such that it becomes a Regulated Dairy, shall not commence construction of new or expanded operations until the Department has issued a Dairy Air Emissions Permit to the applicant.

b. An owner or operator of a Regulated Dairy that was engaged in operations on or before the date on which this rule went into effect shall apply for a Dairy Air Emissions Permit no later than 365 days following the effective date of this rule.

(6) Completeness. An application shall not be considered complete until the required information is received by the Department or Regional Authority having jurisdiction. If no timely written request is made for additional information, the application shall be considered complete.

Section 6. Dairy Air Emission Permit Requirements

(1) Permit Content. A Dairy Air Emissions Permit must include at least the following:

a. A requirement to construct and/or operate according to approved plans;

b. A requirement to comply with the conditions of the permit;

c. Emission best management practices for aggregated dairy source activity and operations;

d. A Monitoring and Reporting Schedule, as specified in Section 6, subsection (3) of this rule;

e. Any specialized monitoring equipment (e.g. continuous monitoring systems) requirements, if applicable;

f. A permit expiration date of no more than five years.

(2) Emission Best Management Practices. If the applicant's Air Impact Assessment indicates that the project's baseline emissions will or may exceed the applicable emissions limits specified in Section 6, subsection (2)(b) of this rule, the applicant must implement emissions best management practices capable of achieving emissions reductions from each of the following emissions sources within the Regulated Dairy:

animal housing; milking parlors; feed storage and handling; manure storage, handling and treatment; and land application.

a. **Selection of Emission Best Management Practices.** The Department will determine emission best management practices for each of the emissions sources listed in Section 6, subsection (2) of this rule, based on those practices identified as capable of achieving quantifiable emissions reductions by EPA and USDA in the "Agricultural Air Quality Conservation Measures: Reference Guide for Poultry and Livestock Production Systems;" The University of Idaho College of Agricultural and Life Sciences in "Dairy Ammonia Control Practices;" and the San Joaquin Valley Air Pollution Control District in "Phase II Rule 4570 Permit Application Form."[3]

b. **Tiered System.** The Department will require the adoption and implementation of emission best management practices based on a two-tiered system, whereby Regulated Dairies with greater baseline emission estimates will be subject to more stringent best management practices for each emissions source, and Regulated Dairies with smaller baseline emission estimates will be subject to less stringent requirements. The tiered categories will be as follows:

   i. Regulated Dairies with a potential to emit any regulated pollutants in excess of any federal Clean Air Act permitting thresholds shall obtain the requisite federal Clean Air Act permit, and shall additionally implement all best management practices required of "Tier 1" sources, as determined by the Department to constitute Best Available Control Technology (BACT);

   ii. Regulated Dairies with a potential to emit any regulated pollutants at rates below all federal Clean Air Act permitting thresholds shall implement all best management practices required of "Tier 2" sources, as determined by the Department.

c. **Additional Requirements for Facilities that are or will emit Hazardous Air Pollutants exceeding federal permitting thresholds.** If any Regulated Dairy requires a Title V Operating permit for any hazardous air pollutant (HAP), the Department will promulgate and apply Maximum Achievable Control Technology (MACT) pursuant to OAR 340-244-0210(2).

d. **Enforceable Permit Conditions.** Adoption and implementation of best management practices must be fully enforceable through permit conditions.

(3) **Monitoring and Reporting Schedule.** A Dairy Air Emissions Permit shall include a Monitoring and Reporting Schedule (MRS) for the best management practices required by the permit. An MRS shall outline how the best management practices will be implemented and how compliance will be documented, and must include the following information:

[3] *See* Appendix A for a representative list of best management practices.

a. Standards for determining compliance with best management practices, such as record keeping, reporting, installation of monitoring devices, and/or contracting requirements;
b. A monitoring schedule;
c. A reporting schedule;
d. A requirement to notify the Department of any permit violations within 24-hours of their occurrence; and
e. Provisions for failure to comply.

Section 7. Issuance or Denial of Permits

(1) Issuance of a Dairy Air Emissions Permit shall not relieve the permittee from compliance with other applicable provisions of the Clean Air Act Implementation Plan for Oregon.
(2) After reviewing a complete Dairy Air Emissions Permit application, the Department or Regional Authority having jurisdiction shall act to either disapprove a permit application or approve it with possible conditions.
(3) No permit may be issued unless the Department determines that:
a. The Regulated Dairy will not cause or contribute to a violation of the Clean Air Act Implementation Plan for Oregon;
b. The Regulated Dairy will not cause or contribute to a delay in the attainment of or cause or contribute to a violation of any National Ambient Air Quality Standard based on modeling performed consistent with 40 C.F.R. § 52.21 Appendix W;
c. The Regulated Dairy will not cause or contribute to air pollution in excess of any maximum allowable increase or maximum allowable concentration more than one time per year for any pollutant in any area to which such limits apply, nor will the Regulated Dairy cause or contribute to air pollution in excess of any annual increment based on modeling performed consistent with 40 C.F.R. § 52.21 Appendix W;
d. The Regulated Dairy will not cause air pollution in excess of workplace safety standards set by the U.S. Occupational Safety and Health Administration, as enforced under the Oregon Safe Employment Act;
e. In the Department's best professional judgement, the Regulated Dairy will not cause or contribute to a nuisance;
f. The Regulated Dairy has fully disclosed all relevant facts during the application and/or permit issuance process;
g. The Regulated Dairy has met all applicable requirements for a Dairy Air Emissions Permit application; and
h. In the Department's best professional judgment, the construction and/or operation of the Regulated Dairy is not contrary to the public interest and does not pose an undue threat to public health, environmental justice, or the environment.

(4) Notice and opportunity for public participation. The issuance or denial of a Dairy Air Emissions Permit is subject to the public participation requirements established under OAR 340-209-0030 for a Category III permit action. The public notice shall provide written copies of the following:

- **a.** The Department's draft approval or disapproval determination of the permit application;
- **b.** The Air Impact Assessment submitted by the applicant; and
- **c.** The emission best management practices that shall be implemented, as required by the permit.

After the 35-day written comment period has closed, the Department shall notify the applicant and public in writing of its proposed decision regarding the application.

Section 8. Permit Duration

(1) A Dairy Air Emissions Permit issued by the Department or a Regional Authority having jurisdiction shall remain in effect until modified or revoked by the Department or such Regional Authority, or until the permit expires.

(2) The Department or Regional Authority having jurisdiction may revoke the permit of any Dairy in violation of the construction, modification, or operating conditions set forth in the permit.

(3) An approved Dairy Air Emissions Permit may be conditioned to expire if construction or modification is not commenced within 18 months after receipt of the approved permit. The Director may extend such time period upon a satisfactory showing by the permittee that an extension is justified.

(4) A permit expiration date will be set for no more than five years from the permit's effective date.

(5) Upon permit expiration, the applicant may seek renewal for another five-year term, and shall submit any and all information the Department deems necessary for reaching a renewal determination. A Regulated Dairy must submit a renewal application 180 days before its current permit expires. If the renewal application is timely submitted, and the Department does not reissue the permit prior to the existing permit's expiration date, the permit shall be administratively continued until such time that the renewal is issued.

Section 9. Compliance and Enforcement Actions

(1) Any owner or operator of a Regulated Dairy operating without a permit required by this rule, or operating in violation of any of the conditions of an issued permit shall be subject to civil penalties, injunctions, and permit revocation.

(2) Nothing in this rule shall preclude a city, county, Regional Authority, or other political subdivision of this state from establishing additional permit conditions or requirements for Dairy Air Emissions Permit applicants or permittees within its jurisdiction, so long as such permit conditions or requirements are no less stringent than those established in this rule.

(3) If the Department denies, revokes, or modifies a Dairy Air Emissions Permit, it shall issue an order setting forth its reasons in essential detail.

II. FACTS AND ARGUMENTS

As required per OAR 137-001-0070(1)(b), Petitioners submit the following facts and arguments:

Over the last 20 years, Oregon has seen a sharp increase in large dairy operations in the state. These dairy concentrated animal feeding operations ("Dairy CAFOs"), the largest of which are sometimes referred to as factory farms, present serious threats to air and water quality, as well as to animal welfare and local quality of life.[4] In recognition of the serious threat to water quality these operations present, DEQ requires large dairy CAFOs (those with over 700 cows) to obtain a permit in order to control the storage, handling, and disposal of vast quantities of manure generated by these operations, and prevent the harmful effect this waste has on the state's waters.[5] Yet, despite the direct and serious impact Dairy CAFOs also have on air quality, these operations are subject to virtually no requirements to control or mitigate the numerous toxic air pollutants they release.[6] In other words, DEQ has utterly failed to address air quality concerns through its current CAFO regulations.[7]

This total absence of CAFO air regulations undermines state law and executive policies that have urged regulatory action to address the threat these operations present to air quality and the climate. In 2007, the Oregon State Legislature passed a bill to address air emissions from dairies, specifically directing DEQ to enter into a memorandum of understanding ("MOU") with the Oregon Department of Agriculture ("ODA") to address the administration and enforcement of air quality laws applicable to agricultural operations.[8] The 2007 legislation also created a Dairy Air Quality Task Force ("Dairy Task Force") comprised of government officials, Oregon State University faculty, members of the dairy industry, family farm organizations, and environmental and public health professionals, charged with studying the emissions from dairy operations,

[4] This document's use of the term "CAFO" refers to federally defined Large CAFOs, meaning dairies with at least 700 mature dairy cattle as defined by EPA, as opposed to the broader term "confined animal feeding operation" as defined under Oregon state regulations. *Compare* 40 C.F.R. § 122.23 *with* OR. ADMIN R. 340-051-0010.

[5] *See* OR. ADMIN. R. 603-074-0005. *See also* Wym Matthews, Ranei Nomura & Beth Moore, *State of Oregon Confined Animal Feeding Operation Permit Program*, OR. DEP'T OF AGRIC. (Mar. 31, 2016), https://www.oregon.gov/oda/shared/Documents/Publications/NaturalResources/CAFONPDESPermitAndEvalFactSheet.pdf.

[6] *See, e.g.*, George Plaven, *Boardman Mega-dairy Up for Further Review*, E. OREGONIAN (Dec. 13, 2018), https://www.eastoregonian.com/news/agriculture/boardman-mega-dairy-up-for-further-review/article_fbb55f5c-aa35-5187-b308-7e2a78503cfa.html. *But see* Or. Dep't Env't Quality, Or. Title V Operating Permit No. 25-0047-TV-01–WOF PNW Threemile Project, LLC (2019), https://www.deq.state.or.us/AQPermitsonline/25-0047-TV-01_PM_2019_2.PDF (demonstrating that Oregon requires air quality permits for some methane digester facilities). *See generally*, CONG. RSCH. SERV., RL32948, AIR QUALITY ISSUES AND ANIMAL AGRICULTURE: A PRIMER (2016) ("Several states have recognized a need to regulate air emissions from agricultural operations, but many states have not yet adopted or enacted programs affecting AFO emissions.").

[7] *See, e.g.*, Tracy Loew, *Proposed Mega-Dairy Draw Protests*, STATESMAN J. (Aug. 5, 2016) [hereinafter Loew, *Proposed Mega-Dairy*], https://www.statesmanjournal.com/story/tech/science/environment/2016/08/05/proposed-mega-dairy-draws-protests/88308804; Tracy Loew, *Oregon Approves Five Controversial Dairy Expansions*, STATESMAN J. (Jan. 7, 2016), https://www.statesmanjournal.com/story/tech/science/environment/2016/01/07/oregon-approves-five-controversial-dairy-expansions/78379000.

[8] OR. REV. STAT. § 468A.790.

evaluating strategies for reducing emissions, and presenting findings and recommendations to DEQ and ODA to inform the regulatory process.[9]

The Dairy Task Force examined a wide body of scientific literature regarding major air pollutants emitted from large dairy farms, none of which Oregon currently regulates from livestock operations.[10] These pollutants include ammonia, hydrogen sulfide, methane, methanol, volatile organic compounds, nitrogen oxides, particulate matter, and odors.[11] Based on a comprehensive analysis of the magnitude of CAFO air emissions, and the dangers posed by the air pollutants emitted, the Dairy Task Force "strongly" urged the agencies to initiate regulatory action to address the threat of Dairy CAFO air pollution.[12]

Despite the agencies' clear statutory mandate, and the Dairy Task Force's urgent recommendation to act, nearly fifteen years have passed, and DEQ and ODA have yet to establish how federal and state air quality laws apply to agriculture, nor have the agencies attempted to define the contours of a CAFO air regulatory program.[13] In fact, it appears the agencies have simply shelved the prospect of regulating dairy air pollution altogether, having made little effort since 2008 to take up the issue.[14] Meanwhile, Oregonians continue to suffer from the adverse effects of Dairy CAFO air pollution.

When it comes to CAFOs, DEQ and ODA have also ignored more recent directives from the Governor to address the climate impacts of this industry. Governor Brown's recent Climate Executive Order No. 20-04 directed both ODA and DEQ to take action and use "any and all discretion vested in them by law" to reduce and regulate Greenhouse Gas ("GHG") emissions. Under EO 20-04, the agencies are subject to both general and specific directives set forth to accomplish a state-wide strategy for reducing GHG emissions (1) at least 45% below 1990 emissions levels by 2035 and (2) at least 80% below 1990 emissions levels by 2050.

Despite the fact that the CAFO sector contributes significantly to climate change in Oregon and nationwide, DEQ entirely omits CAFO-related methane and nitrous oxide emissions from its proposed Climate Protection Program ("CPP") rule.[15] This latest example of agency inaction illustrates yet another missed opportunity to finally begin holding this industry accountable for the negative impact its air pollution has on Oregon.

By focusing only on the largest of dairy operations, the proposed rule is designed to have a broad impact on CAFO air pollution without unduly burdening the industry. As proposed, the permitting program would regulate a minority of the State's Dairy CAFOs, but address the vast majority of

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[9] OR. DAIRY AIR QUALITY TASK FORCE, FINAL REPORT TO THE DEPARTMENT OF ENVIRONMENTAL QUALITY & DEPARTMENT OF AGRICULTURE 3 (2008) [hereinafter DAQTF Report].
[10] *See id.* at 7; OR. DAIRY AIR QUALITY TASK FORCE, TECHNICAL SUPPORT DOCUMENT FOR DAIRY AIR QUALITY TASK FORCE REPORT 31 (2008) [hereinafter DAQTF Technical Support]; *see also* Loew, *Proposed Mega-Dairy*, *supra* note 7.
[11] DAQTF Technical Support, *supra* note 10, at 32–38.
[12] *Id*. at 4, 8; Tracy Loew, *Second Mega-Dairy Proposed for Oregon*, STATESMAN J. (July 25, 2016), https://www.statesmanjournal.com/story/tech/science/environment/2016/07/25/second-mega-dairy-proposed-oregon/86951016.
[13] DEQ email to petitioner NEDC (Apr. 29, 2021) (confirming that "ODA and DEQ did not develop or finalize a CAFO air program MOU.").
[14] DEQ open records request response and production (Apr. 29, 2021).
[15] *See generally Notice of Proposed Rulemaking: Greenhouse Gas Emissions Program 2021, Rulemaking Climate Protection Program*, OR. DEP'T ENV'T QUALITY (Aug. 5, 2021), https://www.oregon.gov/deq/Regulations/rulemaking/RuleDocuments/GHGCR2021Notice.pdf.

the industry's emissions. Petitioners estimate the rule would only apply to 39 percent of Oregon's Grade A Dairy operations—approximately 91 facilities—yet control emissions from 84 percent of the states' dairy cows.[16]

Without sufficient air emissions regulation, Oregon CAFOs present unjustifiable risks to public health—particularly for environmental justice communities—the environment, animal welfare, and the economic livelihoods of more sustainable family farms. By freely emitting toxic pollutants into the air, these operations disproportionately harm the public health of Oregon's low-income communities and communities of color who live nearby, threatening already vulnerable populations with increasing rates of respiratory illness and death, and lower quality of life. The environmental impact is also significant, as these emissions exacerbate climate change and threaten natural resources and wildlife habitat. Furthermore, unchecked and unregulated air pollution worsens the already often inhumane conditions for the workers and animals within these facilities. Finally, refusing to regulate Dairy CAFO air emissions is contributing to the economic imbalances disadvantaging family farmers by allowing these operations to continue circumventing accountability for their pollution.

A. Failing to Immediately Regulate Dairy CAFO Air Emissions Threatens Public Health

Dairy CAFO air pollution poses a direct threat to public health, particularly for the dairy workers that work in, and communities that live near these operations. Not only can exposure to CAFO emissions cause acute poisoning and asphyxiation, this toxic pollution also causes serious chronic illness leading to thousands of deaths in the United States every year.

According to the U.S. Government Accountability Office, storing large quantities of livestock manure on factory farms can cause emissions of "unsafe quantities" of ammonia, hydrogen sulfide and particulate matter.[17] Ammonia is a "strong respiratory irritant" that causes chemical burns to the respiratory tract, skin, and eyes, severe coughing, and chronic lung disease.[18] Recent peer-reviewed research found that nationwide, ammonia emissions from industrial livestock production claim 12,400 lives each year – more deaths than are caused by coal-fired power plants.[19] Hydrogen sulfide is also acutely dangerous, causing "inflammation of the moist membranes" in the eyes and respiratory tract as well as olfactory neuron loss, pulmonary edema, and even death.[20] Likewise, particulate matter exposure can lead to "chronic bronchitis, chronic obstructive airways disease . . .[and] declines in lung function," as well as "organic dust toxic syndrome."[21]

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[16] *See* ODA, List of Oregon Dairy Operations (Aug. 12, 2022) (obtained via public records request).
[17] U.S. GOV'T ACCOUNTABILITY OFF., GAO-08-944, CONCENTRATED ANIMAL FEEDING OPERATIONS 7 (2008) ("[CAFOs] can potentially degrade air quality because large amounts of manure may emit unsafe quantities of ammonia, hydrogen sulfide, and particulate matter.").
[18] *Concentrated Animal Feedlot Operations (CAFOs) Chemicals Associated with Air Emissions*, CAFO SUBCOMM. MICH. DEP'T ENV'T QUALITY & TOXICS STEERING GRP. 4 (May 10, 2006) [hereinafter Michigan CAFO Subcommittee], https://www.michigan.gov/-/media/Project/Websites/mdhhs/Folder1/Folder50/CAFOs-Chemicals_Associated_with_Air_Emissions_5-10-06.pdf; Carrie Hribar, *Understanding Concentrated Animal Feeding Operations and Their Impact on Communities*, NAT'L ASS'N LOC. BDS. HEALTH 6 (2010).
[19] Nina G. G. Domingo et al., *Air Quality-Related Health Damages of Food*, 118 PNAS e2013637118, 2 (2021), https://www.pnas.org/doi/pdf/10.1073/pnas.2013637118.
[20] Michigan CAFO Subcommittee, *supra* note 18, at 6.
[21] *Id.* at 9–10.

Figure 1, Typical Pollutants Found in Air Surrounding CAFOs[22]

CAFO Emissions	Source	Traits	Health Risks
Ammonia	Formed when microbes decompose undigested organic nitrogen compounds in manure	Colorless, sharp pungent odor	Respiratory irritant, chemical burns to respiratory tract, skin, and eyes, severe cough, chronic lung disease
Hydrogen Sulfide	Anaerobic bacterial decomposition of protein and other sulfur containing organic matter	Odor of rotten eggs	Inflammation of the moist membranes of eye and respiratory tract, olfactory neuron loss, death
Particulate Matter	Feed, bedding materials, dry manure, unpaved soil surfaces, animal dander	Comprised of fecal matter, feed materials, pollen, bacteria, fungi, skin cells, silicates	Chronic bronchitis, chronic respiratory symptoms, declines in lung function, organic dust toxic syndrome

Indeed, CAFO emissions are so potent that it can be dangerous even to approach a waste lagoon, particularly in hot summer months and when waste is agitated prior to being pumped out.[23] Workers in these facilities experience high levels of asthma-like symptoms, bronchitis and other respiratory diseases.[24] What's worse, "the oxygen-deficient, toxic, and/or explosive atmosphere which can develop in a manure pit has claimed many lives."[25] There are multiple incidents of farm workers approaching lagoons to make repairs and succumbing to the emissions; some died from hydrogen sulfide poisoning, while others asphyxiated in the oxygen-starved air.[26] Still others have died after collapsing during rescue attempts.[27]

But it is not necessary to be near a lagoon to suffer grave health effects from the emissions. Dairy CAFOs also have the potential to threaten entire communities. For instance, one 1,500-cow dairy in Minnesota released so much hydrogen sulfide gas in 2008 that the state evacuated nearby

[22] Hribar, *supra* note 18, at 6.
[23] Robbin Marks, *Cesspools of Shame: How Factory Farm Lagoons and Sprayfields Threaten Environmental and Public Health*, NRDC 26 (July 2001), https://www.nrdc.org/sites/default/files/cesspools.pdf; *Iowa Concentrated Animal Feeding Operations Air Quality Study: Final Report*, IOWA STATE UNIV. & UNIV. IOWA STUDY GRP. 118, 124 (Feb. 2002).
[24] Kelley J. Donham et al., *Community Health and Socioeconomic Issues Surrounding Concentrated Animal Feeding Operations*, 115 ENV'T HEALTH PERSP. 317, 318 (2007) ("It is clear that at least 25% of confinement workers suffer from respiratory diseases including bronchitis, mucus membrane irritation, asthmalike syndrome, and acute respiratory distress syndrome."); Hribar, *supra* note 18, at 6–7.
[25] *NIOSH Warns: Manure Pits Continue to Claim Lives*, CTRS. DISEASE CONTROL & PREVENTION (July 6, 1993), https://www.cdc.gov/niosh/updates/93-114.html.
[26] Marks, *supra* note 23, at 19; *see also Manure Pite Fatalities Spur Awareness*, DAIRY BUS. (Aug. 24, 2021), https://www.dairybusiness.com/manure-pit-fatalities-spur-awareness (reporting the death of three brothers caused by toxic fumes released from a manure pit on their family's farm); Rachael Rettner, *3 Men Die in Manure Pit: Here's Why it's a 'Death Trap'*, LIVE SCIENCE (Aug. 12, 2021), https://www.livescience.com/brothers-die-manure-pit-fumes-toxic.html; *Gas from Manure Pit Kills 5 on Dairy Farm*, CBS NEWS (July 3, 2007), https://www.cbsnews.com/news/gas-from-manure-pit-kills-5-on-dairy-farm (describing the deaths of five people overcome by deadly methane gas emanating from a dairy farm's manure pit).
[27] *See* Marks, *supra* note 23, at 26.

residents and declared the dairy a public health hazard.[28] Residents had complained about odors from the dairy for years before the state began monitoring hydrogen sulfide emissions in the area, which soon revealed dangerously high emissions.[29] Moreover, studies show that people in CAFO-occupied communities suffer disproportionate levels of tension, anger, confusion, fatigue, depression, upper respiratory symptoms, and gastrointestinal ailments than neighbors of other types of farms and non-livestock areas.[30] There is also consistent evidence demonstrating that CAFOs increase asthma in neighboring communities. The risk is especially great for children, who take in 20–50 percent more air than adults, making them more susceptible to lung disease and other health effects.[31]

In addition to respiratory illnesses, CAFOs also spawn new viruses.[32] When the U.S. Centers for Disease Control and Prevention (CDC) sequenced the DNA of the swine flu that killed thousands of Americans in 2009, they traced its origin to a single North Carolina pig CAFO.[33] The CDC estimates that the 2009 swine flu pandemic sickened 60.8 million Americans, hospitalized 274,304, and killed 12,469, including more than a thousand children.[34] Similarly, the novel coronavirus, which has killed over 6 million people across the world, very likely originated in animal markets, with the full consequences of the coronavirus yet to be seen.[35]

B. Failing to Immediately Regulate Dairy CAFO Air Emissions Exacerbates Environmental Injustices Across the State

CAFOs in general are disproportionately sited in low-income communities and communities of color,[36] most of which lack the political power to successfully oppose their construction.[37]

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[28] *See Residents Living Near Northwestern Minn. Feedlot Evacuate*, PIONEER PRESS (June 10, 2008), https://www.twincities.com/2008/06/10/residents-living-near-northwestern-minn-feedlot-evacuate/amp.
[29] Tom Meersman, *Dairy Odors Drive Out Families, But Attract Lawsuit*, Minn. Star Trib., June 20, 2008; Tom Meersman, *Thief River Falls Feedlot Declared Public Health Hazard*, Minn. Star Trib., Oct. 7, 2008.
[30] Hribar, *supra* note 18, at 5; Sarah C. Wilson, Comment, *Hogwash! Why Industrial Animal Agriculture is Not Beyond the Scope of Clean Air Act Regulation*, 24 PACE ENV'T L. REV. 439, 441, 445 n.45 (2007).
[31] Hribar, *supra* note 18, at 6–7.
[32] *Id.* at 10 ("These viruses generate through mutation or recombinant events that can result in more efficient human-to-human transmission.").
[33] Felicity Lawrence, *The Pig's Revenge*, GUARDIAN (May 1, 2009), https://theguardian.com/world/2009/may/02/swine-flu-pandemic-mexico-pig-farming ("At CDC the head of virology had completed the genetic fingerprinting of the swine flu and was able to say that it has arisen from a strain first identified on industrial pig units in North Carolina in the late 1990s."); *see also* Gavin J. D. Smith et al., *Origins and Evolutionary Genomics of the 2009 Swine-origin H1N1 Influenza of Epidemic*, 459 NATURE 1122 (2009); Bernice Wuethrich, *Chasing the Fickle Swine Flu*, 299 SCIENCE 1502 (2003).
[34] Sundar S. Shrestha et al., *Estimating the Burden of 2009 Pandemic Influenza of (H1N1) in the United States (April 2009–April 2010)*, 52 CLINICAL INFECTIOUS DISEASES S75–82 (2011).
[35] Aylin Woodward, *Both the New Coronavirus and SARS Outbreaks Likely Started in Chinese Wet Markets*, BUS. INSIDER (Feb. 26, 2020), https://www.businessinsider.com/wuhan-coronavirus-chinese-wet-market-photos-2020-1 (discussing the potential for zoonotic diseases to jump from animals to humans); Carl Zimmer & Benjamin Mueller, *New Research Points to Wuhan Market as Pandemic Origin*, N.Y. TIMES (Feb. 27, 2022), https://www.nytimes.com/interactive/2022/02/26/science/covid-virus-wuhan-origins.html (detailing newly released studies concluding the coronavirus very likely originated in live mammals sold at the Wuhan Market).
[36] *See* Letter from EPA External C.R. Compliance Off. to N.C. Dep't Env't Quality, EPA File No. 11R-14-R4 (Jan. 12, 2017), https://www.epa.gov/sites/production/files/2018-05/documents/letter_of_concern_to_william_g_ross_nc_deq_re_admin_complaint_11r-14-r4_.pdf (describing discriminatory health and quality of life impacts from pig and poultry CAFOs); Donham, *supra* note 24; Steve Wing, Dana Cole & Gary Grant, *Environmental Injustice in North Carolina's Hog Industry*, 108 ENV'T HEALTH PERSPS. 225 (2000) (studying the disproportionate impact of pollution and offensive odors on poor and nonwhite communities).
[37] *See* Steve Wing et al., *Air Pollution from Industrial Swine Operations and Blood Pressure of Neighboring Residents*, 121 ENV'T HEALTH PERSPS. 92, 96 (2013) (noting that marginalized communities lack the political power necessary to prevent CAFO

Accordingly, these populations disproportionately bear the consequences of Dairy CAFOs' externalities, including public health harms, diminished quality of life,[38] and plummeting property values.[39]

Nowhere are these health disparities more apparent than in Morrow and Umatilla Counties. The Boardman and Hermiston areas are home to the State's largest Dairy CAFOs, which collectively confine over 100,000 cows.[40] The surrounding communities are significantly overburdened by air and water pollution, as well as other socioeconomic factors that exacerbate the CAFO health risk. According to EPA's Environmental Justice Screening and Mapping Tool, which considers the combined impact of environmental and demographic indicators to characterize an area's overall environmental justice index, these communities shoulder some of the states' highest pollution burdens, consistently ranking in the 80–90th percentiles[41] for numerous environmental hazards as compared to the rest of the State.

Figure 2, Boardman Area Environmental Justice Indexes[42]

Environmental Justice Index	State Percentile
Particulate Matter 2.5	88
Ozone	89
2017 Diesel Particulate Matter	83
2017 Air Toxics Cancer Risk	87
2017 Air Toxics Respiratory Hazard Index	88
Superfund Proximity	90
Risk Management Plan (RMP) Facility Proximity	92
Hazardous Waste Proximity	81
Underground Storage Tanks	83
Wastewater Discharge	88

facility operations); Steve Wing & Jill Johnston, *Industrial Hog Operations in North Carolina Disproportionately Impact African-Americans, Hispanics and American Indians*, N.C. POL'Y WATCH 3 (2014), http://www.ncpolicywatch.com/wp-content/uploads/2014/09/UNC-Report.pdf (concluding that the "disproportionate location in communities of color represented an environmental injustice"); Wendee Nicole, *CAFOs and Environmental Justice: The Case of North Carolina*," 121 ENV'T HEALTH PERSPS. A182, A183–89 (2013).

38 Hribar, *supra* note 18, at 7–8 (noting odors and insect vectors that plague CAFO-occupied communities).

39 *Id.* at 11 (noting that "property value declines can range from a decrease of 6.6% within a 3-mile radius of a CAFO to an 88% decrease within 1/10 of a mile from a CAFO").

40 List of Oregon Dairy Operations, *supra* note 16.

41 According to EPA, the state percentile "tells you what percent of the [state] population *has an equal or lower value*, meaning less potential for exposure/risk/proximity to certain facilities, or a lower percent minority." *See How to Interpret a Standard Report in EJScreen*, EPA (Feb. 18, 2022), https://www.epa.gov/ejscreen/how-interpret-standard-report-ejscreen.

42 EJScreenReport (Version 2.3) for User Specified Area: Boardman Area, EPA 1 (last accessed Aug. 1, 2022) [hereinafter Boardman EJScreen Report].

Figure 3, Hermiston Area Environmental Justice Indexes[43]

Environmental Justice Index	State Percentile
Particulate Matter 2.5	86
Ozone	86
2017 Diesel Particulate Matter	83
2017 Air Toxics Cancer Risk	85
2017 Air Toxics Respiratory Hazard Index	84
Superfund Proximity	88
Risk Management Plan (RMP) Facility Proximity	92
Hazardous Waste Proximity	80
Underground Storage Tanks	85
Wastewater Discharge	87

As compared with the rest of Oregon, these communities are also populated by a high percentage of low-income residents and people of color, who struggle with higher rates of unemployment and linguistic isolation than the rest of the State.

Figure 4, Boardman/Hermiston Demographic Indicators[44]

Demographic Index	Value	Stage Average	State Percentile
Boardman Area			
People of Color	45%	28%	87
Low Income	46%	24%	88
Unemployment Rate	5%	5%	56
Linguistically Isolated	7%	2%	88
Less Than High School Education	28%	9%	95
Under Age 5	8%	6%	76
Hermiston Area			
People of Color	42%	28%	84
Low Income	43%	24%	83
Unemployment Rate	8%	5%	77
Linguistically Isolated	7%	2%	87
Less Than High School Education	23%	9%	91
Under Age 5	8%	6%	76

To make matters worse, on top of the CAFO air quality threat and other environmental and socioeconomic stressors the region's residents face, these communities are also dealing with a groundwater contamination emergency that is jeopardizing their drinking water supplies. In June of 2022, the Morrow County Commission declared a local state of emergency over groundwater

[43] EJScreen Report (Version 2.0) for User Specified Area: Hermiston Area, EPA 1 (last accessed Aug. 1, 2022) [hereinafter Hermiston EJScreen Report].
[44] Boardman EJScreen Report, *supra* note 42, at 3; Hermiston EJScreen Report, *supra* note 43, at 3.

nitrate pollution that has compromised drinking water for as many as 1,300 homes throughout the region.[45] Though the State has been aware of the groundwater crisis for over three decades, little has been done to curb the pollution responsible for the contamination, including the Dairy CAFOs that are contributing to the problem by overapplying manure to farmland throughout the area.[46] The cumulative impact this industry is having on the health and wellbeing of these Oregonians is undeniable, and DEQ should immediately take action to safeguard these vulnerable populations from any further harm.

Indeed, DEQ has a legal duty to consider Dairy CAFOs' impacts on environmental justice communities. ORS § 182.545(1), "Duties of Natural Resource Agencies," states: In order to provide greater public participation and to ensure that all persons affected by decisions of the natural resource agencies have a voice in those decisions, each natural resource agency shall:

1. In making a determination whether and how to act, consider the effects of the action on environmental justice issues.
2. Hold hearings at times and in locations that are convenient for people in communities that will be affected by the decisions stemming from those hearings.
3. Engage in public outreach activities in the communities that will be affected by decisions of the agency.
4. Create a citizen advocate position that is responsible for (a) Encouraging public participation; (b) Ensuring that the agency considers environmental justice issues; and (c) Informing the agency of the effect of its decisions on communities traditionally underrepresented in public processes.

DEQ is a "Natural Resource Agency" under ORS § 182.535. Accordingly, DEQ must consider, and work to redress, the clear environmental injustices associated with its failure to regulate Dairy CAFO air pollution. This proposed rulemaking presents the agency with the opportunity to do so.

C. Failing to Immediately Regulate Dairy CAFO Air Emissions Poses a Direct and Serious Threat to Oregon's Environment

For years, unchecked Dairy CAFO air pollution has been degrading Oregon's environment and natural resources. Not only do these facilities emit substantial quantities of climate-altering pollutants that intensify the negative impacts of climate change, but they are contributing significantly to the State's regional haze problems.

Mega-dairies are a significant source of methane emissions, a potent anthropogenic GHG.[47] Methane comes directly from cows (enteric emissions) and off-gasses from the enormous manure lagoons where waste anaerobically rots. According to the U.S. Environmental Protection Agency ("EPA"), livestock production is the dominant source of methane in the United States, and manure

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[45] Alex Baumhardt, *Morrow County Declares Emergency Over Groundwater Nitrate Pollution*, OR. CAP. CHRON. (June 9, 2022), https://oregoncapitalchronicle.com/2022/06/09/morrow-county-declares-emergency-over-groundwater-nitrate-pollution.

[46] *Id.*; *see also* Food & Water Watch et al., Petition to EPA for Emergency Action Pursuant to the Safe Drinking Water Act § 1431, 42 U.S.C. § 300i, to Protect Citizens of the Lower Umatilla Basin in Oregon from Imminent and Substantial Endangerment to Public Health Caused by Nitrate Contamination of Public Water Systems and Underground Sources of Drinking Water (Jan. 16, 2020).

[47] *Overview of Greenhouse Gases*, EPA (May 16, 2022), https://www.epa.gov/ghgemissions/overview-greenhouse-gases ("The Agriculture sector is the largest source of CH_4 emissions in the United States.").

management is the fastest growing major source of methane, with total emissions increasing by more than 62 percent between 1990 and 2020.[48] Dairy operations *specifically* are a large part of these increases in manure methane emissions, with overall dairy emissions increasing 122 percent within that same timeframe.[49] In Oregon, agriculture is the *leading source* of methane emissions,[50] and animal agriculture (enteric fermentation and manure management) is responsible for over 3 million metric tons of carbon dioxide ("CO_2") equivalent each year.[51]

These GHG emissions contribute to rising global temperatures and the serious public health and welfare problems associated with climate change. EPA recognized the significance of these climate impacts in 2009, when the agency found that methane and five other anthropogenic GHGs "endanger both the public health and the public welfare of current and future generations by causing or contributing to climate change."[52] As the recent Intergovernmental Panel on Climate Change ("IPPC") reports concluded, rapidly restricting methane is crucial, given that its potency far outstrips CO_2 in the short term.[53] Climate change also threatens the viability of agriculture as a whole, including the dairy industry.

In addition to these serious climate impacts, Dairy CAFOs also harm Oregon's natural resources and wildlife through their ammonia emissions. CAFOs produce nearly 75 percent of all ammonia pollution in the United States,[54] and a single CAFO is capable of emitting millions of pounds of ammonia each year.[55] Ammonia emissions are particularly high for CAFOs that rely on land application for manure management, which volatilizes the ammonia in the manure and further increases emissions.[56] This is especially true for dairy operations that use anaerobic digesters to generate methane from livestock manure, as studies have shown that the process increases the ammonia content of resulting waste.[57] Oregon dairies in particular have some of the highest ammonia emissions in the country. For instance, when operating with just over 50,000 cows in 2005, Threemile Canyon Farms reported ammonia emissions that ranked among the highest in the

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[48] *Id; see also Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2020*, EPA (July 13, 2022), https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2020.
[49] *Id.* at 2-20.
[50] *See The Urgent Case for a Moratorium on Mega-Dairies in Oregon*, FOOD & WATER WATCH, (Nov. 2020), https://www.foodandwaterwatch.org/wp-content/uploads/2021/03/fs_2011_ormegadairies-fin.pdf (citing *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990- 2018*, EPA (2018) at ES-16, ES-22, 2-20).
[51] *See Oregon Greenhouse Gas Sector-Based Inventory Data*, OR. DEP'T ENV'T QUALITY, https://www.oregon.gov/deq/aq/programs/Pages/GHG-Inventory.aspx (last visited Aug. 4, 2022.
[52] Endangerment & Cause or Contribute Findings from GHGs Ender Section 202(a) of the Clean Air Act, 74 Fed. Reg. 66,496 (Dec. 15, 2009) (final rule).
[53] *See generally Climate Change 2021: The Physical Science Basis*, IPCC (2021), https://www.ipcc.ch/report/ar6/wg1 (describing how human influence, specifically greenhouse gas emission, has unequivocally warmed the atmosphere, ocean, and land); *Climate Change 2022: Impacts, Adaptation and Vulnerability*, IPCC (2022), https://www.ipcc.ch/report/ar6/wg2 (detailing the degradation and loss of ecosystems due to greenhouse gas emissions).
[54] *CAFOs Ordered to Report Hazardous Pollution*, WATERKEEPER ALL. (Apr. 11, 2017), http://waterkeeper.org/cafos-ordered-to-report-hazardous-pollution.
[55] Michele M. Merkel, Speech at Albany Law School: The Use of CERCLA to Address Agricultural Pollution 1 (Sept. 15, 2006), http://www.environmentalintegrity.org/pdf/publications/The_Use_Cercla.pdf.
[56] Hribar, *supra* note 18, at 5.
[57] Michael A. Holly et al., *Greenhouse Gas and Ammonia Emissions from Digested and Separated Dairy Manure During Storage and After Land Application*, 239 AGRIC., ECOSYSTEMS, & ENV'T 410, 413 (2017); *Conservation Practice Standard: Anaerobic Digester*, USDA (Oct. 2017), https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=nrcseprd1335265&ext=pdf; *see also Agricultural Air Quality Conservation Measures: Reference Guide for Poultry and Livestock Production Systems*, EPA & USDA, Appendix A.1 (Sep. 2017), https://www.epa.gov/sites/default/files/2017-01/documents/web_placeholder.pdf (estimating anaerobic digesters increase on-farm ammonia emissions by 30-50%).

nation.[58] If operated at its current permitted capacity of 90,667 dairy cows, it would emit a dangerous 27,000 pounds of ammonia a day, or 4,972.5 tons per year.[59]

This ammonia pollution is wreaking havoc on the Columbia River Gorge Scenic Area, Crater Lake National Park, and Oregon's other natural treasures. Not only do these emissions degrade overall ambient air quality,[60] DEQ reports that livestock manure management, including field application of manure, is "by far the most significant source of ammonia" contributing to regional haze and harming iconic natural features of the Oregon landscape.[61] They also contribute to acid rain, which threatens ecosystems and Native American rock paintings.[62]

There are also serious water quality implications related to a CAFO's ammonia emissions. When ammonia is released into the air, it rapidly settles to surfaces, leading to significant deposition—up to 20 percent—to nearby land and waterways.[63] Ammonia is often found in surface waters surrounding CAFOs, and causes oxygen depletion from water, which itself can kill aquatic life.[64] Ammonia also converts to nitrates, and can therefore deposit increased loads of nitrogen into water bodies, which harm sensitive ecosystems like coastal estuaries by accelerating vegetative growth and toxic algae blooms, leading to oxygen depletion and reduced fish and shellfish populations.[65]

D. Failing to Immediately Regulate Dairy CAFO Air Emissions Exacerbates Inhumane Living Conditions for Farmed Animals

Dairy CAFOs force farmed animals into intense confinement in factory-like conditions that inhibit their ability to carry out natural behaviors and increase their susceptibility to injury, illness, and disease.[66] Most cows living on Dairy CAFOs are kept indoors, either allowed to move around the barn freely in what are known as "free stall" systems, or tethered in place in "tie stall" systems where they are unable to leave their small individual stalls. Dairy CAFO flooring is typically concrete, which can cause cows to develop painful pressure lesions on their hooves, along with laminitis and even lameness.[67] CAFOs often force dairy cows to stand in their own manure, which

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[58] Lindley, Tom. Perkins Cole, *Letter to EPA Regional Office. Re: CR-ENS Number 754198* (Apr. 5, 2005); FWW analysis of EPA, *Toxic Release Inventory, 2005, Ammonia* (accessed Feb. 10, 2017), available at https://iaspub.epa.gov/triexplorer/tri_release.chemical and on file at FWW; FWW analysis of U.S. Coast Guard, *National Response Center: 2005 Data* (accessed Feb. 10, 2017), available at http://nrc.uscg.mil and on file at FWW.
[59] *See* DAQTF Report, *supra* note 9, Appendix I at 6.
[60] Hribar, *supra* note 18, at 7.
[61] *Oregon Regional Haze Plan: 5-Year Progress Report and Update*, OR. DEP'T ENV'T QUALITY I, 21 (Feb. 2016), http://www.deq.state.or.us/aq/haze/docs/2016ORRegHazeUpdate.pdf; *see also* Mark Green, Marc Pitchford & Chris Emery, *The Columbia River Gorge Air Quality and Visibility Study*, EM 21, 24 (2008) (concluding that CAFO emissions are a significant source of haze in the Gorge).
[62] *See* DAQTF Report, *supra* note 9, at 6–7; DAQTF Technical Support, *supra* note 10, at 41–42.
[63] Shabtai Bittman and Robert Mikkelsen, *Ammonia Emissions from Agricultural Operations: Livestock*, Better Crops/Vol. 93, 29 (2009).
[64] Hribar, *supra* note 18, at 4.
[65] Hribar, *supra* note 18, at 4–5; DAQTF Technical Support, *supra* note 10, at 40–41.
[66] *See, e.g.*, *The Critical Relationship Between Farm Animal Health and Welfare*, ANIMAL WELFARE INST. (2018), https://awionline.org/sites/default/files/uploads/documents/FA-AWI-Animal-Health-Welfare-Report-04022018.pdf.
[67] S. Platz et al., *What Happens with Cow Behavior When Replacing Concrete Slatted Floor by Rubber Coating: A Case Study,* 91 J. DAIRY SCI. 999, 999 (2008).

causes those wounds to become infected—Lost Valley Farm, for example, confined dairy cows to barns overflowing with manure, leaving them to stand or lie all day and night in their own waste.[68]

Like humans and other mammals, cows only produce milk as a result of pregnancy and birth. Accordingly, cows on Dairy CAFOs are repeatedly impregnated and their offspring taken away, generally within the first 24 hours after birth, so that all of their milk can be collected and none of it is "lost" to nursing. Dairy cows are bred for unnaturally high milk production and as a result often develop mastitis, which is a painful inflammation of the mammary gland that results from physical trauma or microorganism infection.[69] Dairy cows exist in these inhumane systems until their milk production slows below desired levels or they become too crippled or ill to stay on farms, at which point they are considered "spent" and are sent to slaughter. A dairy cow's utility on a Dairy CAFO generally only lasts between two and five years, which is in stark contrast to a cow's natural life span, which can be upwards of 20 years.[70] The demanding nature of the dairy industry is most evident at the end of cows' lives—an estimated 75% of downed animals who arrive at slaughterhouses unable to stand are dairy cows.[71]

Unregulated Dairy CAFO air emissions are making conditions even worse for farmed animals by exposing the animals themselves to high levels of ammonia, particulates, and other pollutants of concern. As discussed above, failure to regulate Dairy CAFOs also fuels the climate crisis, and the resulting increasing temperatures and extreme weather events further harm farmed animals' health and well-being.[72] Specifically, farmed animals are "greatly affected by resulting heat stress, metabolic disorder, oxidative stress, and immune suppression," which cause them to experience increased rates of disease and death.[73] They also experience other health impacts from the advancing climate crisis, including those associated with the "multiplication and distribution of parasites, reproduction, virulence, and transmission of infectious pathogens and/or their vectors."[74]

E. Failing to Immediately Regulate Dairy CAFO Air Emissions Jeopardizes the Economic Livelihoods of Oregon's Few Remaining Small and Mid-sized Dairy Farms

Lastly, the rise of Dairy CAFOs across the state is driving small and mid-sized dairy farms, which are historically the backbone of Oregon's rural economy, to extinction. The "catastrophic decline" in small and mid-sized dairy farms is a powerful illustration of this trajectory.[75] The total number of dairy farms has fallen from 1,900 in 1992 to fewer than 230 today,[76] and the number of mid-

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[68] Leah Douglas, *Lost Valley Debacle Leads to Effort to Limit Mega-Dairies in Oregon*, OR. LIVE (Apr. 5, 2019), https://www.oregonlive.com/business/2019/04/lost-valley-debacle-leads-to-effort-to-limit-mega-dairies-in-oregon.html (featuring a photo of a dairy cow forced to stand in manure up to her ankles).
[69] Wei Nee Cheng & Sung Gu Han, *Bovine Mastitis: Risk Factors, Therapeutic Strategies, and Alternative Treatments — A Review*, 33 ASIAN-AUSTRALASIAN J. ANIMAL SCI. 1699, 1699 (2020).
[70] A. De Vries & M.I. Marcondes, *Review: Overview of Factors Affecting Productive Lifespan of Dairy Cows*, 14 ANIMAL s155, s159 (2020).
[71] *An HSUS Report: The Welfare of Cows in the Dairy Industry*, HUMANE SOC'Y U.S. 8 (2009), https://www.humanesociety.org/sites/default/files/docs/hsus-report-animal-welfare-cow-dairy-industry.pdf.
[72] Md Zulfekar Ali et al., *Impact of Global Climate Change on Livestock Health: Bangladesh Perspective*, 10 OPEN VETERINARY J. 178, 178 (2020).
[73] *Id.*
[74] *Id.*
[75] George Plaven, *Groups Call for "Mega-Dairy" Moratorium*, CAP. PRESS (Dec. 13, 2018), https://www.capitalpress.com/ag_sectors/dairy/groups-call-for-mega-dairy-moratorium/article_a7a01e2a-fcb5-11e8-bc5c-1f802a55fc28.html.
[76] *See* Douglas, *supra* note 68.

sized dairies in Oregon dropped by a third just between 2007 and 2012.[77] Meanwhile, the number of dairy cows in the state more than tripled between 1997 and 2012 as the number of mega-dairies spiked.[78] In 1997, Oregon had 8 dairies with over 1,000 cows, and as of 2012 it had 25 such facilities.[79] As of August 2022, there are 68 such facilities.[80] Oregon's family farms cannot—and will not—survive CAFOs, especially when Dairy CAFOs need not account for the true cost of their pollution and other negative impacts.[81]

III. PROPOSITIONS OF LAW

As required under OAR 137-001-0070(1)(c), petitioners submit the following propositions of federal and state law that support EQC's authority and obligation to regulate emissions from Dairy CAFOs to protect air quality in Oregon.

A. EQC Has Broad Authority to Regulate State Air Quality

The Oregon Legislature has established both broad policy and specific direction to DEQ and EQC with regard to the control of air pollution in Oregon. The Legislature's overriding policy for Oregon, as stated in ORS 468A.010, is "[t]o restore and maintain the quality of the air resources of the state in a condition as free from air pollution as practicable, consistent with the overall public welfare of the state." EQC's expansive authority to regulate Oregon air pollution also extends to the regulation of GHG emissions.[82]

To carry out this policy, EQC is authorized to set standards for air purity in Oregon, to set emissions limitations on air contamination sources, and then to regulate air contaminant emissions in order to meet those standards.[83] Specifically, and in relevant part, the State Legislature has empowered the Commission to: (1) set statewide emissions standards;[84] (2) adopt mandatory pollution control equipment and technology requirements;[85] (3) require sources of air contaminants to obtain permits;[86] (4) impose registration and reporting requirements on air contaminant

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77 Food & Water Watch analysis of USDA National Agriculture Statistics Service 2012 Census of Agriculture State Data – Oregon. A mid-sized dairy is one with between 50 and 199 cows. *See 2012 Census of Agriculture: Oregon State and County Data*, USDA, Table 12. Cattle and Calves – Inventory: 2012 and 2007 (May 2014), https://agcensus.library.cornell.edu/wp-content/uploads/2012-Oregon-orv1-1.pdf.

78 Food & Water Watch calculations based on U.S. Department of Agriculture (USDA) Census of Agriculture 1997 and 2012.

79 Food & Water Watch calculation of USDA National Agriculture Statistics Service. 2002 Census of Agriculture State Data – Oregon. *See 2002 Census of Agriculture: Oregon State and County Data*, USDA, Table 12. Cattle and Calves – Inventory: 2002 and 1997 (June 2004), https://agcensus.library.cornell.edu/wp-content/uploads/2002-Oregon-01-full.pdf; *see also* 2012 Oregon Census of Agriculture, *supra* note 77 and accompanying text.

80 *See* List of Dairy Operations, *supra* note 16.

81 *See* Douglas, *supra* note 68.

82 *See Program Options to Cap and Reduce Greenhouse Gas Emissions: Final Report,* OR. DEP'T ENV'T QUALITY 5–7 (June 2020) [hereinafter DEQ GHG Report], https://www.oregon.gov/gov/Documents/2020%20DEQ%20CapandReduce_FinalReport.pdf (detailing EQC's legal authority to regulate greenhouse gas emissions).

83 *See* OR. REV. STAT. § 468.025; OR. REV. STAT. § 468A.040; and OR. REV. STAT. § 468A.045.

84 OR. REV. STAT. § 468A.025(3) (authorizing EQC to "set forth the maximum amount of air pollution permissible" and to distinguish between air contaminants and air contamination sources when setting such standards).

85 OR. REV. STAT. § 468A.025(4) (authorizing EQC to "require specific permit conditions for the operation and maintenance of pollution control equipment," and "technology" necessary to protect public health and achieve ambient air quality standards and federal requirements).

86 OR. REV. STAT. § 468A.040(1) (authorizing EQC to require air permits for air contamination sources classified by types of air contaminants or source).

sources;[87] (5) mandate pre-construction requirements on proposed sources;[88] and (6) require emission monitoring and testing.[89]

B. EQC Has Express Authority to Adopt Air Quality Rules Applicable to Agricultural Sources

Although "agricultural operations" are generally exempt from State air quality laws, the Legislature has authorized EQC to regulate air contaminant emissions from agricultural operations, and specifically dairies, to the extent "necessary to implement the federal Clean Air Act," and as "necessary for the [EQC], in the commission's discretion, to implement a recommendation of the Task Force on Dairy Air Quality created under section 3, chapter 799, Oregon Laws 2007, for the regulation of dairy air contaminant emissions."[90]

In other words, EQC *must* regulate Dairy CAFO emissions that trigger federal Clean Air Act requirements. In fact, state law has explicitly directed DEQ and ODA to enter a MOU to address the administration and enforcement of federal and state air quality laws applicable to agricultural operations, but the agencies have to date failed to do so.[91] This proposed rulemaking requests that the agencies fulfill this statutory mandate.

Additionally, EQC may regulate Dairy CAFO emissions beyond federal Clean Air Act requirements, by adopting the recommendations made by the Dairy Task Force in 2008. The law gives EQC discretion with respect to the adoption of Dairy Task Force recommendations, and we urge the Commission to exercise this discretion as to all air contaminants identified by the Task Force as pollutants of concern. Importantly, with regard to GHG emissions, Governor Brown's Climate Change directive eliminated EQC's discretion, requiring the agency to use its authority fully—in this case, to regulate dairy methane and nitrous oxides.[92]

1. EQC Must Regulate Dairy CAFO Emissions that Trigger Clean Air Act Permitting Requirements

As recognized by the Dairy Task Force, the federal Clean Air Act applies to dairy operations that emit federally regulated air pollutants at sufficient quantities to trigger air quality permitting requirements.[93] These air pollutants include Hydrogen Sulfide, Nitrogen Oxides, Particulate Matter, and VOCs (collectively, "CAA pollutants").[94] Additionally, DEQ has long acknowledged

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[87] OR. REV. STAT. § 468A.050(1) (authorizing EQC to classify air contamination sources according to levels and types of emissions, and other characteristics which contributed to air pollution and require registration and/or reporting for any such class).
[88] OR. REV. STAT. §§ 468A.055(1)-(2) (authorizing EQC to require notice prior to construction of new air contamination sources, and as a condition precedent to approval, the submission of plans and specifications, and the adoption of corrections and revisions to those plans).
[89] OR. REV. STAT. §§ 468A.070(1)-(2) (authorizing EQC to require sampling and testing of contamination sources necessary to determine the nature, extent, quantity, and degree of air contaminants emitted from the source).
[90] OR. REV. STAT. §§ 468A.020(2)(b)-(c).
[91] OR. REV. STAT. § 468A.790.
[92] *See* Or. Exec. Order No. 20-04 (Mar. 10. 2020) [hereinafter Oregon EO], https://www.oregon.gov/bcd/Pages/energy-eo.aspx (requiring EQC to "use *any and all* discretion vested in them by law" to help achieve the state's greenhouse gas reduction goals).
[93] DAQTF Technical Support, *supra* note 10, at 42–43.
[94] *Id.* at 44.

that should agricultural sources require federal permits, then such sources, including Dairy CAFOs, would also need to comply with State air quality requirements.[95]

EPA also recognizes the applicability of the Clean Air Act to CAFOs. Not only has the federal agency historically taken a series of legal actions designed to bring delinquent CAFOs into the Clean Air Act permitting program,[96] it has also explicitly confirmed that when such operations emit CAA pollutants in quantities that exceed regulatory thresholds, EPA "can and will require [animal feeding operations] to comply with all applicable [Clean Air Act] requirements."[97] While EPA acknowledges that the Clean Air Act applies to CAFOs generally, it has also entered into an agreement with a subset of CAFO operators, which provides safe harbor from federal enforcement of the Clean Air Act until EPA has developed new emissions modeling tools for the industry.[98] Though this agreement remains in place, it does *not* exempt the industry at large from Clean Air Act requirements, nor does it prevent Oregon from regulating Dairy CAFOs under the Clean Air Act and other applicable state law.[99]

California's regulation of Dairy CAFOs under the Clean Air Act for the past two decades underscores this point. Much like Oregon,[100] California state law used to exempt agricultural sources from Clean Air Act regulation, until EPA ruled in 2003 that doing so clearly violated federal law and exposed the State to sanctions, including the loss of billions of dollars of federal highway funds.[101] Removing the blanket exemption for agriculture propelled the State to create a comprehensive Clean Air Act permitting program for agricultural sources, and issue CAFO-specific regulations in recognition of the industry's outsized impact on air quality.[102]

Though Oregon has similarly repealed its blanket exemption for agricultural source emissions, as instructed by EPA,[103] DEQ has failed to drive Clean Air Act implementation for the sector. Unlike California regulators, who developed their Dairy CAFO permitting program amidst a dearth of scientific research on CAFO air emissions, now there are several tools available to DEQ that can

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[95] In updating DEQ rules to conform with the 2007 revisions to ORS 468A.020, DEQ acknowledged that "if agricultural source types are required to obtain a federally required permit because of the revisions to ORS 468A.020, then they will need to comply with the existing testing, monitoring, recordkeeping and reporting requirements under Divisions 216 (ACDP), 218 (Title V) or 224 (major New Source Review)." *Chapter 340 Proposed Rulemaking Statement of Need and Fiscal and Economic Impact*, OR. DEP'T ENV'T QUALITY 2 (Oct. 26, 2007).

[96] *See, e.g.*, Press Release, DEP'T OF JUSTICE, *Ohio's Largest Egg Producer Agrees to Dramatic Air Pollution Reductions from Three Giant Facilities* (Feb. 23, 2004), available at https://www.justice.gov/archive/opa/pr/2004/February/04_enrd_105.htm; Press Release, DEP'T OF JUSTICE, *Government Reaches Settlements with Seaboard Foods and PIC USA* (Sep. 15, 2006), available at https://www.justice.gov/archive/opa/pr/2006/September/06_crm_625.html; Press Release, DEP'T OF JUSTICE, Nation's Second Largest Hog Producer Reaches Settlement With U.S. & Citizen's Group (Nov. 1, 2001), available at https://www.justice.gov/archive/opa/pr/2001/November/01_enrd_604.htm.

[97] 70 Fed. Reg. 4957, 4959 (Mar. 2, 2005).

[98] *Id.*

[99] *Id.*

[100] Oregon fell under similar EPA scrutiny in 2007 for its blanket exemption of agricultural sources from air quality regulation, prompting the state legislature to clarify that DEQ was empowered to regulate such sources under the Clean Air Act. S.B. 235, 74th Leg. Assemb., Reg. Sess. (Or. 2007).

[101] EPA, *California New Source Review: Call for Revisions to California State Law*, Region 9 Air Programs, available at https://19january2017snapshot.epa.gov/www3/region9/air/ca/nsr/index.html. *See also* Senate Committee on Envt'l Quality, SB 700 Bill Analysis, 2003-2004 Sess., at 4 (Cal. 2003), https://leginfo.legislature.ca.gov/faces/billAnalysisClient.xhtml.

[102] *See, e.g.*, San Joaquin Valley Air Pollution Control District Rule 4570 (Adopted June 15, 2006) (aimed at reducing VOC and ammonia emissions by requiring best available mitigation measures).

[103] *See* Senate Committee on Envt'l and Nat. Resources, S.B. 235 Staff Measure Summary, 2007 Reg. Sess., at 1 (Or. 2007), https://olis.oregonlegislature.gov/liz/2007R1/Downloads/MeasureAnalysisDocument/4951.

quantify Dairy CAFO emissions and determine whether these stationary sources exceed Clean Air Act permitting thresholds. The California Air Resource Board has developed and refined a suite of emissions factors over the past sixteen years in partnership with UC Davis agricultural researchers to estimate Dairy CAFO VOC and PM emissions for the purpose of federal Title I and Title V permitting.[104] Additionally, the USDA has created two high-quality, process-based models to assess Dairy CAFO air emissions, both of which take into account the particular structural and management characteristics of CAFOs.[105] These include the Integrated Farm Systems Model, which models ammonia and GHG emissions released from an array of on-farm sources and activities,[106] and the Dairy Gas Emissions Model, which projects ammonia, hydrogen sulfide, and greenhouse gas emissions.[107] EPA currently uses these models in its National Emissions Inventory,[108] and also anticipates releasing additional statistical modeling tools to quantify Dairy CAFO air emissions by late 2023.[109]

In other words, DEQ and CAFO operators have resources at their disposal to accurately determine which Oregon Dairy CAFOs exceed Clean Air Act permitting thresholds. The Clean Air Act has two types of permit programs that apply to all major stationary sources of air pollution: Title I permits for construction approval, and Title V operating permits. As detailed below, both of these programs are applicable to Oregon's largest dairy operations.

a. A Dairy CAFO is a "stationary source" within the meaning of the Clean Air Act

Clean Air Act permitting programs only apply to "stationary sources," which the Act broadly defines as "any source of an air pollutant" excluding internal combustion engines for transportation and certain nonroad engines.[110] EPA regulations further refine the meaning of this term, defining a "stationary source" as "any building, structure, facility, or installation which emits or may emit a regulated [New Source Review] pollutant."[111] "Building, structure, facility or installation" means "all of the pollutant-emitting activities which belong to the same industrial grouping, are located on one or more contiguous or adjacent properties, and are under the control of the same person (or persons under common control) except the activities of any vessel."[112]

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[104] *See Air Pollution Control Officer's Revision of the Dairy VOC Emission Factors*, SAN JOAQUIN VALLEY AIR POLLUTION CONTROL DIST. 5 (Feb. 23, 2012) [hereinafter VOC Emission Factors], https://www.valleyair.org/busind/pto/emission_factors/2012-Final-Dairy-EE-Report/FinalDairyEFReport(2-23-12).pdf; SJVAPCD, *Dairy and Feedlot PM_{10} Emission Factors* (Oct. 14, 2017), http://www.valleyair.org/busind/pto/dpag/FYI-Dairy_Feedlot_PM10_Emission_Factors_Revised_10-24-2017.pdf.

[105] C. Alan Rotz et. al., *Ammonia Emission Model for Whole Farm Evaluation of Dairy Production Systems*, 43 J. Envt'l Qual. 1143, 1145 (2014).

[106] *Id.*, *See also* USDA Agricultural Research Service, *Integrated Farm System Model*, (last modified Mar 3, 2020), https://www.ars.usda.gov/northeast-area/up-pa/pswmru/docs/integrated-farm-system-model/.

[107] USDA Agricultural Research Service, *Dairy Gas Emission Model* (last modified Mar. 20, 2020), https://www.ars.usda.gov/northeast-area/up-pa/pswmru/docs/dairy-gas-emissions-model/.

[108] EPA, 2017 NATIONAL EMISSIONS INVENTORY: JANUARY 2021 UPDATED RELEASE, TECHNICAL SUPPORT DOCUMENT 4-61 (2021); A. McQuilling & P. Adams, *Semi-Empirical Process-Based Models For Ammonia Emissions From Beef, Swine, & Poultry Operations In The United States*, 120 ATMOS. ENVTL. 127 (Nov. 2015).

[109] *See* EPA, *Draft Air Emission Models for Dairy Animal Feeding Operations* (June 2022), available at https://www.epa.gov/system/files/documents/2022-07/Dairy_PreliminaryDraft_report.pdf; EPA *National Air Emissions Monitoring Study* (last updated July 14, 2022), https://www.epa.gov/afos-air/national-air-emissions-monitoring-study#naems-status (outlining timeline for finalization and publication of emission estimating methodologies).

[110] 42 U.S.C. § 7602

[111] 40 C.F.R. § 51.165(a)(1)(I).

[112] *Id.* at § 51.165(a)(1)(ii).

A Dairy CAFO is made up of a combination of "buildings" and "structures" that house cows, manure, and/or feed, all of which emit CAA pollutants. These pollutant-emitting buildings and structures include, but are not limited to freestall barns, manure storage lagoons, open corrals with flushed alleys, milking barns, and feed storage facilities. Together, these components comprise the dairy facility and are collectively a stationary source within the meaning of the Clean Air Act.[113]

b. *Large Dairy CAFOs must be permitted under the Title I Prevention of Significant Deterioration Program*

Title I of the Clean Air Act focuses on the construction phase, and requires construction approval and the implementation of pollution control technology for all new major sources and existing major sources proposing major modifications.[114] The severity of the air pollution in a given air basin determines a certain tons per year emissions threshold, above which a stationary source must obtain a Title I permit.

In air quality attainment areas, where air quality complies with National Ambient Air Quality Standards ("NAAQS"), the source is permitted under the Prevention of Significant Deterioration ("PSD") program, whereas in nonattainment areas, where the concentration of a pollutant exceeds NAAQS, the source is permitted under the Nonattainment New Source Review ("NNSR)" program. In Oregon, both the NNSR and PSD programs are implemented through the state's Air Contaminant Discharge Permit ("ACDP") program.[115]

Most Oregon Dairy CAFOs operate in attainment areas.[116] Therefore, to be considered a "Major Source" triggering PSD permit requirements, a new operation must have the potential to emit at least 250 tons per year of any CAA pollutant.[117] An existing major source proposing modifications would trigger PSD permitting requirements if the modification would result in significant emissions increases known as "significant emission rates," as detailed below.

Figure 5, Significant Emission Rates[118]

Total Particulate (PM)	25 tons/year
Particulate 10 microns and less in size (PM_{10})	15 tons/year
Nitrogen Oxides (NO_x)	40 tons/year
Volatile Organic Compounds (VOCs)	40 tons/year
Hydrogen Sulfide (H_2S)	10 tons/year

When an air pollution source is subject to the PSD program, it must install Best Available Control Technology ("BACT"), which imposes emission limits on a facility based on the "maximum

[113] *See Ass'n of Irritated Residents v. Fred Schakel Dairy*, CIV F 05-00707, 2005 U.S. LEXIS 36769, *29-31 (E.D. Cal. Dec. 2, 2005) (holding that a dairy was sufficiently alleged to be a stationary source); *Idaho Conservation League v. Boer*, 362 F. Supp. 2d 1211, 1214-1215 (D. Idaho 2004) (same). *See also*, 70 Fed. Reg. at 4959 (EPA noting that CAFOs emit several pollutants regulated under the Clean Air Act "from many different areas at AFOs, including animal housing structures (e.g. barns, covered feed lots) and manure storage areas (e.g. lagoons, covered manure piles).")
[114] 40 C.F.R § 52.21(j) (2021).
[115] OR. ADMIN. R. 340-216-0010 *et seq.*; *see also* DAQTF Technical Support, *supra* note 10, at 50.
[116] DAQTF Technical Support, *supra* note 10, at 49–52.
[117] 40 C.F.R. §§ 51.166(a)(7), (b)(1); OR. ADMIN. R. 340-224-0010.
[118] *See* OR. ADMIN. R. 340-200-0020 Table 2.

degree of reduction achievable."[119] Per EPA guidance, BACT is considered the highest level of control achieved for a similar source in any state, unless the source demonstrates that implementation of such controls would result in unusually high energy, environmental, or economic impacts. The PSD program also requires sources to conduct an analysis of impacts on NAAQS, air quality degradation, and visibility, the results of which could lead to requirements for further controls or design changes.[120]

Based on the Dairy Task Force's scientific review of dairy air emissions, very large dairy operations emit significant quantities of VOCs, sufficient to trigger these PSD permit requirements. The Task Force considered a range of representative emission factors, assembled by DEQ to quantify dairy air emissions.[121] Depending on the emission factor, a Dairy CAFO ranging in size from 13,110 cows to 25,920 cows will trigger PSD permitting requirements for VOCs:

Figure 6, Dairy Operation VOC Emissions Triggering Title I (2008 estimate)[122]

VOC Emission Factor	Herd Size	VOC Emissions *(kg/yr)*	In Tons/Year
8.75 kg/head-yr	25,920 cows	226,800	**250.004**
17.3 kg/head-yr	13,110 cows	226,803	**250.007**

VOC emissions factors developed after the Task Force issued its report and currently utilized by California regulators further refines this estimate.[123] This updated scientific research suggests that a dairy operation consisting of 16,515 cows or more emits sufficient VOCs to trigger PSD permitting. At the time of petition filing, there are currently two Oregon dairies that exceed this threshold.

[119] DAQTF Technical Support, *supra* note 10, at 53.
[120] *Id.*
[121] *Id.* at 70; Appendix W. The chosen emission factors were based on DEQ's "best scientific judgment from university reports and the EPA using the following criteria: emission factors used by EPA (if available); emissions factors from studies conducted in geographic areas with climates similar to Oregon, [and] emissions factors utilized in other countries with climates similar to Oregon." According to the Task Force, the variability in the range of emission factors selected is attributable to "the fact that some research only accounted for a portion of an operation's emissions, while other research captured a more complete accounting of total emissions" *Id.* at 69–70.
[122] Petitioners have compiled a spreadsheet entitled "EmissionsCalculationsFigs.6-12" detailing the emissions calculations for Figures 6–12 of the Petition. This document is saved in the Google Drive Link referenced above.
[123] *See* VOC Emission Factors, *supra* note 104.

Figure 7, Dairy Operation VOC Emissions Triggering Title I (2021 estimate)

Herd Size	**Non-Feed Related VOC Emissions**[124] ***(lb/yr)***	**Silage Pile VOC Emissions**[125] ***(lb/yr)***			**Total Mixed Ration Emissions**[126] ***(lb/yr)***	**Total VOC Emissions** ***(lbs/yr)***
		Corn Silage	Alfalfa Silage	Wheat Silage		
16,515 cows	297,435.15	1,001.85	505.84	1,267.05	199,818.329	500,028.22 **[= 250 tons/yr]**

c. *Very large Dairy CAFOs also require Title V Operating Permits*

Title V of the Clean Air Act requires all major sources to have an operating permit. Except in areas with severe air pollution, Title V applies to major sources that have the potential to emit 100 tons per year or more of CAA pollutants.[127] The purpose of a Title V permit is to ensure compliance with all air quality requirements that otherwise apply to a permitted source. Therefore, while an operating permit generally does not, by itself, impose any additional requirements for emission reductions on sources, it does include monitoring conditions for each existing requirement, and also mandates that permitted sources certify compliance every six months.[128]

However, when a major source also emits a legally significant amount of a hazardous air pollutant ("HAP"), operating permits do impose stringent substantive requirements to control and reduce those HAP emissions. HAPs are a special class of toxic air pollutants that EPA or DEQ has found cause serious health effects, including cancer.[129] A source need only emit 10 tons per year of any listed HAP in order to trigger Title V permit requirements, which include application of National Emission Standards for Hazardous Air Pollutants ("NESHAPs") based on the Maximum Achievable Control Technology ("MACT") for the relevant source category.[130] If, for any reason, EPA has not yet promulgated NESHAPs for particular HAPs or source categories, DEQ must determine state MACT and establish state HAP emission limitations for that source category.[131]

Based on the VOC emission factors detailed in Section III.B.1.a and Figures 6 and 7, the following dairy operations likely require Title V operating permits for VOCs.

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[124] Applying an 18.01 emissions factor, which excludes fugitive emissions related to manure application to land. *See id.* at 5; *see also Association of Irritated Residents v. Fred Schakel Dairy*, 460 F. Supp. 2d 1185, 1189 (E.D. Cal. 2006) (explaining that "the enteric emissions from cows in the freestall barns and the milking barn, emissions from decomposing feed, and emissions from decomposing manure in the manure lagoons and compost piles are non-fugitive emissions in that they can reasonably pass through a stack, chimney, vent, or other functionally equivalent opening.").

[125] Assuming the facility has one of each type of silage pile, which are all covered except for one open face of 25 m^2.

[126] Based on average feed lane area of 0.8 m^2 per cow.

[127] 42 U.S.C. § 7661(2)(A); 42 U.S.C. § 7602(j).

[128] DAQTF Technical Support, *supra* note 10, at 53.

[129] *See* 42 U.S.C. § 7412; DAQTF Technical Support, *supra* note 10, at 45, 53–54.

[130] DAQTF Technical Support, *supra* note 10, at 50; *see also* OR. ADMIN. R. 340-244-0030(16) (defining "MACT" to mean the "maximum degree of reduction in emissions deemed achievable for either new or existing sources").

[131] OR. ADMIN. R. 340-244-0120(2).

Figure 8, Dairy Operation VOC Emissions Triggering Title V (2008 estimate)

VOC Emission Factor	Herd Size	VOC Emissions *(kg/yr)*	In Tons/Year
8.75 kg/head-yr	10,368 cows	90,720	**100.001**
17.3 kg/head-yr	5,244 cows	90,721	**100.003**

Figure 9, Dairy Operation VOC Emissions Triggering Title V (2021 estimate)

Herd Size	Non-Feed Related VOC Emissions[132] *(lb/yr)*	Silage Pile VOC Emissions[133] *(lb/yr)*			Total Mixed Ration Emissions[134] *(lb/yr)*	Total VOC Emissions *(lbs/yr)*
		Corn Silage	Alfalfa Silage	Wheat Silage		
6,575 cows	118,415.75	1,001.85	505.84	1,267.05	79,459.86	200,650.35 **[= 100 tons/yr]**

Additionally, the Task Force concluded that Dairy CAFOs emit significant quantities of the HAP methanol, which "may be large enough to require an air quality permit.[135] A review of the most current scientific literature identifying dairy-related methanol sources and quantifying emissions confirms the Task Force's finding. For instance, a University of California, Davis study reported directly to the California Air Resources Board documents enteric methanol emissions—emitted directly from the animals—as well as emissions from fresh manure.[136] The study found that cow and waste emissions averaged 3.09 and 11.12 pounds/year-head for dry cows and milk cows, respectively.[137] This means that a dairy operation consisting of 1,800 milk cows would surpass the HAP regulatory threshold based on cow and waste emissions alone. There are currently 33 Oregon dairies that exceed this threshold.

Figure 10, Cow and Waste Methanol Emissions Triggering Title V

Herd Type	Herd Size	Emission Factor	Estimated Cow & Waste Emissions *(tons/year)*
Milk Cows	1,799	11.12 lb/year-head	**10.00**
Dry Cows	6,473	3.09 lb/year-head	**10.00**

Studies commissioned by the California Air Resources Board also show that the storage and handling of dairy cattle feed, in particular the corn silage component of total mixed rations (TMR),

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[132] Applying an 18.01 emissions factor, which excludes fugitive emissions related to manure application to land. *See* VOC Emission Factors, *supra* note 124, at 5.
[133] Assuming the facility has one of each type of silage pile, which are all covered except for one open face of 25 m^2.
[134] Based on average feed lane area of 0.8 m^2 per cow.
[135] DAQTF Report, *supra* note 9, at 6.
[136] *See* Frank Mitloehner, *Volatile Fatty Acid, Amine, Phenol, and Alcohol Emissions from Dairy Cows and Fresh Waste*, U.C. DAVIS (May 31, 2006); Huawei Sun et al., *Alcohol, Volatile Fatty Acid, Phenol, and Methane Emissions from Dairy Cows and Fresh Manure*, 37 J. Env't Quality 615–622 (2008).
[137] Mitloehner, *supra* note 136, at 31–32.

emit high levels of methanol.[138] Considering cow, waste, and feed-related emissions together, a 981 milk cow-dairy would surpass the HAP regulatory threshold for methanol. Based on currently permitted herd capacities, there are 69 Oregon dairies that exceed this threshold.

Figure 11, Cow, Waste and Feed Methanol Emissions Triggering Title V

Herd Type	**Herd Size**	**Estimated Cow/Waste Emissions** *(tons/yr)*	**Estimated Feed Emissions** *(tons/yr)*			**Total Estimated Methanol Emissions** *(tons/yr)*
			Silage Pile (Disturbed Face)[139]	*Silage Pile (Undisturbed Face)*[140]	*Total Mixed Rations*[141]	
Milk Cows	981	5.45	0.009	0.006	4.53	**10.00**
Dry Cows	1,620	2.5	0.009	0.006	7.48	**10.00**

d. *Dairy CAFOs subject to Title I or V permitting are also subject to regulation for Greenhouse Gas Emissions*

Because very large Dairy CAFOs are subject to Clean Air Act requirements for regulated air pollutants including VOCs and Methanol, the facilities' GHG emissions are also subject to federal regulation. Under the Clean Air Act and EPA's "tailoring rule," where a new major stationary source for a regulated pollutant also has the potential to emit 75,000 tons per year or more of CO_2 equivalent, those GHG emissions are also subject to regulation.[142] The same is true for an existing major stationary source that will have an emissions increase of a regulated pollutant, as well as a GHG emissions increase of 75,000 tons per year of CO_2e or more.[143] In other words, when a CAFO would otherwise be subject to Clean Air Act permitting requirements (a so-called "anyway" source"), its GHG emissions are also subject to the Clean Air Act when they surpass the specified threshold.

Very large Dairy CAFOs in Oregon are subject to this GHG tailoring rule. Per EPA regulations, the CO_2 equivalent of GHGs like nitrous oxide and methane can be calculated by multiplying the mass amount of emissions for each GHG pollutant by the gas's associated global warming potential.[144] Applying the emission's factors considered by the Task Force for these pollutants to the herd sizes referenced above demonstrates this rule applies to Oregon's largest CAFOs:

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[138] Charles Krauter & Donald Blake, *Dairy Operations: An Evaluation and Comparison of Baseline and Potential Mitigation Practices for Emissions Reductions in the San Joaquin Valley*, CAL. AIR RESOURCES BD. 22–34 (May 1, 2009).

[139] Based on an average methanol flux rate of 632 µg/m^2/min, and a disturbed silage pile area of 25 m^2. Per the Krauter study, estimated methanol emission = 632 µg/m^2/min x 25 m^2 x 1,440 min/day x 365 days/yr = .009 tons/yr. *Id.* at 29 & 34.

[140] Based on an average methanol flux rate of 416 µg/m^2/min, and an undisturbed silage pile face of 250 m^2. Per the Krauter study, estimated methanol emission = 416 µg/m^2/min x 250 m^2 x 1,440 min/day x 365 days/yr = .006 tons/yr. *Id.*

[141] Based on an average methanol flux rate of 996.75 µg/m^2/min and an average feed lane area of 0.8 m^2 per cow. *Id.* at 22 & 34.

[142] 40 C.F.R. § 51.166(b)(48)(iv). *See also Util. Air Regulatory Group v. EPA*, 573 U.S. 302, 332 (2014) (upholding this aspect of the rule); 40 C.F.R. § 52.21(b)(49) (defining "subject to regulation" to mean that the pollutant is subject to either a provision in the Clean Air Act, or a nationally-applicable regulation codified by the Administrator in subchapter C of this chapter, that requires actual control of the quantity of emissions of that pollutant").

[143] 40 C.F.R. § 51.166(b)(48)(iv).

[144] 40 C.F.R. § 51.166(b)(48)(ii)(a).

Figure 12, CO_2e Emissions Subject to Regulation

Herd Size	N_20 Emissions *(tons/year)*	CH_4 Emissions *(tons/year)*	Total CO_2e Emissions[145] *(tons/year)*
13,110 cows	2.02 – 40.46	1800.63 – 2,375.79	45,619 – 71,453
16,515 cows	2.55 – 50.97	2,268.30 – 2,992.85	57,467 – **90,011**
25,920 cows	4.00 – 80.00	3,560.06 – 4,697.22	**90,194 – 141,271**

2. EQC Should Regulate Dairy CAFO Emissions Beyond Federal Requirements Per Dairy Task Force Recommendations, and *Must* Do So with Regard to GHG Emissions

In addition to the authority granted to EQC to regulate Dairy CAFOs pursuant to the federal Clean Air Act, EQC is also authorized to adopt rules when necessary, in the Commission's discretion, to implement a recommendation of the Dairy Task Force for the regulation of dairy air contaminants.[146] Task Force recommendations may go above and beyond current requirements under federal law, and "may include, but need not be limited to" findings and recommendations for technical studies, voluntary actions, regulation, and proposed legislation.[147]

In 2008, the Dairy Task Force found that Oregon Dairy operations emit numerous pollutants of concern, including a "notable portion of the state's ammonia and methane emissions."[148] Of particular concern to the task force was the "key role" that ammonia plays in haze pollution, visibility problems, acidic deposition, and ecosystem degradation, and the fact that methane is a "potent greenhouse gas" contributing to climate change.[149]

As a result of its environmental and health impact analysis, the Task Force specifically and "strongly" recommended that EQC adopt rules to implement an "Oregon Dairy Air Emissions Program" that:

i. Applies to all existing Grade A dairies in Oregon that have or need a CAFO permit;
ii. Initially focuses on ammonia, methanol and odors;
iii. Makes technical decisions based on a review of the available science;
iv. Is modeled after Oregon's CAFO Program to prevent water pollution, which ultimately phased into a mandatory regulatory program;
v. Is based on a best management practice approach that (1) uses California and Idaho programs as points of reference, (2) requires structural and management practices to reduce air emissions, (3) establishes clearly defined BMP targets, and creates tiers of required BMPs based on dairy size (and thus potential to emit).[150]

The rule Petitioners propose would accomplish exactly that. The program would require Oregon Dairy CAFOs to obtain air emission permits that address all pollutants of concern identified by the Task Force through the application of science-based best management practices tiered to a CAFO's

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[145] Multiplying N_20 emissions by a 298 global warming potential and CH_4 emissions by a 25 global warming potential. *See* 40 C.F.R. § 98 Table A-1 to Subpart A-Global Warming Potentials.
[146] OR. REV. STAT. § 468A.020(2)(c).
[147] DAQTF Technical Support, *supra* note 10, at 8.
[148] DAQTF Report, *supra* note 9, at 10.
[149] *Id.* at 9.
[150] *Id.* at 8–10.

projected air quality impact, just as the Task Force envisioned. For this reason, insofar as the federal Clean Air Act does not provide the legal authority for any one aspect of the proposed permitting system, the Dairy Task Force recommendations provide the necessary legal grounding.

While state law vests EQC with the discretion to implement these recommendations, the Governor has made clear that EQC *must* "use any and all discretion vested in them by law" in order to help achieve the state's GHG reduction goals of 45 percent below 1990 emissions levels by 2035; and at least 80 percent below 1990 emissions levels by 2050.[151] Additionally, the governor directed DEQ to "take actions necessary to cap and reduce GHG emissions from large stationary sources of GHG emissions."[152] Because implementing the Task Force recommendations would address a "notable portion" of the state's methane emissions, per Governor Brown's directive, EQC *must* use its discretion to do so.[153]

IV. CONCLUSION

Dairy CAFO emissions currently pose significant threats to human health, the environment, and animal welfare in Oregon, and are preventing the State from achieving its greenhouse gas reduction targets. The proposed Dairy Air Emissions rule would work to reduce harmful emissions associated with these polluting operations, thereby improving air quality and advancing Oregon's climate goals. The rule would also uphold DEQ's statutory obligation to advance environmental justice, and result in meaningful benefits for Oregonians who have too long shouldered the burden of exposure to Dairy CAFO air pollution. We therefore strongly urge EQC to exercise its rulemaking authority and adopt the Dairy Air Emissions rule proposed by this petition.

Respectfully submitted,

Dated: August 17, 2022 *<u>/s/ Emily Miller</u>*

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[151] Oregon EO, *supra* note 92.
[152] *Id.*
[153] In DEQ's Final Report to Governor Brown, in response to the cap and reduce directive, the agency states that because the legislature has exempted "most agricultural operations" from air quality regulation, "any greenhouse gas regulations EQC adopts" should not regulate these exempted activities. *See* DEQ GHG Report, *supra* note 82, at 7–8. For the reasons explained above, dairy operations are *not* exempt from the proposed regulation. Based on the Task Force recommendations, EQC has clear authority to create a comprehensive dairy air emissions regulatory program that includes mandatory caps and reductions of GHG emissions.

APPENDIX A

Representative List of Best Management Practices

Emissions Source	Best Management Practice Description	Emissions Targeted for Reduction
Feed Management, Storage, and Handling		
Feed Management	Implement phase feeding.[1]	NH_3, Odors
	Feed in accordance with NRCS Guidelines.[2]	NH_3, VOCs
Feed Storage	Store grain in weather-proof structure or under a weather-proof covering.[3]	NH_3, Methanol, VOCs
	Cover surface of silage piles, except for the area where feed is being removed from the pile, with a plastic tarp at least 5 mm thick (.005 in) within twenty-four (24) hours of delivery of material to the pile.[4]	NH_3, Methanol, VOCs
Feed Handling	Push feed so that it is within three (3) feet of feedlane fence within two hours of putting out the feed or use a feed trough or other feeding structure designed to maintain feed within reach of cows.[5]	NH_3, Methanol, VOCs
	Begin feeding total mixed rations within two (2) hours of grinding and mixing rations and remove uneaten feed from feed bunks within twenty-four (24) hours.[6]	NH_3, Methanol, VOCs
Animal Housing and Milking Parlors		
Freestall Barns	Scrape freestall flush lanes at least two (2) times per day.[7]	NH_3, GHGs, VOCs
	Separate solids in house via a floor design that allows fecal material to remain in place while urine is removed.[8]	H_2S, GHGs, NH_3
	For fully enclosed/mechanically ventilated barns, channel exhaust through biofilters, and for naturally ventilated bars, install reception pit fans and channel exhaust through biofilters.[9]	H_2S, GHGs, NH_3, Odors, PM, VOCs
Milking Parlors	Flush or hose milk parlor immediately prior to, immediately after, or during each milking.[10]	VOCs
	Vent enclosed/mechanically ventilated milk parlors to a biofilter.[11]	H_2S, GHGs, NH_3, Odors, PM, VOCs

[1] *See* EPA/USDA, *Agricultural Air Quality Conservation Measures Reference Guide for Poultry and Livestock Production Systems* ("EPA BMP Guide"), 10 (Sep. 2017); Ron E. Sheffield and Bruce Louks, *Dairy Ammonia Control Practices* ("Idaho Ammonia BMPs"), University of Idaho Extension, 5 & 11 (Apr. 2007).
[2] *See* EPA BMP Guide at 10; Idaho Ammonia BMPs at 5 & 11; San Joaquin Valley Air Pollution Control District*, Phase II Rule 4570 Permit Application Form: Dairy CAFO Mitigation Measures* ("CA BMP Worksheet"), 2 (July 1, 2019).
[3] *See* EPA BMP Guide at 16; CA BMP Worksheet at 2.
[4] *See* EPA BMP Guide at 16; CA BMP Worksheet at 3.
[5] *See* EPA BMP Guide at 16; CA BMP Worksheet at 2.
[6] *Id.*
[7] CA AAMPs at 2; CA BMP Worksheet at 4; Idaho Ammonia BMPs, at 5 & 9.
[8] Idaho Ammonia BMPs, at 5 & 7; CDFA, *List of Manure Management Practices Incentivized Through the Alternative Manure Management Program* ("CA AAMPs"), 1 (Aug. 2021).
[9] EPA BMP Guide at 24–26; Idaho Ammonia BMPs, at 5 & 10.
[10] CA BMP Worksheet at 3; EPA BMP Guide at 39.
[11] EPA BMP Guide at 24–26; Idaho Ammonia BMPs, at 5 & 10.

Corrals	Clean manure from corrals at least four (4) times per year, and manage corrals such that manure depth in the corral does not exceed twelve (12) inches at any point in time.[12]	NH3, VOCs, PM
	Maintain corrals to ensure proper drainage preventing water from standing for more than forty-eight (48) hours.[13]	PM, VOCs
Manure Storage, Handling and Treatment		
Liquid Manure[14]	Cap lagoon structures with a synthetic/impermeable or geotextile cover and treat vented air using a biofilter.[15]	H_2S, GHGs, NH_3, Odors, PM, VOCs
	Remove solids from the waste system with a solid separator system prior to the waste entering the lagoon.[16]	H_2S, GHGs, NH_3, VOCs
Solid Manure	Compost solid manure using static pile composting, forced aeration composting with biofilter or another method of composting with comparable emission reductions.[17]	NH_3, GHGs, Odors
	Cover solid and separated solid manure/compost piles.[18]	NH_3, GHGs, Odors, PM, VOCs
Land Application		
Incorporation	Incorporate all manure as soon as possible, and no later than within twenty-four (24) hours of land application.[19]	H_2S, NH_3, VOCs
Low Pressure Application	Apply liquid/slurry manure via low pressure application system, or another method of application with comparable reductions in H_2S, NH_3 and VOCs.[20]	H_2S, NH_3, Odors, VOCs
General Practices		
Windbreaks and Shelterbelts	Establish vegetative or wooded buffers around production area, lagoon structures, and unpaved roadways.[21]	NH_3, Odors, PM

[12] CA BMP Worksheet at 4; EPA BMP Guide at 30; Idaho Ammonia BMPs, at 5 & 10.
[13] CA BMP Worksheet at 4; EPA BMP Guide at 30.
[14] Note that Petitioners have not included anaerobic methane digesters as a recommended best management practice for liquid manure management, nor should the Agency consider digesters as a viable BMP option. Studies have shown that using digester technology to capture methane from manure lagoons increases the ammonia content of the resulting digestate, which when land applied can lead to substantially higher ammonia emissions. *See* Michael A. Holly et. al., *Greenhouse gas and ammonia emissions from digested and separated dairy manure during storage and after land application*, 239 Agric., Ecosystems & Env't 410, 418 (Feb. 15, 2017); NRCS Conservation Practice Standard 366, 6 (Jun. 2017). *See also* EPA BMP Guide at 73 (estimating anaerobic digesters increase on-farm ammonia emissions by 30-50%); Idaho Ammonia BMPs at 8 (excluding digesters from its ammonia BMP list due to increased ammonia content of waste). Because the Dairy Task Force was particularly concerned with ammonia impacts, and thus recommended prioritizing BMPs that would *reduce* ammonia emissions, *see* DAQTF Final Report at 8–9, the Agency should not adopt a practice that yields the opposite effect. Moreover, studies have also shown that digestate emits so much nitrous oxide that it cancels out the purported climate benefits of methane capture. *See* Holly at 418.
[15] EPA BMP Guide at 24–26 & 36–39; Idaho Ammonia BMPs at 5–6.
[16] CA AAMPs at 1–2; CA BMP Worksheet at 5; EPA BMP Guide at 35; Idaho Ammonia BMPs at 5–7.
[17] CA AAMPs at 2; EPA BMP Guide at 44; Idaho Ammonia BMPs at 5 & 11–13.
[18] EPA BMP Guide at 37 & 44; CA BMP Worksheet at 5.
[19] CA BMP Worksheet at 5; EPA BMP Guide at 49 & 53–54; Idaho Ammonia BMPs at 5 & 13.
[20] CA BMP Worksheet at 5; EPA BMP Guide at 56; Idaho Ammonia BMPs at 5 & 14.
[21] EPA BMP Guide at 28–29 & 68; Idaho Ammonia BMPs at 5 & 9.

Appendix B

Timeline

Federal Dairy Air Regulation History

Below is a summary of federal activities and key reports issues regarding air emissions from agricultural sources.

The 1980 Comprehensive Environmental Response, Compensation & Liability Act (CERCLA) provides authority for EPA to respond to a release or threat of a release of any pollutant or contaminant which may pose a potential threat to human health and/or the environment. One provision within the CERCLA regulations requires generators/facility owners to notify the National Response Center (NRC) when certain quantities of "hazardous substances" are released into the environment.

The 1986 Emergency Planning and Community Right-to-Know Act (EPCRA) was created to help communities plan for chemical emergencies. It also requires industry to report on the storage, use and releases of hazardous substances to federal, state, and local governments.

The 1996 Farm Bill created the USDA Task Force on Agricultural Air Quality Research (Task Force) to promote USDA research efforts and identifies cost-effective ways the agriculture industry can improve air quality. The Task Force advises the Secretary of Agriculture on air quality and its relationship to agriculture based on sound scientific findings.

On February 25, 1998, the USDA and EPA announced a Memorandum of Understanding (MOU) to ensure that the two agencies work together to provide a healthy environment with clean air in harmony with a strong agriculturally productive nation[1]. The MOU establishes a framework for the two agencies to share expertise and a process for involving the agricultural community in a cooperative effort to address agriculture-related air quality issues, including emissions from agricultural burning.

In August 2001, EPA published a report, *Emissions from Animal Feeding Operations*, which contained methodologies for estimating farm-level emissions from AFOs in the beef, dairy, swine, and poultry (broilers, layers, and turkeys) animal sectors[2].

After publication of EPA's 2001 report, EPA and the U. S. Department of Agriculture (USDA) jointly requested that the National Academy of Sciences (NAS) evaluate the current knowledge base and the approaches for estimating air emissions from AFOs.

In 2002, the NAS published the paper "Scientific Basis for Estimating Air Emissions from Animal Feeding Operations: Interim Report." In this report they concluded that "estimating air emissions from CAFOs by multiplying the number of animal units by existing emissions factors is not appropriate for most substances." The traditional use of simplified emission factors multiplied by the number of animals may be an adequate way to estimate statewide emissions from dairies, however it does a poor job of calculating the emissions from a specific site for

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[1] Memorandum of Understanding Between the U.S. Department of Agriculture and the U.S. Environmental Protection Agency, NRCS A-3A75-8-30. Available online September 27, 2022: https://www.epa.gov/sites/default/files/2016-06/documents/usda_epa_mou_1998.pdf

[2] U.S. Environmental Protection Agency, August 15, 2001, *Emissions from Animal Feeding Operations – Draft*, Office of Air Quality Planning and Standards, EPA Contract No. 68-C6-0011, Task Order 71

compliance determination. This is due to the complex nature of emission from AFOs, varied management practices, varied infrastructure, and complex chemistry[3].

In a 2003 report, *Air Emissions from Animal Feeding Operations: Current Knowledge, Future Needs*, the NAS concluded the following: reliable emission factors for AFOs were not available at that time; additional data were needed to develop estimating methodologies; current methods for estimating emissions were not appropriate; and EPA should use a process-based approach to determine emissions from an AFO[4].

In January 2005, EPA announced the voluntary Air Compliance Agreement with the AFO industry[5]. The goals of the Air Compliance Agreement were to reduce air pollution, monitor AFO emissions, promote a national consensus on methodologies for estimating emissions from AFOs, and ensure compliance with the requirements of the CAA, the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), and the Emergency Planning and Community Right-to-Know Act (EPCRA). Fees assessed from the AFOs participating in the Air Compliance Agreement were used to fund the National Air Emission Monitoring Study (NAEMS).

The NAEMS air monitoiring began in the summer of 2007; barns and lagoons at 25 AFOs in 10 states (including 9 dairy AFOs in 6 states) were each monitored for two years to measure emissions of ammonia, hydrogen sulfide, particulate matter, and volatile organic compounds. The study gathered this data to develop emission models, as recommended by the National Academy of Sciences. Two dairies in Washington State and one dairy in California were included in the study, no dairies from Oregon were included in the study.

In September 2008, the United States Government Accountability Office (GAO) issued the report *Concentrated Animal Feeding Operations: EPA Needs More Information and a Clearly Defined Strategy to Protect Air and Water Quality from Pollutants of Concern*[6]. The GAO recommended that EPA complete its inventory of permitted CAFOs, reassess the current nationwide air emissions monitoring study, and establish a strategy and timetable for developing a process-based model for measuring CAFO air emissions.

On December 18, 2008, EPA published a final rule that exempted most farms from certain release reporting requirements under CERCLA and EPCRA[7]. The rule exempted farms releasing hazardous substances from animal waste to the air above threshold levels from reporting under CERCLA. For EPCRA reporting, the rule exempted reporting of such releases if the farm had fewer animals than a large CAFO (700 cows).

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[3] National Research Council 2002. *The Scientific Basis for Estimating Emissions from Animal Feeding Operations – Interim Report.*
[4] National Research Council 2003. *Air Emissions from Animal Feeding Operations: Current Knowledge, Future Needs*. Washington, DC: The National Academies Press. https://doi.org/10.17226/10586.
[5] Animal Feeding Operations Consent Agreement and Final Order, 70 Fed. Reg. 4958 (Jan 31, 2005)
[6] United States Government Accountability Office, Report to Congressional Requesters, September 2008, *Concentrated Animal Feeding Operations. EPA Needs More Information and a Clearly Defined Strategy to Protect Air and Water Quality from Pollutants of Concern*. GAO-08-944
[7] CERCLA/EPCRA Administrative Reporting Exemption for Air Releases of Hazardous Substances from Animal Waste at Farms, 73 Fed. Reg. 76948 (Dec 18, 2008)

In 2012, EPA presented draft NAEMS results and proposed methodology for dairy emissions of ammonia, but they were unable to develop a methodology for VOC. EPA's Science Advisory Board (SAB) reviewed and rejected the 2012 data and methodologies. In 2013 the SAB recommended re-working the data to develop a different methodology.

In September 2017, EPA Office of Inspector General issued the report *Eleven Years After Agreement, EPA has not Developed Reliable Emission Estimation Methods to Determine Whether Animal Feeding Operations Comply with Clean Air Act and Other Statutes*[8]. According to this report, EPA's ability to characterize and address AFO air emissions is unchanged since its 2005 Agreement with the AFO industry intended to produce reliable emissions estimation methods. As a result, individual AFOs have not estimated their emissions to determine whether they are required to implement controls to reduce emissions and/or report their emissions to the appropriate emergency responders. Additionally, other important agency actions pertaining to AFO air emission estimates continue to be on hold.

On April 11, 2017, the Unites States Court of Appeals overturned EPA's 2008 final rule[9].

In September 2017, EPA and the USDA issued a joint report titles *Agricultural Air Quality Conservation Measures, Reference Guide for Poultry and Livestock Production Systems*[10]. This guide was intended to provide a compilation of conservation measures for air pollutant emission reductions and/or reduction of air quality impacts from livestock and poultry operations.

On March 23, 2018, the Fair Agricultural Reporting Method Act (FARM Act), amended CERCLA section 103(e) to exempt air emissions from animal waste at a farm from reporting under CERCLA, it did not amend the EPCRA section 304 reporting requirements. However, based on the relationship between EPCRA and CERCLA, EPA interpreted EPCRA section 304 to not require reporting of air emissions from animal waste at farms.

On May 2, 2018, the U.S. Court of Appeals for the D.C. Circuit issued a mandate vacating the 2008 administrative reporting exemption[11]. However, air emissions from animal waste at farms remain exempt from CERCLA reporting requirements as a result of the 2018 FARM Act.

On August 1, 2018, EPA published a final rule revising the CERCLA reporting regulations to incorporate the FARM Act's amendments to CERCLA[12].

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[8] EPA Office of Inspector General, September 19, 2017, *Eleven Years After Agreement, EPA Has Not Developed Reliable Emission Estimation Methods to Determine Whether Animal Feeding Operations Comply with Clean Air Act and Other Statutes*, Report No. 17-P-0396.
[9] Waterkeeper Alliance, Et Al., v. Environmental Protection Agency, USCA Case No. 09-1017, On Petitions for Review of Final Regulation Issued by the U.S. Environmental Protection Agency. Filed April 11, 2017
[10] USDA and EPA, September 2017, *Agricultural Air Quality Conservation Measures, Reference Guide for Poultry and Livestock Production Systems.*
[11] Waterkeeper Alliance, Et Al., v. Environmental Protection Agency, USCA Case No. 09-1017, Mandate. EPA-73FR76948-60. Filed May 2, 2018
[12] Vacatur Response - CERCLA/EPCRA Administrative Reporting Exemption for Air Releases of Hazardous Substances from Animal Waste at Farms; FARM Act Amendments to CERCLA Release Notification Requirements, 83 Fed. Reg. 37444 (Aug 1, 2018)

On June 4, 2019, EPA signed a final rule amending the emergency release notification regulations under EPCRA[13]. The amendments clarify that reporting of air emissions from animal waste at farms is not required under EPCRA.

In June 2022, EPA published the draft *Development of Emissions Estimating Methodologies for Dairy Operations*. This report contains draft emissions estimating models for NH_3, H_2S, PM, and total suspended particulate (TSP) emissions for various dairy operations.

According to EPA's National Air Emissions Monitoring Study website, draft models for VOC emissions from swine, poultry, and dairy farms were scheduled for release in August 2022. EPA expects to finalize all AFO emission models in late 2023.

Oregon Dairy Air Regulation History

Legislation adopted in 1993, and updated in 1995 and 2001, declares farm and forest practices as critical to the welfare of the Oregon economy and establishes Farming and Forest Practices Act. This law protects growers from court decisions based on customary noises, smells, dust or other nuisances or trespasses. It also limits local governments and special districts from administratively declaring certain farm and forest products to be nuisances or trespasses (ORS 30.930).

Until 2007, Oregon law exempted agricultural operations from air quality regulations, except for field burning in the Willamette Valley. On November 1, 2005, several environmental groups filed a petition requesting EPA to determine that Oregon's Title V program does not meet CAA requirements because state law exempts agricultural operations.

The 2007 Oregon Legislature passed Senate Bill 235 (SB 235, the Bill) to allow the EQC to regulate agricultural operations to the extent needed under the CAA. The Bill directed DEQ and ODA to enter into a Memorandum of Understanding in order to implement the federal CAA requirements for agriculture. Additionally, SB 235 established a Dairy Air Task Force (DATF), legislated its membership, charged it with studying the emissions from dairy operations, evaluating available alternatives for reducing emissions, and presenting findings and recommendations to the DEQ and ODA. The Bill also allowed the EQC to implement recommendations of the Task Force beyond CAA requirements.

DEQ and ODA both submitted Fiscal Impact Statements indicating they could provide staff support to a task force with existing resources but would need resources later to implement the recommendations.

On July 1, 2008, the DATF published the *Final Report to the Department of Environmental Quality & Department of Agriculture* that provided recommendations on the development of a "Oregon Dairy Air Emissions Program" (the Program)[14].

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[13] Amendment to Emergency Release Notification Regulations on Reporting Exemption for Air Emissions from Animal Waste at Farms; Emergency Planning and Community Right to-Know Act, 84 Fed. Reg 27533 (June 13, 2019)

[14] Oregon Dairy Air Quality Task Force, July 1, 2008, *Final Report to the Department of Environmental Quality & Department of Agriculture.*

In 2009, DEQ requested General Fund resources to begin implementing the Dairy Air Task Force recommendations. The Governor did not include this proposal in their recommended budget.

In 2017, Senate Bill 197 and House Bill 3308 were introduced, both which would have directed EQC to establish rules and a program for regulating dairy air emissions. Neither bill made it out of committee[15,16].

During the 2017 Oregon Legislative Session, ODA and OSU were asked to prepare a report on the air emission mitigation best management practices (BMPs) implemented at Threemile Canyon Farms (TMCF) and Lost Valley Farm (LVF). The study found that BMPs implemented at LVF and TMCF met the requirements of both the Idaho BMP and the YRCAA BMP programs[17].

In 2019, two Senate Bills (SB 103 and 104) and House Bill 3083 were introduced regarding air emissions from dairy CAFOs and other agricultural operations. None of these bills made it out of committee[18,19,20].

In 2021, Senate Bill 583 and House Bill 2924 were introduced and would have prohibited DEQ and ODA from permitting, or renewing permits for industrial dairy operations. Neither of these bills made it out of committee[21,22].

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[15] S.B. 197, 2017 Legislative Session (Or. 2017). https://olis.oregonlegislature.gov/liz/2017R1/Measures/Overview/SB197

[16] H.B. 3308, 2017 Legislative Session (Or. 2017). https://olis.oregonlegislature.gov/liz/2017R1/Measures/Overview/HB3308

[17] Oregon Department of Agriculture, October 2017. *Dairy Air Emissions and Analysis*, Prepared for: Senate Committee on Environment and Natural Resources.

[18] S.B. 103, 2019 Legislative Session (Or. 2019). https://olis.oregonlegislature.gov/liz/2019R1/Measures/Overview/SB103

[19] S.B. 104, 2019 Legislative Session (Or. 2019). https://olis.oregonlegislature.gov/liz/2019R1/Measures/Overview/SB104

[20] H.B. 3083, 2019 Legislative Session (Or. 2019). https://olis.oregonlegislature.gov/liz/2019R1/Measures/Overview/HB3083

[21] S.B. 583, 2021 Legislative Session (Or. 2021). https://olis.oregonlegislature.gov/liz/2021R1/Measures/Overview/SB583

[22] H.B. 2924, 2021 Legislative Session (Or. 2021). https://olis.oregonlegislature.gov/liz/2021R1/Measures/Overview/HB2924

Appendix C

Dairy Air Task Force Recommendations

Oregon Dairy Air Quality Task Force

Final Report to the Department of Environmental Quality & Department of Agriculture

July 1, 2008

Executive Summary

The 2007 Oregon Legislature passed Senate Bill 235 to address the inconsistency between state and federal law by allowing the Oregon Environmental Quality Commission (EQC) to regulate agricultural operations to the extent needed under the Clean Air Act. The Bill directed the Oregon Department of Environmental Quality (DEQ) and the Oregon Department of Agriculture (ODA) to enter into a Memorandum of Understanding in order to implement the federal Clean Air Act requirements for agriculture. **(Section I)**. Additionally, SB 235 established a Task Force on Dairy Air Quality, legislated its membership, **(Section II)** charged it with, among other things, studying the emissions from dairy operations, evaluating available alternatives for reducing emissions, and presenting findings and recommendations to the DEQ and ODA.

The Task Force met seven times from January through June 2008. It studied, explored, and debated the current state of the science, regulatory frameworks outside of Oregon, and various options from doing nothing to traditional regulation. The members reached a consensus on the included Findings **(Section III)** and Recommendations **(Section IV)**. The package recommendation was the thoughtful and deliberate result of the Task Force members navigating through very thorny issues and collaboratively balancing deeply held, diverse opinions.

By way of overview, the Task Force found that under certain circumstances, air emissions from dairy operations might become subject to regulation under the Clean Air Act. However, the current uncertainties in our quantitative knowledge of air emissions from dairies make the application of Clean Air Act requirements uncertain. There is a need to improve our understanding of emissions from dairies and improve our ability to quantify these emissions, especially if those estimates are to inform future regulatory decisions. While we build our knowledge and certainty of dairy emissions, there is a desire by the Task Force to reduce these air emissions to prevent future problems from arising.

Specifically, the Task Force recommends the EQC, working with ODA, DEQ, and the Department of Human Services (DHS), should adopt rules to implement the proposed "Oregon Dairy Air Emissions Program" (Program), as a whole, **(Section IV. A.),** based upon carefully crafted Guiding Principles **(Section IV. B.)**. The Program **(Section IV. C.)** would start as a voluntary program, and move into a state mandatory program pursuant to the recommended conditions and schedule. The Task Force also recommends that DEQ and ODA, in consultation with DHS, should convene a Dairy Air Advisory Committee (DAAC) to advise and make recommendations about the Program implementation details. **(Section IV. D.)** It recommends the needed resources **(Section IV. E.)** that are essential to implement and administer the Program. Finally, the Task Force provides an overall recommended program structure, staging and funding. **(Section IV. E.)**

In conclusion, The Task Force thanks the Legislature for the opportunity to serve and formulate this consensus package of recommendations. Taken as a whole, the recommendations represent an optimal balance between the need to protect air quality and ensure the viability of Oregon's dairies, and they chart a clear and positive path forward for all Oregonians. These recommendations were created because the Task Force worked hard to achieve the necessary levels of understanding, trust, and respect. In order to maintain this positive and balanced momentum, the Task Force believes it is imperative that the Legislature provide the funding for this necessary and evolving program. The monetary requests are modest and responsibly staged over time to ensure the Program can accomplish its purposes without negatively affecting the state's other priorities.

Table of Contents

I. Background

Until 2007, Oregon law exempted agricultural operations from air quality regulations with the exception of field burning in the Willamette Valley. In the fall of 2005, several environmental and public interest groups petitioned the U.S. Environmental Protection Agency (EPA) asserting that Oregon's air quality program was deficient because Oregon statute exempted agriculture from regulation if those regulations were necessary to comply with the Clean Air Act.

Senate Bill 235 addressed the inconsistency between state and federal law by allowing the Oregon Environmental Quality Commission (EQC) to regulate agricultural operations to the extent needed under the Clean Air Act. The Bill directed the Oregon Department of Environmental Quality (DEQ) and the Oregon Department of Agriculture (ODA) to enter into a Memorandum of Understanding in order to implement federal Clean Air Act requirements for agriculture. In addition, it established a Task Force on Dairy Air Quality, and charged it with, among other things, studying the emissions from dairy operations, evaluating available alternatives for reducing emissions, and presenting findings and recommendations to the DEQ and ODA by July 1, 2008. The findings and recommendations could include technical studies, voluntary actions, regulation, and proposed legislation. The recommendations are not limited to current requirements of the federal Clean Air Act and may recommend that the EQC adopt rules beyond the authorities in the Clean Air Act. The Task Force Charter can be found in the Technical Supporting Document

The Task Force's work plan follows:

A. Study the emission of air contaminants from dairy operations, including but not limited to, emissions regulated under the Clean Air Act.

B. Study available data on the emission of air contaminants, including but not limited to, the United States EPA national air study of animal feeding operations.

C. Determine the problem(s) that need to be solved.

D. Formulate a plan to reduce emissions.

E. Identify the option(s) to reduce emissions:
   1) voluntary measures, including education, demonstration projects, and incentives;
   2) regulatory measures;
   3) legislative measures or funding; and
   4) other recommendations.

F. Select the solutions(s) for fixing the problem(s) and accomplishing the goals by taking into consideration:
   1) The diverse nature and economic viability of dairies and the economic contribution dairies make to the state economy;
   2) The impact that federal Clean Air Act regulations have, and that actions to address air emissions would have, on Oregon's dairies in the Pacific Northwest markets;
   3) The protection of human health, the environment, and scenic and cultural resources; and
   4) The impact of available alternatives on other environmental media, energy, the cost of producing dairy products, and the feasibility of implementation.

G. Make Other Observations and Recommendations

The Task Force began its work in January 2008 and has studied the air emissions associated with dairy operations, including but not limited to, emissions regulated under the Clean Air Act. It has evaluated alternatives for reducing air emissions, and explored voluntary measures, including education, demonstration projects, and incentive options, together with regulatory and/or legislative options for emission reduction.

This summary Report provides a broad overview of the Task Force findings and the information related to quantifying, managing, and reducing air emissions from dairy operations. The Technical Support Document (TSD), http://www.deq.state.or.us/aq/dairy/report.htm, accompanying this Report provides considerably more detail, served as the foundation for some of discussions, contains the Task Force Meeting Notes, and is intended for background purposes only. This Report contains the final Task Force findings and recommendations.

II. Task Force Members

- Two members of the Senate, appointed by the President of the Senate:
    - Senator Betsy Johnson
    - Senator David Nelson
- Two members of the House of Representatives, appointed by the Speaker of the House:
    - Representative Debbie Boone
    - Representative Jackie Dingfelder
- One representative from the Oregon Department of Environmental Quality (DEQ), appointed by the DEQ Director:
    - Andrew Ginsburg, Air Quality Division Administrator, DEQ
- One representative from the Oregon Department of Agriculture (ODA), appointed by the ODA Director:
    - Lisa Hanson, Deputy Director, ODA
- One representative from the Department of Human Services (DHS) having expertise in public health, appointed by the Director of Human Services:
    - Gail Shibley, Administrator, Environmental Public Health , ODHS
- Three representatives, appointed by the governor from the dairy industry:
    - Dan Bansen, Dairyman, Forest Glen Jerseys, Forest Glen Heifer Ranch, and Forest Glen Oaks
    - Martin Myers, General Manager, Threemile Canyon Farms
    - Dr. Mark Wustenberg, Vice President, Dairy Services Tillamook Creamery Association
- Three representatives, appointed by the governor from environmental-public interest organizations:
    - Jeremiah Baumann, Environment Oregon
    - Dana Kaye, Executive Director for Oregon Chapter American Lung Association
    - Kendra Kimbirauskas, Friends of Family Farmers
- Two representatives, appointed by the governor from institutions of higher education listed in ORS 352.002 having expertise in science and technology relevant to air emissions generated by dairy operations:
    - Dr. Jim Males, Department Head Animal Science, OSU
    - Dr. Jim Moore, Professor Emeritus, OSU

III. Findings

A. Oregon Dairy Farm Overview

There are currently more than 60,000 dairy farms in the United States. Seventy seven percent of these dairies have herds of less than 100 mature cows. The remaining dairies provide 77% of all milk sold in the United States. To place Oregon within the national context, as of October 31, 2007, there were 370 permitted dairy operations. Of those 370 permitted dairy operations, 39 of them were heifer raising facilities and 331 of them were milking operations with 116,335 milking cows contained in the milking operations. Of the 331 permitted dairy operations, 39 were registered as large federal concentrated animal feeding operations (CAFOs), meaning that they had 700 or more dairy milking cows. All dairies in Oregon that provide milk for public consumption (grade A licensed) are permitted by the ODA Confined Animal Feeding Operation (CAFO) Program.

Oregon dairies are an important component of the state's economy. Milk products were the fifth most valuable agricultural commodity in Oregon in 2006 with a farm gate value of $329,574,000. Oregon dairies range in size from 25 to 16,000 milking cows and produce both conventional and organic milk; most are family farms and a few are corporately owned. Dairy production in Oregon spans across the state with at least one permitted dairy operation in 27 of Oregon's 36 counties. Currently, dairy production systems in Oregon include pasture-based production systems, partial confinement in free stall barns, total confinement in free stall barns, and dry lot operations.

During the last decade, the increased cost of fuel, feed, and transportation have had a direct effect on the cost of operating a dairy and, therefore, net dairy income. Milk price volatility has become greater in recent years, and this increased volatility has added significant challenges for dairy farm businesses. The number of dairy operations in Oregon has remained fairly constant over the last several years, but following a national trend, the Oregon industry has seen smaller farms ceasing milking operations or consolidating and the newer operations coming into production tending to be larger than the ones going out of business.

While the three new dairy facilities registered to the CAFO Permit in the last five years are all located on the east side of the Cascades, a large geographic movement or relocation of facilities does not seem to be occurring in Oregon at this time. This is because niche marketing of artisan cheeses and organic production have provided opportunities for dairies to remain in their current locations and current sizes.

There are significant regional differences in the conditions under which Oregon dairies operate. These include variations in climate (i.e. temperature, humidity, rainfall) and site characteristics (soil types for growing crops, availability of grassland for feed, etc.). The variation in these conditions affects what types of approaches and challenges operators evaluate when considering changing the production system to address existing and future environmental regulations.

B. Environmental Regulations

The EPA, under the authority of the federal Clean Water Act (CWA), primarily drives today's environmental requirements for large dairies. The Oregon CAFO program began in the early 1980s to prevent CAFO wastes from contaminating groundwater and surface water. When the program began, the DEQ was the permit issuing and enforcement authority, and the ODA acted as program administrator and investigating authority. This relationship has been modified and changed over time so that currently ODA operates the program under Memoranda of Agreement (MOA) with DEQ and EPA.

All CAFOs that require a permit are required to prepare an animal waste management plan. This plan is a detailed description of facilities and operations with respect to containment, treatment, storage, and disposal of waste including wastewater. The plan also describes how compliance with permit conditions and water quality laws will be achieved and maintained. The level and amount of information required will depend upon the size, complexity, and other specifics of each facility. The Oregon CAFO Program is a national leader in adopting and implementing innovative and effective ways to address water quality. Good communication with the industry and regular routine inspections of permitted operations have contributed to the participants actively seeking opportunities that meet, and in many cases exceed, state water quality expectations. It serves as a strong model and foundation to address air quality issues.

Other states have recently begun regulating dairy air emissions through permitting and by requiring the adoption of "best management practices." These regulations have targeted specific emissions of local concern.

Current Regulations for Air Quality in Oregon:

1. **Federal Clean Air Act**
   a) National Ambient Air Quality Standards (NAAQS) – The EPA establishes standards to protect public health, including sensitive people. State and local air agencies determine if these standards are being met, and devise emissions reduction strategies in any location where standards are exceeded.

   b) Hazardous Air Pollutants - Congress provided EPA with a list of hazardous air pollutants and EPA has identified categories of sources for control of these pollutants. Currently, dairies are not one of the identified categories, although methanol emissions may be large enough to require an air quality permit.

   c) Regional Haze – The Clean Air Act requires air agencies to protect visibility in wilderness areas and National Parks. Visibility degradation in the Columbia River Gorge Scenic Area, however, is not subject to authorities in the Clean Air Act.

2. **Oregon Air Program**
   a) Air Toxics – Oregon has established a program to complement the federal approach by focusing on urban areas where many smaller sources contribute to air toxics concentrations that affect public health.

   b) Nuisance – DEQ has the authority to identify and reduce certain nuisance odors through existing rules. (OAR 340-208-0300). However, this state authority does not include odors from agricultural operations under ORS 30.930. Finally, odors are not subject to regulation under the Federal Clean Air Act.

3. **Other Federal Authorities**
   a) Occupational Safety and Health - Worker health concerns are within the authority of OR-OSHA, which has established standards for exposure.

   b) Emergency Planning and Community Right to Know Act (EPCRA) and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) – Reporting to EPA is required for both episodic and continuous releases of regulated substances by facilities that meet certain criteria.

C. Air Emissions from Dairies

The National Research Council of the National Academy of Sciences, in its 2003 report titled ***Air Emissions from Animal Feeding Operations: Current Knowledge and Future Needs***, identified these air pollutants from animal feeding operations in general, not specifically from dairies. The report identified: Ammonia (NH_3); Nitrous Oxide (N_2O); Nitrogen Oxides (NOx); Methane (CH_4); Volatile Organic Compounds (VOC); Hydrogen Sulfide (H_2S); and Particulate Matter (PM_{10} and $PM_{2.5}$). In addition, the Task Force identified Methanol, a Hazardous Air Pollutant, and Odors as important emissions.

D. Human Health and Dairy CAFOs

There is very sparse research regarding human health issues related to dairy CAFO air emissions. No Oregon industry-wide study was presented to the Task Force that established there was or was not a human health problem associated with dairies. However, if inhaled at sufficiently high concentrations, each of the emissions types associated with dairy CAFOs could be harmful to human health. Health impacts may be acute (immediate) or chronic (long-term). This dairy-specific data gap is important to fill, in order to better understand and protect human health because conclusions drawn from other livestock CAFO studies are not directly transferable to dairy operations.

Research in this area is needed to identify, quantify health risks, and determine appropriate measures to protect: 1) *worker health* (because of their proximity to emission sources, people working and residing on dairies have the greatest risk of experiencing health effects.) 2) *community health* (little is known about health effects on nearby people that are a direct result from dairy air emissions), and 3) *odors* (sensitive individuals experience these effects at lower levels than the general population, and concentrated odors over time are known to cause changes in behavior.)

E. Environmental Impacts

Air emissions from dairies, together with emissions from many other sources, contribute to the following environmental effects:

1. Visibility Degradation: Ammonia plays a key role in the formation of small sulfate and nitrate particles leading to haze pollution, thus degrading scenic vistas in our wilderness areas, National Park, and the Columbia River Gorge

Scenic Area.

2. Acidic Deposition: The same pollutants that affect visibility (sulfates and nitrates) can also increase acidic deposition, increasing risks to ecosystems and cultural resources.

3. Climate Change: Methane is a potent Greenhouse Gas (GHG). The role that methane emissions from Oregon dairies play in overall statewide greenhouse gas emissions is not well understood.

In summary, dairy operations have the potential to release several different kinds of air emissions that under certain circumstances could contribute to environmental degradation. The extent to which this occurs in Oregon is currently unclear because of uncertainty in quantifying air emissions from dairies (discussed below).

F. Quantifying Emissions from Oregon Dairies

DEQ estimates air emissions from all types of sources. A compilation of emissions estimates from all source sectors is known as an "emissions inventory." These inventories are routinely developed by DEQ and updated over time to reflect changing conditions. Each source category in the emissions inventory (such as transportation, industry, burning, and agriculture) has its own state-of-knowledge and level of uncertainty inherent in its emissions estimate.

In the absence of a national emissions estimation method, DEQ currently estimates dairy emissions by simply multiplying the number of animals reported for each dairy operation by a fixed amount of emission per animal for each air pollutant, using the best available factors from the scientific literature. This methodology does not reflect what occurs on individual dairies, as it does not consider the variation of emissions over time or the variation in mitigation practices that may be in place. Using the current methods and understanding their limitations, initial statewide dairy emissions estimates indicate that they are a notable portion of Oregon's ammonia and methane emissions, but are a relatively small portion of other types of emissions on a statewide level.

In 2006, the National Air Emission Monitoring Study (NAEMS) was initiated to address the lack of scientific data needed to estimate emissions accurately from individual agricultural operations, including dairies. It originated from a voluntary air compliance agreement (also known as a consent decree) between the EPA and the pork, dairy, egg, and broiler industries. Livestock producers have provided the financial support for the NAEMS so that emissions data can be collected at select sites to:

1. Accurately assess emissions from livestock operations and compile a database for estimation of emissions rates, and

2. Promote a national consensus for emissions estimation methods/procedures from livestock operations.

This study is being led by Purdue University and researchers are currently collecting data at twelve sites across the nation. While interim results from these studies will provide useful information, improved national guidance on estimating emissions from individual dairies will not be available until approximately 2012. EPA has said that the results from this research will be used to construct the official method for estimating CAFO emissions, and that it will be of sufficient quality to be used in regulatory decisions.

IV. Recommendations

The Task Force respectfully and strongly makes the following recommendations:

A. Program Development

The EQC, working with ODA, DEQ, and DHS, should adopt the rules to implement the following "Oregon Dairy Air Emissions Program" (Program), as a whole, as authorized by ORS 468A.020(2)(c) (SB 235). The Program consists of and is guided by this Recommendation. (Report Section (IV). Over time, Program adjustments should be made, as needed, to implement the intent of these recommendations.

B. Guiding Principles

Program development, implementation and compliance are guided by the following principles:

1. Initially focus on reducing ammonia, methanol, and odors, and instill public confidence in the Program.

2. Make technical decisions based on a review of the available existing science.

3. Allow flexibility for dairy farmers to make decisions that are compatible with their operations and other environmental obligations.

4. Provide economic feasibility and stability for dairy farmers.

5. Model program implementation after the development of Oregon's CAFO Program to prevent water pollution, which was phased from a voluntary program to a regulatory program in a gradual manner as information and experience were obtained.

6. Encourage early, voluntary action and efforts to go beyond requirements.

7. Tailor Program over time to the realities of the state budget, and regularly review and update it as more is learned about dairy emissions.

8. Ensure level playing field and equity for all Oregon dairy producers within Oregon and in the Northwest.

9. Recognize that the Clean Air Act, the Clean Water Act, and the Occupational Safety and Health Act still apply.

10. Create a solution that all interests can support.

C. Program Elements

The Program development, implementation, and compliance are guided by the following elements:

1. Apply to all existing Grade A dairies in Oregon that have or need a CAFO permit;

2. Based on a Best Management Practices (BMP) approach using California and Idaho models as points of reference and the recommendations of a Dairy Air Advisory Committee (DAAC) as specified in section IV. D., below. The BMPs should:

    a. Include structural and management practices to reduce air emissions while considering other impact factors specified herein;

    b. Establish clearly defined BMP targets that are economically feasible for Oregon dairy producers; and

    c. Provide guidance on implementation;

3. Start as a voluntary program, known as "Phase I" at the completion of the Dairy Air Quality Task Force process.

Move into a state mandatory program during "Phase II," pursuant to the conditions and schedule contained below, and as adequate resources to implement and administer the Program become available. New dairies should be required to comply with the Program upon startup.

4. ODA and DEQ develop an interim list of recommended air BMPs in collaboration with the Oregon Dairy Farmers Association (ODFA), Oregon State University (OSU), National Resources Conservation Service (NRCS), and the stakeholders identified for DAAC. Collect and assess baseline data about what is currently occurring on Oregon dairies to decrease air emissions as soon as practical after the creation of an interim list of air Best Management Practices (BMPs). This data set should be as inclusive as resources allow.

5. Level of implementation, monitoring, and compliance may change over time as resources and research results become available;

6. Tax incentives should be provided to encourage dairies to meet BMP targets established for Phase I and should be provided for dairies to create an incentive for early action. Any proposed tax credits should be transferable to a third party and should be phased out over time. Tax credits should be reauthorized beyond five years for those dairies that go beyond the minimum requirements in Phase II. If tax credits are adopted by the legislature, DEQ or ODA could administer the tax credits. Tax incentives will require approval of the Governor and legislative authorization. They should be subjected to the usual restrictions (e.g. only available for voluntary capital investments made for the primary purpose of reducing emissions).

7. DEQ, ODA, DHS, NRCS, and OSU, working with the industry, should provide technical assistance, education and outreach, as follows:

   a. develop and maintain technical expertise in BMPs to reduce ammonia, methanol, and odors;

   b. provide technical assistance to dairies in selecting BMPs that are compatible with water quality and other factors pursuant to the Guiding Principles;

   c. develop and distribute educational materials encouraging dairies to participate in the Program hold a series of meetings held around the state to describe the Program to all dairy producers;

   d. provide information to dairies about potential federal requirements, including the potential for methanol emissions to trigger Title V permitting;

   e. provide information about dairies, emissions, and health to the public, the media, and neighboring communities; and

   f. provide information of federal regulations and the new state Program; and

8. ODA should receive funds necessary to determine compliance, provide technical assistance, and conduct any enforcement. ODA should develop a periodic report of BMPs in use based on reports and inspections. ODA should check Program implementation and compliance at the time of the annual CAFO water quality inspection. The annual reports should be provided to EQC and the Board of Agriculture, posted on the web, and otherwise communicated to the public. ODA should communicate to CAFO permit holders the requirements for air BMPs, record keeping, and reporting. ODA should determine compliance, provide technical assistance, and conduct any enforcement.

D. Dairy Air Advisory Committee

DEQ and ODA, in consultation with DHS, should convene a Dairy Air Advisory Committee (DAAC) to advise and make recommendations about Program implementation details. While the overall Program direction is within the purview of the EQC in consultation with ODA and DHS, DAAC should be structured and empowered as follows:

1. A balanced committee with knowledge of the dairy industry, such as representatives from OSU, NRCS, ODA, USDA, DEQ, DHS, ODFA, dairy farmers, health, environmental groups and the public The initial members of DAAC should include members of the Dairy Air Quality Task Force;

2. Use of consensus decision making. If no consensus can be reached, a majority and minority report should be prepared;

3. Make implementation detail recommendations for both Phases that are designed to accomplish the Program in a fashion consistent with these recommendations;

4. Have, if it desires, subcommittees to manage the work, (e.g. a technical committee and a policy subcommittee), each with balanced representation;

5. Create a program that accommodates the diversity of the Oregon dairy industry;

6. Recommend BMPs as soon as possible, including:

   a) Structural and management approaches to reduce ammonia, methanol, and odors;

   b) Guidance for the implementation of the BMPs;

   c) Tiers based on dairy size/resources (for example, 700 cows and above could be one level, 200 - 699 could be another level, and less than 200 cows could be another level); and

   d) Phase I and II BMP targets for each tier;

7. Evaluate BMP effectiveness on air emissions while considering other impact factors like compatibility with water or land quality issues, affects on other air emissions and livestock health. DAAC should also consider existing third party standards when evaluating BMPs. To the extent possible, the menu should be coordinated with BMPs developed by neighboring states, particularly Washington.

8. Consult with DEQ, ODA, and DHS on procedures and criteria for evaluating the potential for public health risks from any air emissions from dairy operations. These procedures could be used, as needed, if public health concerns at specific dairies need to be investigated. Criteria and procedures to be discussed may cover topics such as emissions estimation, air quality analysis methods, and risk assessment procedures.

9. Report regularly to DEQ, ODA, and DHS on the progress and success of the Program; and

10. Recommend changes to the Program, as needed over time, based on new scientific information and an evaluation of Program effectiveness. This could include updates to the emissions of concern. DAAC should not make recommendations that change the core of this recommended Program and this Task Force’s intent.

E. Overall Program Resources

The Task Force recommends that the following resources be provided to implement the recommended Program:

1. Tax credits for voluntary participation during Phase I and exceeding the requirements during Phase II if the tax credit program is extended;

2. Resources to ODA for Program implementation, monitoring and compliance;

3. Resources to DEQ for rule development, Program implementation, and air monitoring;

4. Resources to DHS for technical assistance, consultation, and risk communication; and

5. Funding for OSU to conduct research and development of demonstration projects, BMPs tailored to Oregon’s needs, the effectiveness of BMPs, their impact on air emissions, and funds for education, outreach, and technical assistance.

F. Overall Recommended Program Structure, Staging and Funding Summary

The Task Force recommends that the following structure, staging and funding:

July 2008	Oregon Dairy Air Quality Task Force (With Co-Chairs) report to ODA and DEQ.
Sept 2008	Task Force, ODA, and DEQ report (with Co-Chairs) to interim legislative committees.
Oct/Nov 2008	Possible Task Force reconvening based upon interim legislative committee input.
Late 2008	ODA and DEQ approve an interim list of recommended air BMPs in collaboration with ODFA, OSU, NRCS, and the stakeholders identified for DAAC.
Jan 2009	ODFA begins outreach to educate industry about the Program and encourages the use of the interim air BMPs.
Jan-July 2009	**2009 Legislative Session:** • Request initial staffing for the program: 1 ODA and 1 DEQ staff to do outreach and assistance, conduct a baseline survey, develop rules, and implement tax credits; • Request $500K for OSU research and development of BMPs that are specific to Oregon's needs; and • Request tax credits for voluntary BMPs to begin in 2010 and continue through 2014.
Late 2009	1) EQC adopts initial program rules under ORS 468A.020(2)(c) based upon the Dairy Air Quality Task Force recommendations in section IV of this report, including: a) Framework for Program; b) Membership and structure of the Dairy Air Advisory Committee (DAAC); d) Tax credits if EQC is authorized by the 2009 legislature. 2) DAAC starts. Initial focus is to refine the air BMP list. Subsequent focus is to refine the program structure. 3) ODA conducts baseline survey of air BMPs in use in Oregon.
2010	**Phase I Begins:** • ODA/DEQ/OSU Outreach / Education begins to encourage voluntary participation in phase 1 of the Program and provide assistance to dairies in the selection of BMPs; • DEQ implements the tax credits for dairies that meet the phase 1 targets. • DAAC recommends Program revisions, including revisions to the BMP list, targets and program structure.
2011	**2011 Legislative Session:** • Request increased staffing for the program: 2 additional ODA staff to expand outreach implementation, and 1 DHS FTE (parts of three positions) to conduct risk communication. • Request additional funding for BMP research and development if needed. • Request $500K for OSU research and development of BMPs that are specific to Oregon's needs. DAAC continues to evaluate Program and make recommendations, including mandatory targets to apply in 2015.
Late 2011 and 2012	• EQC revises rules to incorporate DAAC recommendations. • ODA expands outreach and assistance, conducts follow-up survey of BMP use in Oregon, and issues Annual Program Report. • DEQ continues to implement tax credits for dairies that meet the phase 1 targets. • DAAC continues to evaluate Program; assess EPA's NAEMS preliminary results; make recommendations as needed.
2013	**2013 Legislative Session:** • Request increased staffing for the program: 2 additional ODA staff to further implementation, monitoring, and compliance. • Request $500 K for OSU research and development of BMPs that are specific to Oregon's needs. DAAC continues to evaluate Program and make recommendations as needed.
Late 2013 and 2014	• EQC revises rules to incorporate any further DAAC recommendations. • ODA conducts follow-up survey of BMP use in Oregon, and issues Biennial Program Report. • DEQ continues to implement tax credits for dairies that meet the phase 1 targets. • DAAC continues to evaluate Program; assess EPA's NAEMS results; make recommendations as needed.
2015	**2015 Legislative Session:** • Request $500 K for OSU research and development of BMPs that are specific to Oregon's needs.
2015	**Phase II begins:** • Targets become mandatory. • ODA implements the program, ensures compliance, and issues annual Program Report. • DAAC continues to evaluate Program and make recommendations, as needed.

V. Conclusion

In conclusion, The Task Force thanks the Legislature for the opportunity to serve and formulate this consensus package of recommendations. Taken as a whole, they represent an optimal balance between the competing interests and chart a clear and positive path forward for all Oregonians. These recommendations were created because the Task Force worked hard to achieve the necessary levels of understanding, trust, and respect. In order to maintain this positive and balanced momentum, the Task Force believes it is imperative that the Legislature provide the funding for this necessary and evolving program. The monetary requests are modest and responsibly staged over time to ensure the Program can accomplish its purposes without negatively affecting Oregon's other priorities.

Respectfully Submitted on July 1, 2008

Oregon Dairy Air Quality Task Force

Appendix D

NEI Dairy Emissions by County

Appendix G - NEI Dairy Emissions by County

County	Dairy Ammonia, ton	Total Ammonia, ton	% Dairy of Total Ammonia	Dairy Methanol, lb	Total Methanol, lb	% Dairy of Total Methanol	Dairy PM10 (Filt + Cond), ton	Total PM10 (Filt + Cond), ton	% Dairy of Total PM10	Dairy PM2.5 (Filt + Cond), ton	Total PM2.5 (Filt + Cond), ton	% Dairy of Total PM2.5	Dairy Toluene, lb	Total Toluene, lb	% Dairy of Total Toluene	Dairy Volatile Organic Compounds, ton	Total Volatile Organic Compounds, ton	% Dairy of Total VOC	Dairy Xylenes (Mixed Isomers), lb	Total Xylenes (Mixed Isomers), lb	% Dairy of Total Xylenes
Baker	60	1,124	5	3,410	3,956,758	0	15	5,900	0	3	1,442	0	17	123,168	0	5	27,764	0	44	83,037	0
Benton	44	313	14	2,517	1,487,722	0	11	5,722	0	2	1,196	0	13	220,748	0	4	10,591	0	33	138,801	0
Clackamas	73	1,427	5	4,152	4,312,536	0	18	23,143	0	4	5,428	0	21	1,010,857	0	6	37,281	0	54	656,421	0
Clatsop	8	356	2	478	1,887,145	0	2	6,899	0	0	2,503	0	2	187,064	0	1	14,684	0	6	120,310	0
Columbia	8	533	2	469	1,329,941	0	2	4,368	0	0	947	0	2	158,714	0	1	10,496	0	6	98,467	0
Coos	96	692	14	5,449	3,510,950	0	23	9,503	0	5	2,574	0	28	261,084	0	8	28,194	0	71	166,019	0
Crook	34	884	4	1,899	4,107,225	0	8	9,915	0	2	3,092	0	10	158,319	0	3	26,920	0	25	99,619	0
Curry	10	10,539	0	558	31,321,904	0	2	70,904	0	0	56,504	0	3	2,648,315	0	1	175,406	0	7	1,672,671	0
Deschutes	19	3,520	1	1,093	10,514,614	0	5	51,873	0	1	20,082	0	6	1,086,156	0	2	84,186	0	14	686,480	0
Douglas	41	6,725	1	2,341	22,661,217	0	10	46,774	0	2	32,094	0	12	1,512,917	0	3	161,083	0	30	952,461	0
Gilliam	15	469	3	852	1,257,365	0	4	3,163	0	1	742	0	4	44,531	0	1	4,297	0	11	28,109	0
Grant	30	693	4	1,714	7,070,449	0	7	5,202	0	2	1,807	0	9	121,430	0	2	63,856	0	22	87,053	0
Harney	64	1,729	4	3,653	9,108,686	0	16	8,537	0	3	2,047	0	19	113,582	0	5	32,144	0	47	75,243	0
Hood River	7	6,273	0	389	13,854,015	0	2	39,642	0	0	31,928	0	2	1,251,105	0	1	100,050	0	5	792,755	0
Jackson	26	2,459	1	1,455	11,046,707	0	6	21,598	0	1	10,994	0	7	924,829	0	2	81,180	0	19	575,536	0
Jefferson	19	570	3	1,081	2,984,207	0	5	10,052	0	1	1,969	0	5	119,478	0	2	19,954	0	14	74,728	0
Josephine	36	1,191	3	2,063	6,704,041	0	9	12,046	0	2	5,916	0	10	499,018	0	3	46,390	0	27	338,163	0
Klamath	190	7,482	3	10,766	22,038,464	0	46	51,781	0	10	31,857	0	55	1,319,532	0	15	176,167	0	140	842,171	0
Lake	58	2,310	3	3,285	9,014,022	0	14	8,792	0	3	2,807	0	17	212,822	0	5	52,687	0	43	146,079	0
Lane	111	7,371	2	6,276	21,847,734	0	27	58,209	0	6	35,973	0	32	2,047,995	0	9	163,387	0	82	1,291,655	0
Lincoln	3	271	1	168	2,826,498	0	1	7,508	0	0	1,703	0	1	181,980	0	0	15,826	0	2	112,845	0
Linn	122	1,677	7	6,903	6,140,214	0	30	15,701	0	6	4,880	0	35	500,777	0	10	39,394	0	90	319,141	0
Malheur	236	3,217	7	13,356	9,196,447	0	58	15,662	0	12	2,915	0	68	160,880	0	19	24,740	0	173	101,505	0
Marion	397	2,204	18	22,481	3,969,551	1	97	22,643	0	20	7,361	0	114	983,612	0	32	32,277	0	292	627,607	0
Morrow	1,088	2,038	53	61,646	2,251,296	3	266	8,637	3	55	1,880	3	313	62,167	1	87	12,093	1	801	39,140	2
Multnomah	7	2,090	0	413	5,151,377	0	2	30,318	0	0	12,662	0	2	1,753,606	0	1	46,816	0	5	1,141,668	0
Polk	143	587	24	8,120	1,580,786	1	35	9,755	0	7	2,102	0	41	223,679	0	11	11,517	0	105	177,309	0
Sherman	3	319	1	178	875,416	0	1	5,424	0	0	901	0	1	20,267	0	0	2,802	0	2	13,054	0
Tillamook	620	1,089	57	35,109	2,278,302	2	151	7,651	2	31	2,374	1	178	185,114	0	50	18,183	0	456	121,476	0
Umatilla	112	2,024	6	6,326	3,789,384	0	27	18,675	0	6	3,603	0	32	256,442	0	9	25,200	0	82	163,489	0
Union	17	791	2	983	3,377,224	0	4	6,110	0	1	1,339	0	5	124,065	0	1	29,544	0	13	83,750	0
Wallowa	22	497	4	1,237	4,372,420	0	5	3,192	0	1	633	0	6	84,537	0	2	37,989	0	16	65,601	0
Wasco	21	916	2	1,205	3,893,034	0	5	10,869	0	1	3,337	0	6	215,737	0	2	21,062	0	16	137,553	0
Washington	54	685	8	3,038	2,186,188	0	13	22,339	0	3	4,636	0	15	1,195,304	0	4	21,465	0	39	793,022	0
Wheeler	13	279	5	744	2,402,598	0	3	1,697	0	1	504	0	4	20,929	0	1	16,030	0	10	12,877	0
Yamhill	193	1,012	19	10,949	1,637,707	1	47	9,358	1	10	2,212	0	56	282,973	0	15	11,848	0	142	175,320	0
Grand Total	**4,001**	**76,356**		**226,752**	**245,944,144**		**977**	**649,562**		**203**	**304,944**		**1,152**	**20,273,733**		**320**	**1,683,503**		**2,945**	**13,011,135**	
NOTES:				113.38	122,972.07	0.1%															

Emissions data from 2017 NEI
Dairy Emissions are from
two SCCs:
2805018000
2805001010

Appendix E

DEQ Analysis of Emission Methodologies and BMPs

Emissions Estimations and Best Management Practices

The rules proposed by the petitioners would require DEQ to select emissions estimation methods that would be used to permit dairies and to establish best management practices (BMPs) that dairies would use to reduce emissions. While there has been significant research into this topic, there is no established emissions estimating method that has been through public scrutiny and regulatory validation that would be easily applied to Oregon dairies. Any method used in Oregon would need to be flexible enough to account for the wide variety of meteorological conditions and management practices used throughout the state. DEQ reviewed the current emission estimation methods and BMP reduction estimates to determine if those methods would be able to be applied in Oregon, and if so, what the level of effort would be to do so. Below are overviews of specific authoritative sources on emission estimation methods and BMPs for the dairy sector. More specific information may be found in the appendices to this report. Appendix E.1 includes a compilation of best management practices used for this review. Appendix E.2 includes a compilation of emission factors used for this review.

Emission Factor Summary

Table 3 below illustrates the range of possible emission factors and emissions available for estimating dairy emission. The extreme variability in the range of possible factors may reflect the fact that some research only accounted for a portion of an operation's emissions, while other research captured a more complete accounting of total emissions. This table was originally published in the Dairy Air Task Force Technical Support Document and has been updated with emission factors published since this report was finalized. With the exemption of VOCs, all emission factors fall within the same ranges.

Table 1: Range of Potential Emission Factors (kilograms per head (cow) per year)[1]

Pollutant	Min EF	Max EF
NH_3	8.45	97
H_2S	0.012	9.9
CH_4	124.6	164.4
NO_x	NE	NE
$PM_{2.5}$	NE	NE
PM_{10}	0.84	3.04
VOC	2.9[a]	17.3
N_2O	0.14	2.8

1 – Data from Dairy Air Task Force Technical Support Document with updates from SJVAPCD and SCAQMD
a – SCAQMD VOC emission factor for sites with controls[1]

California Air Resources Board

Under Senate Bill 700 (2003), the California Air Resources Board developed a regulation to define which confined animal facilities are subject to emissions mitigation rules. The San

[1] http://www.aqmd.gov/docs/default-source/planning/annual-emission-reporting/guidecalcemisdairypoultryoperdec13.pdf

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Joaquin Valley Air Pollution Control District (SJVAPCD) and the South Coast Air Quality Management District (SCAQMD) have both developed emission factors for dairy emissions.

Research efforts are also ongoing in California to better quantify livestock emissions and identify practices that will reduce emissions. The Dairy Manure Technology Feasibility Panel evaluated livestock emission mitigation technologies and the San Joaquin Valley Dairy Permitting Advisory Group (DPAG) evaluated dairy emissions research and Best Available Control Technologies (BACT) for dairies.

Idaho

The Idaho Dairy Emissions Program focuses on control of ammonia emissions. The Idaho Regulation IDAPA 58.01.01.760 through 764 is based off the number of animal units or mature cows that would produce at least 100 ton of ammonia per year based on liquid manure land application methods. Dairy farms that meet or exceed this threshold are required to implement BPMs using a point system, with BMPs adding up to 27 points required.

Idaho DEQ and a group of interested persons created the system by reviewing "scientific studies, extension bulletins, NRCS handbooks, and EPA guidance documents". Through this review, the group developed "[a]n arbitrary point system, with a maximum of 20 points, was assigned to each practice. A practice receiving 20 points equates to a system or practice resulting in a major reduction in ammonia emissions—approximately 70%—for that specific process."

USDA

The United States Environmental Protection Agency (EPA) and the United States Department of Agriculture (USDA) collaborated to develop a reference guide to provide a compilation of conservation measures for air pollutant emission reductions and/or reduction of air quality impacts from livestock and poultry operations[2]. These measures include reductions for emissions of particulate matter, ammonia, hydrogen sulfide, volatile organic compounds, and greenhouse gases. The reductions are provided in a range of percent reductions.

According to the USDA and EPA, the reference guide can be used to address agriculturally related air resource concerns in areas where agricultural emissions from livestock operations are determined to be significant contributors to air quality impairment. The guide is not developed to provide regulatory measures.

The EPA/USDA Reference Guide includes a "Table of Mitigation Effectiveness for Selected Measures". This table provides a range of potential reductions for PM, NH_3, H_2S, VOCs, and GHG. The measures target generation, transport, and/or emission of the pollutants and are based off USDA-NRCS Practices[3].

A note provided in this table describes the variability of the control effectiveness.

> "The effectiveness of the measures presented in this document depends on site-specific conditions that vary widely across livestock operations. Additionally, reductions of

[2] See 1 above

[3] USDA, NRCS, EPA, September 2017, *Agricultural Air Quality Conservation Measures, Reference Guide for Poultry and Livestock Production Systems.*

individual air pollutants have not been studied or quantified for every measure presented."

The note goes on to say:

> "Although not comprehensive, this summary table provides examples of the ranges of expected emissions reductions from applying a specific conservation measure (in isolation). Note that these values do not reflect the potential emission reduction at the farm level, as the impact on overall emissions will vary based on a combination of factors specific to that operation. Additionally, not all the emission reductions that have been observed in agricultural studies of the conservation measures have been quantified."

USDA DairyGEM

The Dairy Gas Emissions Model (DairyGEM) is a software tool for estimating ammonia, hydrogen sulfide, and greenhouse gas (GHG) emissions of dairy production systems as influenced by climate and farm management[4].

DairyGEM uses process level simulation to predict ammonia and hydrogen sulfide emissions from manure in the housing facility, during long term storage, following field application and during grazing. Daily emission values of each gas are summed to obtain annual values. DairyGEM was developed as a part of the Integrated Farm System Model, which is a software simulation of dairy and beef production facilities for systems research and used as a teaching aid. It uses chemistry, benchtop studies and equilibrium equations to predict emissions.

EPA NAEMS

In 2022, EPA's National Air Emissions Monitoring Study published the draft updated methodologies for estimating dairy emissions for ammonia, hydrogen sulfide, particulate matter, and total suspended particulate. The new methodologies are not process based, they are statistical based models with emissions normalized by easily monitored parameters such as temperature, relative humidity, and windspeed. During 2023, EPA will provide a stakeholder review period. The goal is to publish the final methodologies by the end of 2023. EPA will include the dairy emissions methodologies to future AP-42 updates, which is EPA's compilation of air emissions factors. Table 4 includes EPA's estimated schedule for finalizing NAEMS.

Table 2: EPA: Timeline for Release of Dairy AFO Emission Model

Date	Milestone	Status
September 2019	Call for Information for additional VOC data	Complete
June 2022	Draft models for ammonia, hydrogen sulfide and particulate matter emissions from dairy farms	Complete
August 2022	Draft models for volatile organic compound emissions from swine, poultry, and dairy farms	
Mid-2023	Stakeholder review period	
Late-2023	Finalization of all AFO emission models	

[4] USDA Agricultural Research Service, https://www.ars.usda.gov/northeast-area/up-pa/pswmru/docs/dairy-gas-emissions-model/

Other states

Numerous other states regulate various air emissions from dairies. The pollutants regulated, farm requirements, and implementation vary significantly throughout the states. A summary of these states is provided in Table 5.

Table 3: CAFO air emission oversight in other states

State	Pollutant	Requirement	Notes on requirements
Arizona	PM_{10}	BMPs	Must implement some BMPs
California – South Coast	VOCs, PM, NH_3	Reporting	Uses Emission Factors
California – San Joaquin Valley	VOCs, PM, NH_3	BACT and Mitigation Measures	Uses Emission Factors
Colorado	Odor / NH_3		Mostly focused on swine
Idaho	NH_3	BMPs	Must implement some BMPs
Iowa	Odor, NH_3, H_2S, PM		Extensive studies conducted.
Illinois	Odor	Setbacks	
Minnesota	Odor (H_2S)	Odor management plan	Included in the NPDES and State Disposal System permits
Missouri	Odor (H_2S)	Odor control plans	Operational requirements
North Carolina	Odor	Management practices	Mostly focused on swine
Pennsylvania	Odor		
Texas	Odor (H_2S)	Permit by rule	Consolidated water/air program
Washington – Yakima Regional Clean Air Agency	PM, NH_3, VOCs, NO_x, H_2S, odor, CH_4 and N_2O	BMPs	Must implement some BMPs
Wisconsin	Odor (H_2S, NH_3)		Extensive study

Conclusions on Emission Methods and BMPs

As discussed above, estimating emissions from dairy CAFOs is more complicated than many air emissions sources and does not lend itself well to use of per-head emission factors. Emission estimating methods currently available can provide a wide range of results and there is not currently a comprehensive method to quantify emissions reductions from implementing best management practices at farms. Additional research is needed to determine the best estimation method to apply for Oregon.

Appendix E.1

Compilation of Best Management Practices

IDAHO DEPARTMENT OF AGRICULTURE
DAIRY BUREAU
PO BOX 7249
BOISE ID 83707 (208) 332-8550

IDAHO DEPARTMENT OF ENVIRONMENTAL QUALITY
1410 NORTH HILTON
BOISE ID 83706 (208) 373-0502

DAIRY AMMONIA REGISTRATION FORM

IDAPA 58.01.01.763

DEQ Form PBRD
1/5/2021 (v2.0)

DAIRY NAME: ______________ OWNER'S NAME: ______________ DATE: ________
STREET ADDRESS: ______________ CITY: ______________ ZIP CODE: ________
MAILING ADDRESS (if different from Street Address): ______________ CITY: ______________ ZIP CODE: ________
TELEPHONE (____) ____ - ________
NUMBER OF COWS ________ OR ANIMAL UNITS: ________
WHAT PERCENTAGE OF YOUR FARM IS: DRYLOT ________ % FREESTALL/SCRAPE ________% FREESTALL/FLUSH ________%

	System/Component	BMP Employed	Ammonia Control Effectiveness[1] Open Lot	Freestall Scrape	Freestall Flush	Compliance Method[3]	BMP Points
	Mark below the BMPs you employ to total 27 points: (For an explanation of BMPs, see the Fact Sheet at (http://www.deq.idaho.gov/)						
1.	***Waste Storage and Treatment***						
a	Synthetic Lagoon Cover	☐	15	20	20	1	
b	GeoteXtile Covers	☐	10	13	13	1	
c	Solids Separation	☐	3	3	3	3, 4	
d	Composting	☐	4	4	4	1	
e	Separate Slurry and Liquid Manure Basins	☐	6	10	-	1	
f	In-House Separation	☐	0	12	0	1	
g	Direct Utilization of Collected Slurry	☐	6	10	-	1, 3, 4	
h	Direct Utilization of Parlor Wastewater	☐	10	10	10	1	
i	Direct Utilization of Flush Water	☐	8	0	13	3, 4	
j	Aerated Lagoon	☐	10	12	15	2	
k	Sequencing-Batch Reactor	☐	15	20	20	2	
l	Lagoon Nitrification/Denitrification Systems	☐	15	20	20	2	
m	Fixed-Media Aeration Systems	☐	15	20	20	2	
2.	***General Practices***						
a	Vegetative or Wooded Buffers (established)	☐	7	7	7	1	
b	Vegetative or Wooded Buffers (establishing)	☐	2	2	2	1	
3.	***Freestall Barns***						
a	Scrape Built Up Manure	☐	-	3	3	1	
b	Frequent Manure Removal	☐	UD	UD	UD	-	
c	Tunnel Ventilation w/Biofilters	☐	-	10	10	1	
d	Tunnel Ventilation w/Washing wall	☐	-	10	10	3, 4	
4.	***Open Lots and Corrals***						
a	Rapid Manure Removal	☐	4	2	2	1, 2	
b	Corral Harrowing	☐	4	2	2	1	
c	Surface Amendments	☐	10	5	5	2	
d	In-Corral Composting / Stockpiling	☐	4	2	2	1	
e	Summertime Deep Bedding	☐	10	5	5	1	
5.	***Animal Nutrition***						
a	Manage Dietary Protein	☐	2	2	2	2	
6.	***Composting Practices***						
a	Alum / Zeolite Incorporation	☐	12	8	6	2	
b	Carbon:Nitrogen Ratio (C:N) Ratio Manipulation	☐	10	7.5	5	2	
c	Composting Static Pile	☐	6	4.5	3	1	
d	Forced Aeration Composting	☐	10	7.5	5	1	
e	Forced Aeration Composting w/ Biofilter	☐	12	8	6	1	
7.	***Land Application[2]***						
a	Soil Injection - Slurry	☐	10	15	7.5	2	
b	Incorporation of manure within 24 hrs	☐	10	10	10	2	
c	Incorporation of manure within 48 hrs	☐	5	5	5	2	
d	Nitrification of lagoon effluent	☐	10	10	15	3, 4	
e	Low Energy/Pressure Application Systems	☐	7	7	10	1	
f	Freshwater Dilution	☐	5	8	8	1, 2	
g	Pivot Drag Hoses	☐	8	8	10	1	
h	Subsurface Drip Irrigation	☐	10	10	12	1	
	Producer must have at least 27 points for compliance					***BMP TOTAL***	

Notes:

1. The ammonia emission reduction effectiveness of each practice is rated numerically based on practical year-round implementation. Variations due to seasonal practices and expected weather conditions have been factored into these ratings. Not implementing a BMP when it is not practicable to do so, does not reduce the point value assigned to the BMP, nor does it constitute failure to perform the BMP. UD indicates that the practice is still under development.
2. Land application practices assume practice is conducted on all manure; points will be pro-rated to reflect actual waste treatment; points can be obtained on exported material with sufficient documentation.
3. Method used by inspector to determine compliance:
   - 1. = Observation by Inspector
   - 2. = On-Site Recordkeeping Required
   - 3, 4 = Deviation Reporting Required. Equipment upsets and/or breakdowns shall be recorded in a deviation log and if repaired in a reasonable timeframe does not constitute non-compliance with this rule.

I certify that the statements and information contained herein are true, accurate and complete to the best of my knowledge and belief.

Producer Signature

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Within thirty (30) days receipt of this registration, the state of Idaho will conduct a qualifying inspection to ensure the requisite point total of BMPs are employed.

Instructions:

Note:
Two copies of this form are required. Send one copy of completed form to ISDA and one copy of completed form to DEQ at the following addresses:

Idaho State Department of Agriculture
Dairy Bureau
Attn: Mitchell Vermeer
P.O. Box 7249
Boise, ID 83707

Idaho Department of Environmental Quality
air.permits@deq.idaho.gov

1. Provide identifying information (dairy name, owner, address, city).
2. Fill in date form is submitted.
3. Provide information on number of cows or animal units.
4. Indicate what percentage of your farm which is drylot, freestall/scrape, and/or freestall/flush.
5. Check BMPs employed and indicate corresponding points attained for each. ***A total of 27 points are required for compliance.***
6. Sign form.
7. Send completed form to ISDA and DEQ at addresses listed above.

Questions?

Idaho State Department of Agriculture, Dairy Bureau: (208) 332-8550

APPENDIX A: LARGE CAF MITIGATION MEASURES

Owners/operators of a LCAF that is a Dairy shall also comply with the following applicable requirements:

Table 1 - Dairy LCAF Mitigation Measure Requirements

(A).	**Feed and Silage Operations:** Owners/operators shall incorporate at least five (5) of the following feed and silage mitigation measures:
	Class One Mitigation Measures
1.	Feed according to National Research Council (NRC) guidelines.
2.	Feed animals high moisture corn or steam-flaked corn and not feed animals dry rolled corn.
3.	Remove spoiled feed from feed lane at least once every seven (7) days
4.	Remove spilled feed from feed alleyways at least bi-weekly.
5.	Remove uneaten wet feed from feed bunks within twenty-four (24) hours of a rain event.
6.	Feed or dispose of rations within forty-eight (48) hours of grinding and mixing rations.
7.	Store grain in a weatherproof storage structure from October through May.
8.	Cover the horizontal surface of silage piles, except for the area where feed is being removed from the pile.
9.	Collect leachate from the silage piles and send it to a waste treatment system such as a lagoon at least once every twenty-four (24) hours.
10.	Implement alternative mitigation measure(s), not listed above, subject to approval of the Executive Officer.
	Class Two Mitigation Measures
11.	a. Enclose silage in a silage bag system designed for that purpose, or b. Enclose silage in a weatherproof structure and vent to a control device with at least 80% control efficiency, or c. Eliminate silage from animal diet.

(B).	**Milk Parlor:** Owners/operations shall incorporate at least one (1) of the following mitigation measures in each milk parlor:
	Class One Mitigation Measures
1.	a. Flush or hose milk parlor immediately prior to, immediately after, or during each milking in accordance with the recommendations in NRCS Agricultural Waste Management Field Handbook Chapter 10 Section 651.1002 or more recent NRCS guidance.
2.	Implement alternative mitigation measure(s), not listed above, subject to approval of the Executive Officer.
	Class Two Mitigation Measures
3.	a. Enclose and vent the milk parlor to a control device certified by the District to achieve at least 80% capture and control efficiency when animals are in the parlor.

Table 1 - Dairy LCAF Mitigation Measure Requirements (Continued)	
(C).	**Freestall Barns:** Owners/operations housing animals in freestalls shall incorporate at least two (2) of the following mitigation measures in each freestall barn.
	Class One Mitigation Measures
1.	Vacuum or scrape freestalls consistent with, during, after, or prior to each milking. Vacuum or scrape freestalls in accordance with NRCS Agricultural Waste Management Field Handbook Chapter 10 Section 651.1002 or more recent NRCS guidance.
2.	Inspect water pipes and troughs and repair leaks at least once a day.
3.	Use non-manure-based bedding for at least 90% of the bedding material, by weight, for freestalls (e.g. rubber mats, almond hulls, sand, or waterbeds).
4.	Remove wet manure from individual cow freestall beds at least once a day.
5.	Rake, harrow, scrape, or grade bedding in freestalls at least twice every seven (7) days.
6.	Use a dry manure handling system, such as scraping, instead of a liquid manure handling system such as a flush system.
7.	Have no animals in exercise pens, corrals, or dry lots at any time.
8.	Flush freestalls more frequently than the milking schedule. Flush in accordance with NRCS Agricultural Waste Management Field Handbook Chapter 10 Section 651.1002 or more recent NRCS guidance.
9.	Implement alternative mitigation measure(s), not listed above, subject to approval of the Executive Officer.

(D).	**Corrals:** Owners/operators housing animals in corrals shall incorporate at least six (6) of the following mitigation measures in each corral where animals have been housed in the last thirty (30) days.
	Class One Mitigation Measures
1.	a. Clean manure from corrals at least four (4) times per year with at least sixty (60) days between cleaning, or b. Clean corrals at least once between April and July and at least once between October and December, or c. Clean concreted areas such that the depth of manure does not exceed twelve (12) inches at any point or time, except for in-corral mounding, or d. Manage corrals such that the manure depth in the corral does not exceed. twelve (12) inches at any time or point, except for in-corral mounding.
2.	Knockdown fence line manure build-up prior to it exceeding a height of twelve (12) inches at any time or point.
3.	Scrape or flush feed aprons in accordance NRCS Agricultural Waste Management Field Handbook Chapter 10 Section 651.1002, or more recent NRCS guidance in all corrals at least once every seven (7) days.
4.	Slope the surface of the pens at least 3% where the available space for each animal is 400 square feet or less. Slope the surface of the pens at least 1.5% where the available space for each animal is more than 400 sq. feet per animal.
5.	a. Maintain corrals to ensure drainage and prevent water from standing more than

Table 1 - Dairy LCAF Mitigation Measure Requirements (Continued)	
	forty-eight (48) hours after a storm, or b. Maintain corrals and drylots so that there are no indentions in the surface where puddles may form and remain for more than forty-eight (48) hours.
6.	Install floats on the troughs or use another method approved by the Executive Officer to ensure that the water in the troughs does not intentionally or unintentionally overflow or spill onto an earthen ground.
7.	Inspect water pipes and troughs and repair leaks at least once a day.
8.	Harrow, rake, or scrape pens sufficiently to maintain a dry surface, unless the corrals have not held animals in the last thirty (30) days.
9.	a. Use lime or a similar absorbent material in the pens according to the manufacturer's recommendations to minimize moisture in the pens, or b. Apply thymol to corral soil in accordance with the manufacturer's recommendation, or c. Apply eugenol to corral soil in accordance with the manufacturer's recommendation.
10.	Implement alternative mitigation measure(s), not listed above, subject to approval of the Executive Officer
Class Two Mitigation Measures	
11.	Install shade structures.
12.	House animals in an enclosure vented to a control device certified by the District to achieve at least 80% control efficiency.

(E).	**Handling of Solid Manure or Separated Solids:** Owners/operators that handle or store solid manure or separated solids outside the animal housing shall incorporate at least two (2) of the following mitigation measures:
Class One Mitigation Measures	
1.	Cover dry manure piles outside the pens with a waterproof covering from October through May, except for times, not to exceed twenty-four (24) hours per year, when wind events remove the covering. The covering shall be in accordance with applicable recommendations in NRCS Agricultural Waste Management Field Handbook Chapter 10 Section 651.1003, or more recent NRCS guidance.
2.	Cover dry separated solids outside the pens with a waterproof covering from October through May, except for times, not to exceed twenty-four (24) hours each, when wind events remove the covering. The covering shall be in accordance with NRCS Agricultural Waste Management Field Handbook Chapter 10 Section 651.1003 or more recent NRCS guidance.
3.	Remove manure from the facility within seventy-two (72) hours of removal from the pens or corrals.
4.	Implement alternative mitigation measure(s), not listed above, subject to approval of the Executive Officer.
Class Two Mitigation Measures	
5.	Compost manure removed from pens with an aerated static pile vented to a biofilter or other control device with at least 80% control efficiency designed, constructed, operated, and maintained in accordance with NRCS Practice

Table 1 - Dairy LCAF Mitigation Measure Requirements (Continued)	
	Standard 317 (Composting Facility), or more recent NRCS standard.
6.	Store all removed manure in an enclosure vented to a control device with at least 80% control efficiency.
7.	Send at least 51% of the animal waste removed from site to a digester, with a control device with a control efficiency of at least 80%, within seventy-two (72) hours of removal from the housing. The digester shall be designed, constructed, maintained, and operated in accordance with NRCS Practice Standard 365 (Anaerobic Digester – Ambient Temperature and Practice Standard 366 (Anaerobic Digester – Controlled Temperature), or more recent NRCS standard.

(F).	**Handling Manure in Liquid Form:** Owners/operators that handle manure in a liquid form shall incorporate at least one (1) of the following mitigation measures:
Class One Mitigation Measures	
1**.**	Manage the facility such that lagoons only contain waste from the milking parlor and storm water.
2.	a. Use phototrophic lagoons, or b. Use an anaerobic treatment lagoon
3.	Remove solids from the waste system with a solid separator system, prior to the waste entering the lagoon.
4.	Maintain lagoon at a pH between 6.5 and 7.5.
5.	Implement alternative mitigation measure(s), not listed above, subject to approval of the Executive Officer.
Class Two Mitigation Measures	
6.	a. Use an aerobic lagoon, or b. Use a mechanically aerated lagoon designed, constructed, maintained, and operated in accordance with the recommendations in NRCS Practice Standard 559 (Waste Treatment Lagoon), or more recent NRCS standard, or c. Maintain organic loading in the lagoon such that the total solids is less than 3.5 mg (dry weight)/mL, or total volatile solids is less than 3.5 mg/mL.
7.	Use additional non-standard equipment or chemicals on the solid separator system, such as roller or screw presses or chemical coagulants and flocculants, that increase the percent of solid separation achieved by the separator and that is approved by the Executive Officer.
8.	Cover the lagoon or storage pond and vent to a control device with at least 80% control efficiency.
Continued on next page	

Table 1 - Dairy LCAF Mitigation Measure Requirements (Continued)	
(G).	**Land Application of Liquid or Dry Manure:** Owner/operators who land apply dry or liquid manure to crop land on the facility shall incorporate at least two (2) of the following mitigation measures:
	Class One Mitigation Measures
1.	a. Land incorporate all manure within seventy-two (72) hours of removal in accordance with the recommendations of NRCS Agriculture Waste Management Field Handbook Chapter 11 Section 651.1102, or more recent NRCS standards, or b. Only apply manure that has been treated with an anaerobic digestion process or aerobic lagoon or digester system designed, constructed, maintained, and operated in accordance with the appropriate NRCS Practice Standard 629 (Waste Treatment), Practice Standard 359 (Waste Treatment Lagoon), Practice Standard 365 (Anaerobic Digester – Ambient Temperature and Practice Standard 366 (Anaerobic Digester – Controlled Temperature), or more recent NRCS standard.
2.	Allow liquid manure to stand in the fields no more than twenty-four (24) hours after irrigation and apply liquid manure in accordance with the recommendations of NRCS Agriculture Waste Management Field Handbook Chapter 11 Section 651.1102, or more recent NRCS standards.
3.	Only apply solid manure that has a moisture content of less than 50% in accordance with the recommendations of NRCS Agriculture Waste Management Field Handbook Chapter 11 Section 651.1102, or more recent NRCS standards.
4.	Implement alternative mitigation measure(s), not listed above, subject to approval of the Executive Officer.

Note:

1. An owner/operator may temporarily suspend utilization of a mitigation measure provided all of the following requirements are met:
   (a) It is determined by a certified veterinarian or nutritionist that the mitigation measure may be detrimental to animal health or that suspension of the mitigation measure is necessary for the animal to molt, and
   (b) The operator notifies the District, within forty-eight (48) hours of the veterinarian's or nutritionist's determination, that a measure is being temporarily suspended, and
   (c) If such a situation exists, or is expected to exist for longer than thirty (30) days, the owners/operators shall, within that thirty (30) day period, submit a new mitigation measure to be implemented in lieu of the mitigation measure that was suspended.

2. An owner/operator may substitute a mitigation measure from one section in the applicable table (tables 2 through 6) for a mitigation measure in another section of the applicable table, provided it is demonstrated, to the satisfaction of the Executive Officer, that the substitution would result in equal or greater emission reductions. Substituted measures shall be requested by submittal of an application to modify the mitigation plan required by Rule 223(c)(4) with remittance of fees pursuant to Rule 306.and shall be included as permit requirements.
3. For the purposes of this attachment, the term “Executive Officer” when used for the approval of alternate mitigation measures means the Executive Officer of the SCAQMD, CARB, and U.S. EPA.

San Joaquin Valley AIR POLLUTION CONTROL DISTRICT

Dairy Compliance Checklist

Name of Dairy:

Use this form to keep records by checking off each day that the mitigation measures are performed. NOTE: Not all the measures listed below have to be performed. Only keep records on the measures that you have chosen.

The measures that you have chosen will be listed on your Permit to Operate or your temporary permit also known as an Authority to Construct. Remember that the measures that you have chosen must be followed at all times. **If you wish to change to a different measure, a permit application must be submitted and approved by the Air District.**

Please contact the San Joaquin Valley Air Pollution Control District if you have any questions about record keeping. Modesto office-209-557-6446, Fresno office-559-230-5888, Bakersfield office-661-392-5665. **Checklist can be found at the following addr: www.valleyair.org/busind/comply/compliance_forms.htm**

<table>
<tr><th rowspan="2">MY MEASURES</th><th rowspan="2">Daily*</th><th rowspan="2">Weekly*</th><th rowspan="2">No Report</th><th rowspan="2">OR</th><th colspan="31">Check Day of the Month the Mitigation Measure is Performed</th></tr>
<tr><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th><th>11</th><th>12</th><th>13</th><th>14</th><th>15</th><th>16</th><th>17</th><th>18</th><th>19</th><th>20</th><th>21</th><th>22</th><th>23</th><th>24</th><th>25</th><th>26</th><th>27</th><th>28</th><th>29</th><th>30</th><th>31</th></tr>
<tr><td colspan="36">FEED CHECKLIST:</td></tr>
<tr><td>1. Feed according to National Research Council (NRC) guidelines.</td><td></td><td></td><td></td><td></td><td colspan="31">Maintain records of feed company guaranteed analyses (feed tags), ration sheets, or feed purchase records or other records of feed content and formulation that demonstrate compliance with National Research Council (NRC) guidelines.</td></tr>
<tr><td>2. Check day that feed is pushed within 3 feet of feedlane fence within 2 hrs of placing feed or feed trough is used to keep feed within reach of cows.</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3. Check day when feeding of total mixed rations begins no later than 2 hrs after of mixing</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>4. Check day when grain is stored in a weatherproof structure (October thru May only)</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>5. Feeding steam-flaked, dry rolled, cracked or ground corn or other steam-flaked, dry rolled, cracked or ground cereal grains</td><td></td><td></td><td></td><td></td><td colspan="31">Maintain records of feed company guaranteed analyses (feed tags), ration sheets, or feed purchase records or other records of feed content and formulation that demonstrate that steam-flaked, dry rolled, cracked or ground corn or other steam-flaked, dry rolled, cracked or ground cereal grains were fed</td></tr>
<tr><td>6. Check day uneaten feed is removed after rain event within 24 hrs (leave blank if no rain)</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>7. Moisture content ≥ 45% for total mixed rations that contain at least 30% silage by weight</td><td></td><td></td><td></td><td></td><td colspan="31">Maintain weekly records of formulation of total mixed rations and added moisture to demonstrate that calculated moisture content ≥ 45%</td></tr>
<tr><td colspan="36">SILAGE PILE CHECKLIST:</td></tr>
<tr><td>1. Cover all silage piles, except for the area where feed is being removed from the pile, within 72 hours of last delivery of material to the pile.</td><td></td><td></td><td></td><td></td><td colspan="31">Maintain records of the thickness and type of cover used to cover each silage pile and records of the date of the last delivery of material to each silage pile and the date each pile is covered. Documents from contractor(s) containing this information are acceptable.</td></tr>
<tr><td>2. a. Measurement of average bulk density of silage piles (average bulk density of piles must be ≥ 44 lb/ft^3 for corn silage and 40 lb/ft^3 ft for other silage types)</td><td></td><td></td><td></td><td></td><td colspan="31">Maintain records of date of measurement, type of silage pile measured, and average bulk density</td></tr>
<tr><td>b. Use of District-approved spreadsheet used to determine average bulk density.</td><td></td><td></td><td></td><td></td><td colspan="31">Maintain records of type of silage pile(s), moisture content of crop, and copy of inputs entered into the District-approved spreadsheet or document from contractor indicating that practices were adjusted per the spreadsheet to achieve the required bulk density.</td></tr>
<tr><td>c. Minimum ave. moisture content (65% for corn and 60% for other crops), maximum Theoretical Length of Chop (TLC), and layers ≤ 6 inches.</td><td></td><td></td><td></td><td></td><td colspan="31">Maintain records of type of silage pile(s) moisture content of crop, and TLC roller opening settings of harvest equipment for each crop. Document(s) from contractor(s) containing this information are acceptable.</td></tr>
<tr><td>OWNER/OPERATOR SIGNATURE
I have reviewed the above and I certify that the recordkeeping for this month is correct</td><td colspan="35"></td></tr>
</table>

*By Checking daily and/or weekly, I certify that I perform these mitigation measures on either a daily basis (if daily checked) or on a weekly basis (if weekly checked)

San Joaquin Valley
AIR POLLUTION CONTROL DISTRICT

Month/Year:

Name of Dairy:

MY MEASURES	Daily*	Weekly*	No Report	OR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
SILAGE PILE CHECKLIST cont:																																			
3. Total exposed area of silage piles less than 2,150 ft^2 for a single open silage pile; or less than 4,300 ft^2 for multiple open silage piles					Calculate and record the maximum total exposed area for silage piles; or record date(s) that piles were inspected to verify that the total exposed area was less than 2,150 ft^2 for a single open silage pile; or less than 4,300 ft^2 for multiple open silage piles (inspection of piles required at least one per month):																													
4. Check day that silage piles were visually inspected to verify that the working face was smooth				OR																															
5. Silage Additives (Inoculants: homolactic bacteria and preservatives: propionic acid, benzoic acid, etc.)					For each silage pile maintain records of type of additive and quantity of additive applied.																													
MILK PARLOR CHECKLIST:																																			
1. Check when parlor is flushed either before, during, or after each milking				OR																															
OPEN CORRAL CHECKLIST:																																			
1. a. Check day manure was removed from corral (must be at least 4 times per year); or																																			
b. Check day manure was removed from corrals (must be at least once between April & July and Sept. & Dec)																																			
2. a. Check day concrete lanes in corrals are scraped, flushed, or vacuumed (must be daily for mature cows and at least every 7 days for support stock); or				OR																															
b. Record depth of manure on concrete lanes at highest point every 90 days (must be ≤ 12")				OR																															
3. Check day pipes & water troughs were checked & repaired for leaks (must be at least every 7 days)				OR																															
4. Check day pens/corrals are groomed to maintain a dry surface (not required during rain)				OR																															
5. Check day manure cleaned from under corral shades (at least every 14 days except when weather prevents access to corrals)				OR																															
6. Record depth of manure in the corrals at highest point every 90 days (must be ≤ 12")				OR																															
7. Record depth of manure at highest point at the fenceline every 90 days (must be ≤ 12")				OR																															
8. Check day when lime/thymol was applied to the pens/corrals				OR																															

OWNER/OPERATOR SIGNATURE
I have reviewed the above and I certify that the recordkeeping for this month is correct

*By Checking daily and/or weekly, I certify that I perform these mitigation measures on either a daily basis (if daily checked) or on a weekly basis (if weekly checked)

San Joaquin Valley
AIR POLLUTION CONTROL DISTRICT

Month/Year:	
Name of Dairy:	

MY MEASURES	Daily*	Weekly*	No Report	OR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
FREESTALL CHECKLIST:																																			
1. Check day lanes are vacuumed or scraped either before, during, or after each milking; or lanes are flushed or scraped at least 3 times per day				OR																															
2. Use of non-manure and non-separated solids bedding (e.g. rubber mats, almond shells, sand, or water beds) for at least 90% of bedding material					Maintain records of type and quantity of bedding material used or purchased																														
3. Check day wet manure was removed from freestall beds; or bedding was groomed (must be at least every 7 days for large dairies with ≥ 1,000 milk cows and at least every 14 days for medium dairies with 500 - 999 milk cows)				OR																															
4. Check day animals were not allowed in exercise pens, corrals, or drylots				OR																															
SOLID MANURE CHECKLIST (This Section Only Apples to Large Dairy CAFs with ≥ 1,000 milk cows):																																			
1. a. Check day manure removed from facility (within 72 hrs of removal from corrals); or				OR																															
b. Check day dry manure piles outside the pens are covered (from October through May)				OR																															
2. a. Check day dry separated solids removed from facility (within 72 hrs of removal from drying); or				OR																															
b. Check day dry separated solid piles are covered (from October through May only)				OR																															
LIQUID MANURE CHECKLIST:																																			
1. Phototropic lagoon (testing required at least every calendar quarter)					Test lagoons for bacteria concentration, bacteriochlorophyll concentration, or other approved parameter at least once every calendar quarter, with at least 30 days between tests, and retain records of test.																														
2. Anaerobic treatment lagoon					Maintain records of design specifications and calculations (e.g. Minimum Treatment Volume and Hydraulic Retention Time) demonstrating compliance with the requirements of NRCS Field Office Technical Guide Code 359																														
3. Lagoon pH between 6.5 and 7.5 (testing required at least every calendar quarter)					Test lagoons for pH at least once every calendar quarter, with at least 30 days between tests, and retain records of test.																														
4. Solids separator system (mechanical or gravity)					Remove solids from the waste system prior to the waste entering the lagoon.																														
LAND APPLICATION CHECKLIST:																																			
1. a. Record day solid manure applied and day incorporated (must be incorporated within 72 hrs); or																																			
b. Moisture content of solid manure ≤ 50%					Maintain records of moisture content of solid manure and date applied (records maintained for the Regional Water Quality Board are acceptable)																														
2. Check day fields were visually inspected to verify that liquid animal waste did not remain in the fields for more than 24 hrs after irrigation.				OR																															

OWNER/OPERATOR SIGNATURE **I have reviewed the above and I certify that the recordkeeping for this month is correct**	

*By Checking daily and/or weekly, I certify that I perform these mitigation measures on either a daily basis (if daily checked) or on a weekly basis (if weekly checked)

Item A 000107

Appendix A.1: Table of Mitigation Effectiveness for Selected Measures

Measure	Category	Target	PM	NH_3	H_2S	VOCs	GHGs	USDA-NRCS Practice
Group and Phase Feeding	Nutrition and Feed Management	Generation	---	15-45%	---	---	---	Feed Management (592)
Feed Additives	Nutrition and Feed Management	Generation	---	20-70%	30%	---	---	Feed Management (592)
Feed Processing, Storage & Delivery	Nutrition and Feed Management	Generation	---	20%	---	---	---	Feed Management (592)
Dietary Formulation Changes	Nutrition and Feed Management	Generation	50-80%	30-50%	30-50%	---	---	Feed Management (592)
Litter Amendments and Manure Additives	Animal Confinement Manure Management	Generation Emission	---	0-85%	0-80%	10-40%	0-60%	Amendments for Treatment of Agricultural Waste (591)
Electrostatic Precipitation	Animal Confinement	Emission	30-80%	---	---	---	---	Air Filtration and Scrubbing (371)
Oil Spray/ Sprinkling	Animal Confinement	Emission	60-85%	0-30%	20-30%	---	---	Air Filtration and Scrubbing (371)
Biofilters	Animal Confinement Manure Management	Emission	80%	45-75%	80-95%	70-90%	---	Air Filtration and Scrubbing (371)
Wet Scrubbers	Animal Confinement	Emission	60-90%	70-90%	---	50-90%	---	Air Filtration and Scrubbing (371)
Windbreaks and Shelterbelts	Animal Confinement	Transport	50-70%	---	---	---	---	Windbreak/Shelterbelt Establishment (380) Windbreak/Shelterbelt Renovation (650)
Manure Storage Covers	Manure Management	Emission	---	50-95%	50-80%	---	30%	Roofs and Covers (367)
Solid-Liquid Separation	Manure Management	Generation	---	0-10%	0-20%	---	---	Waste Separation Facility (632)
Oxygenation of Liquid Manure Lagoons	Manure Management	Generation Emission	---	-20-70%	-10-70%	---	---	Waste Treatment (629)
Composting	Manure Management	Generation Emission	-10-30%	-10-10%	30-70%	10-60%	10-60%	Composting Facility (317)
Anaerobic Digester	Manure Management	Generation Emission	---	-50-30%	0-10%	60%	80-85%	Anaerobic Digester (366) Roofs and Covers (367)
Timing of Land Application	Land Application	Generation Emission	---	65-70%	---	---	50-70%	Nutrient Management (590)
Injection	Land Application	Generation Emission	---	70-90%	50-75%	87%	---	Nutrient Management (590)
Incorporation	Land Application	Generation Emission	---	20-90%	50-75%	80%	---	Nutrient Management (590)
Banding	Land Application	Generation Emission	---	30-40%	---	---	---	Nutrient Management (590)
Stocking Density	Pasture and Range Management	Generation Emission	80%	---	---	---	---	Prescribed Grazing (528)

The effectiveness of the measures presented in this document depends on site-specific conditions that vary widely across livestock operations. Additionally, reductions of individual air pollutants have not been studied or quantified for every measure presented. This table provides a summary of the mitigation effectiveness available for measures in this document, largely based on the literature review conducted for the Air Management Practices Assessment Tool, which included examination of 265 papers on the mitigation of PM, NH_3, H_2S, VOC, GHG and odor emissions.[1] Although not comprehensive, this summary table provides examples of the ranges of expected emissions reductions from applying a specific conservation measure (in isolation). Note that these values do not reflect the potential emission reduction at the farm level, as the impact on overall emissions will vary based on a combination of factors specific to that operation. Additionally, not all of the emission reductions that have been observed in agricultural studies of the conservation measures have been quantified. Refer to the text for each measure for a broader discussion of potential emissions impact and tradeoffs.

Measures for which no agricultural specific emission reduction values were found include: pen surface management, thermo-chemical treatment, low pressure irrigation systems, subsurface application, improved vegetative and forage quality, mortality management, dust suppressants, vehicular controls, and equipment modifications.

[1] Maurer, D., J.A. Koziel, J.D. Harmon, S.J. Hoff, A.M. Rieck-Hinz, D.S. Andersen. 2016. *Summary of performance data for technologies to control gaseous, odor, and particulate emissions from livestock operations: Air management practices assessment tool (AMPAT).* Data in Brief, 2016, vol.7, 1413-1429. DOI = 10.1016/j.dib.2016.03.070.

Appendix E.2

Compilation of Emission Factors

Development of Emissions Estimating Methodologies for Dairy Operations

Draft

Prepared by:

U.S. Environmental Protection Agency
Office of Air and Radiation
Office of Air Quality Planning and Standards
109 T.W. Alexander Drive
Research Triangle Park, N.C. 27709

June 2022

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GLOSSARY / ACRONYMS

Acronyms	Defintion
-2LogL	negative twice the likelihood
ACI	Akaike information criterion
ACIc	Adjusted Akaike information criterion
ADMs	average daily means
AFO	animal feeding operation
BIC	Schwarz Bayesian Information Criterion
bLS	backward Lagrangian Stochastics
d	day
dsm^3	Dry standard cubic meter
EEMs	Emissions estimating methodologies
EPA	Environmental Protection Agency
FANS	Fan Assessment Numeration System
g	gram
g/d	grams/day
H_2S	hydrogen sulfide
hd	head – inventory of cows
hPa	hectopascal
kg	kilogram
LAW	live animal weight
LNME	Normalized mean bias of natural log data
m	meter
MB	mean bias
MC	milking center
ME	Mean error
MS	Manure solids
MUN	Milk urea nitrogen
NAEMS	National Air Emissions Monitoring Study
NCEI	National Centers for Environmental Information
NH_3	ammonia
NMB	normalized mean bias
NME	normalized mean error
PI	Principal Investigator
PM	particulate matter
PM_{10}	particulate matter with aerodynamic diameters less than 10 micrometers
$PM_{2.5}$	PM with aerodynamic diameters less than 2.5 micrometers
QAPP	quality assurance project plan
QC	quality control
s	second
SAB	science advisory board
SDS	Separated digested solids
SP	Settling ponds
SS	Solid separation
SS	separated solids

Std Dev	Standard deviation
TAN	total ammoniacal nitrogen
TEOM	tapered element oscillating microbalance
TKN	total Kjeldahl nitrogen
TSP	total suspended particulate
USDA	U.S. Department of Agriculture
VOCs	volatile organic compounds
VRPM	vertical radial plume mapping

1 INTRODUCTION

1.1 Confinement Site Descriptions

Five milk production facilities (dairy operations) had barns monitored under NAEMS. The locations were selected based on site-specific factors including representativeness of facility age, size, design and management, and herd diet and genetics. Three free stall and two open free stall dairy facilities were monitored as a part of NAEMS. Table 1-1 summarizes the sites and their characteristics.

Table 1-1: Dairy Confinement Sites Monitored Under NAEMS

Site	Monitoring Period	Site Type	Ventilation type	Number of barns measured	Manure Collection	Manure Storage[4]	Bedding Type[5]
NY5B	10/24/07 – 10/23/09	Free stall	Mechanically Ventilated	1[3]	Scrape	Digester/ SS/SSP	SDS
IN5B	8/24/07 – 8/23/09	Free stall	Mechanically Ventilated	2[3]	Scrape	Digester/ SS/Lagoon	SDS
WI5B[1]	9/12/07 – 10/31/09	Free stall	Mechanically Ventilated	2	Flush	SP/Lagoon	Mattress/ shavings
CA5B	9/26/07 – 2/1/10	Open free stall[2]	Naturally Ventilated	2	Flush	SP/Lagoon	Soil/MS/ Almond shells
WA5B[1]	9/28/07 – 9/27/09.	Open free stall[2]	Naturally Ventilated	2	Flush	SP/SS/ SSP/Basin	MS

[1]Barn sites that also have measured area sources.
[2]Cows are free to walk from open free stall barn into dry lots between the barns.
[3]Monitored units include the milking center.
[4]Labeled consistent with the site reports, where: SP = Settling Pond; SS = solid separation; SSP= Solid Storage Pad
[5]MS = Manure solids; SDS = Separated digested solids

1.1.1 CA5B

In 2010, the California site (CA5B) was a 1,200-cow Holstein dairy farm. The farm has two naturally ventilated free stall barns, a milking center, and a lagoon and settling ponds (Figure 1-1). The farm also included exercise lots, which were located adjacent to each barn. Lactating cows were milked two times daily in the centrally located milking center. The on-site heifer program (i.e., activities to raise their own heifer calves until they can join the milking herd) was held on the north end of the farm, separated from the study area.

The two naturally ventilated free stall barns, barn 1 (B1) and barn 2 (B2), were monitored as part of NAEMS (Zhao, et al., 2010). Each barn had four free stall rows, two on each side of a central feed lane, housing 600 cows each. Barn 1 had the fresher cows (i.e., cows that recently gave birth) and served as the breeder barn, while barn 2 had pregnant lactating cows and the hard breeders (i.e., cows that have a hard time getting pregnant). The cows were generally inside the barns, particularly on hot days to provide shade.

The manure handling system included a barn flushing system, three settling ponds and a lagoon. Manure solids taken from the settling ponds were spread on nearby fields in the spring and fall.

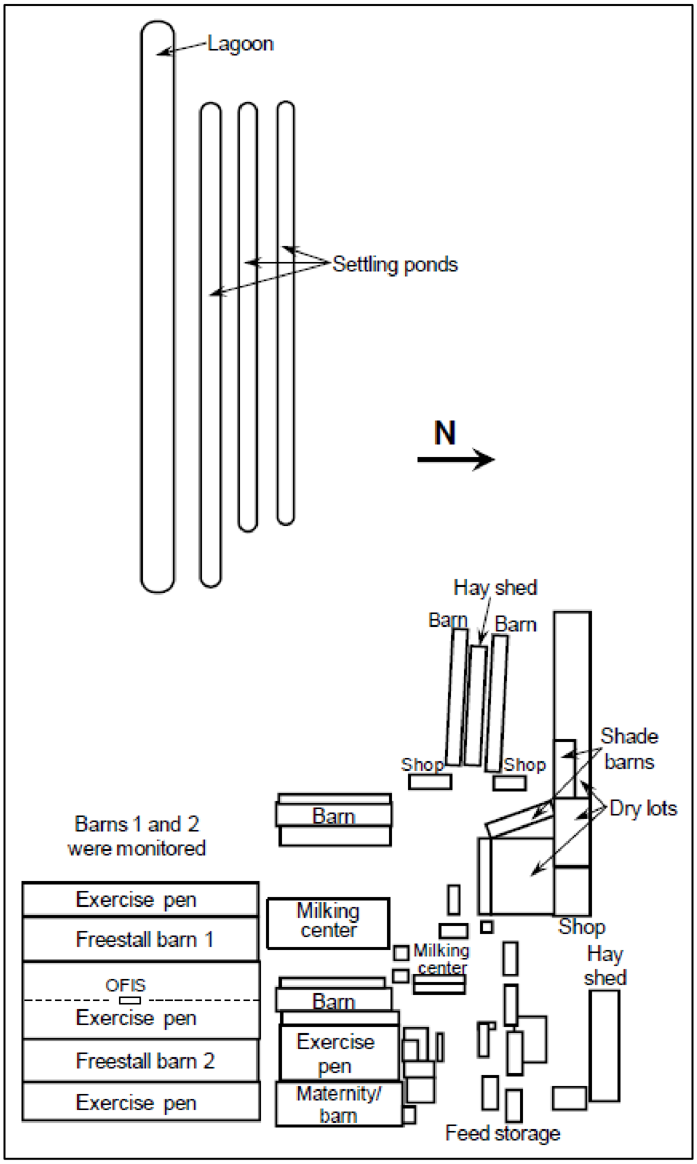

Figure 1-1: CA5B farm layout.
Source: Zhao, et al. (2010)

1.1.2 IN5B

The dairy farm in Indiana (IN5B) had 3,400-head capacity of Holstein cows. The dairy consisted of two free stall barns, a holding barn, milking parlor, and a dry cow barn (Figure 1-2). NAEMS gathered measurements from the two freestall barns, barn 1 (B1) and barn 2 (B2), and the milking center (MC), which consisted of the holding barn (area where cows waited approximately 45 minutes prior to milking) and milking parlor (Lim, et al., 2010). Each barn used a bank of exhaust fans to pull air through the barns. Each barn housed typically housed up to 1,700 cows, with approximately 3,400 Holstein cows were milked three times a day in the 72-stall rotary parlor. For the NAEMS, measurements of airflow and emissions focused on the western half of each of the barns.

The manure was removed from both freestall barns by scraper, while the manure from the holding barn and milking parlor was flushed. The manure removed from the freestall barn and milking center are held in a reception pit, and then then directed to a digester that produced methane gas which was used in generators on the farm. Digester effluent was separated, with the digested solids moved a storage area and the liquid stored in a two-stage pond/lagoon system. The liquid was then either irrigated onto or injected into land in the surrounding area. The separated digested solids were used as bedding in the free stall barns.

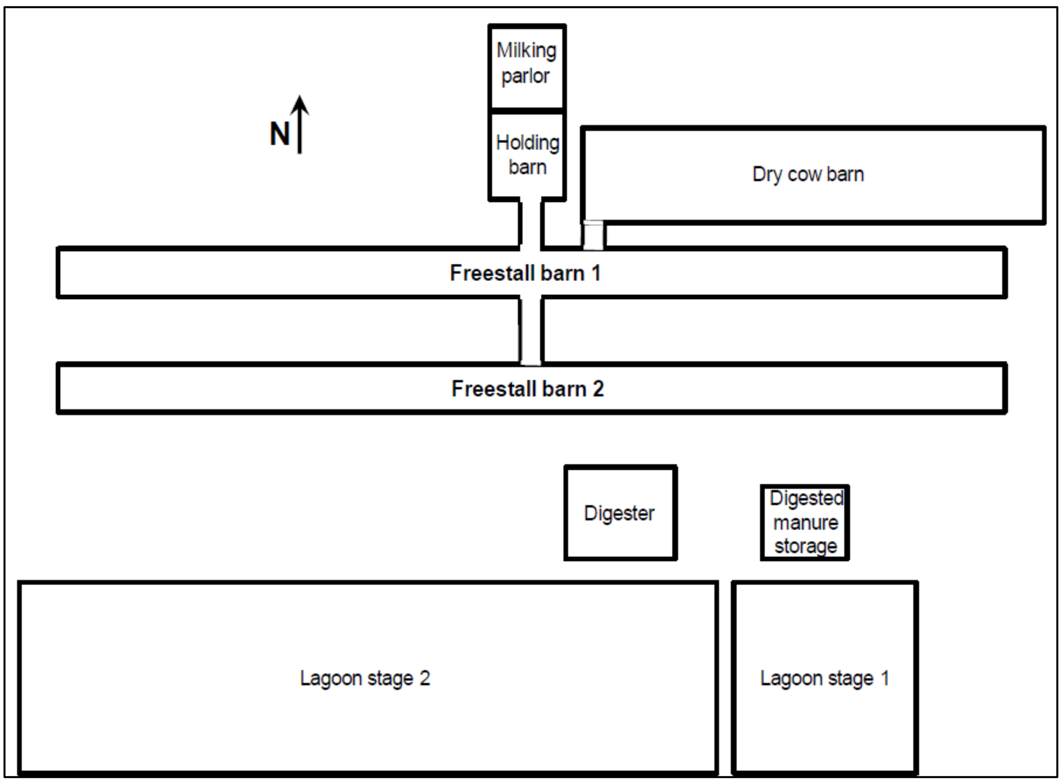

Figure 1-2. IN5B farm layout.
Source: Lim et al. (2010)

1.1.3 NY5B

The dairy facility monitored in New York (NY5B) had a capacity of 1,000 Holstein cows and consisted of a mechanically ventilated free stall barn and a milking center, a naturally ventilated free stall barn, along with housing facilities for dry cows, steers, and calves on the same site (Figure 1-3). Measurements were collected from the mechanically ventilated 6 row free stall barn (barn 1 or B1) and the MC during the study (Bogan, et al., 2010). The MC included a double-20 milking parlor, 31 free stalls and four bedded-pack box stalls for special-needs cows. Cows were brought in for milking three times per day.

The manure was removed from both the B1 and MC by scraper and deposited in a below-grade gravity flow channel that led to a centralized agitation and pumping station located in the covered connecting alley between the structures. From the alley, the manure was transferred to an anaerobic digester. The digester effluent was processed with a screw-press solid-liquid separator. The separated solids were stockpiled as bedding, land-applied to far-off fields, or sold. The liquid was pumped to long-term storage that was about 2.3 km away to the northeast.

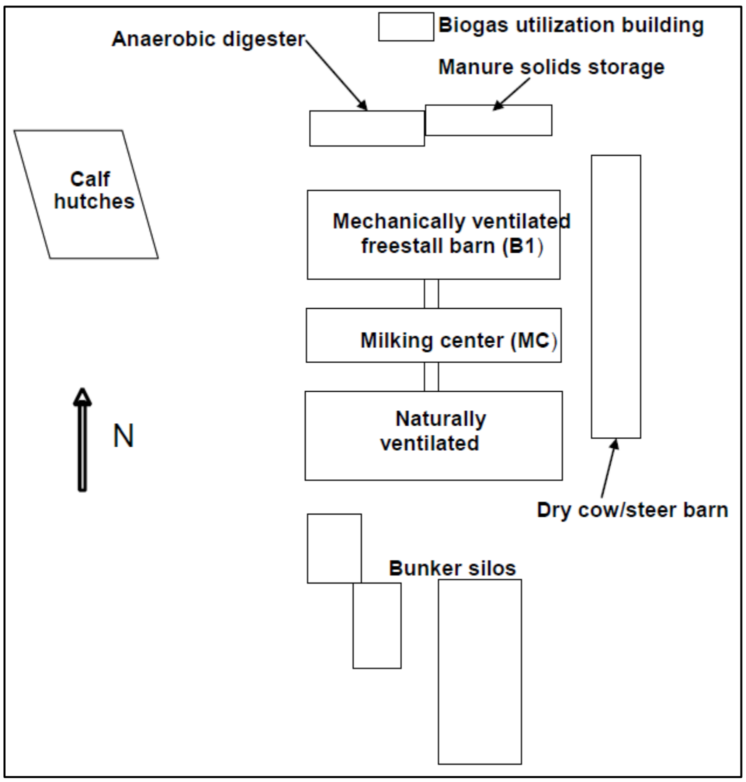

Figure 1-3. NY5B farm layout.
Source: Bogan, et al. (2010)

1.1.4 WA5B

The dairy facility located in Washington State (WA5B) was a 5,600-head Holstein dairy farm. The farm buildings included the milking parlor and six naturally ventilated symmetrically-distributed free stall barns (Figure 1-4). The farm also includes a total of ten corrals/exercise pens that are distributed around the barns. Two of the free stall barns, barn 2 (B2) and barn 4 (B4), were monitored as part of NAEMS (Ramirez-Dorronsoro, et al., 2010). Barn 2 housed 600 cows in four rows of free stalls and Barn 4 housed 700 cows in six free stall rows.

Manure from the free stall barns was flushed automatically three times daily and scraped as needed. The effluent was directed, via pipes, to the waste handling and treatment system that included a sand separation pit, two primary settling ponds, a manure separation pad (which includes screen separators and centrifugal solid separators), and a pair of serpentine settling systems, in which each one had five sequential settling cells. Both serpentine cells then discharged into a central cell. The liquid effluent from the central cell was directed to the storage lagoon. The solid effluent from the sand separation pit, depending on the season and temperature, also was directed to two manure drying ponds, located south of the manure separator pad. The dried manure was used for bedding and land application, and the liquid was applied to surrounding fields. The site's lagoon was also monitored as a part of NAEMS (Section 1.2.3).

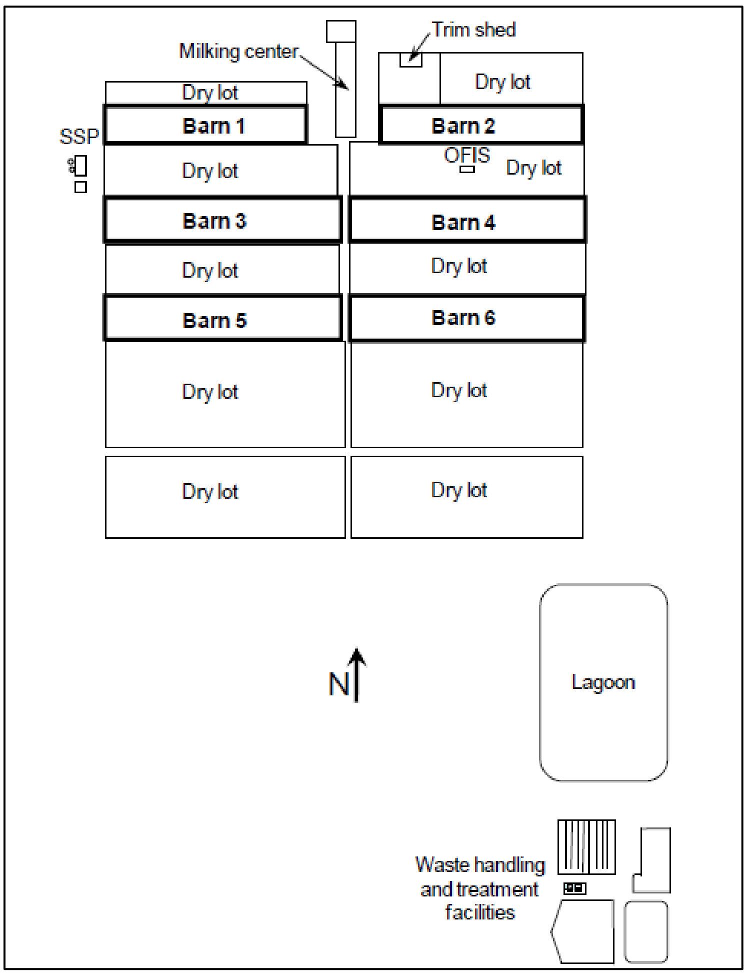

Figure 1-4. WA5B farm layout.
Source: Ramirez-Dorronsoro, et al. (2010)

1.1.5 WI5B

The dairy facility monitored in Wisconsin (WI5B) had a total capacity of 1,700 Holstein dairy cows, and consisted of four free stall barns, a holding barn, and sixth barn that is divided into the calving pen for 2-year-olds and a hospital barn (Figure 1-5). Two of the free stall barns, barns 1 (B1) and 2 (B2), located on the north side of the farm, were monitored as a part of NAEMS (Cortus et al., 2010). Barn 1 (B1) had capacity of 275 cows in four rows of free stalls, and barn 2 (B2) had a capacity of 375 cows housed in five rows of free stalls.

Approximately halfway through the study, the manure removal system was changed in the barns. Initially, manure was removed by flushing three time per day. The manure flushed from the parlor, holding pens, and free stall barns was directed to a solid separator. Solids were directed to pads to wait for land application, while the liquid portion was pumped back into the vertical tanks to flush the barns. After September 19, 2008, the flush system was replaced with a tractor scrape system, which was already in use in barns 5 and 6.

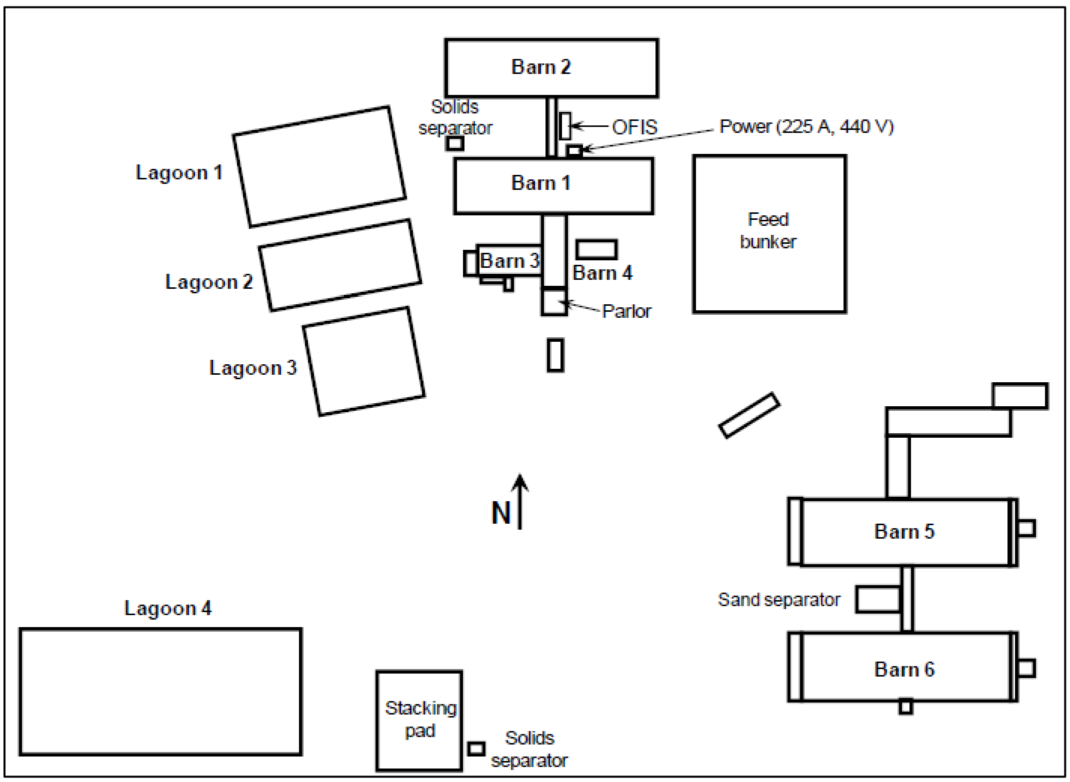

Figure 1-5. WI5B farm layout.
Source: Cortus et al. (2010).

1.2 Open Source Site Descriptions

Three dairy lagoons and a dairy corral (TX5A) were monitored under NAEMS (Table 1-2). Sites were selected to capture different stages and manure practices typical of the industry. The sites selected also represent the broad geographical extent of dairy production to also represent different climatological settings for farm and any regional differences in farm practices.

Dairy lagoon emissions were measured continuously at one farm (IN5A) for one year and for up to 21 days each season for two years at the two other farms (WA5A and WI5A). The dairy corral (TX5A) was also monitored for up to 21 days each season for two years.).

Table 1-2: Dairy Open Source Sites Monitored Under NAEMS

Site	Source Monitored	Manure Collection	Manure Storage[3]
IN5A	Lagoon	Flush	Lagoon
WA5A[1]	Lagoon	Flush	Lagoon
WI5A[1]	Lagoon[2]	Flush	Lagoon
TX5A	Open Corral	Scrape	SB/Lagoon

[1] Site that also had barn monitoring sites during NAEMS
[2] Lagoon can be single or double stage.
[3]SB= Settling Basin

1.2.1 IN5A

The Indiana open source site consisted of three barns, a feed storage area, special needs barn, milking parlor, and an office and tool and repair shops (Figure 1-6). The facility had a capacity of 2,600 cows (Grant and Boehm, 2010a).

The monitored lagoon received effluent from the parlor and holding area. Manure was flushed from the holding area and milking parlor every half hour. A small fraction of waste was held in a slurry tank. The wastewater (flush) from the holding area and milking parlor was transferred to a settling basin before being transferred to the clay-lined lagoon. The clay-lined waste lagoon was 85m (280 ft) wide and 116m (380 ft) long, with a surface area of 9,884 m^2 (106,400 ft^2). Sludge had never been removed from the lagoon (Grant and Boehm, 2010a).

Figure 1-6:Aerial view of IN5A
Source: Grant and Boehm (2010a)

1.2.2 TX5A

The Texas dairy (TX5A) consisted of ten corrals, milking parlor, office, hay shed, commodities barn, calving/fresh cow barn and truck scale (Figure 1-7). The facility had a capacity of 3,400 Holstein cows (Grant and Boehm, 2010b). Wastewater from the dairy drains to two earthen sludge/settling basins before entering a retention/treatment structure. Runoff from the corrals drains to the larger of two retention structures which are connected in series.

Manure was scraped twice a week from the corral surface with some scrapings used as bedding and the remainder was pushed to the south into ditches, which drained into the runoff pond. Manure was vacuumed instead of scraped if persistent wet conditions occurred.

Figure 1-7. Aerial view of TX5A
Source: Grant and Boehm (2010b)

1.2.3 WA5A

The Washington farm (WA5A) consisted of six barns, a milking parlor, and an office (Figure 1-8). The facility has a capacity of 4,400 milking cows and 1,200 dry cows in three units (Grant and Boehm, 2010c). The farm has free stall style barns, with automated flushing that occurred four times daily. Manure was transferred to an upper settling basin from a sand separation pit. Liquids were skim separated and then returned as flush to the barns. One lagoon was actively filled while the other was drying or sludge was being entirely removed. The settled solids (sludge) were completely removed within a year by front end loader. The settled solids (sludge) were removed annually by a front-end loader. These remaining solids were then strained through screens and centrifugal/screw presses, and the liquid transferred to large serpentine concrete basins for secondary settling. These solids are then dried for bedding. The water removed from the settled solids is stored in a large, clarified water storage basin for dilution of barn flush water from the lagoons.

The two upper lagoon/settling basins were measured as part of NAEMS, as well as two free stall barns described as in Section 1.1.4. Gaseous emissions occur both during lagoon filling and during sludge removal. The east lagoon was rectangular with dimensions of 183m (600 ft) by 72 m (235 ft). The west lagoon was five-sided with dimensions of approximately 183 m (600 ft) long and 83m (271 ft) wide with the southwest corner of the lagoon cut off. The east lagoon was measured for gaseous emissions. At maximum capacity this lagoon had a liquid depth of 5 m (18 ft), surface area of 13,098 m^2 (141,000 ft^2) and a volume of 186,300 m^3 (2,005,500 ft^3).

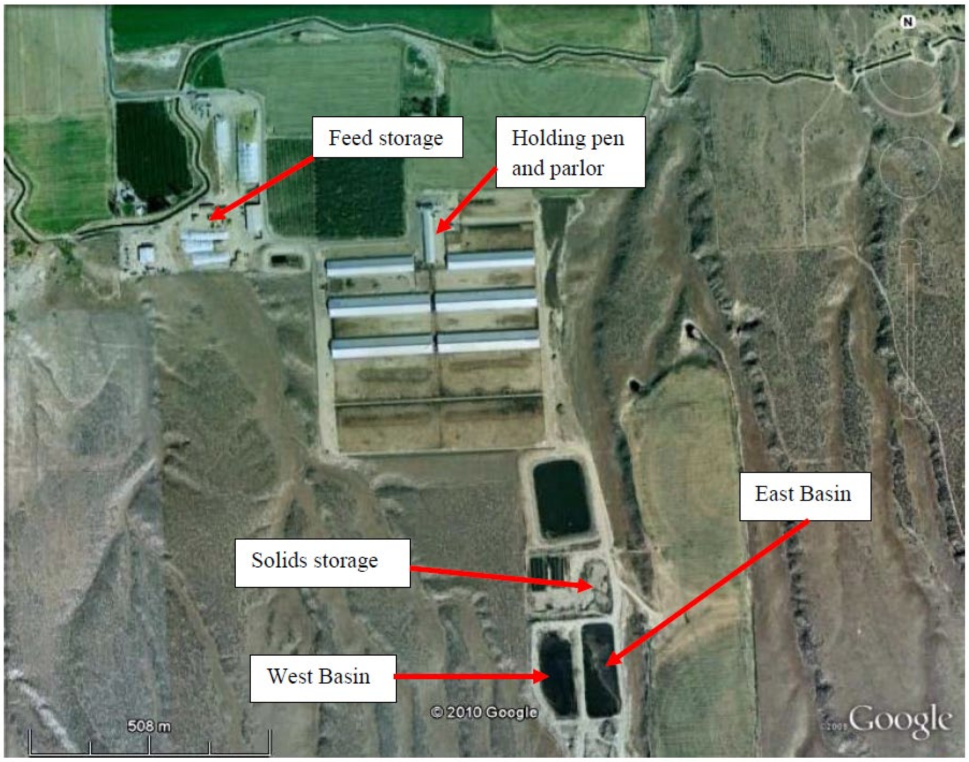

Figure 1-8. Aerial view of WA5A
Source: Grant and Boehm (2010c)

1.2.4 WI5A

In 2010, the Wisconsin farm (WI5A) had a total of six barns, a milking parlor with holding pen, and a special needs area (Figure 1-9). The farm had a capacity of 1,700 Holstein cows (Grant and Boehm, 2010d). Manure from the free stall barns and the milking parlor complex was removed by flushing three times daily. The manure flushed from the parlor, holding pen, and free stall barns flows to a solids separator, from which the solids are removed and stacked on a pad until they were spread on fields. The liquid effluent from the solids separator was pumped back into vertical tanks for reuse to flush the barns. Once a week, enough water was removed from the third stage of the three-stage lagoon and added to the flush tanks to make up for water lost in the recycled flush system. The three-stage lagoon receives effluent from the two free stall barns measured by the barn component of NAEMS (Section 1.1.5), as well as the other barns and milking parlor. The lagoons are pumped out into trucks twice yearly. The first and second stages of the three-stage lagoon system were monitored, as well as two free stall barns as described in Section 1.1.5.

The first lagoon had a width of 52 m (170 ft) and length of 82 m (270 ft). At maximum capacity, the first lagoon had a surface area of 4,264 m2 (45,900 ft^2) and a volume of 10,561 m^3 (373,000 ft^3). The second lagoon had a width of 37 m (120 ft) and length of 79 m (260 ft). At maximum capacity, the second lagoon had a surface area of 2,898 m^2 (31,200 ft^2) and a volume of 6,420 m^3 (226,700 ft^3). Both lagoons had liquid depths of 3 m (11 ft) and sludge was last removed from the second lagoon in 2006.

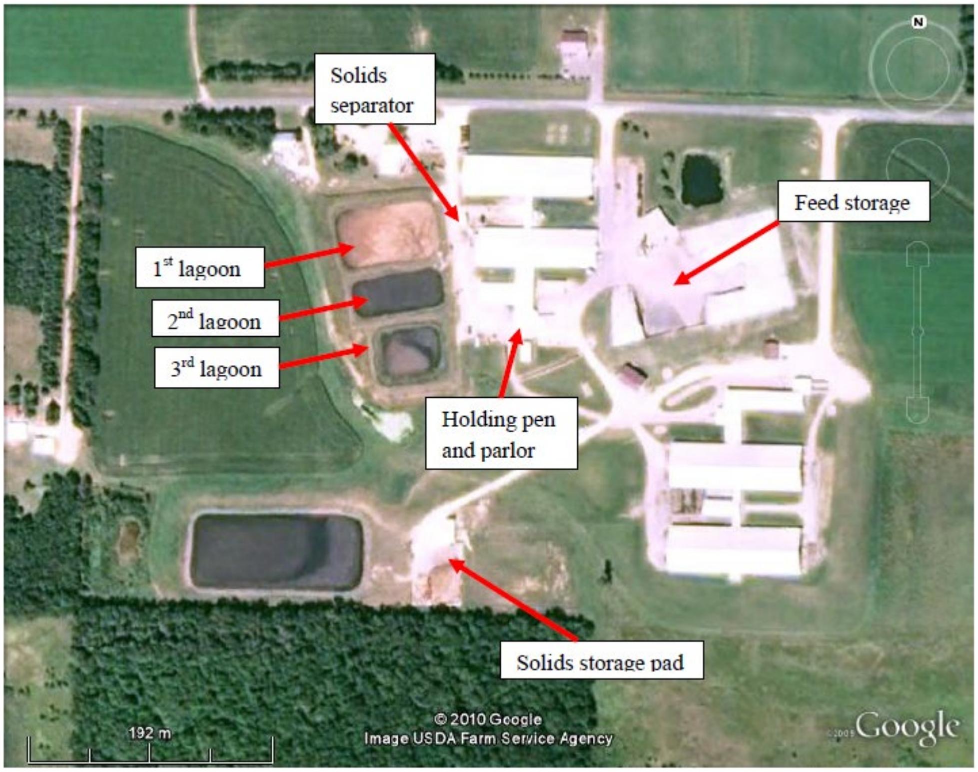

Figure 1-9. Aerial view of WI5A
Source: Grant and Boehm (2010d)

1.3 Data Sampled

NAEMS collected a host of data from the sites. Data collected included gaseous pollutant samples, particulate matter samples, meteorological data, confinement parameters, and biomaterial samples. All procedures for barn sites were outlined in the project Quality Assurance Project Plan (QAPP) (Heber et al., 2008) and open sources were summarized in open source project QAPP (Grant, 2008), and are summarized in Section 4 of the main report. The following section outlines any collection specific to the dairy sites.

1.3.1 Particulate Matter

At any one time, the sampled filterable particulate matter (PM) size class was either equal to or less than a nominal aerodynamic diameter of 10 micrometers (PM_{10}), and 2.5 micrometers ($PM_{2.5}$) or total suspended particulate (TSP). Appendix A contains summary tables, which note the particulate matter sampling schedules for the confinement sites. Particulate matter emissions data were not collected specific to the open sources.

1.3.2 Animal Husbandry

In general, the producer provided pen inventories and information about changes to site operational procedures like bedding, on a weekly basis. For NY5B, the producer also provided daily milk production.

1.3.3 Biomaterials Sampling Methods and Schedule

All analyses of biomaterials were performed by an independent laboratory (Midwest Laboratories, Omaha, NE). Samples were collected based on procedures outlined in the QAPP (Heber, 2008). Specific sampling details for each site are summarized below. There were no lagoon samples collected for content analysis.

1.3.3.1 CA5B

Manure sampling was conducted approximately bimonthly during the second year of the study, with samples collected from the reception lane for the flushed manure in B1 and B2. The samples were analyzed for solids content, total nitrogen, ammoniacal nitrogen, and ash content to provide data for the nitrogen balance of the barns.

At the same time as manure sampling, samples of feed and fresh bedding (scraped soil and manure solids blended with almond shells or rice hulls) were taken from each barn. The samples were analyzed for solids content, total nitrogen, and ash. Sampling was added late in the study and only cover the second year of the study (Zhao, et al., 2010).

1.3.3.2 IN5B

Manure in the barns was sampled quarterly between 11/26/07 and 1/20/10. For each collection, at least four samples were collected from each of the two barns and analyzed for ammoniacal nitrogen, total nitrogen, pH, total solids, and ash (added later in the study). Samples of feed were also taken quarterly from each barn and analyzed for total nitrogen, total solids, and ash. Sampling was added late in the study and only cover the second year of the study (Lim, et al., 2010).

Bedding and milk tank samples were collected semiannually. Bedding samples were analyzed for total nitrogen and total solids, while the milk tank samples were only analyzed for total nitrogen.

1.3.3.3 NY5B

The daily volume of milk shipped (total milk less non-saleable milk) from the farm was copied manually from the yearly calendar where milk production was recorded daily by farm staff. Milk production data from B1 included the cows housed in the MC. Additionally, the farm reported milk urea nitrogen (MUN) and protein content nearly every day.

Bedding (post-digested separated manure solids) was sampled from each pen on approximately a monthly basis during the study's second year. The samples were analyzed for pH, solids content, total nitrogen, and ammoniacal nitrogen, and ash content. A single sample of the feed and water were taken at the end of the study. The feed was analyzed for solids content, total nitrogen, and ammoniacal nitrogen, and ash content, while the water sample was analyzed for total nitrogen, and ammoniacal nitrogen, and sulfur content.

Representative manure samples were collected in B1 from each the four pens, and the two manure alleys between the outside row of free stalls and the adjacent row of the head-to-head free stalls. Sampling was conducted approximately monthly during the second year. The samples were analyzed for pH, solids content, total nitrogen, and ammoniacal nitrogen.

1.3.3.4 WA5B

Sampling was conducted approximately bimonthly during the second year of the study. Samples of feed, bedding, and manure were taken from each barn. Bedding and feed samples were analyzed for total solids and total nitrogen content. Manure samples were analyzed for pH, total solids, total nitrogen, and ammonia content. Milk samples were taken from the holding tank and analyzed for total nitrogen only.

1.3.3.5 WI5B

Manure in the barns was sampled quarterly for the last year of the study. Each collection was composed of four samples from each of the two barns. Samples were analyzed for ammoniacal nitrogen, pH, and total solids.

2 REVISIONS TO DATA SET AND EMISSIONS DATA SUMMARY

The section catalogs the changes made to the dairy dataset prior to model development (Section 2.1), considers further changes to the data completeness criteria (Section 2.2), and finally compares the model development dataset to the initial dataset received in 2010 (Section 2.3) and published literature (Section 2.4) to determine the effect of the data revisions.

2.1 Revisions to the 2010 Data Set

As described in Section 4.2 of the main report, the NAEMS monitoring data were submitted to EPA in 2010, with revisions submitted in 2015. Revisions included modifying the approach used to determine the inlet concentrations of ammonia (NH_3) and hydrogen sulfide (H_2S) to align time used to determine valid concentrations at the barn inlet and outlet, using a 10-day running average of inlet concentrations rather than interpolation, and invalidating air flow rates for periods when the ventilation system was not operating. Corrections were submitted for IN5B, NY5B, WA5B, and WI5B. A revised file for CA5B was not submitted by the NAEMS principal investigator (PI).

In addition to the revisions submitted by the PI, EPA reviewed the validity of negative emission values present in the data set. Negative calculated emission values can occur in the NAEMS data set due to a range of different scenarios as described in the SAB review of the 2012 emissions estimating methodologies (EEMs) developed by EPA (U.S. EPA SAB, 2013). These different negative emission scenarios include calculation biases for emission values that were close to the instrument's detection limit, biases due to lack of lag time corrections, or from outdoor events that increased pollutant concentration outside of the barns. EPA developed a procedure for removing negative emission values that resulted from elevated background concentrations. For this procedure, EPA determined the median emission value for each pollutant., then excluded negative emissions values that fell outside of a range based on uncertainty range established in the QAPP for each pollutant the. Appendix B describes this process in more detail. The negative emissions removed accounted for between 2% (NH_3 and TSP) and 26% ($PM_{2.5}$) of the total number of average daily emission values available for the pollutant. Appendix B provides a summary of the number of values removed due to this process by barn for each pollutant.

The 2010 data sets for dairy open sources (lagoons, basins, and corrals) were provided to EPA by the NAEMS PI. The datasets contain 30-minute NH_3 values obtained using the backward Lagrangian Stochastics (bLS) model and vertical radial plume mapping (VRPM), and H_2S emissions obtained using the bLS model. The extensive data sets also include fields used to determine the quality and validity of the emissions data. Based on a literature review of papers published since NAEMS (Grant & Boehm 2020, Grant et al., 2020, Grant & Boehm 2015, Grant et al., 2013a), EPA revised the acceptance criteria for the 30-minute data. Overall, the number of valid 30 minute bLS NH_3 values for lagoons increased and H_2S decreased. The opposite occurred for the corral site, TX5A, as the number of bLS measure estimates NH_3 and H_2S decreased and increased, respectively. Appendix B summarizes the changes in data acceptance criteria and the affects it had on the number of 30-minute values available for each site.

Literature (Grant et al., 2013a) also suggested bLS measurements could be adjusted to be comparable to VRPM results. To prepare the 2012 NAEMS data sets of 30-minute values for use in calculating daily averages, the bLS NH_3 values for sites IN5A and WI5A were adjusted by multiplying the emissions values by 1.19 (Grant & Boehm 2020) and 1.13 (Grant & Boehm 2020), respectively. After the adjustment, the bLS and VRPM data were used together to determine which day had more than 24 half hour values to meet the revised 52% completeness criteria days. In cases where 30-minute emissions flux values were available for both the bLS model and VRPM, the average of the bLS and VRPM values were used. A practical example of the calculation is provided in Appendix B. The Table B-23 presents an example calculation for two days at site IN5A, (one day with both bLS and VRPM data, and one day with only bLS data).

2.2 Comparison between the 2010 and Revised Barn Data Sets

The influence of the previous described corrections on the revised data sets can be observed by comparing the summary statistics of all the valid emission values (at 75% data completeness) between the 2010 dataset, as summarized in the final site reports, and the revised data set. The following sections summarize the differences between the 2010 data set and revised data set for each of the barn types for a set of standard summary statics (e.g., mean, standard deviation, count (N), minimum, maximum, and number less than 0 (N<0)) of the average daily emissions. For summary tables presented, the percent difference was calculated as the revised data set minus the 2010 version of the data set, divided by the 2010 version of the data set (e.g., % Diff = (Revised - $Data_{2010}$)/$Data_{2010}$ * 100). This calculation yields negative values when decreases were seen in the revised version of the dataset.

2.2.1 Mechanically Ventilated Barns

In general, the 2010 and revised data set vary less than 10% for the barns at IN2B for NH_3 (Table 2-1) and H_2S (Table 2-2), while the data sets for the PM size fractions (Table 2-3) were not changed. The exceptions are the increase in the number of H_2S values less than zero (N<0) at IN2B (Table 2-2). There was more of a difference in the data sets for NY5B, particularly with the minimum value of H_2S (Table 2-2), which was revised from a very large negative value (-226 g/d) to a small positive value (34.05 g/d). NY5B was the only site that had changes to the particulate matter data set (Table 2-3), most notable of which was a decrease in the number of negative values for PM_{10}. The WI5B saw some of the biggest differences in NH_3 data, largely due to the increase in the number of valid average daily means (ADM) available for NH_3 after the revisions. The WI5B data sets for PM_{10}, $PM_{2.5}$, and TSP were unchanged.

Table 2-1. Percent difference in NH_3 summary statistics between the 2010 and revised dataset (at 75% data completeness).

Parameter	IN5B B1	IN5B B2	NY5B B1	WI5B B1	WI5B B2
Mean	3%	3%	6%	-4%	-3%
Standard Deviation	5%	5%	5%	-11%	-3%
N	0%	0%	-12%	19%	20%
Minimum	-6%	-6%	-1%	25%	-26%
Maximum	4%	9%	7%	-2%	-2%
N<0	0%	0%	0%	0%	0%

Table 2-2. Percent difference in H_2S summary statistics between the 2010 and revised dataset (at 75% data completeness).

Parameter	IN5B B1	IN5B B2	NY5B B1	WI5B B1	WI5B B2
Mean	1%	-2%	10%	0%	0%
Standard Deviation	0%	1%	3%	0%	-3%
N	2%	4%	-12%	-3%	-2%
Minimum	2%	2%	764%	0%	0%
Maximum	-2%	8%	-3%	4%	-5%
N<0	47%	67%	0%	33%	-88%

Table 2-3. Percent difference in PM summary statistics between the 2010 and revised dataset (at 75% data completeness).

Parameter	NY5B B1, PM_{10}	NY5B B1, $PM_{2.5}$	NY5B B1, TSP	IN5B, PM	WI5B, PM
Mean	5%	2%	2%	No difference	No difference
Standard Deviation	5%	1%	0%	No difference	No difference
N	0%	2%	0%	No difference	No difference
Minimum	0%	0%	0%	No difference	No difference
Maximum	7%	1%	1%	No difference	No difference
N<0	-50%	13%	0%	No difference	No difference

2.2.2 Naturally Ventilated Barns

For the naturally ventilated barns, there were no changes in the CA5B datasets for any pollutant and no changes in the WA5B datasets for NH_3, H_2S, or $PM_{2.5}$. For PM_{10} (Table 2-4), both WA5B barns saw an increase in the number of valid ADM, including new maximums more than 50% larger than in the 2010 data set. The TSP data set (Table 2-5) also changed, most notably there was an 18% decrease in the number of valid ADM at both barns and an increase in the minimum value for barn 2.

Table 2-4. Percent difference in PM_{10} summary statistics between the 2010 and revised dataset (at 75% data completeness).

Parameter	CA5B B1	CA5B B2	WA5B B1	WA5B B2
Mean	No difference	No difference	20%	12%
Standard Deviation	No difference	No difference	63%	38%
N	No difference	No difference	1%	1%
Minimum	No difference	No difference	0%	0%
Maximum	No difference	No difference	83%	68%
N<0	No difference	No difference	0%	0%

Table 2-5. Percent difference in TSP summary statistics between the 2010 and revised dataset (at 75% data completeness).

Parameter	CA5B B1	CA5B B2	WA5B B1	WA5B B2
Mean	No difference	No difference	3%	1%
Standard Deviation	No difference	No difference	5%	6%
N	No difference	No difference	-18%	-18%
Minimum	No difference	No difference	522%	0%
Maximum	No difference	No difference	0%	0%
N<0	No difference	No difference	0%	0%

2.2.3 Milking Centers

For the IN5B MC, most changes were minor for NH_3 (Table 2-6) and H_2S (Table 2-7). The most notable change is the increase in the number of negative ADM for both gaseous pollutants due to the changes in emission calculation. There were no measurements of PM_{10}, $PM_{2.5}$ or TSP made at the IN5B milking center.

The NY5B MC had minor changes to the NH_3 dataset and mostly minor changes to the H_2S data set. One of the largest changes was an increase in the minimum value for H_2S (Table 2-7), which was the result of the removal of a large negative ADM. The data sets for the PM size fractions (Table 2-8) generally saw minor changes. The notable exception is the 33% decrease in the number of negative values for ADM. This statistic is a little misleading, as there were only four values, and one of which was dropped during the revision.

Table 2-6. Percent difference in NH_3 summary statistics between the 2010 and revised dataset (at 75% data completeness).

Parameter	IN5B	NY5B
Mean	7%	0%
Standard Deviation	8%	0%
N	0%	-7%
Minimum	0%	15%
Maximum	4%	-2%
N<0	8%	0%

Table 2-7. Percent difference in H_2S summary statistics between the 2010 and revised dataset (at 75% data completeness).

Parameter	IN5B	NY5B
Mean	2%	-2%
Standard Deviation	-4%	0%
N	1%	1%
Minimum	0%	764%
Maximum	-12%	-2%
N<0	39%	0%

Table 2-8. Percent difference in NY5B MC PM summary statistics between the 2010 and revised dataset (at 75% data completeness).

Parameter	PM_{10}	$PM_{2.5}$	TSP
Mean	-1%	2%	1%
Standard Deviation	11%	1%	0%
N	8%	0%	0%
Minimum	0%	11%	0%
Maximum	0%	1%	1%
N<0	-33%	0%	0%

2.3 Data Completeness Criteria for the Revised Data Set

The appropriate data completeness criteria to use in a study depends on the size of the dataset and the accuracy needed. A study by Grant et al. (2013b), in which NH_3 emissions were modeled from swine lagoons based on NAEMS data, investigated data completeness and associated accuracy. The swine lagoon NH_3 emissions dataset had limited data availability at a data completeness of 75%. Grant et al. (2013b) explored how much the data completeness criteria could be relaxed but still result in data with acceptable error. The study suggested an error of ±25% to be acceptable and determined that a daily data completeness of 52% (or 25 out of 48 30-minute periods) gave less than ±25% error (see Figure 2-1). Using this revised daily completeness criteria resulted in a substantial increase in the size of the dataset.

Based on Figure 2-1 from the Grant et al. (2013b) study, it can be observed that a daily completeness criterion of 75% (36 out of 48 30-minute periods) would give an error of approximately 10%. If it is assumed that the relationship between data completeness and error from the Grant et al. (2013b) study is representative of other NAEMS datasets, the effect of relaxed data completeness criteria can be investigated for other NAEMS sources.

The NAEMS PI provided EPA with additional analysis that examined the effect of different completeness criteria by comparing the number of valid ADM. EPA reviewed these data for the barn data site and retained the 75% completeness criterion. For the open source sites, EPA review found that adjusting the daily data completeness to 52% provided significantly more data and justified the increase in the error. The full analysis can be found in Appendix C.

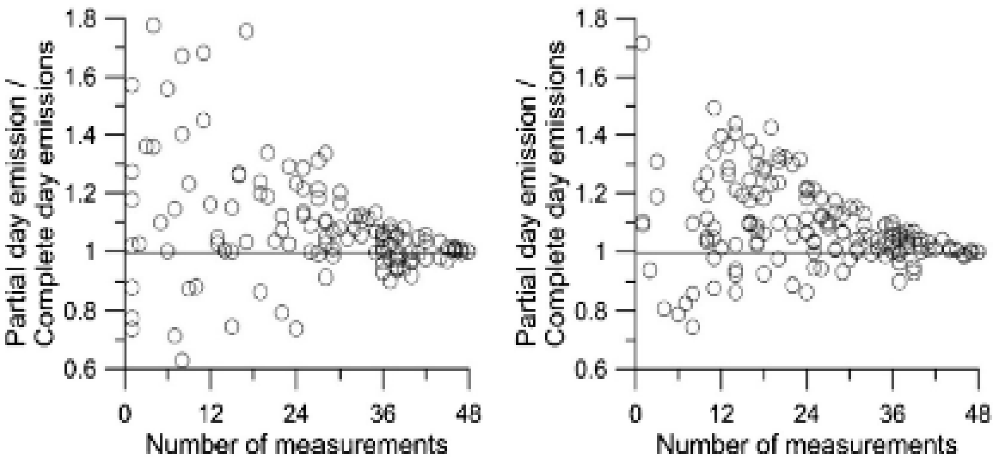

Figure 2-1. Ratio of mean predicted emissions for portion of day with valid emissions measurements to mean predicted emissions for the complete day at the finishing (A) and sow (B) farm. Error plotted against number of valid 30-minute measurements (from Grant et al., 2013b).

2.4 Comparison Between the Revised Data Sets and NAEMS Datasets Used in Peer-reviewed Published Papers

Where possible, EPA compared the revised dataset developed for this report to values presented in peer reviewed journals and reports to quantify any differences due to the application of the revised calculation methods and other adjustments discussed in Section 2.1. Summaries of the gaseous emissions from naturally ventilated barns can be found in Joo et al. (2015). Lagoon and basin summaries have been presented in Grant and Boehm (2015), and corrals in Grant et al. (2020). Summaries of the mechanically ventilated barn data and particulate matter data could not be found at the time of writing.

A simple comparison of the summary statistics presented in these papers and the summary statistics of the revised dataset is presented in the following sections. Overall, the dataset used for model development and presented in the papers are different due to difference in data screening methods. For NH_3 and H_2S at naturally ventilated barns, the model development dataset contains at least twice the number of observations than used in the article due to different choices in processing the data. Similarly, the revisions to the acceptance criteria for open sources noted in Section 2.1 also resulted in difference in differences between the published data set and the modeling data set. For the open sources, the acceptance criteria used by EPA are the culmination of several published papers aiming to improve the data quality and go beyond what was discussed in the compared work. Overall, the comparison highlights that EPA has done extensive analysis and review of the dairy data sets to obtain a robust data set for model development.

2.4.1 Naturally Ventilated Barns

Despite no difference between NH_3 and H_2S in the revised data set and the submitted 2010 data set (Section 2.2.2) for WA5B, the published data has different maximum, minimum, and average values for both (Table 2-9 and Table 2-10). A closer examination of Joo et al. (2015) reveals a more extensive outlier removal process, whereby anything outside 1.5 times the interquartile range were designated as outliers. The article also only reports on data collected in the second year of the study (November 2008 to October 2009) since there were "more and longer trouble-free periods" (Joo et al., 2015). The article further truncates the data by focusing on one-week data sets of continuously collected measurements selected every two months, for a total of 7 weeks (49 days) of data. The model data set contains at least twice as many days as the published data set, which quickly explains the differences seen.

Table 2-9. Comparison of naturally ventilated NH_3 emissions in the model dataset to published datasets.

Site	Units	Statistic	Model Dataset	Published Studies	Study
WA5B B2	Emissions (kg day^{-1})	Mean	26.6	14.1	Joo et al. 2015
		Minimum	-156.4	10.8	
		Maximum	96.6	19.7	
WA5B B4	Emissions (kg day^{-1})	Mean	54.7	19.4	Joo et al. 2015
		Minimum	9.0	17.2	
		Max	170.9	21.2	

Table 2-10. Comparison of naturally ventilated H_2S emissions in the model dataset to published datasets.

Site	Units	Statistic	Model Dataset	Published Studies	Study
WA5B B2	Emissions (g day^{-1})	Mean	555.6	397.4	Joo et al. 2015
		Minimum	-5,400.9	123.5	
		Maximum	6,513.6	542.4	
WA5B B4	Emissions (g day^{-1})	Mean	1,130.9	627.7	Joo et al. 2015
		Minimum	-11,640.1	0.0	
		Max	17,960.3	1711.8	

2.4.2 Open sources

Section 2.1 and Appendix B outline how EPA altered the acceptance criteria for the open sources. The changes were culled from several peer reviewed journal articles (Grant & Boehm 2020, Grant et al., 2020, Grant & Boehm 2015, Grant et al., 2013a) published since the 2010 receipt of the NAEMS data. While each of the articles referenced typically focus on one site, EPA developed a list of revisions to be applied to each site that represent the state of the science for the method. As such, the lagoon NH_3 values (Table 2-11) differ from the values published in Grant & Boehm (2020) due to difference in the acceptance criteria.

Table 2-11. Comparison of lagoon and basin NH_3 emissions in the model dataset to published datasets.

Site	Units	Statistic	Model Dataset	Published Studies	Study
IN5A	Emissions (g s^{-1})	Mean	0.23	0.27	Grant & Boehm 2020
		Minimum	-0.14	0.17	
		Maximum	1.07	0.39	
WI5A	Emissions (g s^{-1})	Mean	0.07	0.22	Grant & Boehm 2020
		Minimum	-0.04	0.07	
		Maximum	0.91	0.42	

Similarly, NH_3 emissions from dairy corrals varied from the published work due to revisions to the acceptance criteria that EPA implemented. These revisions resulted in 6 additional daily average emission values from the Grant publication (Table 2-12). These additional days shift the average of the daily means higher than in the published work and increased the variability, as shown by the increase in the standard deviation. As noted previously, the acceptance criteria used by EPA are an attempt to apply the revisions from several published papers aiming to improve the data quality and go beyond what was discussed in the compared work. Overall, the comparison highlights that EPA has done extensive analysis and review of the dairy sets to obtain a robust data set for model development.

Table 2-12. Comparison of corral (TX5A) NH_3 emissions in the model dataset to published datasets.

Source	N	Mean (kgd^{-1})	Standard Deviation
Revised	73	755.0	317.5
Grant et al. 2020	67	287.6	144.7

3 RELATIONSHIPS ESTABLISHED IN LITERATURE

Developing EEMs for dairy AFOs is complex as many variables potentially influence emissions. Therefore, to be efficient as possible in this study, a focused approach was used. The focused approach involved developing models based on variables that could potentially have a major influence on air emissions. This assessment was made based on theoretical considerations and observations reported by previous studies that have investigated the influence of variables on emissions from dairy AFOs.

3.1 NH_3 and H_2S from Confinement Sources

Emissions from barns originate from the nitrogen and sulfur content in urine and manure deposited in pits or on the floor along with any bedding material present in the barn. The amount of NH_3 and H_2S emitted depend on the amount of manure produced and its characteristics, that is the total ammoniacal nitrogen (TAN) and sulfur content, (Sanchis, Calvet, del Prado, and Estelles (2019)). Multiple factors influence the generation and release of NH_3 and H_2S emissions, such as the type of building and its volume, flooring type, housing density, manure management, livestock management practices, milk yield, diet, animal behavior, and factors affecting the microclimate within the buildings (e.g., temperature, humidity, airflow) (Bjerg et al., 2013, Bougouin et al. 2016, Herbut and Angrecka 2014). The following section outlines the relationship between these specific parameters and emission rates, as well as whether the parameter, or suitable proxy, is available in the NAEMS data set.

Manure volume is a key factor influencing NH_3 and H_2S emissions in both mechanically ventilated and naturally ventilated barns. That is, the more manure and urine there is, the more precursor material there is for NH_3 and H_2S emissions. No estimates or measurements on the amount of manure generated were taken at any of the dairy sites. However, other parameters, such as inventory and live animal weight (LAW), can be used as proxies for fresh waste generation as more or larger animals would produce more waste. Both inventory and LAW were determined daily at each site and were selected for further investigation.

Second to volume, the compositional characteristics—that is nitrogen, ammonia, and sulfur content of the waste—provides information on the amount of NH_3 and H_2S than can form and be emitted by the barn. As noted in Section 2.3, sampling for total ammoniacal nitrogen content (TAN), total Kjeldahl nitrogen (TKN), and sulfur content occurred for various components of the barn, including bedding material and the waste collected from the floor. However, a limited number of samples were taken over the course of the study. Including them in the regression analysis would limit the number of days available for model development, and thereby the variability of other factors included in the model. EPA has looked at interpolating the data between samplings to extend the data to more days, however, this does require assumptions about the behavior of nitrogen and sulfur content in the manure between samples. Knowing the incoming nitrogen and sulfur content of the feed, water, and bedding would inform the interpolation process, leading to better assumptions as this would indicate the maximum amount of nitrogen and sulfur introduced into the system, allowing from mass balance checks. However, data on feed and water and was not provided by the producers. As such, the limited data available on waste characteristics (i.e., TAN, TKN, sulfur content) were excluded from the model development dataset.

Manure pH has a strong correlation with both NH_3 and H_2S emissions (Rotz et al. 2014, Montes et al., 2009). The ammonia fraction of TAN is partly a function of pH, so pH would provide an indication of NH_3 available in the manure (Montes et al., 2009). For H_2S, water with an acidic pH has an increased concentration of molecular hydrogen sulfide, which increases the potential for H_2S emissions. However, like TAN and TKN measurements, only limited pH data were collected during NAEMS. As such, the limited data available were excluded from the model development dataset.

The Sanchis et al. (2019) review overwhelmingly found air temperature in the barn had a positive relationship with NH_3 emissions for both mechanically and naturally ventilated barns. The higher temperatures increase NH_3 losses by decreasing the solubility of NH_3 and increasing the proportion of TAN as NH_3 gas (Meisinger and Jokela, 2000). For a similar reason, manure temperature is highly correlated to NH_3 emissions. NAEMS collected barn exhaust temperature and ambient temperature at all sites and these factors were selected for further investigation. Ambient temperature was chosen for further investigation, as it is related to barn conditions and would provide an alternative barn based temperature monitoring for operators.

The studies cited by Sanchis et al. (2019) found, in some cases, the relationship between temperature was affected by the floor type (e.g., slatted versus solid) and manure handling system. EPA investigated the type of manure management system (i.e., flush or scrape) for the mechanical barns for further analysis. A similar analysis was not included for the naturally ventilated barns, as both sites used flush systems. Bedding type was also considered, however the study data only indicated in general the type of bedding used in the barns. In the case of CA5B, the operator used several bedding types as they were available (Zhao et al., 2010) with no reliable indication of when those changes occur or what the percentage of each bedding type was on any given day.

Schmithausen et al. (2018) also noted permanent under floor storage of slurry potentially contributed to higher NH_3 emissions. The site description of two mechanically ventilated sites, IN5B and NY5B, suggest that they utilize a reception pit to hold scraped material as part of their manure management system. While the NY5B notes the deep reception pit is in the connecting alley between the freestall barn and milking center, the location of the pit at IN5B was not documented. It was noted that the material in the reception pits, at both sites, were transferred to a digester on a regular basis. Because the material was transferred on a regular basis and was not long term, a variable to account for under floor storage was not included at this time.

The ventilation rate of mechanically ventilated barns has been shown as having a positive correlation to NH_3 emissions across several studies (Kavolelis, 2003; Philippe, et al., 2011; Samer et al., 2012). Ventilation rates are typically driven by the temperature inside the barn, which is affected by the outside temperature. For modeling purposes, this suggests that temperature, either barn or ambient, might make a good proxy for ventilation rate.

For naturally ventilated barns, the ventilation or air flow through the barn is driven by the wind. Many studies (Arogo et al., 1999; Bjerg et al. 2013, Wu et al. 2012; Schrade et al., 2012; and Herbut and Angrecka, 2014) have found a strong correlation between emissions and wind speed, and occasionally wind direction (Feidler and Müller (2011)). However, Saha et al. (2014) did not find the clear relationship between wind speed and emissions. Saha et al. (2014) suggested that the effects of wind speed might be masked by other environmental parameters, such as temperature and relative humidity, or the presence of other buildings and slurry tanks that might influence wind entering the building. Bjerg et al. (2013) noted that the more important component to release was air velocity over the manure, which is not necessarily correlated to wind speed in the barn, as air movement could be affected by numerous things, such as animals and other obstructions in the barn. For modeling purposes, wind speed was selected for further study for naturally ventilated barns.

The literature review did not find references showing a correlation between either NH_3 or H_2S emission in mechanically ventilated barns and relative humidity. Sanchis et al. (2019) suggests that there are no significant effects due to the high variability of relative humidity in the barn environment. However, Sanchis et al. (2019) noted studies of naturally ventilated barns showed that higher relative air humidity leads to reduced NH_3 emission rates. In general, higher air humidity values are expected to yield reduced NH_3 concentrations, since NH_3 is highly water-soluble and would be absorbed by the water vapor in the air and less gaseous NH_3 would be measured. However, this is only true within a certain temperature range and the management strategies would also affect this relationship. Saha et al. (2014) also noted the effect of relative humidity might be related to the changes in animal activity and performance in response to heat stress. Because of the potential relationship between NH_3 and moisture, relative humidity was selected for further study for both mechanically and naturally ventilated barns.

Animal and management activities, such as feeding and milking, can affect emission rates (Ngwabie, et al. 2011, Hempel 2016). There was no specific daily information on management activities recorded by NAEMS.

3.2 Particulate Matter from Barns

The release of PM_{10}, TSP, and $PM_{2.5}$ (collectively referred to as PM) into the air of dairy barns is caused by the physical suspension of a range of different materials in the barns including feed, manure, bedding, and skin or hair (Cambra-Lopez et al., 2011). Accordingly, the EPA chose live animal weight and inventory as predictor variables, as they are related to the amount of source material. One study, Garcia et al. (2013), found an inverse relationship between milking center capacity and $PM_{2.5}$ concentration on the farm, which was attributed to the larger dairies being newer and more efficiently operated. This suggests there are different management practices at newer barn that can affect particulate emissions. Likely making the use of inventory more nuanced than with other animal types.

Physical suspension of PM from barn surfaces can be caused by air flow, animal activity, and human activity (Aarnink and Ellen, 2007); however, EPA did not receive barn activity measurements and could not explore the influence of this variable further. Airflow, or ventilation rate, was recorded for all barn sources. As mentioned in the previous section, mechanical ventilation rates are related to ambient and barn temperature, thus meaning that temperature could be a potential surrogate variable that represents airflow. For naturally ventilated buildings wind speeds may have an influence on the air flow, which in turn could potentially affect the PM emissions from the buildings. Accordingly, EPA selected the airflow for further review, as well as wind speed from naturally ventilated barns. Temperature was selected for both mechanically ventilated barns, due to the correlation with airflow, and naturally ventilated barns. While Takai et al. (1998) did not find seasonal variation with PM emission from naturally ventilated barns, Mostafa et al. (2016) did see greater emissions in summer and lower values in winter. The longer observation periods of PM during NAEMS showed some seasonality, with the highest values occurring in the summer.

Physical suspension may also be influenced by moisture conditions and relative humidity (Cambra-Lopez et al., 2010). A study by Takai et al. (1998) examined PM emissions from a variety of livestock types including dairy cattle and reported that relative humidity greater than 70% contributed to particles aggregating together and thus reducing emissions. Accordingly, for dairy barns, the variables ambient relative humidity and barn relative humidity were selected for further investigation.

3.3 NH_3 and H_2S for Open Sources

The release of NH_3 and H_2S from open sources follows similar mechanics as release from waste in the barns. That is, the amount of NH_3 and H_2S emitted will depend on some of the same factors as the barn, such as the compositional characteristics. With lagoons and basins, the amount of waste can be characterized by the lagoon surface area in addition to farm level inventory and live animal weight. For open source model development, EPA used lagoon surface area to normalize emissions, as it represents the amount of the manure that can exchange gas with the atmosphere. For corrals, the area of the corrals was selected along with the inventory for the farm since the emissions measurements covered a wider area. As with barn sources, TAN, TKN, and sulfide content of the manure has a major influence on dairy open source NH_3 and H_2S emissions (see section 3.1 for details). For NAEMS open source sites, there were no measurements of TAN, TKN, or sulfide at the three sites. As a result, EPA could not investigate these parameters further.

Like barn sources, NH_3 and H_2S emissions are a function of the pH, specifically the pH at the surface of the manure, and temperature as both parameters affect the chemistry associated with the generation and release of the pollutants (Arogo et al., 2006, Rotz et al., 2014). Ambient temperature, along with turbulence, typically represented by wind speed, affect the diffusion and dispersion of the released gases from the lagoon surface (Arogo et al., 2006, Sommer et al., 2013). There were continuous measurements of lagoon temperature, lagoon pH for lagoon/basin sites, and air temperature and wind speed for all NAEMS open sources. Accordingly, these four variables were selected for further analysis for lagoon/basin sources and air temperature and wind speed were selected for corral sources.

Like manure in barns, moisture levels can affect the volatilization of NH_3 and H_2S. In drier environments, evaporation and volatilization are going to occur more rapidly. In a lagoon, where waste is held as a slurry, it is likely less of a factor than in a corral where manure is often mixed into the soil creating a drier environment. Grant et al. (2020) suggested that the vapor pressure deficit might be a more compelling parameter than relative humidity to represent the potential for volatilization from the manure and soil mixture present in corrals. The vapor pressure deficit is the difference between how much moisture the air can hold when saturated and the actual amount of moisture in the air. Unlike relative humidity, the vapor pressure deficit is not a function of temperature, which also allows for a more consistent comparison between days. EPA chose to include both relative humidity and vapor pressure deficit to further investigate their relationship with emissions from the corral.

The presence of a crust or cover on a lagoon or basin will inhibit the transfer of NH_3 to the atmosphere, reducing emissions. Similarly, frozen lagoon surfaces will also stop emissions from the surface of the lagoon. The NAEMS made limited observation of the state of the lagoon (e.g., color, crust) during the study. The lack of daily observations would limit the number of days available for EEMs development, as the dataset would be limited to only those days with lagoon surface observations. Due to the limited nature of the observations available, this variable was not explored further.

4 SITE COMPARISON, TRENDS, AND ANALYSIS

Before developing the EEMs, EPA evaluated NAEMS data for each pollutant to identify patterns and trends in the emissions data using a combination of summary statistics (mean, standard deviation, number of data values, median, minimum, maximum, coefficient of variation, and number of data values less than zero) and time series plots. Section 4.1 summarizes the emissions trends from the sites, while Appendix D contains the tables of summary statistics. Appendix E presents the time series plots of the site-specific emissions, environmental and production parameters, and manure data collected under NAEMS.

Based on the analysis described in Section 3.0, EPA identified the key environmental and manure parameters that potentially affect emissions from dairy barns and associated open sources. Parameters of particular interest included inventory, barn conditions (exhaust temperature, exhaust relative humidity, and airflow), ambient temperature, ambient relative humidity, and wind speed.

The next step of the analysis was to look at the key environmental and manure parameters compared to emissions trends. The exploratory data analysis was conducted to confirm that the variables were selected based on the following criteria: (1) data analysis in this study and in the literature suggested that these variables had an influence on emissions; (2) the variables should be easy to measure; and (3) the variables were already in the daily average NAEMS data and were available for most days of monitored emissions. This third selection criterion particularly applies to the manure parameters, such as moisture content and TAN concentration, which were infrequent due to the intensive collection and analysis methods. Additional time could be taken to develop an appropriate methodology for interpolating between the few data points available for these parameters in the dataset. However, these parameters are difficult to acquire as they require chemical analysis from a laboratory.

The exploratory data analysis was also used to explore whether additional parameters could be included to explain trends. To further explore the trends between the predictor variables and emissions and determine whether the parameter should be included in developing an EEM, EPA prepared scatter plots of emissions versus the process, environmental, and manure parameters and conducted least squares regression analysis to assess the influence of each variable on emissions. For the regressions, EPA classified the linear relationships based on the ranges in Table 4-1.

A summary of this analysis for environmental parameters is discussed in Section 4.2. Again, Appendix D contains summary statistics, Appendix E contains the relevant time series plots, and Appendix F contains least squares regression analyses between the identified parameters and emissions.

Table 4-1: Relationship classification based on R^2 values

Range of R^2	Relationship strength
$R^2 \leq 0.001$	none
$0.001 < R^2 \leq 0.2$	slight or weak
$0.2 < R^2 \leq 0.4$	modest
$0.4 < R^2 \leq 0.6$	moderate
$0.6 < R^2 \leq 0.8$	moderately strong
$R^2 > 0.8$	strong

4.1 Mechanically Ventilated Dairy Barns (IN5B-B1, IN5B-B2, NY5-B1, WI5B-B1 and WI5B-B2)

4.1.1 Emissions data

Appendix D, Table D-1 and D-2 presents the summary statistics for daily average emissions of NH_3 for the mechanically ventilated sites in kilograms per day and grams per day per head (kg d^{-1} and g d^{-1} hd^{-1}), respectively. Based on Table D-1, the emissions appear to vary across sites. However, when presented in a per head basis, as in Appendix D, Table D-2, the emissions are consistent across sites with average daily emissions ranging from 31.35 kg d^{-1} hd^{-1} at WIB5-B2 to 48.28 kg d^{-1} hd^{-1} at IN5B-B1. Appendix E, Figure E-1 showed that the emissions follow a seasonal cycle, with greater emissions typically occurring in the summer and decreasing to lows in winter months. Emissions from the WI5B site have a more muted seasonal cycle on the first year, with slightly increased values in the second year of the study. This appears to correlate to a changing from a flush system to a scrape system in September of 2008. As noted in Section 3, manure management systems can affect the emissions generated in the barn. Appendix E, Figure E-1 suggests it is worth pursuing modeling options that account for the manure management system.

The summary statistics for daily average H_2S emissions are presented in Appendix D, Table D-3 and D-4 for g d^{-1} and mg d^{-1} hd^{-1}, respectively. Unlike NH_3, the per head values in Table D-4 show emission values 2 to 4 times greater at the WI5B barns than the other sites. Appendix E, Figure E-2 showed the time series plot for H_2S emissions. The plot showed a seasonal trend in H_2S emissions for the IN5B and NY5B site, with emissions trending higher in warmer months. However, the WI5B barns show a very different trend. The H_2S emission for both barns are quite high and variable for the first half of the plot, and then fall to lower levels. Like the shift with the NH_3 emissions, this change corresponds to the switch to a scrape system in the barns.

Appendix D, Table D-5 and D-6 presents the summary statistics in g d^{-1} and mg d^{-1} hd^{-1}, respectively, for the daily average emissions of PM_{10} for the mechanically ventilated sites. There was variation in emissions between sites, both in the total for the day and when normalized on a per head basis. The average daily emissions ranged from 9.73 g d^{-1} (12.49 mg d^{-1} hd^{-1}) at INB5-B1 to 562.91 g d^{-1} (1,571.90 mg d^{-1} hd^{-1}) at WI5B-B2. The time series plot (Appendix E, E-3) showed readings hovering between 0 and 500 g d^{-1}, with greater spikes typically occurring in the summer months. WI5B does experience maximum values that are twice as high as the other sites. These peaks occur both in the summer of 2008 and 2009, suggesting the change to a scrape manure management system did not contribute to the highest emission days. The dataset used for the exploratory data analysis has several negative values, which were further reviewed during the data review process described in Section 2.

Like, PM_{10}, the $PM_{2.5}$ average daily emissions vary substantially across sites. The average daily emissions summarized in Appendix D, Table D-7, indicate that WI5B emissions are much greater than the other barns. The emissions across all sites range from 21.18 g d^{-1} at IN5B-B1 up to 186.75 g d^{-1} at WI5B-B2. When accounting for inventory difference (Appendix D, Table D-8), the WI5B are still more than twice any other mechanically ventilated barn monitored during NAEMS, with an average value of 662.17 mg d^{-1} hd^{-1} at WI5B-B1 compared to 25.89 mg d^{-1} hd^{-1} at IN5B-B1. Appendix E, Figure E-4 showed the temporal variability of the $PM_{2.5}$ emissions. The plot for IN5B does show some rather large negative numbers in the exploratory data analysis, which were further reviewed during the data set review process described in Section 2. The inclusion of these points is likely reason for the lower average values at IN5B compared to the other sites. The sparse temporal nature of the daily $PM_{2.5}$ values, due to a rotating monitoring schedule for the PM size fractions at the NAEMS sites, makes it hard to determine if there is a seasonal trend to the data. The number of negative daily averages from the sites varied greatly. The barns at IN2B had the least negative values with 28 and 29 at B1 and B2, respectively. The remaining sites had nearly twice as many negative values; NY5B-B1 had 53, while WI5B had 53 and 45 at B1 and B2, respectively.

The daily average TSP emissions followed a similar trend to PM_{10} and $PM_{2.5}$. That is WI5B had average emissions substantially greater than the other two sites (Appendix D, Table D-9), even after accounting for difference in inventory levels (Appendix D, Table D-10). Like $PM_{2.5}$, the sparse temporal nature of the daily TSP values makes it hard to determine if there is a seasonal trend to the data. The plot of WI5B does suggest some seasonality, with slightly greater emissions in the summer. However, a similar pattern is not obvious at the other sites. There were fewer negative daily TSP values, with all sites reporting less than 10 negative values.

4.1.2 Environmental data

The statistical summary of the environmental parameters associated with mechanically ventilated barns are presented in Appendix D, Table D-11. The inventory was varied across the sites, ranging from an average of 211 head at WI5B-B1 to 864 head at IN5B-B2. Appendix E,

Figure E-6 showed that the number of cows present over the course of NAEMS was consistent, with any one barn varying by less than 112 cows over the study duration. Of note, the first-year inventory data from WI5B appears to be based on average inventory of the barn and not actual inventory levels. Appendix F, Figures F-1 through F-5 show the scatter plots of inventory versus each pollutant. A summary of the findings is provided in Table 4-2. In general, there is a weak relationship with inventory across all pollutants, except that NH_3 has a moderate positive relationship. Of note, all the PM size fractions show a weak negative linear relationship with inventory, as the smaller barns have greater emissions. Further investigation showed the barns with greater inventory are newer, which is consistent with the finding from the literature review that newer barns had lower PM emissions. As noted in Section 3.2, the difference between the newer facilities is likely a management practice applied in the newer construction. It is currently unknown what leads to the decrease in emissions for larger newer farms. A possibility to somehow account for this unknown factor is to consider the age of the facility in modeling; however, the limited range in ages (Table 4-1) makes it difficult to incorporate at this time. EPA will continue to pursue identifying the physical or chemical property driving this decrease in Pm emissions in newer barns, and a way to incorporate this into the modeling.

Table 4-2. Year mechanically ventilated barns were constructed

Barn	Year Constructed
WI5B B1	1990
WI5B B2	1994
NY5B B1	1998
IN5B B1	2004
IN5B B2	2004

Average animal weight for the IN5B and WI5B barns were reported as a constant value. For NY5B, the daily value reported only vary by less than 5 kg (576 to 580 kg). This limited range of daily average animal weight is apparent in the time series (Appendix E, Figure E-7). The regression analyses in Appendix F, Figures F-6 through F-10, summarized in Table 4-2, showed only a slight or weak relationship between average animal weight and each pollutant. Trends in live animal weight (i.e., inventory * average animal weight) do not vary dramatically over the monitoring period (Appendix E, Figure E-8). The regression analyses in Appendix F, Figures F-11 through F-15 showed similar relationships as inventory, which is the most variable component of live animal weight.

Exhaust temperatures were comparable across all the sites, ranging from an average of 10.55°C at WI5B-B2 to 12.89°C at NY5B-B1. The time series in Appendix E, Figure E-9 show the typical seasonal trend, where temperatures peak in the summer, decrease to minimums around the new year, and then trend upwards during the spring. The linear regression analyses

(Appendix F, Figures F-16 through F-20) only shows a weak to modest positive relationship to temperature. However, the figure for IN5B suggests a nonlinear relationship with temperature, which might be reducing the overall strength of the correlation. The shift in manure management system at WI5B affected the strength of the relationship for those barns. For example, R^2 reached 0.72 with NH_3 emissions while the house was scrape and only 0.21 as scrape for NH_3. A summary of the findings is provided in Table 4-2.

A review of the exhaust relative humidity summary (Appendix D, Table D-11), were comparable across all the sites, ranging from an average of 66.8% at WI5B-B2 to 75.4% at NY5B-B1. The time series (Appendix E, Figure E-10) show the relative humidity is variable, as there is a spread in the data for any time of the year. The plots suggest dips in humidity for the spring, with IN5B also suggesting a dip in the fall. When regressed with the emissions (Figures F-21 through F-25), there are only slight or weak relationships, which are positive for gaseous pollutants and negative with particulate matter daily emissions (kg/d).

The measured airflow through the barn was comparable across sites and ranged from 131. dry standard cubic meter per second (dsm^3s^{-1}) at WI5B-B1 to 210. dsm^3s^{-1} at IN5B-B1. The time series (Appendix E, Figure E-11) showed a seasonal pattern, as ventilation rates would increase to maintain barn temperatures during warm months. The regression analyses (Appendix F, Figures F-26 through F-30) showed weak to modest positive relationships with emissions, which is supported by literature.

Table 4-3. Mechanically ventilated environmental parameter regression analyses

Pollutant	Parameter	R	R^2	Strength	Figure
NH_3	Inventory	0.660	0.435	moderate	Appendix F, F-1
H_2S	Inventory	0.002	< 0.001	slight or weak	Appendix F, F-2
PM_{10}	Inventory	-0.292	0.085	slight or weak	Appendix F, F-3
$PM_{2.5}$	Inventory	-0.319	0.102	slight or weak	Appendix F, F-4
TSP	Inventory	-0.327	0.107	slight or weak	Appendix F, F-5
NH_3	Average animal weight	-0.423	0.179	slight or weak	Appendix F, F-6
H_2S	Average animal weight	0.114	0.013	slight or weak	Appendix F, F-7
PM_{10}	Average animal weight	0.240	0.058	slight or weak	Appendix F, F-8
$PM_{2.5}$	Average animal weight	0.384	0.148	slight or weak	Appendix F, F-9
TSP	Average animal weight	0.384	0.147	slight or weak	Appendix F, F-10
NH_3	Live animal weight	0.653	0.426	moderate	Appendix F, F-11
H_2S	Live animal weight	0.014	< 0.001	slight or weak	Appendix F, F-12
PM_{10}	Live animal weight	-0.278	0.077	slight or weak	Appendix F, F-13
$PM_{2.5}$	Live animal weight	-0.283	0.080	slight or weak	Appendix F, F-14
TSP	Live animal weight	-0.307	0.094	slight or weak	Appendix F, F-15
NH_3	Exhaust temperature	0.493	0.243	modest	Appendix F, F-16
H_2S	Exhaust temperature	0.323	0.104	slight or weak	Appendix F, F-17
PM_{10}	Exhaust temperature	0.410	0.168	slight or weak	Appendix F, F-18

Pollutant	Parameter	R	R^2	Strength	Figure
$PM_{2.5}$	Exhaust temperature	0.484	0.234	modest	Appendix F, F-19
TSP	Exhaust temperature	0.406	0.165	slight or weak	Appendix F, F-20
NH_3	Exhaust relative humidity	0.390	0.152	slight or weak	Appendix F, F-21
H_2S	Exhaust relative humidity	0.193	0.037	slight or weak	Appendix F, F-22
PM_{10}	Exhaust relative humidity	-0.269	0.072	slight or weak	Appendix F, F-23
$PM_{2.5}$	Exhaust relative humidity	-0.414	0.171	slight or weak	Appendix F, F-24
TSP	Exhaust relative humidity	-0.322	0.104	slight or weak	Appendix F, F-25
NH_3	Airflow	0.536	0.287	modest	Appendix F, F-26
H_2S	Airflow	0.232	0.054	slight or weak	Appendix F, F-27
PM_{10}	Airflow	0.425	0.180	slight or weak	Appendix F, F-28
$PM_{2.5}$	Airflow	0.449	0.202	modest	Appendix F, F-29
TSP	Airflow	0.376	0.141	slight or weak	Appendix F, F-30

4.1.3 Ambient Data

The statistical summary of the ambient parameters associated with mechanically ventilated barns are presented in Appendix D, Table D-12. The average daily temperatures were cooler at WI5B at 7.2°C, compared to 12.2°C at IN5B. The time series in Appendix E, Figure E-12 show the typical seasonal pattern to temperatures (i.e., maximum in summer and minimums in winter). Of note, data is missing starting in January 2008 at IN5B. No reason for the data loss was provided in the final site report. With the inclusion of three sites, there are ample measurements of emissions at the anticipated temperature range for model development. The scatter plots of ambient temperature (Appendix F, Figures F-31- F-35), summarized in Table 4-3, show weak-to-modest positive relationships with emissions. The NH_3 plots (Appendix F, Figures F-31) indicate emissions increased more rapidly with temperature at IN5B than the remaining sites.

Ambient relative humidity is similar between sites, ranging from an average value of 67.8% at NY5B to 68.4% at WI5B. The time series (Appendix E, Figure E-13) show the values vary by at least 20% for any given time of the year. Like the exhaust relative humidity, there is an indication that minimum values are more likely in both spring and fall, though the scatter to the data makes a seasonal pattern hard to discern. The regression analyses (Appendix F, Figures F-36 – F-40) indicate slight or weak negative relationships between ambient relative humidity and emissions, even when looking at sites individually.

Table 4-4. Mechanically ventilated ambient parameter regression analyses

Pollutant	Parameter	R	R^2	Strength	Figure
NH_3	Ambient temperature	0.537	0.289	modest	Appendix F, F-31
H_2S	Ambient temperature	0.257	0.066	slight or weak	Appendix F, F-32
PM_{10}	Ambient temperature	0.370	0.137	slight or weak	Appendix F, F-33
$PM_{2.5}$	Ambient temperature	0.398	0.159	slight or weak	Appendix F, F-34
TSP	Ambient temperature	0.348	0.121	slight or weak	Appendix F, F-35
NH_3	Ambient relative humidity	-0.110	0.012	slight or weak	Appendix F, F-36

Pollutant	Parameter	R	R^2	Strength	Figure
H_2S	Ambient relative humidity	<0.001	<0.001	slight or weak	Appendix F, F-37
PM_{10}	Ambient relative humidity	-0.129	0.017	slight or weak	Appendix F, F-38
$PM_{2.5}$	Ambient relative humidity	-0.331	0.109	slight or weak	Appendix F, F-39
TSP	Ambient relative humidity	-0.155	0.024	slight or weak	Appendix F, F-40

4.2 Milking Centers (IN5B-MC and NY5B-MC)

4.2.1 Emissions Data

Appendix D, Table D-13 and Table D-14 presents the summary statistics, in kg d^{-1} and g d^{-1} hd^{-1}, for daily average emissions of NH_3 for the MCs monitored during NAEMS. The total emissions (kg d^{-1}) are relatively similar between the barns, though IN5B has a larger standard deviation. When scaled for the capacity of the MC (Appendix D, Table D-14), NY5B, at 30.3 g d^{-1} hd^{-1}, was nearly double the average emission of 15. 7 g d^{-1} hd^{-1}at IN5B. The time series plot of NH_3 emissions (Appendix E, Figure E-14) showed some seasonality in the data. The plots for IN5B suggest greater emissions in the warmer months, particularly in the summers of 2008 and 2009. The data at NY5B does not have as strong of a seasonal pattern as IN5B.

In a reversal of what was seen with the NH_3 statistics, IN5B had greater overall H_2S emissions (Appendix D, Table D-15) than NY5B and greater scaled emissions (Appendix D, Table D-16). Average emissions at IN5B were 1,207 g d^{-1} (2,148 mg d^{-1} hd^{-1}) compared to 129g d^{-1} (2,681 mg d^{-1} hd^{-1}). The time series plot of H_2S emissions (Appendix E, Figure E-15) suggests some seasonality to the data, with higher readings in the summer months, which may be related to ventilation rates, and indirectly related to ambient temperature. The peaks at IN5B were much greater than NY5B, suggesting an additional difference in the site. Further review showed that IN5B used a flush system and NY5B used a scrape system for manure removal. Like the emission shift seen at WI5B, it is possible that the manure management system is influencing the emission levels.

Particulate matter emissions observations were only taken at NY5B. Appendix, Table D-17 provides the statistical summary in g d^{-1} and Appendix D, Table D-18 provide them in mg d^{-1} hd^{-1}. Appendix E, Figure E-16 shows the time series of PM_{10} emission estimates. The plot suggests some seasonality to the data, with higher readings in the summer months, which may relate to ventilation rates. The time series of $PM_{2.5}$ emission is in Appendix E, Figure E-17, while Appendix E, Figure E-18 showed the time series for TSP. The sparse nature of the $PM_{2.5}$ and TSP data makes it hard to determine if there is any seasonality to the data.

4.2.2 Environmental data

The statistical summary of the environmental parameters associated with MCs is presented in Appendix D, Table D-19. Daily inventory number were not reported for the MCs. The capacity of the milking center was used to represent the inventory levels. This is evident in the time series (Appendix E, Figure E-19) and the scatter plots (Appendix F, Figures F-41-F-45). Average animal weight for the IN5B MC was reported as a constant value. For NY5B, the daily value reported only vary by less than 5 kg (576 to 580 kg), like the mechanically ventilated barn. This limited range of daily average animal weight is apparent in the time series (Appendix E, Figure E-20). The regression analyses in Appendix F, Figures F-46 through F-50, summarized in Table 4-4, showed only a slight or weak relationship between average animal weight and each pollutant. Because of the constant inventory and near constant average animal weight, trends in live animal weight (i.e., capacity * average animal weight) do not vary dramatically over the monitoring period (Appendix E, Figure E-21). The regression analyses in Appendix F, Figures F-51 through F-55 showed only slight relationships with emissions. To include size of the operation in the models as a proxy for volume of manure produced, EPA opted to test models where the emissions were normalized by the capacity of the MC. The models will yield an estimate of emissions per head capacity of the MC.

Exhaust temperature was comparable between sites (Appendix E, Figure E-22), with average daily means of 12.8°C at NY5B and 13.2°C at IN5B. The regression analyses (Appendix F, Figures F-56 - F-60) showed a weak-to-modest correlation between exhaust temperature and emissions, like the mechanically ventilated barns. Exhaust relative humidity was also comparable between sites (Appendix E, Figure E-23), with average daily values of 74.2% and 73.8% at IN5B and NY5B, respectively. Like with mechanically ventilated barns, there is a tendency for the lowest values to occur in the spring and fall. However, the wide scatter of values for any time of the year, makes any strong seasonal pattern hard to discern. The regression analyses (Appendix F, Figures F-61 - F-65), only showed slight-to-weak positive correlation with emissions.

Airflow rates were much lower at NY5B than IN5B, which is clearly demonstrated in the time series plot (Appendix E, Figure E-24). Average airflow rates were 39.90 dsm^3s^{-1} at NY5B and 183.33 dsm^3s^{-1} at IN5B. The MC at IN5B is connected to Barn 1 at the site (see Figure 1-2 in Section 1), while the MC at NY5B is connected to both Barn 1 and a naturally ventilated barn (see Figure 1-3 in Section 1). It is possible the connection to the naturally ventilated barn reduced the ventilation needs at the MC. The regression analyses (Appendix F, Figures F-66 - F-70) showed only a slight to weak correlation with emissions, except for PM_{10}, which has a modest correlation.

Table 4-5. Milking center environmental parameter regression analyses

Pollutant	Parameter	R	R^2	Strength	Figure
NH_3	Inventory (MC Capacity)	0.279	0.078	slight or weak	Appendix F, F-41
H_2S	Inventory (MC Capacity)	0.360	0.130	slight or weak	Appendix F, F-42
PM_{10}	Inventory (MC Capacity)			None	Appendix F, F-43
$PM_{2.5}$	Inventory (MC Capacity)			None	Appendix F, F-44
TSP	Inventory (MC Capacity)			None	Appendix F, F-45
NH_3	Average animal weight	0.279	0.078	slight or weak	Appendix F, F-46
H_2S	Average animal weight	0.360	0.130	slight or weak	Appendix F, F-47
PM_{10}	Average animal weight	-0.005	< 0.001	slight or weak	Appendix F, F-48
$PM_{2.5}$	Average animal weight	-0.161	0.026	slight or weak	Appendix F, F-49
TSP	Average animal weight	0.154	0.024	slight or weak	Appendix F, F-50
NH_3	Live animal weight	0.279	0.078	slight or weak	Appendix F, F-51
H_2S	Live animal weight	0.360	0.130	slight or weak	Appendix F, F-52
PM_{10}	Live animal weight	-0.005	< 0.001	slight or weak	Appendix F, F-53
$PM_{2.5}$	Live animal weight	-0.161	0.026	slight or weak	Appendix F, F-54
TSP	Live animal weight	0.154	0.024	slight or weak	Appendix F, F-55
NH_3	Exhaust temperature	0.518	0.268	modest	Appendix F, F-56
H_2S	Exhaust temperature	0.322	0.104	slight or weak	Appendix F, F-57
PM_{10}	Exhaust temperature	0.550	0.303	modest	Appendix F, F-58
$PM_{2.5}$	Exhaust temperature	0.401	0.160	slight or weak	Appendix F, F-59
TSP	Exhaust temperature	0.348	0.121	slight or weak	Appendix F, F-60
NH_3	Exhaust relative humidity	-0.188	0.035	slight or weak	Appendix F, F-61
H_2S	Exhaust relative humidity	-0.378	0.143	slight or weak	Appendix F, F-62
PM_{10}	Exhaust relative humidity	-0.111	0.012	slight or weak	Appendix F, F-63
$PM_{2.5}$	Exhaust relative humidity	-0.241	0.058	slight or weak	Appendix F, F-64
TSP	Exhaust relative humidity	0.184	0.034	slight or weak	Appendix F, F-65
NH_3	Airflow	0.381	0.146	slight or weak	Appendix F, F-66
H_2S	Airflow	0.332	0.110	slight or weak	Appendix F, F-67
PM_{10}	Airflow	-0.458	0.210	modest	Appendix F, F-68
$PM_{2.5}$	Airflow	-0.009	< 0.001	slight or weak	Appendix F, F-69
TSP	Airflow	0.106	0.011	slight or weak	Appendix F, F-70

4.2.3 Ambient Data

The statistical summary of the ambient parameters associated with MCs are presented in Appendix D, Table D-20. The summary statistics indicate the ambient temperatures are similar for both sites, with average daily mean of 11.13°C at NY5B and 12.20°C at IN5B. Ambient temperature trends (Appendix E, Figure E-27) follow seasonal patterns, as expected, and the time series reiterates the similarity in temperatures at both sites. The regression analyses (Appendix F, Figures F-71 - F-75) summarized in Table 4-5, showed weak-to-modest positive correlation with emissions.

Ambient relative humidity was also similar between the sites with average daily mean of 67.81% at NY5B and 67.90% at IN5B. The time series (Appendix E, Figure E-28) showed variability in average daily humidity values, with the lowest values occurring in the spring. The regression analyses (Appendix F, Figures F-76 - F-80), summarized in Table 4-5, showed only a slight-to-weak correlation with emissions.

Table 4-6. Milking center ambient parameters regression analyses

Pollutant	Parameter	R	R^2	Strength	Figure
NH_3	Ambient temperature	0.495	0.245	modest	Appendix F, F-71
H_2S	Ambient temperature	0.296	0.088	slight or weak	Appendix F, F-72
PM_{10}	Ambient temperature	0.568	0.323	modest	Appendix F, F-73
$PM_{2.5}$	Ambient temperature	0.399	0.159	slight or weak	Appendix F, F-74
TSP	Ambient temperature	0.348	0.121	slight or weak	Appendix F, F-75
NH_3	Ambient relative humidity	-0.043	0.002	slight or weak	Appendix F, F-76
H_2S	Ambient relative humidity	0.039	0.002	slight or weak	Appendix F, F-77
PM_{10}	Ambient relative humidity	-0.421	0.178	slight or weak	Appendix F, F-78
$PM_{2.5}$	Ambient relative humidity	0.043	0.002	slight or weak	Appendix F, F-79
TSP	Ambient relative humidity	0.066	0.004	slight or weak	Appendix F, F-80

4.3 Naturally Ventilated Barns (CA5B-B1, CA5B-B2, WA5B-B2 and WA5B-B4)

4.3.1 Emissions Data

Appendix D, Table D-21 and Table D-22 presents the summary statistics, in kg d^{-1} and g d^{-1} hd^{-1}, for daily average emissions of NH_3 for the naturally ventilated sites. The average daily emission rate is substantially different between the sites, ranging from 2.76 kg d^{-1} (4.98 g d^{-1} hd^{-1}) at CA5B-B1 to 54.65 kg d^{-1} (56.51 g d^{-1} hd^{-1}) at WA5B-B4. The time series plot (Appendix E, Figure E-29) showed the highest emissions at WA5B occurring in late spring to early summer of 2008. After a break in observations, the emission levels mostly drop to lower levels, though it is still greater than CA5B. CA5B does have quite a few negative days, 37 at B1 and 42 at B2, which are contributing to the lower overall average compared to WA5B. These negative numbers were further reviewed during the data set review process described in Section 2, prior to inclusion in the model development dataset. Appendix E, Figure E-29 also showed the emissions are variable across the year with no obvious seasonal pattern.

The summary statistics for daily average H_2S emissions are presented in Appendix D, Table D-23 and D-24 for g d^{-1} and mg d^{-1} hd^{-1}, respectively. Unlike the NH_3 emissions, the average of the daily emissions are more comparable across the sites. However, reviewing the time series plot (Appendix E, Figure E-30) showed more variability at WA5B, including a few very high values and extreme negative values. There were several negative values at each barn, ranging from 18 values at CA5B-B2 to 45 values at WA5B-B2. Some of the negative numbers were quite large, -609.00 g d^{-1} at CA5B-B2 to -11,640.14 g d^{-1} at WA5B-B2. These negative numbers were further reviewed during the dataset review process described in Section 2, prior to inclusion in the model development dataset. Appendix E, Figure E-30 also showed the emissions are variable across the year with no obvious seasonal pattern.

The summary statistics for PM_{10} are presented in Appendix D, Table D-25 and D-26 for g d^{-1} and mg d^{-1} hd^{-1}, respectively. Like NH_3, the PM_{10} emissions vary between the barns, even when accounting for the differences in inventory. Average daily emissions range from -325.80 g d^{-1} (-636.79 mg d^{-1} hd^{-1}) at CA5B-B1 to 11,391.71 g d^{-1} (11,794.47 mg d^{-1} hd^{-1}) at WA5B-B4. CA5B has quite a few negative days, 372 at B1 and 221 at B2, which are contributing to the lower overall average compared to WA5B, and the overall negative average for CA5B-B1. These negative numbers were further reviewed during the dataset review process described in Section 2, prior to inclusion in the model development dataset. The time series plot (Appendix E, Figure E-31) showed the frequency of the negatives at CA5B, as well as the extremely high values seen at WA5B.

$PM_{2.5}$ was like PM_{10} in that there is a substantial number of negative daily emission values at CA5B (Appendix D, D-27, and D-28). Specifically, at B1, 44 of the 47 values are negative and 40 of 54 are negative at B2. This results in a negative overall average value for CA5B barns. The WA5B site has fewer negative values, 0 at WA5B-B2 and 6 at WA5B-B4. These negative numbers were further reviewed during the dataset review process described in Section 2, prior to inclusion in the model development dataset. The time series plot (Appendix E, Figure E-32) showed the frequency of the negatives at CA5B, as well as the spread in values seen in at WA5B. No seasonal pattern was apparent.

Regarding the TSP summary statistics (Appendix D, D-29, and D-30), the two sites have different daily average values despite fewer negative daily emission values for CA5B than the other PM size fractions. Average TSP daily emissions ranged from 4,766g d^{-1} (9113mg d^{-1} hd^{-1}) at CA5B-B1 to 47,389g d^{-1} (49,099mg d^{-1} hd^{-1}) at WA5B-B4. The time series plot (Appendix E, Figure E-33) showed a lot of variability in readings, which makes a seasonal pattern hard to discern.

4.3.2 Environmental Data

The statistical summary of the environmental parameters associated with naturally ventilated barns are presented in Appendix D, Table D-31. The average inventory for most of the barns is between 514 at WA5B-B2 to 558 at WA5B-B2. WA5B-B4 is the exception, with an average inventory almost double the other barn of 963.20 head. The time series (Appendix E, Figure E-34) showed there is some variability in the inventory at the site, with most only varying by 100 head from the average. The regression analyses (Appendix F, Figures F-81 - F-85) , summarized in Table 4-6, generally showed only slight or weak linear relationship with emissions, except for NH_3, which had a moderate positive linear relationship.

Average animal mass was provided as a single value and not reported daily. The summary table (Appendix D, Table D-31) and the time series (Appendix E, Figure E-35) reiterate the single value. With constant values, the regression analyses (Appendix F, Figures F-86 - F-90) showed only slight or weak relationship with emissions. Combining inventory and average weight into live animal weight produces a size variable with trends (Appendix E, Figure E-36), like inventory. Like the inventory regression analyses, Appendix F, Figures F-91 - F-95 showed a light or weak relationship with all pollutants except NH_3, which had a moderate positive relationship.

Average daily mean exhaust temperatures were slightly higher at CA5B. The means ranged from 11.41°C at WA5B-B2 to 18.75°C at CA5B-B1. The time series (Appendix E, Figure E-37) show similar trends and ranges between the sites, with lower values at the WA5B barns. The regression analyses (Appendix F, Figures F-96 - F-100) indicated modest positive relationships with NH_3 and PM_{10} emissions and slight or weak relationships with other pollutants.

The average daily exhaust relative humidity values are also slightly higher at CA5B. The mean values ranged from 45.16% at WA5B-B4 to 58.49% at CA5B-B1. The time series (Appendix E, Figure E-38) show the highest levels in the winter and lower values in the summer at both sites. There is a lack of variability at the WA5B barns around January 2008 which will be further investigated prior to finalizing the models. The regression analyses (Appendix F, Figures F-101 - F-105) showed only slight to weak relationships with emissions, which were positive for the gaseous pollutants and negative for the all the particulate matter size fractions.

Estimated airflows at the naturally ventilated barns were comparable and ranged from 882.65 dsm^3s^{-1} to 1,151.61 dsm^3s^{-1} at CA5B. The time series (Appendix E, Figure E-39) show variability across the year, with slightly enhanced airflow during the summer. However, peak values can occur at any time of year. The regression analyses (Appendix F, Figures F-106 - F-110) showed modest positive linear relationship with NH_3 and $PM_{2.5}$ emissions. All other pollutants had a slight positive relationship with airflow.

Table 4-7. Naturally ventilated environmental parameter regression analyses

Pollutant	Parameter	R	R^2	Strength	Figure
NH_3	Inventory	0.660	0.435	moderate	Appendix F, F-81
H_2S	Inventory	0.002	< 0.001	slight or weak	Appendix F, F-82
PM_{10}	Inventory	-0.292	0.085	slight or weak	Appendix F, F-83
$PM_{2.5}$	Inventory	-0.319	0.102	slight or weak	Appendix F, F-84
TSP	Inventory	-0.327	0.107	slight or weak	Appendix F, F-85
NH_3	Average animal weight	-0.423	0.179	slight or weak	Appendix F, F-86
H_2S	Average animal weight	0.114	0.013	slight or weak	Appendix F, F-87
PM_{10}	Average animal weight	0.240	0.058	slight or weak	Appendix F, F-88
$PM_{2.5}$	Average animal weight	0.384	0.148	slight or weak	Appendix F, F-89
TSP	Average animal weight	0.384	0.147	slight or weak	Appendix F, F-90

Pollutant	Parameter	R	R^2	Strength	Figure
NH_3	Live animal weight	0.653	0.426	moderate	Appendix F, F-91
H_2S	Live animal weight	0.014	< 0.001	slight or weak	Appendix F, F-92
PM_{10}	Live animal weight	-0.278	0.077	slight or weak	Appendix F, F-93
$PM_{2.5}$	Live animal weight	-0.283	0.080	slight or weak	Appendix F, F-94
TSP	Live animal weight	-0.307	0.094	slight or weak	Appendix F, F-95
NH_3	Exhaust temperature	0.493	0.243	modest	Appendix F, F-96
H_2S	Exhaust temperature	0.323	0.104	slight or weak	Appendix F, F-97
PM_{10}	Exhaust temperature	0.410	0.168	slight or weak	Appendix F, F-98
$PM_{2.5}$	Exhaust temperature	0.484	0.234	modest	Appendix F, F-99
TSP	Exhaust temperature	0.406	0.165	slight or weak	Appendix F, F-100
NH_3	Exhaust relative humidity	0.390	0.152	slight or weak	Appendix F, F-101
H_2S	Exhaust relative humidity	0.193	0.037	slight or weak	Appendix F, F-102
PM_{10}	Exhaust relative humidity	-0.269	0.072	slight or weak	Appendix F, F-103
$PM_{2.5}$	Exhaust relative humidity	-0.414	0.171	slight or weak	Appendix F, F-104
TSP	Exhaust relative humidity	-0.322	0.104	slight or weak	Appendix F, F-105
NH_3	Airflow	0.536	0.287	modest	Appendix F, F-106
H_2S	Airflow	0.232	0.054	slight or weak	Appendix F, F-107
PM_{10}	Airflow	0.425	0.180	slight or weak	Appendix F, F-108
$PM_{2.5}$	Airflow	0.449	0.202	modest	Appendix F, F-109
TSP	Airflow	0.376	0.141	slight or weak	Appendix F, F-110

4.3.3 Ambient Data

The statistical summary of the ambient parameters associated with naturally ventilated barns are presented in Appendix D, Table D-32. Ambient temperatures were generally higher at CA5B leading to an average of the daily mean of 16.34°C compared to 10.07°C at WA5B. The time series (Appendix E, Figure E-40) showed the typical seasonal trend. Of note, the temperatures in summer 2008 were substantially lower than summer 2009. The site report noted the temperature sensor produced a “noisy signal” from late October 2007 to March of 2008. The average of the sonic anemometers was used as a substitute after analysis to confirm agreement with the remaining dates (Ramirez-Dorronsoro et al., 2010). The regression analyses (Appendix F, Figures F-111 - F-115), summarized in Table 4-7, showed a modest positive relationship with temperature and weak positive correlations with all other pollutants.

On average, the ambient relative humidity was lower at WA5B (45.81%) than CA5B (62.01%). The time series (Appendix E, Figure E-41) showed a muted peak around January 2008 for WA5B, like the exhaust relative humidity for the site. The site report offered no explanation for the plateau to the values. The regression analyses (Appendix F, Figures F-116 - F-120) showed slight or weak negative relationships with the emission value. The negative relationship between NH_3 emission and relative humidity is consistent with Sanchis et al. (2019).

Wind speeds averaged slightly higher at WA5B (2.59 ms^{-1}) than CA5B (1.97ms^{-1}). The time series (Appendix E, Figure E-42) showed no distinct seasonal trends, as peak and minimum values occurred throughout the year. The regression analyses (Appendix F, Figures F-121 - F-125) showed a modest positive relationship with NH_3 emissions, and weak positive relationships with all other pollutants.

Table 4-8. Naturally ventilated ambient parameters regression analyses

Pollutant	Parameter	R	R^2	Strength	Figure
NH_3	Ambient temperature	0.537	0.289	modest	Appendix F, F-111
H_2S	Ambient temperature	0.257	0.066	slight or weak	Appendix F, F-112
PM_{10}	Ambient temperature	0.370	0.137	slight or weak	Appendix F, F-113
$PM_{2.5}$	Ambient temperature	0.398	0.159	slight or weak	Appendix F, F-114
TSP	Ambient temperature	0.348	0.121	slight or weak	Appendix F, F-115
NH_3	Ambient relative humidity	-0.110	0.012	slight or weak	Appendix F, F-116
H_2S	Ambient relative humidity	< 0.001	< 0.001	none	Appendix F, F-117
PM_{10}	Ambient relative humidity	-0.129	0.017	slight or weak	Appendix F, F-118
$PM_{2.5}$	Ambient relative humidity	-0.331	0.109	slight or weak	Appendix F, F-119
TSP	Ambient relative humidity	-0.155	0.024	slight or weak	Appendix F, F-120
NH_3	Wind speed	0.537	0.289	modest	Appendix F, F-121
H_2S	Wind speed	0.257	0.066	slight or weak	Appendix F, F-122
PM_{10}	Wind speed	0.370	0.137	slight or weak	Appendix F, F-123
$PM_{2.5}$	Wind speed	0.398	0.159	slight or weak	Appendix F, F-124
TSP	Wind speed	0.348	0.121	slight or weak	Appendix F, F-125

4.4 Open Sources (IN5A, WI5A and TX5A)

4.4.1 Emissions Data

Appendix D, Table D-33 presents the summary statistics for daily average emissions of NH_3 for the open source sites, including corrals. Appendix D, Table D-34 presents the emissions per square meter of surface area. The emissions from the sites with lagoons, IN5A and WI5A, were comparable, with emissions ranging from 19.83 kg d^{-1} (2.01 g d^{-1} m^{-2}) at IN5A to 11.45 kg d^{-1} (1.61 g d^{-1} m^{-2}) at WI5A. The time series (Appendix E, Figures E-43, and E-45) showed the observations from IN5A in the same year and show a seasonal pattern. The observations from WI5B are more spread out over the two-year monitoring period and showed a subtle seasonal pattern. The NH_3 emissions for corrals was higher than for the lagoons on a per day basis with average emissions of 754.97 kg d^{-1} (222.1 g d^{-1} hd^{-1}). However, when normalized for the surface area, it was slightly greater at 3.12 g d^{-1} m^{-2}. The time series for the corral site (TX5A) is available in Appendix E, Figure E-52. There are not many summertime observations, so seasonality is hard to discern.

Appendix D, Table D-35 presents the summary statistics for daily average emissions of NH_3 for the open source sites, including corrals. Appendix D, Table D-36 presents the emissions per square meter of surface area. The average H_2S emissions from the lagoon sites, showed more of a difference, with emissions ranging from to 0.42 kg d^{-1} (0.06 kg d^{-1} m^{-2}) at WI5A to 9.39 kg d^{-1} (0.95 kg d^{-1} m^{-2}) at IN5A. The time series (Appendix E, Figure E-44, and E-46) showed the observations from IN5A in the same year and show a seasonal pattern. The observations from WI5B are more spread out over the two-year monitoring period and showed a subtle seasonal pattern. The H_2S emissions for the corral was greater than for the lagoons at 10.69 kg d^{-1} (3.14 g d^{-1} hd^{-1}) but was much less when normalized by area (44.18 mg d^{-1} m^{-2}). The time series for the corral site is available in Appendix E, Figure E-53. No seasonal pattern was apparent.

4.4.2 Environmental Data

The statistical summary of the environmental parameters associated with dairy lagoons are presented in Appendix D, Table D-37. Lagoon temperatures were colder at WI5A, which had an average daily mean temperature of 18.35°C compared to 21.57°C at IN5A. The time series (Appendix E, Figure E-47) shows the spare nature of the observations but does suggest the expected trend of lagoon temperatures following seasonal temperature patterns. The regression analyses (Appendix F, Figures F-126 - F-127; summarized in Table 4-8) shows moderate relationships with daily emissions (kg/d).

Lagoon pH was consistent between the sites, with average daily mean values at 7.02 and 7.43 for WI5A and IN5A, respectively. The time series (Appendix E, Figure E-48) shows values typically between 7.0 and 7.5 for most of the observations. There is a small cluster of readings for IN5A above 8.0 for Fall 2008. The regression analyses (Appendix F, Figures F-128 - F-129), summarized in Table 4-8, showed only slight or weak relationships with daily emissions (kg/d).

Table 4-9. Open source environmental parameter regression analyses

Pollutant	Parameter	R	R^2	Strength	Figure
NH_3	Lagoon temperature	0.66	0.436	moderate	Appendix F, F-126
H_2S	Lagoon temperature	-0.68	0.462	moderate	Appendix F, F-127
NH_3	Lagoon pH	-0.2	0.040	slight or weak	Appendix F, F-128
H_2S	Lagoon pH	0.4	0.160	slight or weak	Appendix F, F-129

4.4.3 Ambient Data

The statistical summary of the ambient parameters associated with dairy lagoons are presented in Appendix D, Table D-38. The average ambient temperature observed during monitoring periods for WI5A (-3.41°C) was much lower than IN5A (6.25°C). The time series (Appendix E, Figure E-49) show the expected seasonal trend in temperatures. The regression analyses (Appendix F, Figures F-130 - F-131), summarized in Table 4-9, show modest and moderately strong positive relationships with H_2S and NH_3 daily emissions (kg/d), respectively.

Observed ambient relative humidity were comparable between sites, with average daily means ranging from 71.53% at WI5A to 72.02% at IN5A. The time series (Appendix E, Figure E-50) show the relative humidity values vary throughout the year with no seasonal pattern. The regression analyses (Appendix F, Figures F-132 - F-133) shows a slight negative relationship with daily emissions (kg/d) of both NH_3 and H_2S.

Wind speeds were also comparable between sites and ranged from 3.28 m s^{-1} at IN5A to 3.45 m s^{-1} at WI5A. The time series (Appendix E, Figure E-51) average daily wind speeds were equally variable throughout the year at both sites. The regression analyses (Appendix F, Figures F-134 - F-135) showed only slight correlation with daily emissions (kg/d), which was negative for NH_3 and positive for H_2S.

Table 4-10. Open source ambient parameters regression analyses

Pollutant	Parameter	R	R^2	Strength	Figure
NH_3	Ambient temperature	0.84	0.706	moderately strong	Appendix F, F-130
H_2S	Ambient temperature	0.59	0.348	modest	Appendix F, F-131
NH_3	Ambient relative humidity	-0.34	0.116	slight or weak	Appendix F, F-132
H_2S	Ambient relative humidity	-0.18	0.032	slight or weak	Appendix F, F-133
NH_3	Wind speed	-0.25	0.063	slight or weak	Appendix F, F-134
H_2S	Wind speed	0.1	0.010	slight or weak	Appendix F, F-135

The statistical summary of the ambient parameters associated with the monitored dairy corral are presented in Appendix D, Table D-39. Observations of ambient temperature ranged from -5.64°C to 27.50°C, and followed expected seasonal trends (Appendix E, Figure E-54). The regression analyses (Appendix F, Figures F-136 - F-137; summarized in Table 4-10) showed a slight positive relationship between temperature and emissions.

Average daily ambient relative humidity values ranged from 22.3% to 78.54% over the study at TX5A. The time series (Appendix E, Figure E-55) do not suggest any seasonal trends. The regression analyses (Appendix F, Figures F-138 - F-139) shows slight positive relationships with emissions. Average daily wind speeds ranged from 2.35 to 6.79 ms^{-1} and showed no trends in the time series (Appendix E, Figure E-56). The time series did show a peak value in late winter to spring of 2009. The regression analyses (Appendix F, Figures F-140 - F-141) do not show a relationship between wind speed and emissions.

Water vapor deficit estimates ranged from 2.09 to 26.88 hectopascal (hPa) and showed some tendency for higher values in the summer and fall (Appendix E, Figure E-57). The regression analyses (Appendix F, Figures F-142 - F-143) summarized in Table 4-10 indicated a slight relationship between emissions that was positive for NH_3 and negative for H_2S.

Table 4-11. Corral ambient parameters regression analyses

Pollutant	Parameter	R	R^2	Strength	Figure
NH_3	Ambient temperature	0.17	0.029	slight or weak	Appendix F, F-136
H_2S	Ambient temperature	0.003	< 0.001	slight or weak	Appendix F, F-137

NH_3	Ambient relative humidity	0.17	0.029	slight or weak	Appendix F, F-138
H_2S	Ambient relative humidity	0.15	0.023	slight or weak	Appendix F, F-139
NH_3	Wind speed	0.002	< 0.001	slight or weak	Appendix F, F-140
H_2S	Wind speed	0.003	< 0.001	slight or weak	Appendix F, F-141
NH_3	Water vapor deficit	0.32	0.102	slight or weak	Appendix F, F-142
H_2S	Water vapor deficit	-0.16	0.026	slight or weak	Appendix F, F-143

5 DEVELOPMENT AND SELECTION OF MODELS FOR DAILY EMISSIONS

5.1 Mechanically Ventilated Barns

The literature review (Section 3) and exploratory data analysis (Section 4) suggested that EPA should consider ambient temperature, exhaust temperature, ambient relative humidity, exhaust relative humidity, manure management system, and inventory in the development of the emission models for mechanically ventilated barns. Barn airflow, or ventilation rate, can have a substantial influence on the emission rate of gaseous pollutants, but was not included in the parameter list as it may not be easily obtained at all farms. Since ventilation rate is essentially driven by the temperature (i.e., the higher ambient temperature the higher the ventilation rate), the ambient temperature provides an indication of airflow in the models tested.

The various combinations of these parameters were used in test models. For NH_3 and H_2S, 9 different combinations were tested as potential models (Table 5-1). There were 17 models (Table 5-2) tested for particulate matter emissions, which had variations to predict the emissions normalized by inventory.

Table 5-1. Parameter combinations tested as mechanically ventilated barn models for NH_3 and H_2S emissions.

Model	Parameters
MV-G1	Inventory, manure management system (Flush, Scrape)
MV-G2	Inventory, exhaust temperature, Exhaust relative humidity, manure management system (Flush, Scrape)
MV-G3	Inventory, exhaust temperature, manure management system (Flush, Scrape)
MV-G4	Inventory, exhaust relative humidity, manure management system (Flush, Scrape)
MV-G5	Inventory, ambient relative humidity, ambient temperature, manure management system (Flush, Scrape)
MV-G6	Inventory, ambient temperature, manure management system (Flush, Scrape)
MV-G7	Inventory, ambient relative humidity, manure management system (Flush, Scrape)
MV-G8	Inventory, ambient temperature, exhaust relative humidity, manure management system (Flush, Scrape)
MV-G9	Inventory, exhaust temperature, ambient relative humidity, manure management system (Flush, Scrape)

Table 5-2. Parameter combinations tested as mechanically ventilated barn models for PM_{10}, $PM_{2.5}$, and TSP emissions.

Model	Parameters
MV-P1	Intercept, inventory
MV-P2	Intercept, inventory, exhaust temperature, exhaust relative humidity
MV-P3	Intercept, inventory, exhaust temperature
MV-P4	Intercept, inventory, exhaust relative humidity
MV-P5	Intercept, inventory, ambient relative humidity, ambient temperature
MV-P6	Intercept, inventory, ambient temperature

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Model	Parameters
MV-P7	Intercept, inventory, ambient relative humidity
MV-P8	Intercept, inventory, ambient temperature, exhaust relative humidity
MV-P9	Intercept, inventory, exhaust temperature, ambient relative humidity
MV-P10	Intercept, exhaust temperature, exhaust relative humidity (Emissions normalized by inventory)
MV-P11	Intercept, exhaust temperature (emissions normalized by inventory)
MV-P12	Intercept, exhaust relative humidity (emissions normalized by inventory)
MV-P13	Intercept, ambient temperature, ambient relative humidity (Emissions normalized by inventory)
MV-P14	Intercept, ambient temperature (emissions normalized by inventory)
MV-P15	Intercept, ambient relative humidity (emissions normalized by inventory)
MV-P16	Intercept, ambient temperature, exhaust relative humidity (Emissions normalized by inventory)
MV-P17	Intercept, ambient relative humidity, exhaust temperature (Emissions normalized by inventory)

For both NH_3 (Appendix G, Table G-3) and H_2S (Appendix G, Table G-5), models MV-G5 and MV-G7 had terms that were not statistically significant ($p > 0.05$) for both pollutants and were removed from further consideration. For H_2S, model MV-G4 and G9 had insignificant terms. The model fit (-2 log likelihood, AIC, AICc, and BIC) and evaluation statistics (ME, NME, MB, NMB) for NH_3 (Appendix G, Table G-4) and H_2S (Appendix G, Table G-5) indicate the remaining models had comparable performance, which suggested that using ambient parameters was as effective as models that included barn specific parameters. As noted in the Process Overview report, the model selection process also looked at how easily obtainable the parameters are as not to create an undue burden on the operators. Generally, ambient parameters were preferred since ambient meteorological data is actively recorded across the country and representative site data is accessible through the National Centers for Environmental Information (NCEI) website. To further ease any burden, the EPA plans to provide a tool that automatically populates relevant ambient parameters for any given location instead of requiring producers to measure and record environmental parameters either inside or outside of the barn to further reduce the burden of use on the producer.

Therefore, considering ambient temperature is a suitable proxy for barn airflow as exhaust temperature and representative ambient temperature data is accessible, the EPA concluded that a model using ambient temperature and relative humidity would be preferable to one with exhaust temperature and relative humidity. Of the remaining models that used ambient parameters (MV-G1, and G6), EPA selected model MV-G6 (including the parameters: inventory, ambient temperature, and manure management system) for further analysis for both NH_3 and H_2S as it had the best normalized mean bias of the remaining models. The final form of these models is presented in Table 5-3.

Table 5-3. Selected daily models for mechanically ventilated barns.

Pollutant	Formula	Units	Equation Number
NH_3, Flush	$ln(NH_3) = 1.746585 + 1.773832 * Inventory + 0.029586 * Amb_T$	kg/d	Equation 1
NH_3, Scrape	$ln(NH_3) = 1.864935 + 1.773832 * Inventory + 0.029586 * Amb_T$	kg/d	Equation 2
H_2S, Flush	$ln(H_2S) = 7.406887 + 0.86173 * Inventory + 0.012786 * Amb_T$	g/d	Equation 3
H_2S, Scrape	$ln(H_2S) = 6.287004 + 0.86173 * Inventory + 0.012786 * Amb_T$	g/d	Equation 4

For PM_{10} models (Appendix G, Table G-7), models MVP-1 through MVP-9 include inventory as a proxy for volume of manure produced. While all model terms were statistically significant ($p > 0.05$), coefficients for inventory were negative which suggests that emissions decrease as inventory increases. The negative coefficients for inventory are also seen in models MVP-1 through MVP-9 for $PM_{2.5}$ (Appendix G, Table G-9) and TSP (Appendix G, Table G-11). As noted in Section 3.2, Garcia et al. (2012) found a similar inverse relationship with $PM_{2.5}$ concentrations and inventory for MCs, which was attributed to the larger dairies being newer and more efficiently operated. Based on the site reports, the older barns have the lowest average inventory (Table 5-4), which lines up with Garcia et al. (2012). Still unknown is the management practice in the newer barns contributing to the reduced emissions and how to account for that practice in the model. Age of the barn and construction year were discussed as a possible parameter; however, there is not enough variability in construction year available in the NAEMS data for model construction.

Table 5-4. Summary of barn construction dates for mechanically ventilated barns.

Barn	Year Constructed	Average Inventory
IN5B-B1	2004	833
IN5B-B2	2004	864
NY5B-B1	1998	467
WI5B-B1	1990	211
WI5B-B2	1994	355

EPA tested a set of models that normalized emissions by inventory, MVP-10 through MVP-17, which use the same environmental and barn parameters as models MVP-2 through MVP-9. The goal was to determine if these models could be predictive based on the other environmental and ambient parameters alone. The model performance statistics (i.e., ME, NME, MB, NMB) did increase for these models (Appendix G, Tables G-8, G-10, and G-12), suggesting accounting for the difference in newer barns is needed for a successful model. Therefore, EPA is not selecting a model at this time to allow for more research into the reason newer barns have lower particulate matter emissions, despite increased animal populations.

5.2 Milking Centers

The literature review (Section 3) and exploratory data analysis (Section 4) suggested that EPA should consider ambient temperature, exhaust temperature, ambient relative humidity, exhaust relative humidity, milk production, and inventory in the development of the emission models for MCs. Barn airflow, or ventilation rate, can have a substantial influence on the emission rate, but was not included in the parameter list as it may not be easily obtained at all farms. Since ventilation rate is essentially driven by the temperature (i.e., the higher ambient temperature the higher the ventilation rate), the ambient temperature provides an indication of airflow in the models tested. EPA tested 24 combinations of these parameters as potential models (Table 5-5), including which had variations to predict the emissions normalized by inventory (MC-25 through MC-32). The models to predict normalized emissions were added to incorporate a barn size into the model, as the relatively consistent inventory of the MCs could reduce the significance if inventory was used as a predictive parameter. This is demonstrated with the NH_3 modeling results (Appendix G, Table G-13), as inventory is insignificant in models MC-10 through MC-16.

Milk production values were only available for NY5B, and when combined with a static value for barn inventory, as in models MC-1 through MC-8, inventory was dropped from the model, making the result equivalent to models MC-17 through MC-24 for all pollutants. Therefore, the summary presented in this section will focus on models MC-8 through MC-32. Results for all models is summarized in Appendix G.

Table 5-5. Parameter combinations tested as milking center models.

Model	Parameters
MC-1	Intercept, inventory, milk production, exhaust temperature, exhaust relative humidity
MC-2	Intercept, inventory, milk production, exhaust temperature
MC-3	Intercept, inventory, milk production, exhaust relative humidity
MC-4	Intercept, inventory, milk production, ambient relative humidity, ambient temperature
MC-5	Intercept, inventory, milk production, ambient temperature
MC-6	Intercept, inventory, milk production, ambient relative humidity
MC-7	Intercept, inventory, milk production, ambient temperature, exhaust relative humidity
MC-8	Intercept, inventory, milk production, exhaust temperature, ambient relative humidity
MC-9	Intercept, inventory, exhaust temperature, exhaust relative humidity
MC-10	Intercept, inventory, exhaust temperature
MC-11	Intercept, inventory, exhaust relative humidity
MC-12	Intercept, inventory, ambient relative humidity, ambient temperature

MC-13	Intercept, inventory, ambient temperature
MC-14	Intercept, inventory, ambient relative humidity
MC-15	Intercept, inventory, ambient temperature, exhaust relative humidity
MC-16	Intercept, inventory, exhaust temperature, ambient relative humidity
MC-17	Intercept, milk production, exhaust temperature, exhaust relative humidity
MC-18	Intercept, milk production, exhaust temperature
MC-19	Intercept, milk production, exhaust relative humidity
MC-20	Intercept, milk production, ambient relative humidity, ambient temperature
MC-21	Intercept, milk production, ambient temperature
MC-22	Intercept, milk production, ambient relative humidity
MC-23	Intercept, milk production, ambient temperature, exhaust relative humidity
MC-24	Intercept, milk production, exhaust temperature, ambient relative humidity
MC-25	Intercept, exhaust temperature, exhaust relative humidity (Emissions normalized by inventory)
MC-26	Intercept, exhaust temperature (emissions normalized by inventory)
MC-27	Intercept, exhaust relative humidity (emissions normalized by inventory)
MC-28	Intercept, ambient temperature, ambient relative humidity (Emissions normalized by inventory)
MC-29	Intercept, ambient temperature (emissions normalized by inventory)
MC-30	Intercept, ambient relative humidity (emissions normalized by inventory)
MC-31	Intercept, ambient temperature, exhaust relative humidity (Emissions normalized by inventory)
MC-32	Intercept, ambient relative humidity, exhaust temperature (Emissions normalized by inventory)

For NH_3 (Appendix G, Table G-13) models MC-1 through MC-24 had terms that were not statistically significant ($p > 0.05$). All the models predicting NH_3 emissions per head (MC-25 through MC-32) were comprised of significant parameters. The model fit (-2 log likelihood, AIC, AICc, and BIC) and evaluation statistics (ME, NME, MB, NMB) for these models are presented in Appendix G, Table G-14. The ambient parameter models performed comparably to their barn parameter counterparts, suggesting selecting the models with the easier to obtain ambient parameter would be as effective. Therefore, EPA concluded that a model using ambient temperature and relative humidity would be preferable to one with exhaust temperature and relative humidity. Of the remaining models that used ambient parameters (MC-28, MC-29, and MC-30), the NME and ME are comparable for the models. Model MC-30 has a substantially lower MB and NMB. However, this model only includes relative humidity and not temperature. The literature search (Section 3) noted that temperature is strongly linked to NH_3 emissions and should be included in the selected model. The model performance plots (Appendix G, Figures G-20 & G-24) also show better scatter across the one-to-one (1:1) for models MC-28, MC-29, indicating better predictive performance than model MC-30. Therefore, EPA selected model MC-29 (including ambient temperature as the predictive parameter) for further analysis for NH_3

as it had the best NMB of the remaining models. The final form of these models is presented in Table 5-6.

In addition to the models predicting normalized emissions, models MC-9, MC-10, MC-11, MC-13, MC-15, MC-18, and MC-21 were comprised of significant parameters for H_2S (Appendix G, Table G-15). Of the seven additional models, all but MC-11 contained either exhaust temperature or ambient temperature. as well as models MC-25 through MC-32. Comparing the model fit and evaluation statistics (Appendix G, Table G-16) the ambient parameter models performed comparably to their barn parameter counterparts, suggesting models utilizing the easier to obtain ambient parameter would be as effective. Therefore, EPA concluded that a model using ambient temperature and ambient relative humidity would be preferable to one with exhaust temperature and relative humidity. Of the remaining models that used ambient parameters (MC-13, MC-21, MC-28, MC-29, and MC-30), the error statistics (NME and ME) are lower for models MC-13 and MC-21, while the bias statistics (MB and NMB) are lower for MC-21 and MC-30, with other models being comparable. The scatter plots of observed versus predicted (Appendix G, Figures G-26 through G-32) for model MC-21 has more variability in the scatter across the 1:1 line, indicating a slightly better fit. However, this model includes milk production, which is only available for one site. For this study, it is preferred to include multiple sites in the model development dataset to represent variability across the country. Therefore, EPA selected model MC-29 (including ambient temperature as the predictive parameter) for further analysis for H_2S as it had the best NMB the remaining models (i.e., MC-13, MC-30). The final form of these models is presented in Table 5-6.

For the particulate matter size fractions, only NY5B reported emissions. With the dataset dropping to one site with a constant value for MC capacity, the coefficient of inventory in models MC-9 through MC-16 is estimated at zero and eliminates a size estimate from the model. The focus for the particulate matter model narrowed to just models MC-17 through MC-32. For PM_{10}, models MC-17, MC-18, MC-19, MC-20, MC-21, and MC-23 have parameters that are statistically insignificant (Appendix G, Table G-17). The model fit and evaluation statistics (Appendix G, Table G-18) for models with ambient parameters performed comparably to their barn parameter counterparts, suggesting models utilizing the easier to obtain ambient parameter would be as effective. Of the remaining models that used ambient parameters (MC-28, MC-29, and MC-30), the NME and ME are slightly lower for Model 28, and the bias parameters are similar. EPA selected model MC-28 (including ambient temperature and ambient relative humidity as the predictive parameter) for further analysis for PM_{10} as it had the best NMB of the remaining models. The final form of these models is presented in Table 5-6.

As noted in Section 6.4 of the main report, the particulate matter model selection starts with PM_{10} due to the greater quantity of emissions data. The PM_{10} models had between 315 and

436 records available depending on the completeness of the various predictive parameters. For $PM_{2.5}$ and TSP the number of records available ranged between 40 – 44 for $PM_{2.5}$ and 29 – 40 for TSP. This is substantially less data that were available for PM_{10} and does not necessarily cover the breadth of conditions that the PM_{10} data does. Therefore, the models generated with these smaller datasets were examined mainly for consistency with the PM_{10} results to build confidence in using the same model form for all the particulate matter species.

Compared to the PM_{10} models, more of the $PM_{2.5}$ and TSP models have insignificant terms. For both $PM_{2.5}$ (Appendix G, Table G-19) and TSP (Appendix G, Table G-21), only models MC-26 and MC-29 are comprised of significant parameters. Despite the insignificance of the parameters for most of the models, the relationships were consistent with the PM_{10} models and literature. The model performance statistics for $PM_{2.5}$ (Appendix G, Table G-20) and the model performance plots (Appendix G, Figures G-41 through G-48) were consistent, with slightly lower bias metric for model MC-29. For TSP, the performance metrics (Appendix G, Table G-22) and plots (Appendix G, Figures G-49 through G-56) were comparable. Therefore, EPA selected model MC-29 for $PM_{2.5}$ (including ambient temperature as the predictive parameter) and model MC-28 (including ambient temperature and ambient relative humidity as the predictive parameter) for TSP to conduct further evaluation and analysis as an emission estimation method. The full forms of the models are presented in Table 5-6.

Table 5-6. Selected daily models for milking centers.

Pollutant	Formula	Units	Equation Number
NH_3	$ln(NH_3) = 2.505637 + 0.046434 * Amb_T$	g/d/hd	Equation 5
H_2S	$ln(H_2S) = 6.898188 + 0.024053 * Amb_T$	kg/d/hd	Equation 6
PM_{10}	$ln(PM_{10}) = 8.042215 + 0.006791 * Amb_T - 0.003552 * Amb_{RH}$	g/d/hd	Equation 7
$PM_{2.5}$	$ln(PM_{2.5}) = 6.58377 + 0.006698 * Amb_T$	g/d/hd	Equation 8
TSP	$ln(TSP) = 7.457268 + 0.010997 * Amb_T - 0.003639 * Amb_{RH}$	g/d/hd	Equation 9

5.3 Naturally Ventilated Barns

The literature review (Section 3) and exploratory data analysis (Section 4) suggested that EPA should consider ambient temperature, ambient relative humidity, exhaust relative humidity, wind speed, and inventory in the development of the emission models for naturally ventilated barns. EPA tested 8 combinations of these parameters as potential models (Table 5-5). Models predicting emissions normalized by inventory were not pursued at this time. However, based on the initial results of MCs, normalized inventory models may be considered for the final models.

Table 5-7. Parameter combinations tested as naturally ventilated barns models.

Model	Parameters
NV-1	Intercept, inventory
NV-2	Intercept, inventory, ambient temperature, ambient relative humidity, wind speed
NV-3	Intercept, inventory, ambient temperature
NV-4	Intercept, inventory, ambient relative humidity
NV-5	Intercept, inventory, wind speed
NV-6	Intercept, inventory, ambient temperature, ambient relative humidity
NV-7	Intercept, inventory, ambient relative humidity, wind speed
NV-8	Intercept, inventory ambient temperature, wind speed

For the gaseous species, models NV-3 and NV-8 had terms that were not statistically significant ($p > 0.05$) for NH_3 (Appendix G, Table G-24), and models NV-2, NV-3, NV-4, NV-6, NV-7, and NV-8 had insignificant terms for H_2S (Appendix G, Table G-26). The model fit (-2 log likelihood, AIC, AICc, and BIC) and evaluation statistics (ME, NME, MB, NMB) for these models are presented in Appendix G, Table G-25, and Table G-27 for NH_3 and H_2S, respectively. For both pollutants, the statistics for the models were comparable. Therefore, EPA selected model NV-5 (including as the predictive parameters: inventory and wind speed) for further analysis for NH_3 and H_2S as it had the best NMB of the remaining models. The final form of these models is presented in Table 5-8.

For PM_{10}, all models were comprised of statistically significant parameters (Appendix G, Table G-28). The model fit and evaluation statistics (Appendix G, Table G-29) suggested comparable performance across all models, with model NV-2 having slightly better error metrics. EPA selected model NV-2 (including the predictive parameters: inventory, ambient temperature, ambient relative humidity, and wind speed) for further analysis. The final form of the model is presented in Table 5-8.

As noted in Section 6.4 of the main report and with the MC model selection, the particulate matter model selection starts with the PM_{10} due to the greater quantity of emissions data. For naturally ventilated barns, the PM_{10} models had between 1,457 and 1,469 records available depending on the completeness of the various predictive parameters. For $PM_{2.5}$ and TSP, the number of records available was 93 for $PM_{2.5}$ and 205 for TSP. The $PM_{2.5}$ models (Appendix G, Table G-30) all have insignificant parameters. The relationship generally follows the expected trend from literature (e.g., negative relationship with relative humidity). However, inventory has a negative coefficient in each model. For TSP (Appendix G, Table G-32), all models are comprised entirely of significant parameters and the predictive parameters have the same relationships as with PM_{10}. Model NV-2 had reasonable performance for both $PM_{2.5}$ (Appendix G, Table G-31) and TSP (Appendix G, Table G-33) and would be consistent with the PM_{10} formulation that was developed from a much larger dataset. Therefore, EPA selected model NV-2 (including the predictive parameters: inventory, ambient temperature, ambient relative humidity, and wind speed) for further analysis. The final form of the models for $PM_{2.5}$ and TSP are presented in Table 5-8.

Table 5-8. Selected daily models for naturally ventilated barns.

Pollutant	Formula	Units	Equation Number
NH_3	$ln(NH_3) = 0.188357 + 3.451939 * Inventory + 0.048153 * WindSpeed$	g/d	Equation 10
H_2S	$ln(H_2S) = 6.541057 + 0.587702 * Inventory + 0.062678 * WindSpeed$	kg/d	Equation 11
PM_{10}	$ln(PM_{10}) = 7.64258 + 1.525009 * Inventory + 0.011864 * Amb_T - 0.01521 * Amb_{RH} + 0.173698 * WindSpeed$	g/d	Equation 12
$PM_{2.5}$	$ln(PM_{2.5}) = 7.068797 - 0.220453 * Inventory + 0.01121 * Amb_T - 0.003808 * Amb_{RH} + 0.218968 * WindSpeed$	g/d	Equation 13
TSP	$ln(TSP) = 7.868847 + 2.953893 * Inventory + 0.034508 * Amb_T - 0.033997 * Amb_{RH} + 0.248191 * WindSpeed$	g/d	Equation 14

5.4 Open Sources

The literature review (Section 3) and exploratory data analysis (Section 4) suggested that EPA should consider lagoon pH, lagoon temperature, ambient temperature, and wind speed in the development of the emission models for open sources. EPA tested 15 combinations of these parameters as potential models (Table 5-9). Models were developed to predict daily emissions per meter squared (m^2) of surface area of the open source.

Table 5-9. Parameter combinations tested as open source models for NH_3 and H_2S emissions.

Model	Parameters
LB-1	Lagoon pH, lagoon temperature
LB-2	Lagoon pH

LB-3	Lagoon temperature
LB-4	Ambient temperature, wind speed
LB-5	Ambient temperature
LB-6	Wind speed
LB-7	Lagoon pH, lagoon temperature, ambient temperature, wind speed
LB-8	Lagoon pH, lagoon temperature, ambient temperature
LB-9	Lagoon pH, lagoon temperature, wind speed
LB-10	Lagoon pH, ambient temperature, wind speed
LB-11	Lagoon temperature, ambient temperature, wind speed
LB-12	Lagoon pH, ambient temperature
LB-13	Lagoon pH, wind speed
LB-14	Lagoon temperature, ambient temperature
LB-15	Lagoon temperature, wind speed

For NH_3, of the 15 models tested, only LB-3, LB-5, LB-6, and LB-15 were comprised of significant parameters (Appendix G, Table G-34). The model fit (-2 log likelihood, AIC, AICc, and BIC) and evaluation statistics (ME, NME, MB, NMB) for these models are presented in Appendix G, Table G-35, and were consistent across the models with significant terms. This suggests that models with ambient temperature (model LB-5) perform as well as models with lagoon specific parameters (LB-3 and LB-15). Therefore, EPA selected model NV-5 (including ambient temperature as the predictive parameter) for further analysis for NH_3. The final form of this model is presented in Table 5-10.

For H_2S, of the 15 models tested, only LB-3, LB-5, and LB-6 were comprised entirely of significant parameters (Appendix G, Table G-36). The model fit and evaluation statistics (Appendix G, Table G-37), and were consistent across the models with significant terms. This suggests that models with ambient temperature (model LB-5) perform as well as models with lagoon specific parameters (LB-3). Therefore, EPA selected model NV-5 (including ambient temperature as the predictive parameter) for further analysis for H_2S. The final form of this model is presented in Table 5-10.

Table 5-10. Selected daily models for lagoons sources.

Pollutant	Formula	Units	Equation Number
NH_3	$ln(NH_3) = 1.396734 + 0.027201 * Amb_T$	kg/d m^2	Equation 15
H_2S	$ln(H_2S) = 1.189272 + 0.010557 * Amb_T$	kg/d m^2	Equation 16

5.5 Corrals

The literature review (Section 3) and exploratory data analysis (Section 4) suggested that EPA should consider ambient temperature, ambient relative humidity, water vapor deficit, and wind speed in the development of the emission models for corrals. EPA tested 15 combinations of these parameters as potential models (Table 5-11). Models were developed to predict daily emissions per meter squared (g/d-m^2) of surface area of the corral, as well as emissions per m2 per 1,000 head (g/d-m^2-1,000 hd), to account for the stock density of the corral. In total, 30 models were tested to account for the 15 different parameter combinations and two forms of the emissions.

Table 5-11. Parameter combinations tested as corral models for NH_3 and H_2S emissions.

Model	Emissions	Parameters
CR-1a	g/d-m^2	Ambient temperature, ambient relative humidity, wind speed, water vapor deficit
CR-2a	g/d-m^2	Ambient temperature, ambient relative humidity, water vapor deficit
CR-3a	g/d-m^2	Ambient temperature, ambient relative humidity, wind speed
CR-4a	g/d-m^2	Ambient relative humidity, wind speed, water vapor deficit
CR-5a	g/d-m^2	Ambient temperature, wind speed, water vapor deficit
CR-6a	g/d-m^2	Ambient temperature, ambient relative humidity
CR-7a	g/d-m^2	Ambient temperature, water vapor deficit
CR-8a	g/d-m^2	Ambient relative humidity, water vapor deficit
CR-9a	g/d-m^2	Ambient temperature, wind speed
CR-10a	g/d-m^2	Ambient relative humidity, wind speed
CR-11a	g/d-m^2	Wind speed, water vapor deficit
CR-12a	g/d-m^2	Ambient temperature
CR-13a	g/d-m^2	Ambient relative humidity
CR-14a	g/d-m^2	Water vapor deficit
CR-15a	g/d-m^2	Wind speed
CR-1b	g/d-m^2-1,000 hd	Ambient temperature, ambient relative humidity, wind speed, water vapor deficit
CR-2b	g/d-m^2-1,000 hd	Ambient temperature, ambient relative humidity, water vapor deficit
CR-3b	g/d-m^2-1,000 hd	Ambient temperature, ambient relative humidity, wind speed
CR-4b	g/d-m^2-1,000 hd	Ambient relative humidity, wind speed, water vapor deficit
CR-5b	g/d-m^2-1,000 hd	Ambient temperature, wind speed, water vapor deficit
CR-6b	g/d-m^2-1,000 hd	Ambient temperature, ambient relative humidity
CR-7b	g/d-m^2-1,000 hd	Ambient temperature, water vapor deficit
CR-8b	g/d-m^2-1,000 hd	Ambient relative humidity, water vapor deficit
CR-9b	g/d-m^2-1,000 hd	Ambient temperature, wind speed
CR-10b	g/d-m^2-1,000 hd	Ambient relative humidity, wind speed
CR-11b	g/d-m^2-1,000 hd	Wind speed, water vapor deficit
CR-12b	g/d-m^2-1,000 hd	Ambient temperature
CR-13b	g/d-m^2-1,000 hd	Ambient relative humidity
CR-14b	g/d-m^2-1,000 hd	Water vapor deficit
CR-15b	g/d-m^2-1,000 hd	Wind speed

Models CR-3a, CR-4a, CR-6a, CR-8a, CR-12a, CR-13a, CR-14a, CR-4b, CR-6b, CR-8b, CR-12b, CR-13b, CR-14b, CR-15b were comprised of significant parameters for NH_3 (Appendix G, Table G-38). The model fit (-2 log likelihood, AIC, AICc, and BIC) and evaluation statistics (ME, NME, MB, NMB) for these models are presented in Appendix G, Table G-39, and were consistent across all the models. The models predicting the emissions in g/d-m^2-1,000 hd have lower mean bias and mean error values than their counterpart predicting emissions as g/d-m^2. EPA selected model CR-3b (including the predictive parameters: ambient temperature, ambient relative humidity, and wind speed) for further analysis for NH_3. The final form of this model is presented in Table 5-12.

For H_2S, only model CR-13a was comprised entirely of statistically significant parameters (Appendix G, Table G-40). Like NH_3, the model fit and evaluation statistics (Appendix G, Table G-41) for the version of the model predicting emissions as g/d-m^2-1,000 hd (i.e., CR-13b) has slightly lower mean bias and mean error values. EPA selected model CR-13b (including the predictive parameter ambient relative humidity) for further analysis for corral H_2S emissions. The final form of this model is presented in Table 5-12.

Table 5-12. Selected daily models for corrals.

Pollutant	Formula	Units	Equation Number
NH_3	$ln(NH_3) = 1.053805 + 0.004993 * Amb_T + 0.0031 * Amb_{RH} + 0.017832 * WindSpeed$	g/d-m^2-1,000 hd	Equation 17
H_2S	$ln(H_2S) = 2.404792 + 0.007177 * Amb_{RH}$	g/d-m^2-1,000 hd	Equation 18

6 MODEL COEFFICIENT EVALUATION

To ensure reliable prediction of the emissions, the model coefficients were evaluated with the jackknife method (Christensen et al., 2016; Leeden et al., 2008), which examined the cumulative effect on coefficient estimates of multiple "minus-one" runs. The jackknife approach called for removing one of the independent sample units from the dataset. For NAEMS, the individual barns at each site and the lagoons are the mutually exclusive independent sample units. EPA then determined the associated parameter estimates for the selected model based on this dataset. This was repeated for each of the sample units. These results were then compared to the model coefficients based on the full dataset (full model). For each jackknife model, the ME, NME, MB, and NMB were calculated, based on the equations outlined in Section 6 of the main report, to facilitate comparison.

EPA also prepared plots showing the variation in coefficients and standard errors for the selected models and compared to each of the jackknife models. EPA interpreted these plots similar to Tukey confidence interval plots in that if the result for the jackknife model overlapped the results for the full model (i.e., the area highlighted in gray on the figures), then the model coefficients are not inconsistent with one another. If the omission of one monitoring unit (e.g., a barn or lagoon) resulted in a coefficient that was outside ± 1 standard error of the full model, the sample unit was reviewed to determine if a specific characteristic of that unit (e.g., animal placement strategy, manure handling system) might have caused the inconsistency. If the difference could not be ascribed to an operational characteristic of the unit, the data were reviewed for outliers that could be removed from analysis, and other potential remediation measures considered.

6.1 Mechanically Ventilated Barns Model

6.1.1 NH_3 Model Evaluation

Table 6-1 and Figure 6-1 show the variation in coefficients and standard errors for the selected model ("None") and each of the jackknife models. The model coefficients from the jackknife approach were comparable across the withheld sets (Table 6-1) and remained significant (p-value <0.05) across all models. The plots in Figure 6-1 show that the results for all jackknife models overlap the full model estimate ± 1 standard error, except for ambient temperature. In comparison to the full model, that is where the barn removed is "None", the maximum percent differences for parameter estimates across the three models were 7%, 23%, 3%, and 4% for inventory, ambient temperature, intercept for the flush barns, and intercept for scrape barns, respectively. Across all models, the difference in NME and NMB (Table 6-2) in comparison to the selected model were minor. For NME the values differed by less than 8%. For NMB the values varied by less than 34%. The largest difference was seen when WI5B B1 was withheld from the dataset, which decreased the NME and NMB by 8% and 34%, respectively.

Table 6-1. Model coefficients developed using the jackknife approach for NH_3 emissions from mechanically ventilated barns.

Barn out	Effect	Estimate	Standard Error	p-value
NONE	Inventory	1.773832	0.06477	<.0001
	Ambient Temperature	0.029586	0.00088	<.0001
	Flush	1.746585	0.03789	<.0001
	Scrape	1.864935	0.04253	<.0001
IN5BB1	Inventory	1.736301	0.07221	<.0001
	Ambient Temperature	0.024312	0.00093	<.0001
	Flush	1.793836	0.03772	<.0001
	Scrape	1.925841	0.04232	<.0001
IN5BB2	Inventory	1.898712	0.07457	<.0001
	Ambient Temperature	0.024229	0.00091	<.0001
	Flush	1.748491	0.03749	<.0001
	Scrape	1.869675	0.0425	<.0001
NY5BB1	Inventory	1.824003	0.06932	<.0001
	Ambient Temperature	0.030506	0.00095	<.0001
	Flush	1.72461	0.03966	<.0001
	Scrape	1.798078	0.04787	<.0001
WI5BB1	Inventory	1.722238	0.07977	<.0001
	Ambient Temperature	0.036382	0.00101	<.0001
	Flush	1.693687	0.05244	<.0001
	Scrape	1.832478	0.05634	<.0001
WI5BB2	Inventory	1.703501	0.07134	<.0001
	Ambient Temperature	0.032999	0.00105	<.0001
	Flush	1.765095	0.04896	<.0001
	Scrape	1.891018	0.05005	<.0001

Table 6-2. Model fit statistics for the mechanically ventilated barns NH3 jackknife.

Barn out	n	LNME[a] (%)	NME[b] (%)	ME[b] (kg day^{-1})	MB[b] (kg day^{-1})	NMB[b] (%)	Corr
NONE	2192	7.322	24.573	5.959	-0.583	-2.404	0.917
IN5BB1	1771	7.213	25.072	5.003	-0.542	-2.717	0.911
IN5BB2	1762	7.148	25.329	5.042	-0.472	-2.372	0.905
NY5BB1	1846	7.403	24.716	6.115	-0.701	-2.835	0.924
WI5BB1	1676	6.866	22.488	6.538	-0.459	-1.579	0.918
WI5BB2	1713	7.212	23.375	6.523	-0.547	-1.961	0.919

[a] Based on transformed data (i.e., ln(NH_3)).

[b] Based on back-transformed data.

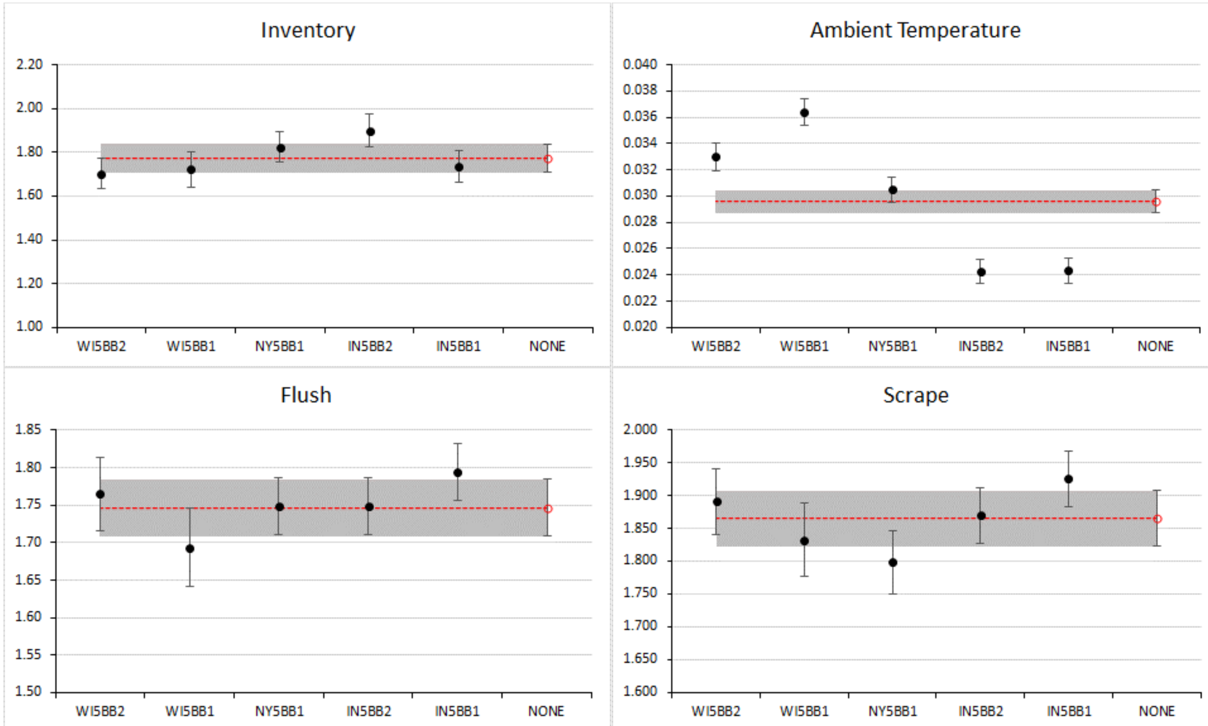

Figure 6-1. Comparison of variation in coefficients and standard errors for NH_3 mechanically ventilated barn model.

Variation in coefficients and standard errors (black closed circle and ± SE bar) for each jackknife model with the selected NH_3 mechanically ventilated model coefficient ("None", gray band for ± SE) for each model parameter.

6.1.2 H_2S Model Evaluation

The variation in coefficients and standard errors for the selected model ("None") and each of the H_2S jackknife models is shown in Table 6-3 and Figure 6-2. The model coefficients from the jackknife approach were comparable across the withheld sets (Table 6-3) and remained significant (p-value <0.05) across all models. The plots in Figure 6-2 show that the results for all jackknife models overlap the full model estimate ± 1 standard error, except for WI5B B1 for ambient temperature. In comparison to the full model, where the barn removed is "None", the maximum percent differences for parameter estimates across the three models were 14%, 26%, 2%, and 1% for inventory, ambient temperature, intercept for the flush barns, and intercept for scrape barns, respectively. Across all models, the difference in NME and NMB (Table 6-4) in comparison to the selected model were minor for NME (< 8%) and more substantial for NMB (<32%).

Table 6-3. Model coefficients developed using the jackknife approach for H_2S emissions from mechanically ventilated barns.

Barn out	Effect	Estimate	Standard Error	p-value
NONE	Inventory	0.86173	0.08664	<.0001
	Ambient Temperature	0.012786	0.00127	<.0001
	Flush	7.406887	0.05129	<.0001
	Scrape	6.287004	0.05691	<.0001
IN5BB1	Inventory	0.974345	0.08989	<.0001
	Ambient Temperature	0.010264	0.00134	<.0001
	Flush	7.389176	0.04755	<.0001
	Scrape	6.282462	0.053	<.0001
IN5BB2	Inventory	0.73697	0.09126	<.0001
	Ambient Temperature	0.010959	0.00124	<.0001
	Flush	7.453061	0.04624	<.0001
	Scrape	6.355244	0.0521	<.0001
NY5BB1	Inventory	0.915728	0.09384	<.0001
	Ambient Temperature	0.012973	0.00147	<.0001
	Flush	7.389581	0.05383	<.0001
	Scrape	6.222805	0.06537	<.0001
WI5BB1	Inventory	0.897494	0.11836	<.0001
	Ambient Temperature	0.016059	0.00149	<.0001
	Flush	7.285544	0.07955	<.0001
	Scrape	6.224063	0.08308	<.0001
WI5BB2	Inventory	0.817846	0.10259	<.0001
	Ambient Temperature	0.014378	0.00148	<.0001
	Flush	7.495271	0.07179	<.0001
	Scrape	6.313356	0.07154	<.0001

Table 6-4. Model fit statistics for the mechanically ventilated barns H_2S jackknife.

Barn out	n	LNME[a] (%)	NME[b] (%)	ME[b] (g day^{-1})	MB[b] (g day^{-1})	NMB[b] (%)	Corr
NONE	2454	4.46	64.308	553.14	-38.66	-4.495	0.58
IN5BB1	1993	4.088	61.644	533.71	-34.72	-4.01	0.592
IN5BB2	1954	3.911	59.42	464	-25.36	-3.248	0.677
NY5BB1	1992	4.736	65.587	615.71	-39.17	-4.173	0.565
WI5BB1	1920	4.696	66.693	561.9	-47.91	-5.686	0.543
WI5BB2	1957	4.653	64.785	564.15	-51.6	-5.925	0.582

[a] Based on transformed data (i.e., ln(H_2S)).
[b] Based on back-transformed data.

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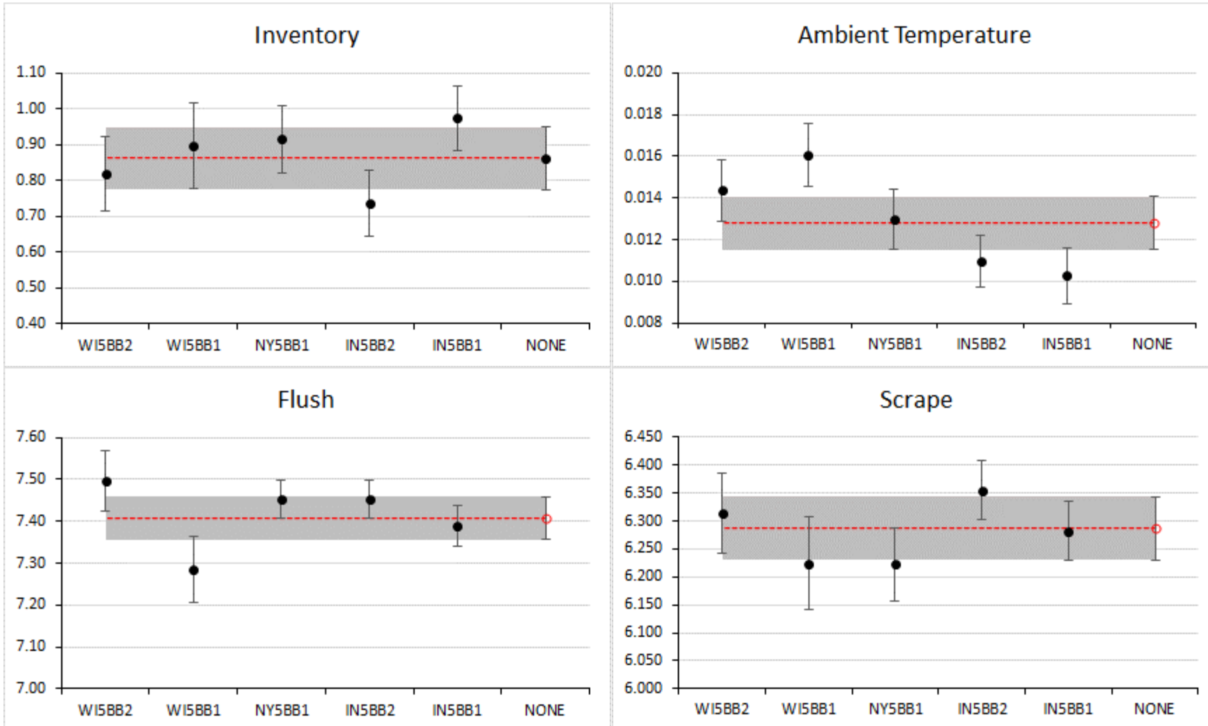

Figure 6-2. Comparison of variation in coefficients and standard errors for H_2S mechanically ventilated barn model.

Variation in coefficients and standard errors (black closed circle and ± SE bar) for each jackknife model with the selected H_2S mechanically ventilated barn model coefficient ("None", gray band for ± SE) for each model parameter.

6.1.3 Particulate Matter Models

Particulate matter models were not selected at this time.

6.2 Milking Centers

6.2.1 NH_3 Model Evaluation

Table 6-5 and Figure 6-3 show the variation in coefficients and standard errors for the selected model ("None") and each of the jackknife models. The model coefficients from the jackknife approach were comparable across the withheld sets (Table 6-5) and remained significant (p-value <0.05) across all models. The plots in Figure 6-3 show that the results for all jackknife models do not overlap the full model estimate ± 1 standard error. The standard error was very small for the full model, where the Barn removed is "None", which prevented the overlap. In comparison to the full model, the maximum percent differences for parameter estimates across the two models were 29% and 44% for the intercept and ambient temperature, respectively. Across all models, the difference in NME and NMB (Table 6-6) in comparison to the selected model were substantial for NME and NMB, with values differing by up to 44% and 104%, respectively. Upon further review, it was determined that the MCs utilize different manure handling techniques. Specifically, IN5B used a flush system while NY5B used a scrape system. Additional models using this distinction will be tested for the final report.

Table 6-5. Model coefficients developed using the jackknife approach for NH_3 emissions from milking centers.

Site out	Effect	Estimate	Standard Error	p-value
NONE	Intercept	2.505637	0.10119	<.0001
	Ambient Temperature	0.046434	0.00335	<.0001
IN5BMC	Intercept	3.155214	0.06261	<.0001
	Ambient Temperature	0.026195	0.00297	<.0001
NY5BMC	Intercept	1.783938	0.09766	<.0001
	Ambient Temperature	0.064815	0.0051	<.0001

Table 6-6. Model fit statistics for the milking center NH_3 jackknife.

Site out	n	LNME[a] (%)	NME[b] (%)	ME[b] (kg day^{-1})	MB[b] (kg day^{-1})	NMB[b] (%)	Corr
NONE	713	18.245	54.184	12.63	3.017	12.941	0.364
IN5BMC	376	8.032	30.564	9.232	1.475	4.884	0.264
NY5BMC	337	16.728	43.666	6.819	-0.088	-0.561	0.706

[a] Based on transformed data (i.e., ln(NH_3)).
[b] Based on back-transformed data.

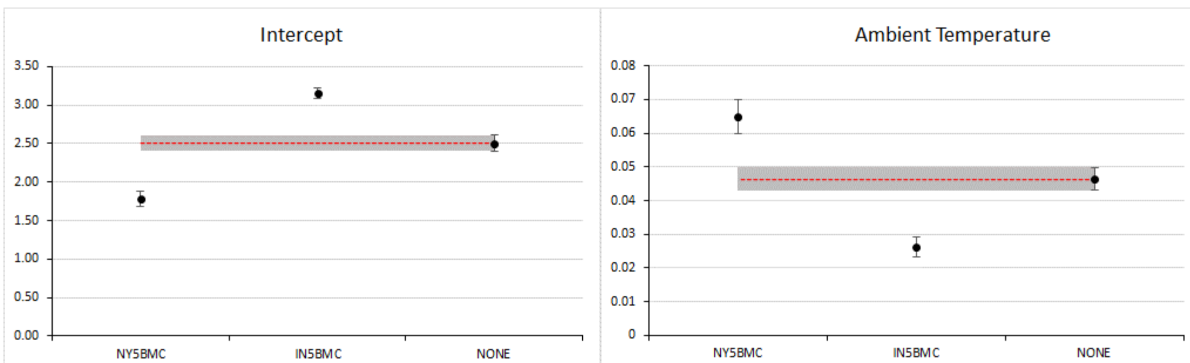

Figure 6-3. Comparison of variation in coefficients and standard errors for NH_3 milking center model.
Variation in coefficients and standard errors (black closed circle and ± SE bar) for each jackknife model with the selected NH_3 for milking center model coefficient ("None", gray band for ± SE) for each model parameter.

6.2.2 H_2S Model Evaluation

Table 6-7 and Figure 6-4 show the variation in coefficients and standard errors for the selected H_2S MC model ("None") and each of the jackknife models. The model coefficients from the jackknife approach were comparable across the withheld sets (Table 6-7) and remained significant (p-value <0.05) across all models. The plots in Figure 6-4 show that the results for all jackknife models do not overlap the full model estimate ± 1 standard error, except the intercept for the IN5B withheld model. Like the NH_3 model, the standard error was very small for the full model, where the Barn removed is "None", which prevented the overlap. In comparison to the full model, the maximum percent differences for parameter estimates across the two models were 4% and 120% for the intercept and ambient temperature, respectively. Across all models, the difference in NME and NMB (Table 6-8) in comparison to the selected model were substantial for NME and NMB, with values differing by less than 32% and 79%, respectively. As with the NH_3 models, adding a parameter for manure management system may account for the variability between sites. Additional models using this distinction will be tested for the final report.

Table 6-7. Model coefficients developed using the jackknife approach for H_2S emissions from milking centers.

Site out	Effect	Estimate	Standard Error	p-value
NONE	Intercept	6.898188	0.07052	<.0001
	Ambient Temperature	0.024053	0.00361	<.0001
IN5BMC	Intercept	6.99747	0.05042	<.0001
	Ambient Temperature	0.006415	0.0025	*0.011*
NY5BMC	Intercept	6.621331	0.13313	<.0001
	Ambient Temperature	0.052894	0.00711	<.0001

Table 6-8. Model fit statistics for the milking center H_2S jackknife.

Site out	n	LNME[a] (%)	NME[b] (%)	ME[b] (g day^{-1})	MB[b] (g day^{-1})	NMB[b] (%)	Corr
NONE	926	6.611	90.97	1204.3	-113.5	-8.571	0.347
IN5BMC	540	4.099	61.55	413.65	-12.28	-1.827	0.466
NY5BMC	386	8.707	84.8	1895.8	-284.9	-12.74	0.448

[a] Based on transformed data (i.e., ln(H_2S)).
[b] Based on back-transformed data.

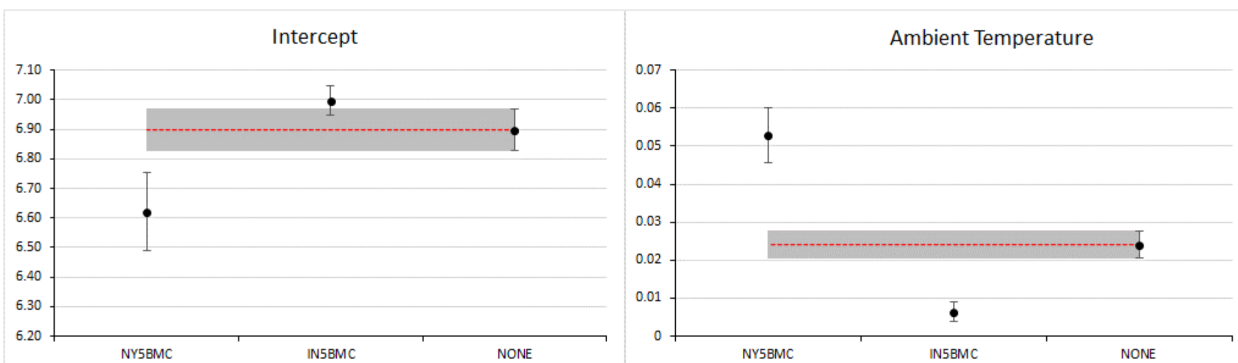

Figure 6-4. Comparison of variation in coefficients and standard errors for H2S milking center model.
Variation in coefficients and standard errors (black closed circle and ± SE bar) for each jackknife model with the selected H_2S milking center model coefficient ("None", gray band for ± SE) for each model parameter.

6.2.3 Particulate Matter Model Evaluation

For the MC particulate matter models, we did not complete jackknife analysis because there was only one site in the dataset. We also did not pursue a model evaluation using a k-fold cross validation technique based on previous SAB comments (SAB, 2013) recommending against using this method to select data for temporally correlated data. Future EPA efforts will investigate obtaining additional data that would allow for further model testing and evaluation and an improved emission model.

6.3 Naturally Ventilated Barn Model

A theme across all the results presented below is withholding WA4B B4 from the data set produces the largest differences across the models. This is likely due to WA4B B4 having an average daily inventory almost twice the other three barns included in NAEMS. Removing this barn greatly reduced the variability of inventory values in the data set that the model must capture.

6.3.1 NH_3 Model Evaluation

Table 6-9 and Figure 6-5 show the variation in coefficients and standard errors for the selected NH_3 naturally ventilated barn model (“None”) and each of the jackknife models. The model coefficients from the jackknife approach had some differences, most notable in the models with WA5B barns withheld (Table 6-9). For the models where WA4B B2 and B4 were withheld, one or both parameters were insignificant (p-value >0.05). The plots in Figure 6-5 show that the coefficients for these models also fall outside the full model estimate ± 1 standard error, except for wind speed. In comparison to the full model, where the barn removed is “None”, the maximum percent differences for parameter estimates across the models were 2292%, 235%, and 23% for the intercept, inventory, and wind speed, respectively. These largest differences all occurred for the model where WA5B B4 was removed. Across all models, the difference in NME and NMB (Table 6-10) in comparison to the selected model were the largest when WA5B B4 was withheld from the dataset, which increased the NME by 32% and decreased NMB by 174%. This is likely due to the reduced variability in inventory values caused by withholding WA4B B4.

Table 6-9. Model coefficients developed using the jackknife approach for NH_3 emissions from naturally ventilated barns.

Site out	Effect	Estimate	Standard Error	p-value[a]
NONE	Intercept	0.188357	0.2678	0.484
	Inventory	3.451939	0.4106	<.0001
	Wind Speed	0.048153	0.01837	0.009
CA5BB1	Intercept	0.734625	0.34491	*0.0385*
	Inventory	2.885717	0.49667	<.0001
	Wind Speed	0.043071	0.01873	*0.022*
CA5BB2	Intercept	0.730143	0.31533	*0.0253*
	Inventory	2.985909	0.45768	<.0001
	Wind Speed	0.040555	0.01847	*0.0288*
WA5BB2	Intercept	-0.84424	0.13064	<.0001
	Inventory	4.709923	0.19931	<.0001
	Wind Speed	0.019312	0.02201	**0.3808**
WA5BB4	Intercept	4.505901	1.29423	0.0009
	Inventory	-4.658465	2.41694	**0.0582**
	Wind Speed	0.037293	0.02361	**0.1149**

[a]Bold indicates insignificant p-values (i.e., > 0.05)

Table 6-10. Model fit statistics for the naturally ventilated barns NH_3 jackknife.

Site out	n	LNME[a] (%)	NME[b] (%)	ME[b] (kg day^{-1})	MB[b] (kg day^{-1})	NMB[b] (%)	Corr
NONE	605	27.084	75.233	12.818	0.828	4.862	0.636
CA5BB1	431	27.885	72.445	16.265	0.754	3.36	0.601
CA5BB2	396	25.139	69.96	16.995	1.728	7.114	0.599
WA5BB2	482	20.19	51.412	7.179	-0.504	-3.611	0.793
WA5BB4	506	32.404	98.929	9.575	-0.249	-2.571	0.207

[a] Based on transformed data (i.e., $\ln(NH_3)$).
[b] Based on back-transformed data.

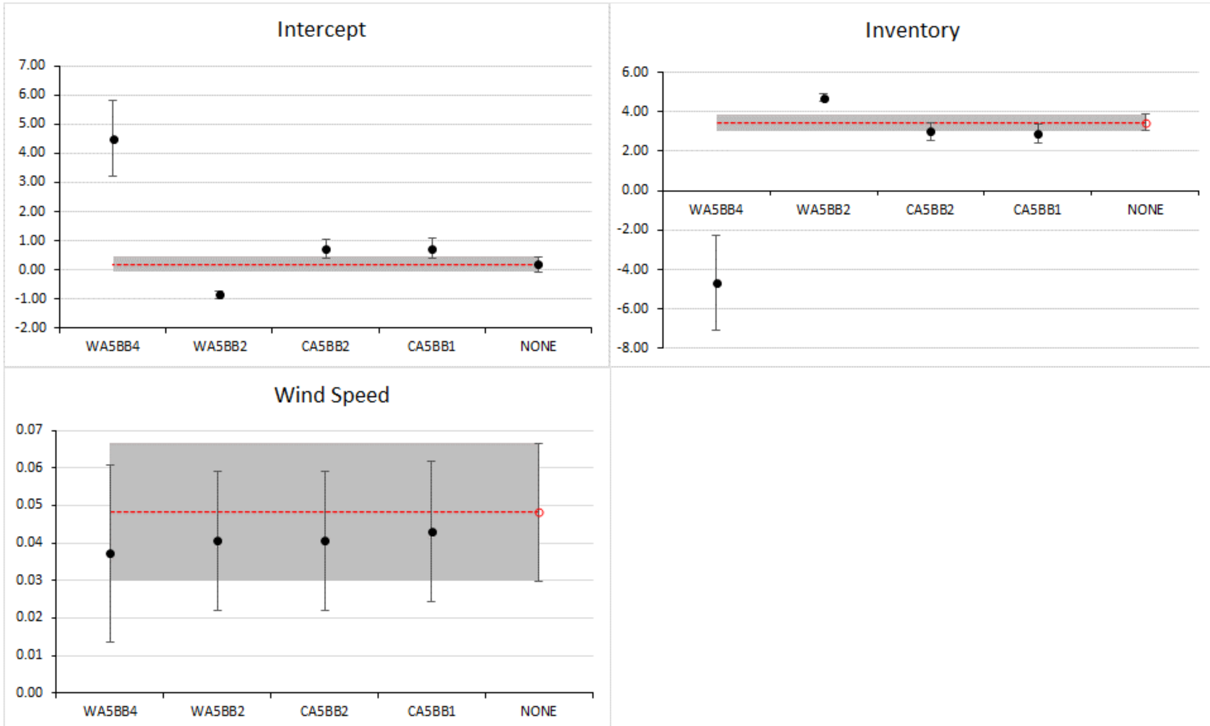

Figure 6-5. Comparison of variation in coefficients and standard errors for NH_3 naturally ventilated barn model.

Variation in coefficients and standard errors (black closed circle and ± SE bar) for each jackknife model with the selected NH_3 naturally ventilated barn model coefficient ("None", gray band for ± SE) for each model parameter.

6.3.2 H_2S Model Evaluation

Table 6-11 and Figure 6-6 show the variation in coefficients and standard errors for the selected H_2S naturally ventilated barn model ("None") and each of the jackknife models. The model coefficients from the jackknife approach had some differences, most notable the coefficient for inventory switched to negative in the model with WA5B B4 withheld (Table 6-11) and was insignificant (p-value >0.05). For the models where CA4B B1 and B2 were withheld, the coefficient from wind speed became insignificant. The plots in Figure 6-6 show that the coefficients for the model where WA5B B4 was withheld fall outside the full model estimate ± 1 standard error, except for wind speed. In comparison to the full model, where the barn removed is "None", the maximum percent differences for parameter estimates across the models occurred when WA5B was withheld and were 12%, 307%, and 75% for the intercept, inventory, and wind speed, respectively. Across all models, the difference in NME and NMB (Table 6-12) in comparison to the selected model were the largest when WA5B B4 was withheld from the dataset, which increased the NME by 17% and decreased NMB by 92%. Withholding WA4B B4 from the dataset reduced variability in inventory, which changed the significance of inventory as a predictive parameter and lowered the bias seen in the model.

Table 6-11. Model coefficients developed using the jackknife approach for H_2S emissions from naturally ventilated barns.

Site out	Effect	Estimate	Standard Error	p-value[a]
NONE	Intercept	6.541057	0.14434	<.0001
	Inventory	0.587702	0.21921	0.008
	Wind Speed	0.062678	0.02193	0.0044
CA5BB1	Intercept	6.593149	0.17451	<.0001
	Inventory	0.661236	0.24717	0.0083
	Wind Speed	0.036373	0.02762	**0.1886**
CA5BB2	Intercept	6.557214	0.18007	<.0001
	Inventory	0.6616	0.24813	0.0085
	Wind Speed	0.03755	0.03114	**0.2288**
WA5BB2	Intercept	6.559682	0.14376	<.0001
	Inventory	0.520217	0.21815	0.0182
	Wind Speed	0.075574	0.02381	0.0016
WA5BB4	Intercept	7.344257	0.58948	<.0001
	Inventory	-1.214405	1.08122	**0.2645**
	Wind Speed	0.109848	0.01931	<.0001

[a]Bold indicates insignificant p-values (i.e., > 0.05)

Table 6-12. Model fit statistics for the naturally ventilated barns H_2S jackknife.

Site out	n	LNME[a] (%)	NME[b] (%)	ME[b] (g day^{-1})	MB[b] (kg day^{-1})	NMB[b] (%)	Corr
NONE	647	6.461	77.092	677.49	-29.02	-3.302	0.33
CA5BB1	449	6.937	80.862	807.4	-34.82	-3.487	0.326
CA5BB2	380	7.784	89.878	915.9	-39.6	-3.886	0.32
WA5BB2	550	5.832	69.934	603.45	-36.4	-4.218	0.371
WA5BB4	562	5.662	69.734	490.88	-1.791	-0.254	0.249

[a] Based on transformed data (i.e., ln(H_2S)).
[b] Based on back-transformed data.

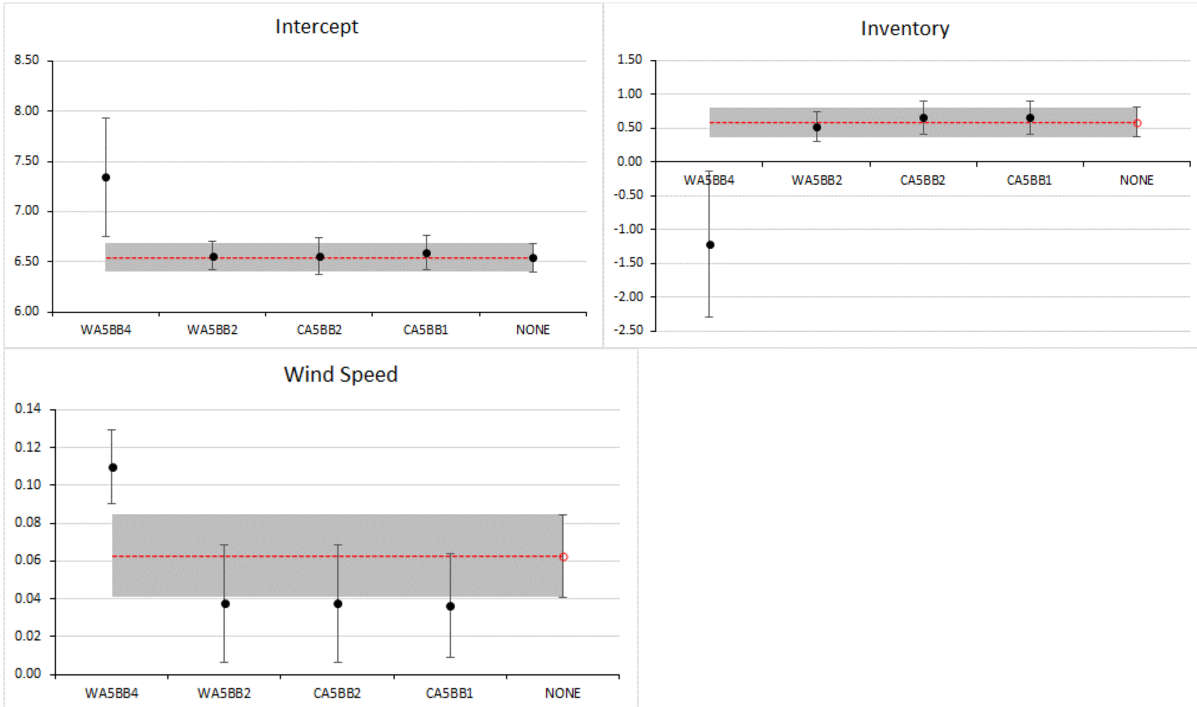

Figure 6-6. Comparison of variation in coefficients and standard errors for H_2S naturally ventilated barn model.

Variation in coefficients and standard errors (black closed circle and ± SE bar) for each jackknife model with the selected H_2S naturally ventilated barns model coefficient ("None", gray band for ± SE) for each model parameter.

6.3.3 PM_{10} Model Evaluation

Table 6-13 and Figure 6-7 show the variation in coefficients and standard errors for the selected PM_{10} naturally ventilated barn model ("None") and each of the jackknife models. The model coefficients from the jackknife approach had some differences, most notably the coefficient for inventory switched to negative in the model with WA5B B4 withheld (Table 6-13) and became insignificant. For the models where WA4B4 was withheld, the coefficient for ambient temperature also became insignificant (p-value >0.05). The plots in Figure 6-7 show that the coefficients for the model where WA5B B4 fall outside the full model estimate ± 1 standard error, except for ambient relative humidity. In comparison to the full model, where the barn removed is "None", the maximum percent differences for parameter estimates across the three models were 15%, 138%, 80%, 24%, and 20% for the intercept, inventory, ambient temperature, ambient relative humidity, and wind speed, respectively. Across all models, the difference in NME and NMB (Table 6-14) in comparison to the selected model were the largest when WA5B B4 was withheld from the dataset, which increased the NME by 16% and decreased NMB by 37%.

Table 6-13. Model coefficients developed using the jackknife approach for PM_{10} emissions from naturally ventilated barns.

Site out	Effect	Estimate	Standard Error	p-value[a]
NONE	Intercept	7.64258	0.16783	<.0001
	Inventory	1.525009	0.14917	<.0001
	Ambient Temperature	0.011864	0.00333	0.0004
	Ambient Relative Humidity	-0.01521	0.00154	<.0001
	Wind Speed	0.173698	0.01064	<.0001
CA5BB1	Intercept	7.695149	0.18357	<.0001
	Inventory	1.399494	0.16322	<.0001
	Ambient Temperature	0.018588	0.00384	<.0001
	Ambient Relative Humidity	-0.01564	0.00178	<.0001
	Wind Speed	0.181527	0.0118	<.0001
CA5BB2	Intercept	7.726456	0.19289	<.0001
	Inventory	1.420078	0.16427	<.0001
	Ambient Temperature	0.014917	0.00397	0.0002
	Ambient Relative Humidity	-0.015634	0.00196	<.0001
	Wind Speed	0.175816	0.01265	<.0001
WA5BB2	Intercept	6.831711	0.24796	<.0001
	Inventory	2.045075	0.17514	<.0001
	Ambient Temperature	0.020629	0.00419	<.0001
	Ambient Relative Humidity	-0.0115	0.00199	<.0001
	Wind Speed	0.192966	0.01355	<.0001
WA5BB4	Intercept	8.81874	0.46389	<.0001
	Inventory	-0.576586	0.90282	**0.5241**
	Ambient Temperature	0.002425	0.00354	**0.494**
	Ambient Relative Humidity	-0.012854	0.00154	<.0001
	Wind Speed	0.138497	0.01071	<.0001

[a]Bold indicates insignificant p-values (i.e., > 0.05)

Table 6-14. Model fit statistics for the naturally ventilated barns PM_{10} jackknife.

Site out	N	LNME[a] (%)	NME[b] (%)	ME[b] (g day^{-1})	MB[b] (kg day^{-1})	NMB[b] (%)	Corr
CA5BB1	1214	5.102	79.404	4772.9	-701.9	-11.68	0.372
CA5BB2	1088	5.412	81.443	5265.9	-688.8	-10.65	0.358
NONE	1457	4.896	82.575	4195.9	-668.8	-13.16	0.374
WA5BB2	1024	4.537	76.692	3944.7	-926.4	-18.01	0.462
WA5BB4	1045	4.156	95.397	2384	-277.5	-11.1	0.208

[a] Based on transformed data (i.e., ln(PM_{10})).

[b] Based on back-transformed data.

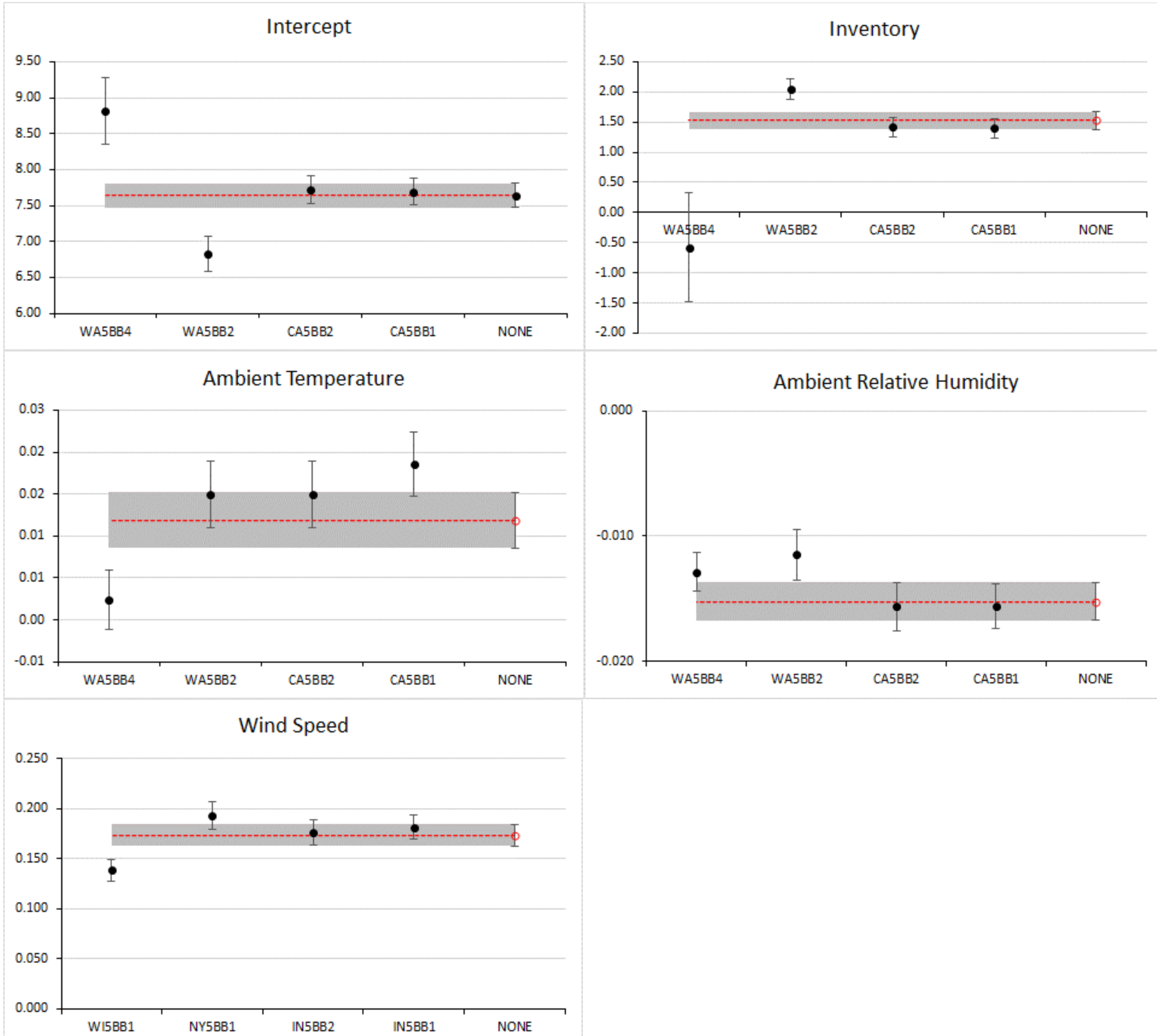

Figure 6-7. Comparison of variation in coefficients and standard errors for PM_{10} naturally ventilated barn model.

Variation in coefficients and standard errors (black closed circle and ± SE bar) for each jackknife model with the selected PM_{10} naturally ventilated barns model coefficient ("None", gray band for ± SE) for each model parameter.

6.3.4 $PM_{2.5}$ Model Evaluation

The analysis for the $PM_{2.5}$ naturally ventilated barns was a departure from the other evaluations, more of the models have coefficients that vary and are insignificant (Table 6-15). When compared to the full model, the coefficients vary up to 125%, 4,370%, 406%, 21,410%, and 25% for the intercept, inventory, ambient temperature, ambient relative humidity, and wind speed, respectively, and the large differences are not limited to the model with WA5B B4 withheld. Table 6-15 and Figure 6-8 show the variation in coefficients and standard errors for the selected $PM_{2.5}$ naturally ventilated barn model ("None") and each of the jackknife models. The plots in Figure 6-8 show that most of the coefficients for the models overlapped the full model estimate ± 1 standard error. The models for the WA5B barn both fell outside for the intercept and inventory, and the WA5B B1 model fell outside for ambient relative humidity. The difference in NME and NMB (Table 6-16) across the models with a barn withheld compared to the selected model changed by as much as 40% for NME and 1,566% for NMB.

Table 6-15. Model coefficients developed using the jackknife approach for $PM_{2.5}$ emissions from naturally ventilated barns.

Site out	Effect	Estimate	Standard Error	p-value[a]
NONE	Intercept	7.068797	1.15954	<.0001
	Inventory	-0.220453	0.75959	**0.7753**
	Ambient Temperature	0.01121	0.02585	**0.6681**
	Ambient Relative Humidity	-0.003808	0.01023	**0.7125**
	Wind Speed	0.218968	0.0563	0.0002
CA5BB1	Intercept	6.922323	1.15234	<.0001
	Inventory	-0.432386	0.76218	**0.579**
	Ambient Temperature	0.015697	0.02584	**0.5493**
	Ambient Relative Humidity	0.001448	0.01082	**0.8946**
	Wind Speed	0.232037	0.05911	0.0002
CA5BB2	Intercept	5.999344	0.97451	<.0001
	Inventory	-0.637279	0.60064	**0.3062**
	Ambient Temperature	0.056741	0.02418	0.0293
	Ambient Relative Humidity	0.012843	0.00944	**0.1876**
	Wind Speed	0.237943	0.06181	0.0002
WA5BB2	Intercept	-1.742952	1.50484	**0.2592**
	Inventory	4.220142	0.79698	<.0001
	Ambient Temperature	0.135315	0.02619	<.0001
	Ambient Relative Humidity	0.049877	0.01071	0.0001
	Wind Speed	0.221498	0.0743	0.0044
WA5BB4	Intercept	13.01778	2.71873	0.0035
	Inventory	-9.854431	5.35402	**0.1099**
	Ambient Temperature	-0.005191	0.0234	**0.8255**
	Ambient Relative Humidity	-0.012329	0.00844	**0.1545**
	Wind Speed	0.163688	0.02852	<.0001

[a]Bold indicates insignificant p-values (i.e., > 0.05)

Table 6-16. Model fit statistics for the naturally ventilated barns $PM_{2.5}$ jackknife.

Site out	n	LNME[a] (%)	NME[b] (%)	ME[b] ($g\ day^{-1}$)	MB[b] ($kg\ day^{-1}$)	NMB[b] (%)	Corr
CA5BB1	89	8.295	59.345	1154	9.362	0.481	0.651
CA5BB2	78	6.288	37.718	820.71	50.306	2.312	0.821
NONE	93	8.789	62.65	1167	-19.48	-1.046	0.665
WA5BB2	56	5.461	48.197	625.08	198.89	15.335	0.901
WA5BB4	56	5.877	54.701	1018.8	-91.41	-4.908	0.718

[a] Based on transformed data (i.e., $\ln(NH_3)$).
[b] Based on back-transformed data.

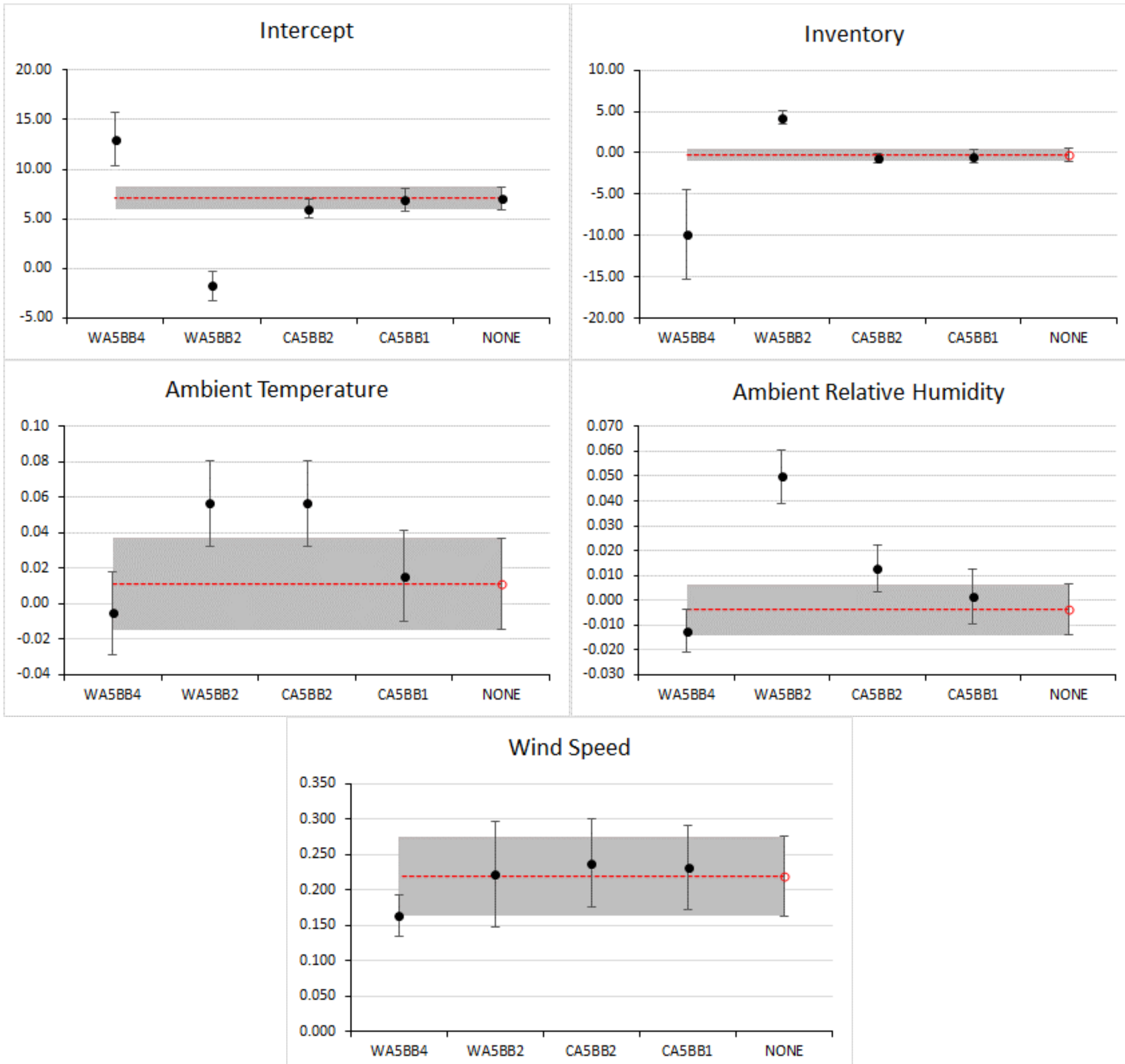

Figure 6-8. Comparison of variation in coefficients and standard errors for $PM_{2.5}$ naturally ventilated barn model.

Variation in coefficients and standard errors (black closed circle and ± SE bar) for each jackknife model with the selected $PM_{2.5}$ naturally ventilated barn model coefficient ("None", gray band for ± SE) for each model parameter.

6.3.5 TSP Model Evaluation

Table 6-17 and Figure 6-9 show the variation in coefficients and standard errors for the selected TSP naturally ventilated barn model ("None") and each of the jackknife models. The model coefficients from the jackknife approach were comparable across the withheld sets (Table 6-17) and remained significant (p-value <0.05) across all models, except for ambient temperature in the model where WA5BB4 was removed. The plots in Figure 6-9 show that all the coefficients overlap the full model estimate ± 1 standard error, except for inventory for the model where WA5BB4 was removed. In comparison to the full model, that is where the barn removed is "None", the maximum percent differences for parameter estimates across the three models were

17%, 141%, 56%, 25%, and 18% for the intercept, inventory, ambient temperature, ambient relative humidity, and wind speed, respectively. Across all models, the difference in NME and NMB (Table 6-18) in comparison to the selected model changed by as much as 16% for NME and 160% for NMB.

Table 6-17. Model coefficients developed using the jackknife approach for TSP emissions from naturally ventilated barns.

Site out	Effect	Estimate	Standard Error	p-value[a]
NONE	Intercept	7.868847	0.58294	<.0001
	Inventory	2.953893	0.48928	<.0001
	Ambient Temperature	0.034508	0.01069	0.0021
	Ambient Relative Humidity	-0.033997	0.00508	<.0001
	Wind Speed	0.248191	0.04211	<.0001
CA5BB1	Intercept	7.667585	0.48937	<.0001
	Inventory	2.477977	0.44054	<.0001
	Ambient Temperature	0.048926	0.01002	<.0001
	Ambient Relative Humidity	-0.026332	0.00445	<.0001
	Wind Speed	0.294612	0.03075	<.0001
CA5BB2	Intercept	7.786063	0.68673	<.0001
	Inventory	2.998098	0.56151	<.0001
	Ambient Temperature	0.034621	0.01325	0.0127
	Ambient Relative Humidity	-0.032651	0.00638	<.0001
	Wind Speed	0.238451	0.05294	<.0001
WA5BB2	Intercept	6.616785	0.81649	<.0001
	Inventory	3.762081	0.52641	<.0001
	Ambient Temperature	0.048947	0.01322	0.0005
	Ambient Relative Humidity	-0.026808	0.00659	0.0001
	Wind Speed	0.235277	0.04912	<.0001
WA5BB4	Intercept	6.558937	1.4622	<.0001
	Inventory	7.12147	2.73945	0.0131
	Ambient Temperature	0.0151	0.01245	**0.2317**
	Ambient Relative Humidity	-0.042411	0.0058	<.0001
	Wind Speed	0.203451	0.05134	0.0001

[a]Bold indicates insignificant p-values (i.e., > 0.05)

Table 6-18. Model fit statistics for the naturally ventilated barns TSP jackknife.

Site out	n	LNME[a] (%)	NME[b] (%)	ME[b] (g day^{-1})	MB[b] (kg day^{-1})	NMB[b] (%)	Corr
CA5BB1	135	4.902	44.574	9954.9	-1381	-6.185	0.875
CA5BB2	146	6.598	55.473	10927	-932.6	-4.734	0.799
NONE	205	6.07	52.783	8639.5	-492.6	-3.009	0.807
WA5BB2	167	5.659	49.037	7695.7	-297.8	-1.898	0.821
WA5BB4	167	6.446	57.093	5315	12.023	0.129	0.666

[a] Based on transformed data (i.e., ln(TSP)).
[b] Based on back-transformed data.

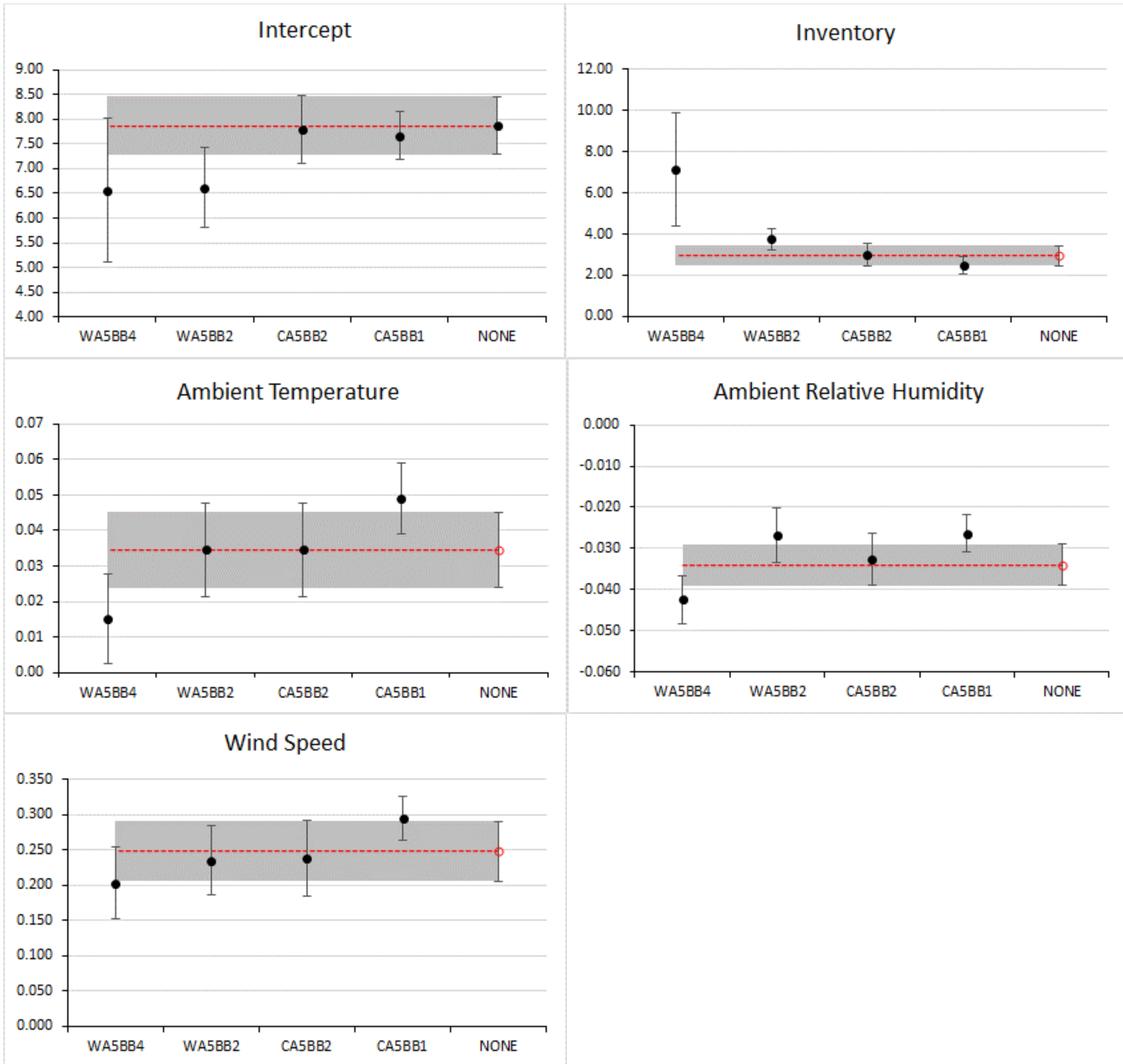

Figure 6-9. Comparison of variation in coefficients and standard errors for TSP naturally ventilated barn model.

Variation in coefficients and standard errors (black closed circle and ± SE bar) for each jackknife model with the selected TSP naturally ventilated barn model coefficient ("None", gray band for ± SE) for each model parameter.

6.4 Open Sources

For the corral models, we did not complete jackknife analysis because there was only one site in the dataset. We also did not pursue a model evaluation using a k-fold cross validation technique based on previous SAB comments (SAB, 2013) recommending against using this method to select data for temporally correlated data. Future EPA efforts will look into obtaining additional data that would allow for further model testing and evaluation and an improved emission model.

6.4.1 NH_3 Model Evaluation

Table 6-19 and Figure 6-10 show the variation in coefficients and standard errors for the selected NH_3 open source model ("None") and each of the jackknife models. The model coefficients from the jackknife approach were comparable across the withheld sets (Table 6-19) and remained significant (p-value <0.05) across all models. The plots in Figure 6-10 show that the results for all jackknife models do not overlap the full model estimate ± 1 standard error, except the model where IN5A was withheld for ambient temperature. In comparison to the full model, the maximum percent differences for parameter estimates across the two models were 13% and 24% for the intercept and ambient temperature, respectively. Across all models, the difference in NME and NMB (Table 6-20) in comparison to the selected model were substantial for NME and NMB, with values differing by up to 38% and 77%, respectively.

Table 6-19. Model coefficients developed using the jackknife approach for NH_3 emissions from open sources.

Site out	Effect	Estimate	Standard Error	p-value
NONE	Intercept	1.396734	0.0248	<.0001
	Ambient Temperature	0.027201	0.00195	<.0001
IN5A	Intercept	1.576653	0.06521	<.0001
	Ambient Temperature	0.033848	0.00616	<.0001
WI5A	Intercept	1.323888	0.01843	<.0001
	Ambient Temperature	0.031531	0.00152	<.0001

Table 6-20. Model fit statistics for the open sources NH_3 jackknife.

Site out	n	LNME[a] (%)	NME[b] (%)	ME[b] (g day^{-1})	MB[b] (kg day^{-1})	NMB[b] (%)	Corr
IN5A	28	12.225	53.586	0.865	-0.048	-2.958	0.84
NONE	157	9.709	38.766	0.712	-0.034	-1.859	0.821
WI5A	129	8.159	31.915	0.601	-0.008	-0.433	0.887

[a] Based on transformed data (i.e., ln(NH_3)).
[b] Based on back-transformed data.

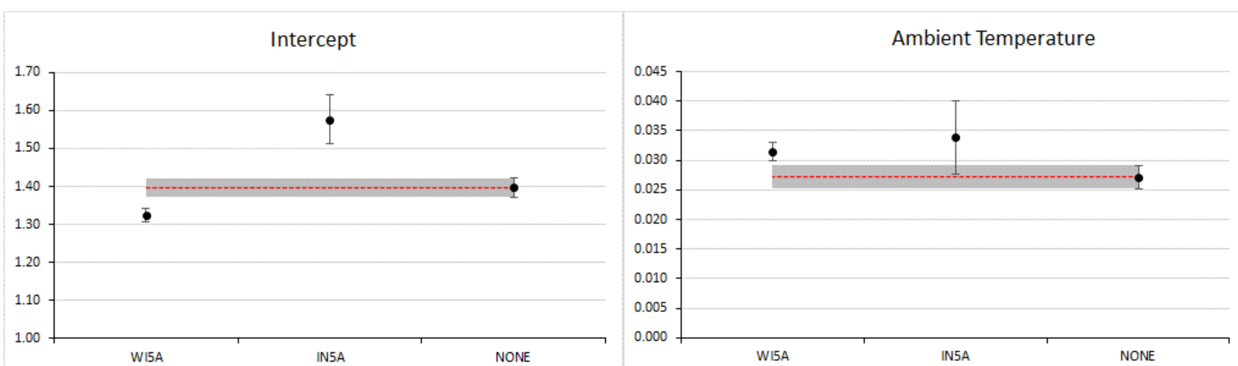

Figure 6-10. Comparison of variation in coefficients and standard errors for NH_3 open source model. Variation in coefficients and standard errors (black closed circle and ± SE bar) for each jackknife model with the selected NH_3 open source model coefficient ("None", gray band for ± SE) for each model parameter.

6.4.2 H_2S Model Evaluation

Table 6-21 and Figure 6-11 show the variation in coefficients and standard errors for the selected H_2S open source model ("None") and each of the jackknife models. The model coefficients from the jackknife approach were comparable across the withheld sets (Table 6-21) and remained significant (p-value <0.05) across all models. The plots in Figure 6-11 show that the results for all jackknife models do not overlap the full model estimate ± 1 standard error, except the model where IN5A was withheld. In comparison to the full model, the maximum percent differences for parameter estimates across the two models were 7% and 68% for the intercept and ambient temperature, respectively. Across all models, the difference in NME and NMB (Table 6-22) in comparison to the selected model were substantial for NME and NMB, with values differing by up to 20% and 98%, respectively.

Table 6-21. Model coefficients developed using the jackknife approach for H2S emissions from open sources.

Site out	Effect	Estimate	Standard Error	p-value
NONE	Intercept	1.189272	0.03163	<.0001
	Ambient Temperature	0.010557	0.0022	<.0001
IN5A	Intercept	1.109037	0.01639	<.0001
	Ambient Temperature	0.003382	0.00127	0.0203
WA5A	Intercept	1.189558	0.03019	<.0001
	Ambient Temperature	0.011581	0.00218	<.0001
WI5A	Intercept	1.226774	0.04029	<.0001
	Ambient Temperature	0.009725	0.00256	0.0005

Table 6-22. Model fit statistics for the open source H_2S jackknife.

Site out	n	LNME[a] (%)	NME[b] (%)	ME[b] (g day^{-1})	MB[b] (kg day^{-1})	NMB[b] (%)	Corr
NONE	70	9.258	63.688	0.499	-0.011	-1.403	0.587
IN5A	13	1.475	76.161	0.052	0	-0.032	0.782
WA5A	69	8.922	61.188	0.484	-0.01	-1.321	0.615
WI5A	58	9.575	58.078	0.542	-0.009	-0.914	0.525

[a] Based on transformed data (i.e., $\ln(H_2S)$).
[b] Based on back-transformed data.

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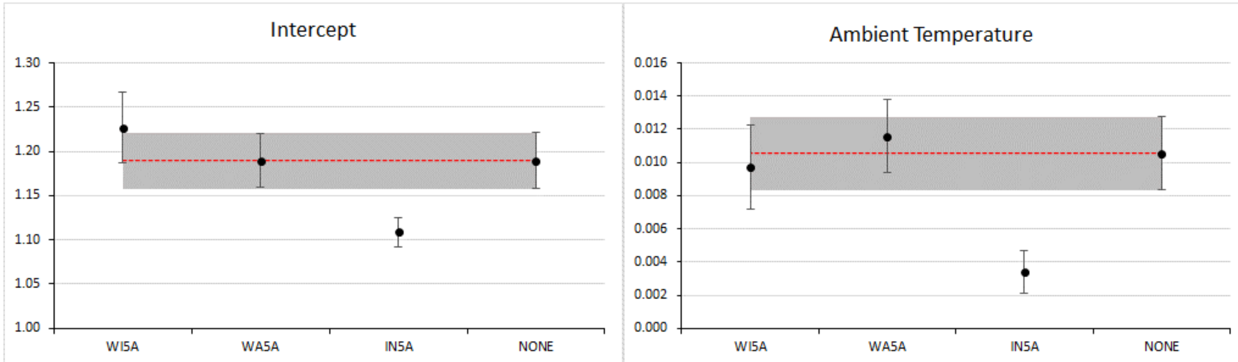

Figure 6-11. Comparison of variation in coefficients and standard errors for H_2S open source model. Variation in coefficients and standard errors (black closed circle and ± SE bar) for each jackknife model with the selected H_2S open source model coefficient ("None", gray band for ± SE) for each model parameter.

7 ANNUAL EMISSION ESTIMATES AND MODEL UNCERTAINTY

To estimate annual pollutant emissions, the results of the daily emission models are summed over the number of operating days per year. This approach requires values for the necessary ambient and barn parameters. For an actual emissions estimate, the daily estimates are based on meteorology from nearby monitors and barn occupancy and weight records for the year from the producer. For farms with multiple barns, annual emissions are determined for individual barns and summed across barns to calculate total annual farm-scale emissions.

As noted in Section 6 of the main report, the model results are transformed values of the emissions. To convert to the native emission units (e.g., kg or g), the back transformation equation (Equation from Section 6 of the main All Sector report) is applied using the values of $\overline{E_i}$ and C provided in Table 7-1 for each emission model. Section 8 contains an example of this calculation.

Table 7-1. Back transformation parameters

Animal Type	Pollutant	$\overline{E_i}$	C	Resulting units
Mechanically Ventilated barn	NH_3	1.03966	3	kg/d
Mechanically Ventilated barn	H_2S	1.11434	628	g/d
Mechanically Ventilated barn	PM_{10}	[a]	[a]	[a]
Mechanically Ventilated barn	$PM_{2.5}$	[a]	[a]	[a]
Mechanically Ventilated barn	TSP	[a]	[a]	[a]
Milking Center	NH_3	1.21693	3	g/d/hd
Milking Center	H_2S	1.30119	628	kg/d/hd
Milking Center	PM_{10}	1.0057	2200	g/d/hd
Milking Center	$PM_{2.5}$	1.00796	680	g/d/hd
Milking Center	TSP	1.0311	978	g/d/hd
Naturally Ventilated barn	NH_3	1.46499	3	g/d
Naturally Ventilated barn	H_2S	1.23366	628	kg/d
Naturally Ventilated barn	PM_{10}	1.27211	2200	g/d
Naturally Ventilated barn	$PM_{2.5}$	1.33005	680	g/d
Naturally Ventilated barn	TSP	1.25126	978	g/d
Lagoon/basin	NH_3	1.0079	3	kg/d m^2
Lagoon/basin	H_2S	1.03006	3	kg/d m^2
Corral	NH_3	1.0066	3	g/d-m^2-1,000 hd
Corral	H_2S	1.00007	3	g/d-m^2-1,000 hd

[a] Annual models were not calculated to allow time to optimize the daily models.

EPA also developed an estimate of uncertainty for total annual emissions, characterized by the random error in the model prediction using an approach similar to the Monte Carlo analysis. Under this approach, EPA developed the statistical properties of predicted annual emissions by replicating annual sums of daily emissions. EPA ran these simulations for several different intervals of a predictor variable that fell within the observed range. For example, naturally ventilated barn inventory ranged from 500 to 600 head. The simulations were then run for inventory intervals of 5 head (e.g., 500, 505, 510). Table 7-2 lists the predictor variable and the number of intervals used for the annual uncertainty simulations for each model.

Table 7-2. Annual Uncertainty Model Details

Source Type	Pollutant	Simulation Variable	Number of Simulations	k	Emission Units
Mechanically ventilated barn - Flush	H_2S	Inventory	10,000	3,457,126	g/d
Mechanically ventilated barn - Scrape	H_2S	Inventory	10,000	3,453,490	g/d
Mechanically ventilated barn - Flush	NH_3	Inventory	10,000	35,180	kg/d
Mechanically ventilated barn - Scrape	NH_3	Inventory	10,000	35,258	kg/d
Mechanically ventilated barn	PM_{10}	[a]			
Mechanically ventilated barn	$PM_{2.5}$	[a]			
Mechanically ventilated barn	TSP	[a]			
Milking Center	H_2S	Ambient temperature	10,000	9,392,217	g/d-1,000 hd
Milking Center	NH_3	Ambient temperature	10,000	55,494	kg/d-1,000 hd
Milking Center	PM_{10}	Ambient temperature	10,000	1,082,872	g/d-1,000 hd
Milking Center	$PM_{2.5}$	Ambient temperature	10,000	498,298	g/d-1,000 hd
Milking Center	TSP	Ambient temperature	10,000	1,557,418	g/d-1,000 hd
Naturally ventilated barn	H_2S	Inventory	10,000	4,963,976	g/d
Naturally ventilated barn	NH_3	Inventory	10,000	73,495.7	kg/d
Naturally ventilated barn	PM_{10}	Inventory	10,000	59,332,385	g/d
Naturally ventilated barn	$PM_{2.5}$	Inventory	10,000	5,181,114	g/d
Naturally ventilated barn	TSP	Inventory	10,000	83,299,795	g/d
Lagoon/basin	H_2S	Ambient temperature	10,000	2,606.3	g/d m^2
Lagoon/basin	NH_3	Ambient temperature	10,000	4,114.1	g/d m^2
Corral	H_2S	Ambient relative humidity	10,000	18,479.4	mg/d-m^2-1,000 hd
Corral	NH_3	Ambient temperature	10,000	1,278.5	g/d-m^2-1,000 hd

[a] Annual models were not calculated to allow time to optimize the daily models.

Simulations were run 10,000 times for each day for each interval to create an average uncertainty associated with the annual emissions from a single barn. EPA added a random residual to each day of the simulation to replicate the variability that would be seen in a realworld application of the model. For each of the intervals run, EPA calculated standard statistics (i.e., minimum, median, mean, maximum, range) and used these to calculate the uncertainty for a single source via:

$$Single\ source\ uncertainty\ =\ 0.5 \times \left(\frac{Range}{Median\ annual\ emission}\right) \times 100 \qquad \text{Equation 19}$$

EPA then plotted this single barn uncertainty against its associated annual emissions. This plot was then fit with a curve to model annual percent uncertainty for a single source (i.e., barn, lagoon, basin). For all uncertainty models, the curve took the form of:

$$Uncertainty\ (\%) = \frac{k}{Annual\ Emissions} \qquad \text{Equation 20}$$

Where:

k is a constant, listed in Table 7-2, and

Annual Emissions are the total sum from the daily models.

EPA has not calculated particulate matter annual uncertainty models for the mechanically ventilated barns in order to allow more time to optimize the models. EPA will include the annual uncertainty models in the final report.

Multiplying this percentage by the annual emissions calculated for the source provides the resulting uncertainty in the native emission units (e.g., kg or g), demonstrated in Equation 21.

$$Resulting\ Uncertainty = \frac{Percent\ uncertainty\ \times Annual\ emissions}{100} \qquad \text{Equation 21}$$

To propagate the uncertainty across all sources at a farm, EPA combined the estimates of absolute uncertainty for each source according to:

$$Total\ farm\ uncertainty = \sqrt{(U_{B1})^2 + \cdots + (U_{Bi})^2 + (U_{L1})^2 + \cdots + \left(U_{Lj}\right)^2} \qquad \text{Equation 22}$$

Where:

Total farm uncertainty = total uncertainty for the total emissions from all farm sources.

UBi = the resulting uncertainty for barns, with i representing the total number of barns on the farm,

ULj = the resulting uncertainty for manure sheds, with j representing the total number of open sources on the farm.

EPA notes that the uncertainty framework described above reflects the random uncertainty (error) in the prediction of daily emissions calculated using the emission models, which includes the random uncertainty in the measurements used to develop the equation. This framework does not, however, consider systematic error (e.g., bias) in either NAEMS measurements or the emission model. Section 8 provides an example of how the daily, annual, and annual uncertainty calculations are completed.

8 MODEL APPLICATION AND ADDITIONAL TESTING

Key to the development of any model is the demonstration of the use and practical examples of how the model behaves and replicates independent data. This section provides a series of example calculations to demonstrate the application of the models (Section 8.1), the sensitivity of the models to their inputs (Section 8.2), a comparison of the models developed to literature (section 8.3), and a test of model performance against an independent data set (Section 8.4). Finally, this section wraps up with a discussion of data limitations that could be driving sensitivity or performance issues.

8.1 Model Application Example

The following sections demonstrate how the daily emission models from Section 5 and the annual uncertainty from Section 7 are used to calculate emissions for an example farm for each structure type. Details about the use of the emission models to demonstrate compliance with Clean Air Act (CAA) permitting thresholds will be addressed in a forthcoming implementation document. This example is provided to walk through a calculation to demonstrate how the system of equations is intended to work.

In Section 6.4 of the main report, the data were log-transformed prior to developing the models, the results of the models will need to be back-transformed per Equation 7 to represent emissions in units of grams or kilograms.

$$Y_{bp} = e^{\widehat{(y_p)}} * \overline{E_\iota} - C$$

Where:

Y_{bp} is the back transformed predicted emissions;
y_p is the model predicted (log transformed) emissions;
$\overline{E_i}$ is the average residual between model-predicted and observed (or measured) emissions on the natural log scale; and
C is a constant added to the data prior to the log transformation.

To complete the back transformation, users need two parameters that are specific to each model: 1) $\overline{E_\iota}$, the residual between model-predicted and observed (or measured) emissions on the natural log scale; and 2) C, which is a constant added to the data prior to the log transformation. The values for $\overline{E_\iota}$ and C for the dairy models are provided in Table 7-1.

Once the emission models are finalized, EPA will work with stakeholders to develop a tool to facilitate the calculation of barn and open source emissions. For transparency and to help stakeholders better understand the process of calculating emissions, this section will walk through example calculations to estimate NH_3 emissions from a mechanically ventilated barn, milking center, naturally ventilated barn, and lagoon.

The examples in this section use a fictional farm located in Brown County, Wisconsin on January 1, 2021. Wisconsin was chosen as it is a top five milk producing state according to the USDA Economic Research Service data (https://www.ers.usda.gov/webdocs/DataFiles/48685/milkcowsandprod.xlsx?v=9708). The ambient weather data used in each equation can be obtained for free from several sources including the National Centers for Environmental Information (NCEI; https://www.ncdc.noaa.gov/cdo-web/). NCEI stores hourly and daily ambient data from various monitors located across the country that can be used for emission estimation. The Green Bay International Airport, WI site (WBAN: 14898), a Local Climatological Data (LCD) Station located in Brown County was selected as to represent the meteorological information for a theoretical farm for testing. Its data file provides the daily average values of the key meteorological parameters needed for calculations.

The naturally ventilated barn and corral models presented in this report use wind speed in the model calculations. The height at which wind speed is measured influences the observation as friction with the surface will affect the observation. That means, the closer to the ground the measurement is made, the more friction will act to slow the speed. NAEMS winds were monitored at a height of approximately 2.5 meters at open sources and site specific heights at barn sources, while the National Weather Service (NWS) sites archived at NCEI are typically monitored at 10m. Therefore, the difference in measurement heights between NAEMS and NWS requires an adjustment to the wind. The relationship between wind speed and height is well established and can be written as:

$$\frac{V}{V_r} = \left(\frac{Z}{Z_r}\right)^m \qquad \text{Equation 23}$$

Where V_r is the wind velocity at a height of 10 m (Z_r) and V is the wind velocity height at 2.5 m (Z), and m is the friction coefficient, which is a function of atmospheric stability and the underlying surface roughness. The value of m can vary, ranging from 0 to 1, with lower values over low roughness surfaces (water) and higher values for rougher terrain (e.g., rolling terrain or urban settings) (Arya, 1999). To adjust the 10m NWS wind measurement to a height comparable to the study data used to develop the model, the equation can be rewritten, resulting in

$$V_{2.5m} = \left(\frac{2.5}{10}\right)^m \times V_{10m} \qquad \text{Equation 23}$$

EPA is determining the best value of m to use for corrals and naturally ventilated barns. For the purposes of the example calculations, we will use the average daily wind speed from the NWS site.

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In addition to weather information, the models also use the number of cows present in the barn. For this fictitious farm, we assume the barn has a capacity of 500 cows. The equations use thousands of cows, so this value will be divided by 1,000 for use in the emission models. A summary of the input values for the example calculations is provided in Table 8-1.

Table 8-1. Daily calculation parameter values

Parameter	Value
Daily Average Ambient Temperature (°C)	-9.4
Daily Average Relative Humidity (%)	86
Average Wind Speed (ms^{-1})	2.55
Inventory (thousand head)	0.50

8.1.1 Mechanically Ventilated Barn Example

For this example, we will assume the barn uses a scrape manure management system, which would use Equation 1, in Section 5.1, to calculate the log transformed values as follows:

$$ln(NH_3) = 1.86494 + 1.773832 * Inventory + 0.029586 * Amb_T$$

$$\ln(NH_3) = 1.86494 + 0.1.773832 * \left(\frac{500}{1{,}000}\right) + 0.029586 * -9.4$$

$$\ln(NH_3) = 1.86494 + 0.8869 - 0.2781$$

$$\ln(NH_3) = 2.4737$$

To back transform the results to NH_3 in kg, use Equation 7, from the main report. For a flush managed mechanically ventilated barn, $\overline{E_\iota}$ is 1.03966 and C is 3.

$$NH_3 = e^{2.4731} \times 1.03966 - 3$$

This comes to 9.34 kg NH_3 for the day. This process is repeated for each day, then the daily emissions are added together to get an annual estimate of emissions. After considering the values for each day in 2021, the total annual emission for the barn was calculated at 7,108 kg. To calculate the uncertainty associated with this estimate, use Equation 17 with the value of k from Table 7-1. This results in an annual uncertainty of:

$$Uncertainty\ (\%) = \frac{35{,}180}{7{,}108.31} = 4.95\%$$

This translates to an uncertainty of ± 351kg. Thus, the final annual estimate for this barn is 7,108kg ± 352 kg. This calculation would be repeated for any other mechanically ventilated barn on the site.

8.1.2 Milking Center Example

For this example, we will use Equation 5, in Section 5.2, to calculate the log transformed values as follows:

$$ln(NH_3) = 2.505637 + 0.046434 * Amb_T$$

$$\ln(NH_3) = 2.505637 + 0.04643 * -9.4$$

$$\ln(NH_3) = 2.505637 - 0.4368$$

$$\ln(NH_3) = 2.0692$$

To back transform the results to NH_3 in kg, use Equation 7, from the main report. For a milking center, $\overline{E_\iota}$ is 1.03966 and C is 3.

$$NH_3(\frac{\text{kg}}{\text{d} \cdot 1{,}000\ \text{head}}) = e^{2.0692} \times 1.2169 - 3$$

$$NH_3(\frac{\text{kg}}{\text{d} \cdot 1{,}000\ \text{head}}) = 6.64$$

This comes to 6.64 kg NH_3/d-1,000 head, which we can multiply by the 0.5 thousand head to get 3.32 kg NH_3 for the day. This process is repeated for each day, then the daily emissions are added together to get an annual estimate of emissions. After considering the values for each day in 2021, the total annual emissions for the milking center were calculated at 4,161.53 kg. To calculate the uncertainty associated with this estimate, use Equation 17 with the value of k from Table 7-1. This results in an annual uncertainty of:

$$Uncertainty\ (\%) = \frac{55{,}494}{4{,}161.53} = 13.33\%$$

This translates to an uncertainty of ± 555 kg. Thus, the final annual estimate for this milking center is 4,161.53 kg ± 554.94 kg.

8.1.3 Naturally Ventilated Barn Example

For this example, we will use Equation 10, in Section 5.3, to calculate the log transformed values as follows:

$$ln(NH_3) = 0.188357 + 3.451939 * Inventory + 0.048153 * WindSpeed$$

$$ln(NH_3) = 0.188357 + 3.451939 * Inventory + 0.048153 * WindSpeed$$

$$\ln(NH_3) = 0.188357 + 3.451939 * \left(\frac{500}{1{,}000}\right) + 0.048153 * 2.55$$

$$\ln(NH_3) = 0.188357 + 1.7260 + 0.1228$$

$$\ln(NH_3) = 2.0371$$

To back transform the results to NH_3 in kg, use Equation 7, from the main report. For a naturally ventilated barn, $\overline{E_\iota}$ is 1.03966 and C is 3.

$$NH_3 = e^{2.0371} \times 1.46499 - 3$$

This comes to 8.23 kg NH_3 for the day. This process is repeated for each day, then the daily emissions are added together to get an annual estimate of emissions. After considering the values for each day in 2021, the total annual emissions for the barn were calculated at 3,462.82 kg. To calculate the uncertainty associated with this estimate, use Equation 17 with the value of k from Table 7-1. This results in an annual uncertainty of:

$$Uncertainty\ (\%) = \frac{73{,}495.70}{3{,}462.82} = 21.\%$$

This translates to an uncertainty of ± 734.96 kg. Thus, the final annual estimate for this barn is 6,192.70 kg ± 351.80 kg. This calculation would be repeated for any other naturally ventilated barn on the site.

8.1.4 Lagoon Example

For this example, we will use Equation 15, in Section 5.4, to calculate the log transformed values as follows:

$$ln(NH_3) = 1.396734 + 0.027201 * Amb_T$$

$$ln(NH_3) = 1.396734 + 0.027201 * -9.4$$

$$ln(NH_3) = 1.396734 - 0.2557$$

$$\ln(NH_3) = 1.1410$$

To back transform the results to NH_3 in kg, use Equation 7, from the main report. For a lagoon, $\overline{E_\iota}$ is 1.0079 and C is 3.

$$NH_3 = e^{1.1410} \times 1.0079 - 3$$

This comes to 0.1548g NH_3/d m^2. This is multiplied by the surface area of the lagoon to estimate emissions for the whole lagoon. For this example, we will assume the lagoon is 10,000 m^2, which would result in emissions of 1,547 kg NH_3 for the day.

This process is repeated for each day, then the daily emissions are added together to get an annual estimate of emissions. After considering the values for each day in 2021, the total annual emissions for the lagoon were calculated at 8,961.21 kg. To calculate the uncertainty associated with this estimate, use Equation 17 with the value of k from Table 7-1. This results in an annual uncertainty of:

$$Uncertainty\ (\%) = \frac{4{,}114.1}{8{,}961.21} = 0.46\%$$

This translates to an uncertainty of ± 41.14 kg. Thus, the final annual estimate for this lagoon is 8,961.21 kg ± 41.14 kg. This calculation would be repeated for any other lagoon on the site.

8.1.5 Corral Example

For this example, we will use Equation 17, in Section 5.5, to calculate the log transformed values as follows:

$$ln(NH_3) = 1.053805 + 0.004993 * Amb_T + 0.0031 * Amb_{RH} + 0.017832 * WindSpeed$$

$$n(NH_3) = 1.053805 + 0.004993 * -9.4 + 0.0031 * 86 + 0.017832 * 2.55$$

$$ln(NH_3) = 1.053805 - 0.0469 + 0.266 + 0.0455$$

$$\ln(NH_3) = 1.3189$$

To back transform the results to NH_3 in kg, use Equation 7, from the main report. For a corral, $\overline{E_\iota}$ is 1.0066 and C is 3.

$$NH_3 = e^{1.3189} \times 1.0066 - 3$$

This comes to 0.07641 g NH_3/d m^2 1,000 head. This is multiplied by the surface area of the corral and inventory to estimate emissions for the whole corral. For this example, we will assume the surface area of the corral is 100,000 m^2 and the farm population is 3,400 head, which would result in emissions of 260 kg NH_3 for the day.

This process is repeated for each day, then the daily emissions are added together to get an annual estimate of emissions. After considering the values for each day in 2021, the total annual emissions for the corral were calculated to be 124,562.33 kg. To calculate the uncertainty associated with this estimate, use Equation 17 with the value of k from Table 7-1. This results in an annual uncertainty of:

$$Uncertainty\ (\%) = \frac{1{,}278.5}{124{,}562.33} = 0.01\%$$

This translates to an uncertainty of ± 12.79 kg. Thus, the final annual estimate for this corral is 124,562.33 kg ± 12.79 kg.

8.1.6 Combining Structures

To calculate total farm emissions, the emissions from each unit are added. As an example, consider a farm with a 500 head mechanically ventilated barn, 500 head naturally ventilated barn, milking center with a 500 head capacity at any given time, and 10,000 m^2 lagoon. That is, the same emissions as the examples in sections 8.1.1 through 8.1.4. The annual farm emission estimate from four sources is:

$$Farm\ Total\ Emissions = 7{,}108.31 + 4{,}161.53 + 6{,}192.70 + 2{,}439.20$$

$$Farm\ Total\ Emissions = 19{,}901.74\ kg\ NH_3$$

To estimate the total farm uncertainty, use Equation 41:

$$Total\ Farm\ Uncertainty = \sqrt{{U_{barn\ 1}}^2 + {U_{barn\ 2}}^2 + {U_{milking\ center}}^2 + {U_{lagoon}}^2}$$

$$Total\ Farm\ Uncertainty = \sqrt{(351.80)^2 + (554.94)^2 + (734.96)^2 + (41.41)^2}$$

$$Total\ Farm\ Uncertainty = 986.71\ \text{kg}$$

The final annual NH_3 estimate for the farm is 19,901.74 ± 986.71 kg. Once the emission models are finalized, EPA will work with stakeholder to develop a tool to facilitate the calculation of barn and open source emissions.

8.2 Model Sensitivity Testing

To further test the models, EPA varied the model parameters to ensure the model results would vary based on these key parameters. Two different tests were conducted: 1) the number of cows was increased while the meteorological parameters were held constant, and 2) inventory was held constant while the meteorological parameters were replaced with the values for a warmer climate.

8.2.1 Sensitivity to Inventory

To test the sensitivity of the confinement sources to inventory, the initial placement was doubled to 1,000 cows. Using the same meteorology from Section 8.1, the emissions for the dairy barns on January 1, 2020, is summarized in Table 8-2. For mechanically ventilated barns and milking centers, doubling the inventory at least doubled the NH_3 emissions for the same meteorological conditions. For naturally ventilated barns, doubling the inventory resulted in a sevenfold increase in NH_3 emissions. The large increase in the naturally ventilated barn emissions is further discussed in Section 8.2.3.3. These same ratios are seen when considering a year’s worth of meteorology (Table 8-3).

Table 8-2. Comparison of confinement source NH_3 emissions (kg) on January 1, 2021, for different inventory levels at a theoretical Brown County farm.

Source Type	500 head	1,000 head
Mechanically Ventilated	9.34	26.91
Milking center	3.32	6.62
Naturally ventilated	8.23	62.49

Table 8-3. Comparison of confinement source total 2021 NH_3 emissions (kg) for different inventory levels at a theoretical Brown County farm.

Source Type	500 head	1,000 head
Mechanically Ventilated	7,108	18,820
Milking center	4,162	8,323
Naturally ventilated	3,463	24,511

For lagoons, doubling the surface area of the lagoon doubles both the daily and annual NH_3 emissions (Table 8-4). For corrals, doubling the inventory present doubles both the daily and annual NH_3 emissions (Table 8-5). The observed relationships suggest the models are sensitive to the size parameters, while scaling appropriately.

Table 8-4. Comparison of lagoon NH_3 emissions (kg) for different surface areas for theoretical Brown County farm.

NH_3 Emissions (kg)	10,000 m^2	20,000 m^2
Daily (1/1/2021)	1.51	3.02
Annual (2021)	8,961	17,922

Table 8-5. Comparison of estimated corral NH_3 emissions (kg) for different inventory levels for theoretical Brown County farm.

NH_3 Emissions (kg)	3,400 head	6,800 head
Daily (1/1/2021)	259.48	518.96
Annual (2021)	124,562	249,125

8.2.2 Sensitivity to Climate

To further test model sensitivity, specifically that climate differences were producing different emission results, EPA calculated the emissions for the same farm in two distinctly different climate regions. The first was the theoretical farm in Brown County, Wisconsin from the previous examples (Section 8.1). The NH_3 emission for these same theoretical barns were calculated using meteorological data from Livermore Municipal Airport in Alameda County, California. These locations were chosen based on 2017 Census of agriculture data indicating areas of high dairy inventory (Figure 8-1). USDA Economic Research Service data (available at: https://www.ers.usda.gov/webdocs/DataFiles/48685/milkcowsandprod.xlsx?v=9708) also notes California and Wisconsin are the top two dairy producing states in the country, further affirming the reasonableness of the testing locations.

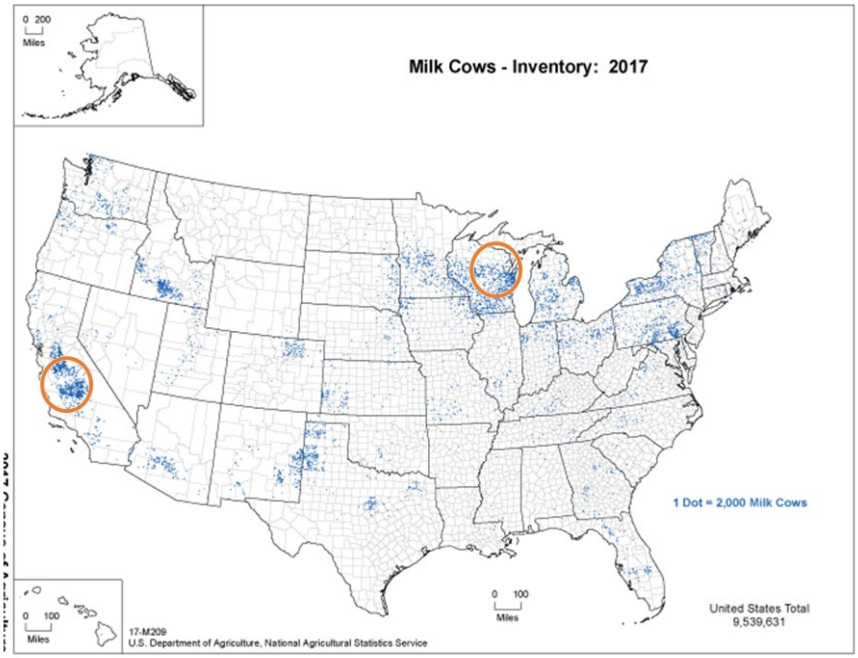

Figure 8-1. 2017 Census of Agriculture plot indicating dairy inventory.
Orange circles indicate approximate locations of test meteorology from Wisconsin (WI) and California (CA). Source: https://www.nass.usda.gov/Publications/AgCensus/2017/Online_Resources/Ag_Atlas_Maps/17-M209g.php

For the test sites, the temperatures from the Wisconsin (WI) site were generally less than the California (CA) site (Figure 8-2). On average, the temperatures in Wisconsin were 7°C less than those in California (Table 8-6), with difference between individual monthly averages varying from 1.6 to 20.8°C lower, except for July when Wisconsin edged 0.6°C higher. With respect to relative humidity, the California and Wisconsin sites experienced a similar range of daily average relative humidities throughout the year (Figure 8-3 and Table 8-7). Wisconsin edged a little higher July through October, leading to an overall average 1.6% higher. Average daily wind speeds (Figure 8-4 and Table 8-7) were generally lower in California, with monthly average barely higher June through August. The following sections provide a summary of the calculations using the California meteorological data compared to the previous examples.

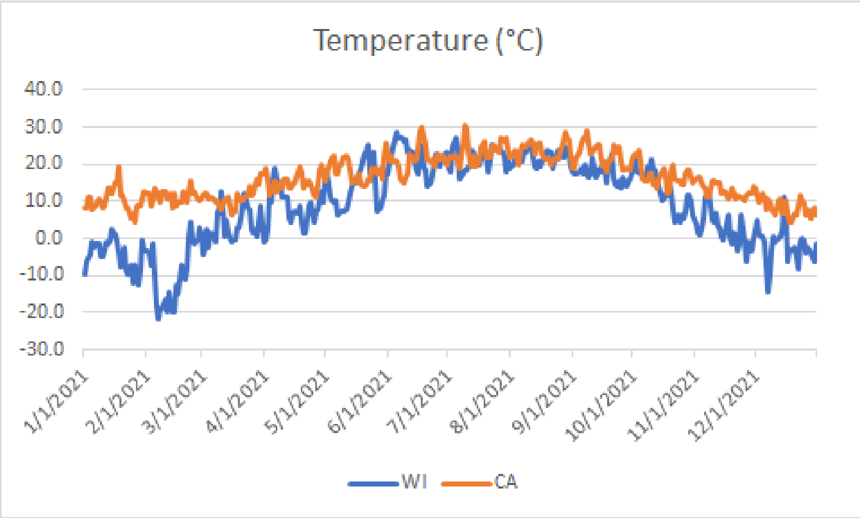

Figure 8-2. Comparison on average daily temperatures at test locations in Wisconsin (WI) and California (CA).

Table 8-6. Summary of average daily temperature at the two meteorological sites.

Site	Statistic	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Overall
WI	Min	-12.8	-21.7	-2.8	1.7	6.1	13.9	16.1	17.8	13.3	3.9	-6.1	-14.4	-21.7
	Max	2.2	4.4	12.8	18.9	25.0	28.3	27.2	25.0	22.8	21.7	12.8	11.1	28.3
	Average	-4.8	-9.5	3.4	9.1	14.0	21.9	21.5	21.9	17.3	12.6	2.2	-2.0	9.0
CA	Min	4.4	8.3	6.1	11.1	13.9	15.0	18.9	18.9	17.8	12.2	10.0	0.0	0.0
	Max	19.4	15.6	18.9	20.0	25.6	30.0	30.6	28.3	28.9	23.9	16.7	12.2	30.6
	Average	10.3	11.3	11.5	15.1	18.4	21.3	23.5	23.4	22.4	16.9	13.0	8.0	16.3

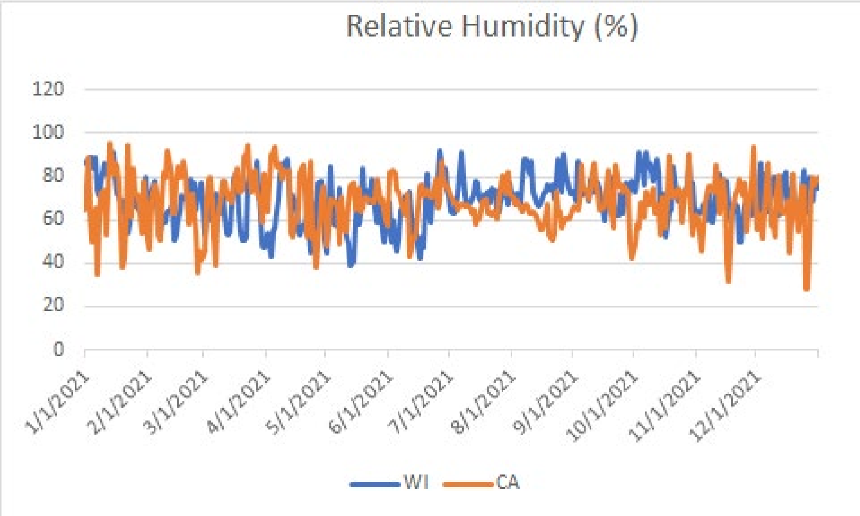

Figure 8-3. Comparison of average daily relative humidities at test locations in Wisconsin (WI) and California (CA).

Table 8-7. Summary of average daily relative humidity at the two meteorological sites.

Site	Statistic	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Overall
WI	Min	54.0	51.0	47.0	43.0	39.0	42.0	63.0	66.0	60.0	52.0	50.0	0.0	0.0
	Max	91.0	79.0	87.0	88.0	85.0	92.0	91.0	90.0	87.0	91.0	81.0	86.0	92.0
	Average	75.9	66.4	64.2	63.7	63.1	64.9	72.1	76.1	72.3	75.8	66.5	69.4	69.2
CA	Min	35.0	35.9	39.4	38.6	49.2	42.7	58.1	51.0	42.3	53.0	31.8	28.0	28.0
	Max	95.3	92.0	94.4	93.5	82.0	86.7	82.1	73.0	86.4	90.7	93.9	86.3	95.3
	Average	68.3	66.2	73.0	70.3	67.5	69.9	67.3	62.3	70.3	67.6	67.5	64.6	67.8

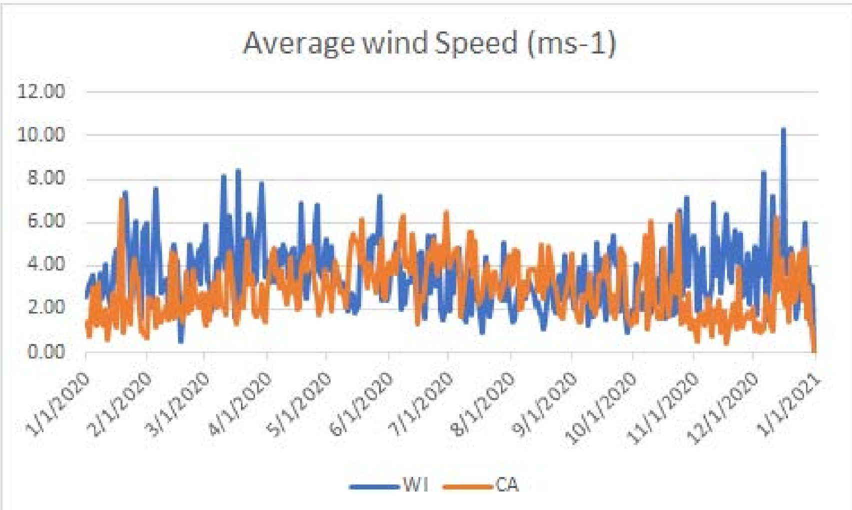

Figure 8-4. Comparison of average daily wind speeds at test locations in Wisconsin (WI) and California (CA).

Table 8-8. Summary of average daily wind speeds at the two meteorological sites.

Site	Statistic	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Overall
WI	Min	1.4	0.5	1.5	2.2	1.8	1.5	0.9	1.1	0.9	1.6	1.9	0.0	0.0
	Max	7.4	7.6	8.4	6.9	7.2	5.4	5.1	4.5	5.4	7.2	6.9	10.3	10.3
	Average	3.6	3.8	4.5	4.1	3.6	3.5	2.9	2.5	3.0	3.4	3.9	4.0	3.6
CA	Min	0.6	1.2	1.2	1.7	1.9	1.3	1.7	1.6	1.2	1.1	0.4	0.0	0.0
	Max	7.0	4.6	5.1	4.9	6.2	6.4	5.6	5.0	4.8	6.4	3.9	6.2	7.0
	Average	2.2	2.4	2.6	3.4	3.7	4.2	3.7	3.2	2.6	2.7	1.6	2.5	2.9

8.2.2.1 Mechanically Ventilated Barn

When the daily calculations are performed for the entire year for a mechanically ventilated dairy barn with 500 cows, the California site typically has higher daily emissions for both NH_3 and H_2S and for either manure management system than the Wisconsin site (Figure 8-5). Table 8-9 contains the estimated annual emissions for the different combinations of pollutant and manure management system. For the mechanically ventilated scrape barn from the example in Section 8.1.1, the total annual NH_3 emissions estimate for the farm using meteorological data from California was 8,689 kg— a 1,581 kg increase from the same mechanically ventilated barn with meteorological data from Wisconsin. A similar trend is seen across the other pollutant and manure management system combinations. This is consistent with the trend of lower temperatures yielding lower emissions seen during the data exploration in Section 4. Overall, this suggests that the emission models can account for regional temperature differences in the results for mechanically ventilated barns.

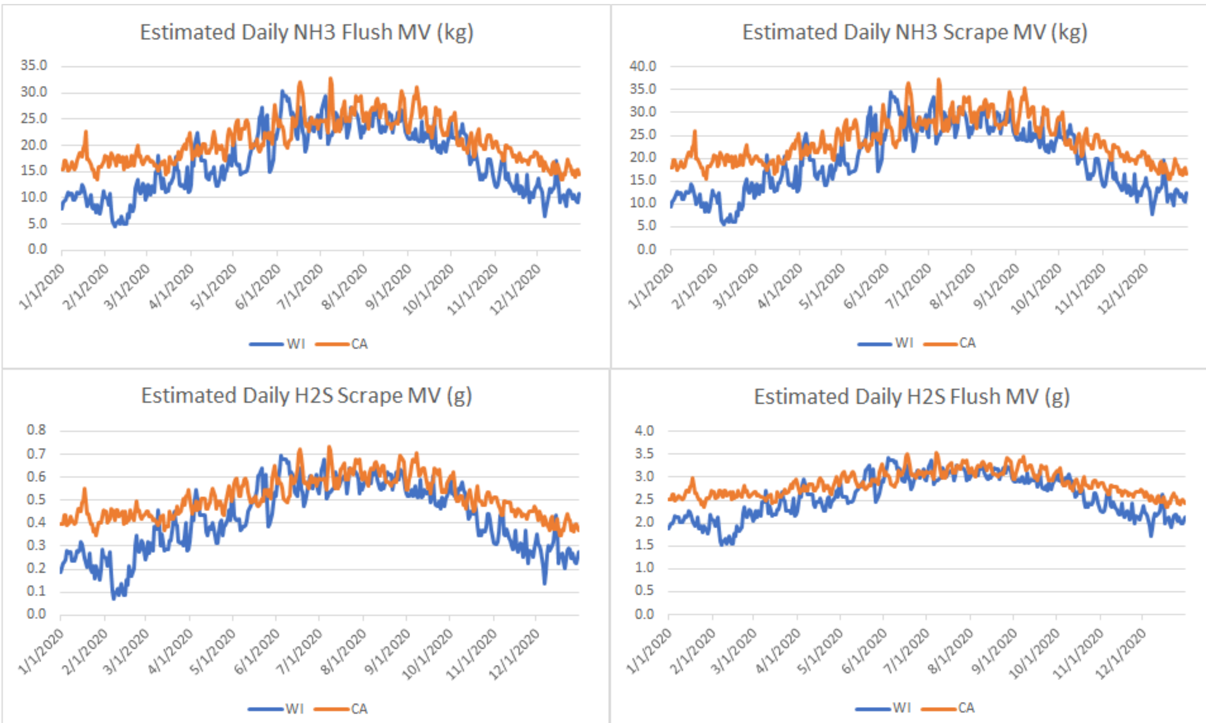

Figure 8-5. Comparison of daily mechanically ventilated barn emission at test dairy in locations WI and CA.

Table 8-9. Total annual emission from a theoretical mechanically ventilated barn in WI and CA.

Pollutant	WI Emissions (kg per year)	CA Emissions (kg per year)
H2S - Flush	152	186
H_2S - Scrape	940	1,044
NH3 - Flush	6,193	7,597
NH3 - Scrape	7,108	8,689

8.2.2.2 Milking Center

Repeating the daily calculations for a 500 head capacity milking center using the California meteorological data show the warmer site typically has greater daily emissions for all pollutants (Figure 8-6). Table 8-10 has the estimated annual emissions of each pollutant studied. For the milking center from the example in Section 8.1.2, the total estimated annual NH_3 emissions increase by 1,317 kg by using California meteorological data. A similar trend is seen across the other pollutants, with increases ranging from 38% to 152%. This is consistent with the trend of lower temperatures yielding lower emissions seen during the data exploration in Section 4. Overall, this suggests that the emission models can account for regional temperature differences in the results for milking centers.

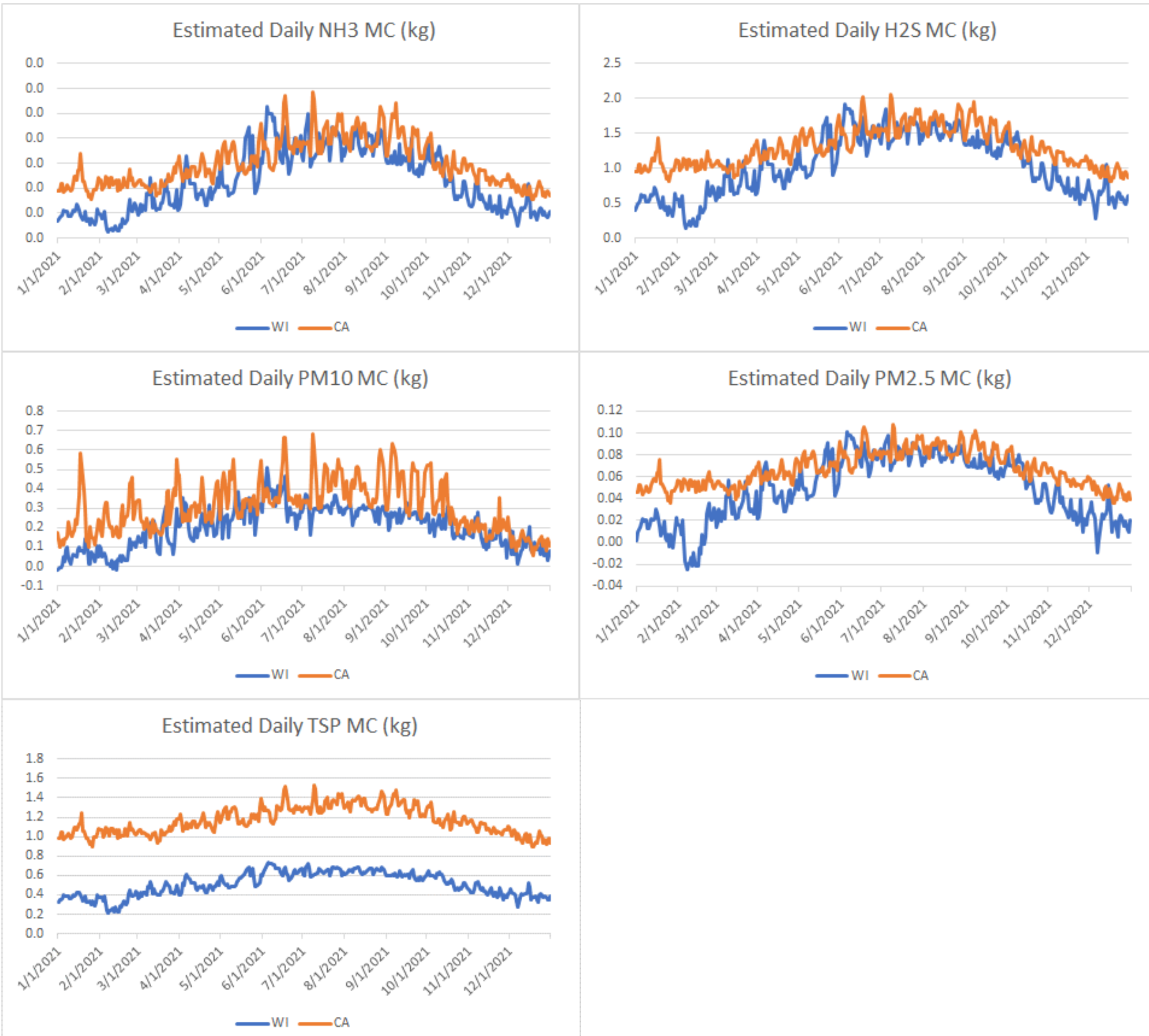

Figure 8-6. Comparison of daily milking center emission at test dairy locations in WI and CA.

Table 8-10. Total annual emission from a theoretical milking center in WI and CA.

Pollutant	WI Emissions (kg per year)	CA Emissions (kg per year)
NH_3	4,162	5,479
H_2S	189	474
PM_{10}	74	112
$PM_{2.5}$	18	24
TSP	185	427

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8.2.2.3 Naturally Ventilated Barn

A naturally ventilated dairy barn with 500 cows in California typically has lower daily emissions than the same barn in Wisconsin (Figure 8-7) for gaseous pollutants and $PM_{2.5}$. Table 8-11 has the estimated annual emissions of the pollutants studied. The differences in the annual gaseous pollutants are minor, as the models are based on average daily wind speed which is only slightly different between the sites. Table 8-11 shows a larger difference with the $PM_{2.5}$ annual emissions, and the plot shows several large spikes when using the Wisconsin meteorological data. Looking into the data, these data points are associated with days with high average daily wind speeds and suggests some limitation in the model performance for these instances. This is discussed further in Section 8.2.3.3. For PM_{10} and TSP, the spikes in emissions are generally due to higher wind speeds combined with lower relative humidities to mitigate the emission. These relationships are explored more in section 8.2.3.3.

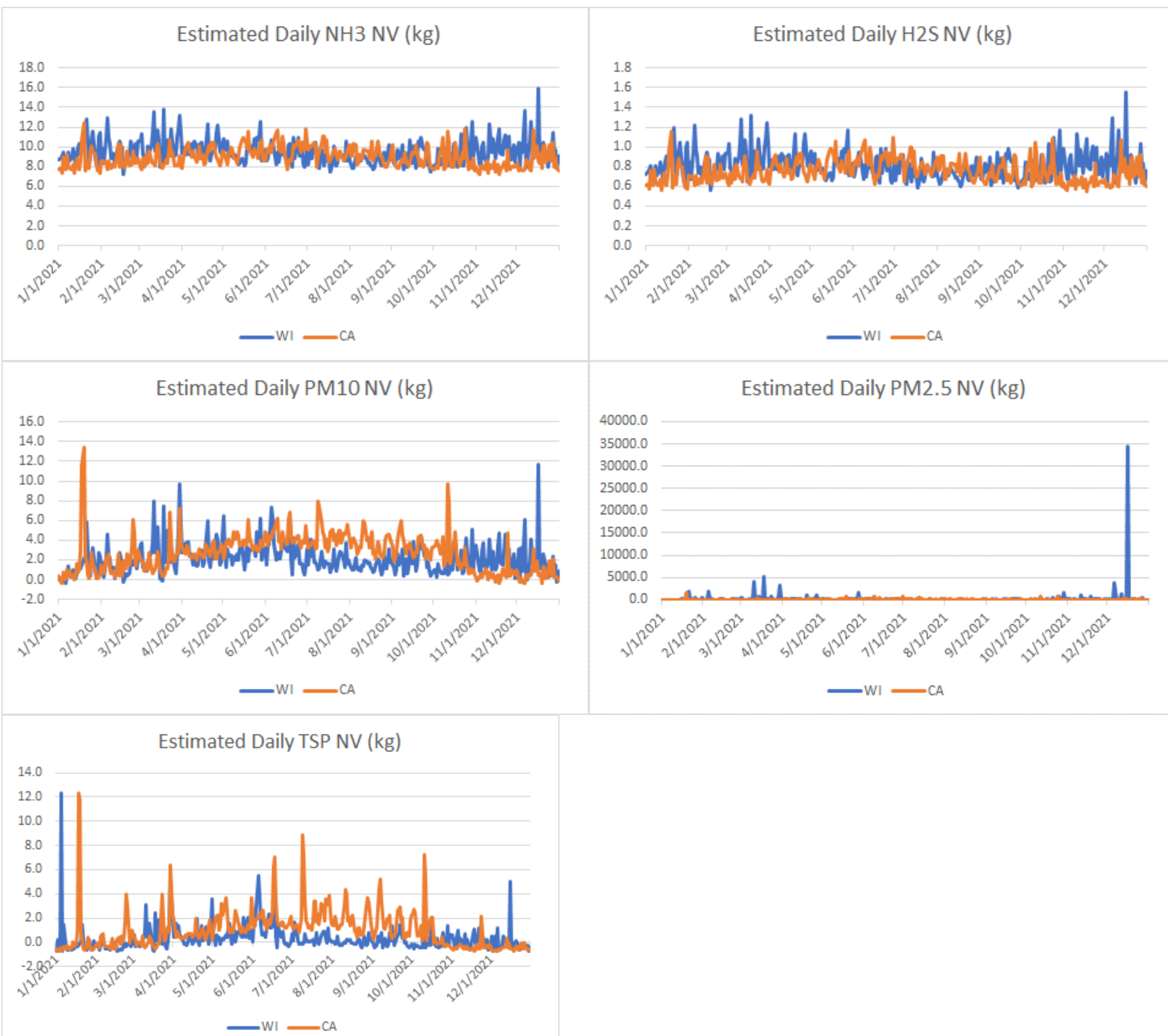

Figure 8-7. Comparison of daily naturally ventilated barn emission at test dairy locations in WI and CA.

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Table 8-11. Total annual emission from a theoretical milking center in WI and CA.

Pollutant	WI Emissions (kg per year)	CA Emissions (kg per year)
NH_3	3,463	3,274
H_2S	297	275
PM_{10}	777	962
$PM_{2.5}$	89,168	23,113
TSP	112	369

8.2.2.4 Lagoon

Repeating the daily calculations for the dairy lagoon using the California meteorological data typically has higher daily emission values than when using the Wisconsin meteorological data (Figure 8-8). Table 8-12 has the estimated annual emissions of each pollutant studied and shows a roughly 40% increase for both pollutants using the warmer temperatures from California. This is consistent with the trend of warmer temperatures yielding greater emissions seen during the data exploration in Section 4 and noted in the literature review in Section 3. Overall, this suggests that the emission models are capable of accounting for the different growing regions in the lagoon results.

Figure 8-8. Comparison of daily lagoon emission at test dairy locations in WI and CA.

Table 8-12. Total annual emission from a theoretical lagoon in WI and CA.

Pollutant	WI Emission (kg per year)	CA Emission (kg per year)
NH_3	8,961	12,525
H_2S	2,734.2	3,748.8

8.2.2.5 Corral

The emission estimates for a corral using the meteorological data from California, are slightly lower than calculations with the Wisconsin meteorological data (Figure 8-9). Table 8-13 has the estimated annual emissions of each pollutant and shows the total annual NH_3 emissions estimate for the theoretical California corral was 124,261 kg, which is a 302 kg decrease from the same theoretical corral in Wisconsin. The H_2S model only shows a minor difference between the emissions for the two climates. This generally limited sensitivity is discussed more in Section 8.2.3.5.

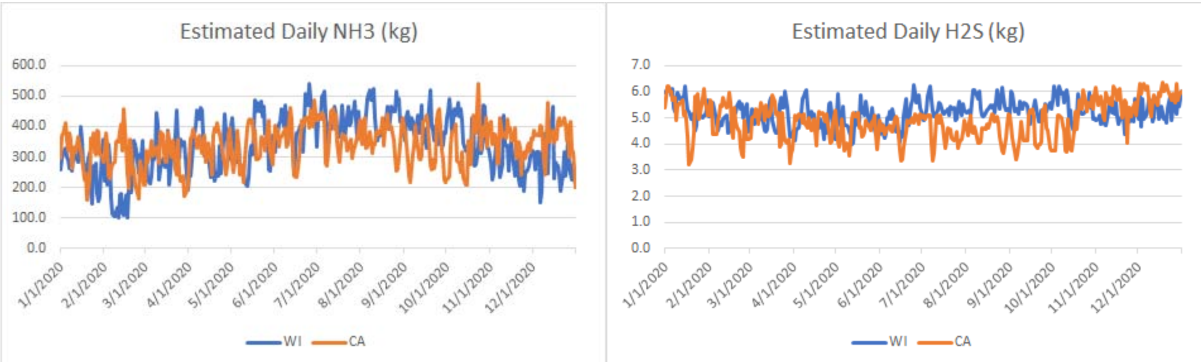

Figure 8-9. Comparison of daily milking center emission at test dairy locations in WI and CA.

Table 8-13. Total annual emission from a theoretical milking center in WI and CA.

Pollutant	WI Emission (kg per year)	CA Emission (kg per year)
NH_3	124,562	124,261
H_2S	1,902.7	1,789.7

8.2.3 Model Limitations

As noted in the 2013 SAB review (US EPA SAB, 2013), extrapolating to conditions beyond those represented in the model development dataset could produce unrealistic results. To test the limitations of the model, EPA conducted a series of emission calculations over a range of conditions that could be seen at a farm in the US. These emission calculations tested one parameter at a time, with the selected parameter varied by a constant value through the range. For example, ambient temperature was increased by 1°C from the minimum value in the model development dataset up to the maximum value. While one parameter was tested, the remaining parameters were held constant at the average value seen in the model development dataset. The resulting emission values were reviewed and plotted to determine if the model resulted in unrealistic emission values, such as negative emissions or rapid increases in emission rates.

The dairy equations included some combination of inventory, ambient temperature, ambient relative humidity, and wind speed. The ranges of ambient parameters are based on the NAEMS dataset. The number of cows in a single barn or milking center are based on barn capacity numbers provided by consent agreement participants. The range values tested for each parameter are in Table 8-14.Table 8-14

This analysis does not account for interaction between multiple terms within an equation, which could further affect the results. For example, a dairy barn with higher ambient temperatures would be able to cover a larger range of inventory per barn before producing negative NH_3 emissions. Conversely, a barn with lower ambient temperatures would cover a smaller range of inventory before producing negative NH_3 emission values. However, the analysis does provide a general range where the model produces reasonable results.

To further explore any limitations in the models, emissions were calculated for all combinations across the range of values specified in Table 8-14. A list of all the combinations of the three inputs was created using the R statistical software. R was then used to calculate the emissions using the method shown in section 8.1. The results were then filtered down to only the results that produced negative values to generate the plots for each pollutant. The following sections outline the analysis for each of the selected models.

Table 8-8-14. Parameter ranges tested for the dairy models.

Parameter	Upper limit	Lower limit	Average Value	Increment
Ambient temperature (°C)	32.0	-23	10.0	0.8
Ambient relative humidity (%)	93	24	68.1	1
Wind speed (ms^{-1})	11.2	0.00	2.3	0.15
Inventory (head)	5,000	0	1,000	70

8.2.3.1 Mechanically Ventilated Barn

The initial analysis for mechanically ventilated barns is presented in Figure 8-10 and Figure 8-11. Neither the H_2S (Figure 8-10) nor NH_3 (Figure 8-11) models produce negative emissions under average conditions. Additional analysis of the 5,110 combinations of conditions tested produced negative values. The models also produce a rapid increase in emissions when estimating barns with inventories greater than 2,000 head. The largest barn in the NAEMS had an average daily population of 833, which would account for the unrealistic behavior with extreme inventory numbers. Based on the consent agreement participant data, more than 90% of the participating barns fall below a capacity of 2,000 head. This suggests the model would still be appropriate for the bulk of the participants. EPA will explore models that predict emissions normalized by inventory, as these models will produce a linear relationship between inventory and emissions (with other factors constant), regardless of the size of the operation.

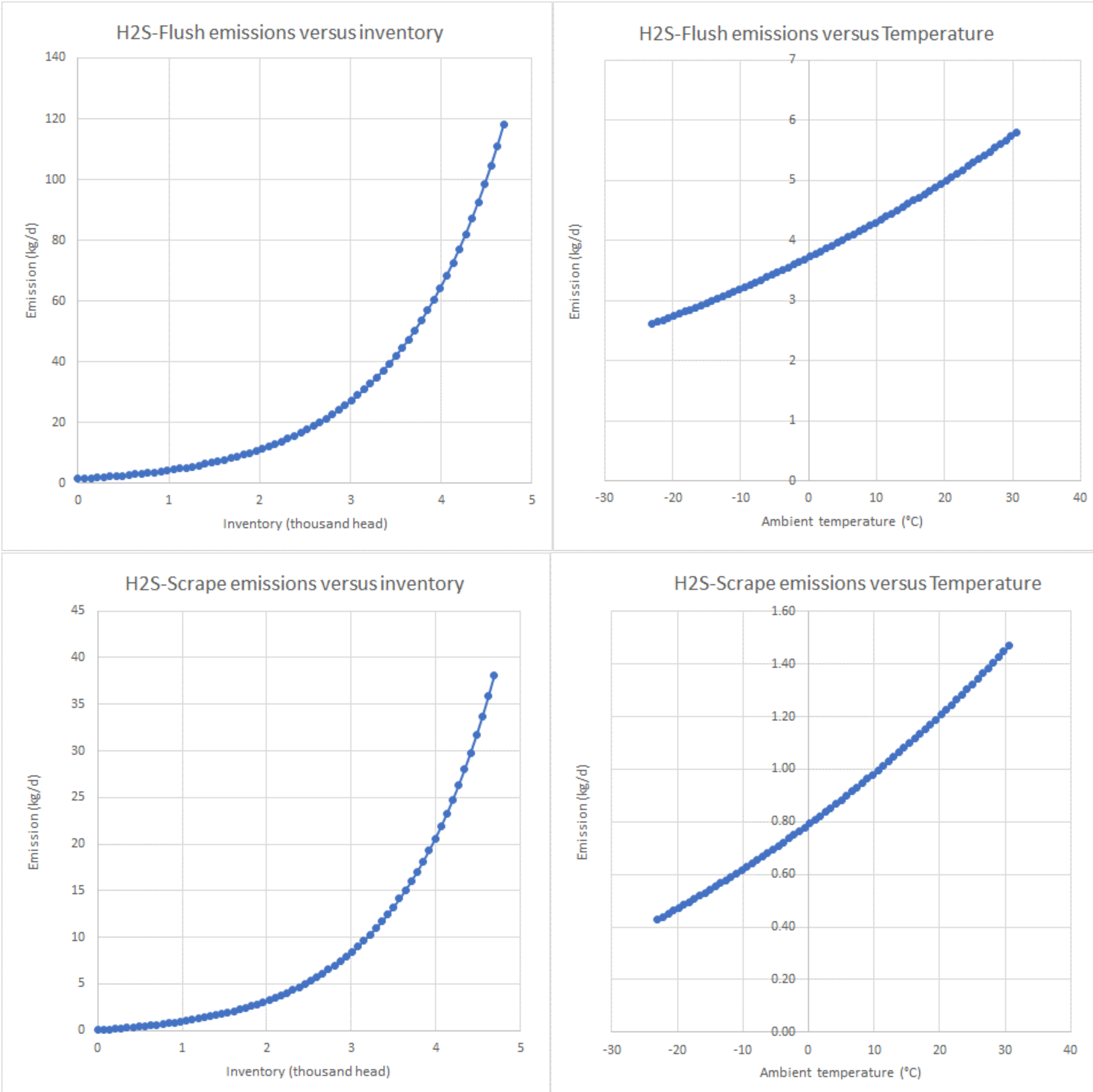

Figure 8-10. Mechanically ventilated barn limitation tests for H_2S.
Visualization of the results for H_2S – Flush (top row) and H_2S – Scrape (bottom row) tests of inventory (left) and ambient temperature (right).

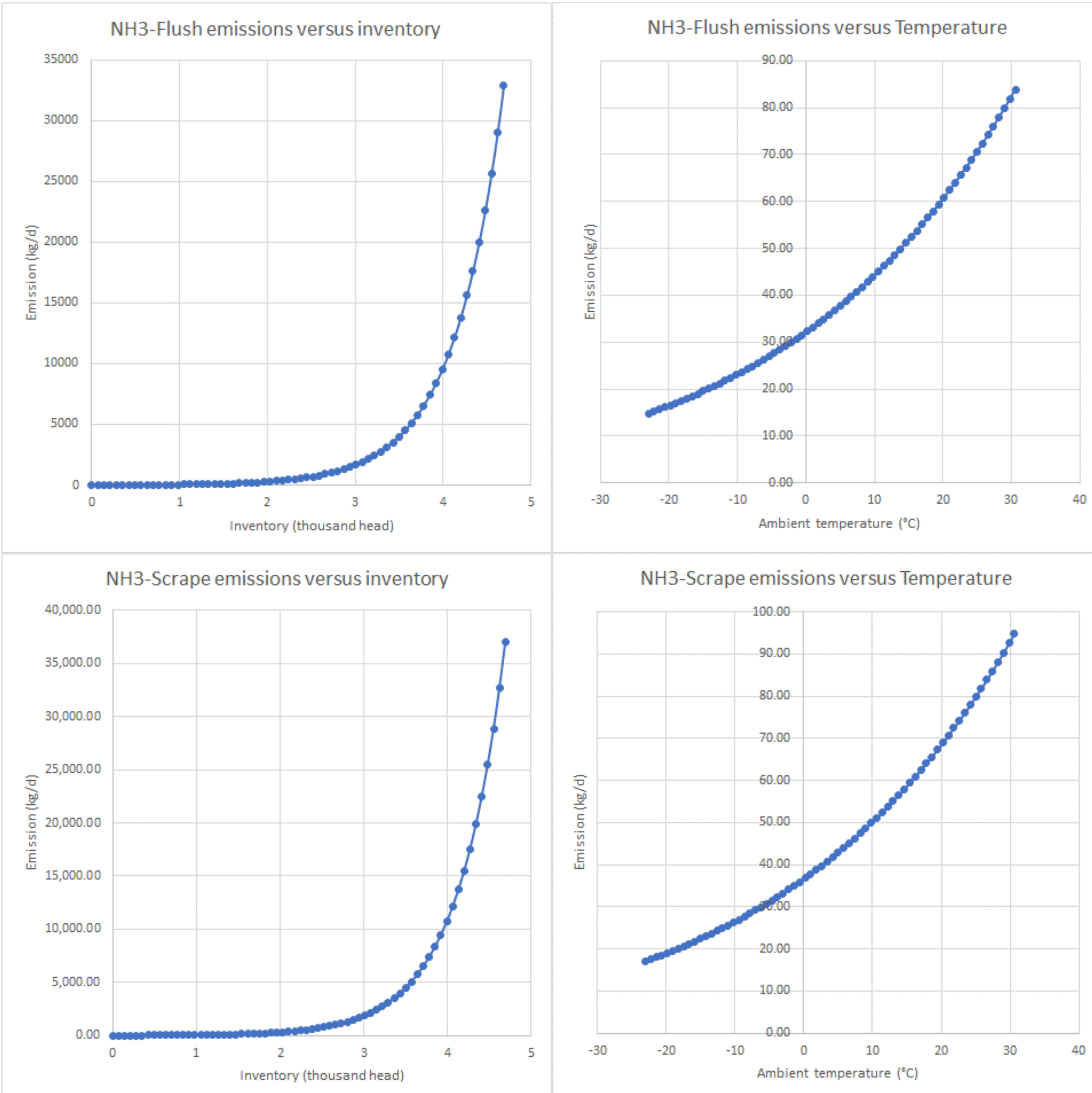

Figure 8-11. Mechanically ventilated barn limitation tests for NH_3.
Visualization of the results for NH_3 – Flush (top row) and NH_3 – Scrape (bottom row) tests of inventory (left) and ambient temperature (right).

8.2.3.2 Milking Center

The milking centers analysis for gaseous pollutants is presented in Figure 8-12 and particulate matter is presented in Figure 8-13. Neither the H_2S nor NH_3 (Figure 8-12) models produce negative emissions under average conditions. The relationship of emissions to increasing temperature is fairly linear through the expected conditions and does not display any extreme behavior that would suggest extrapolation issues.

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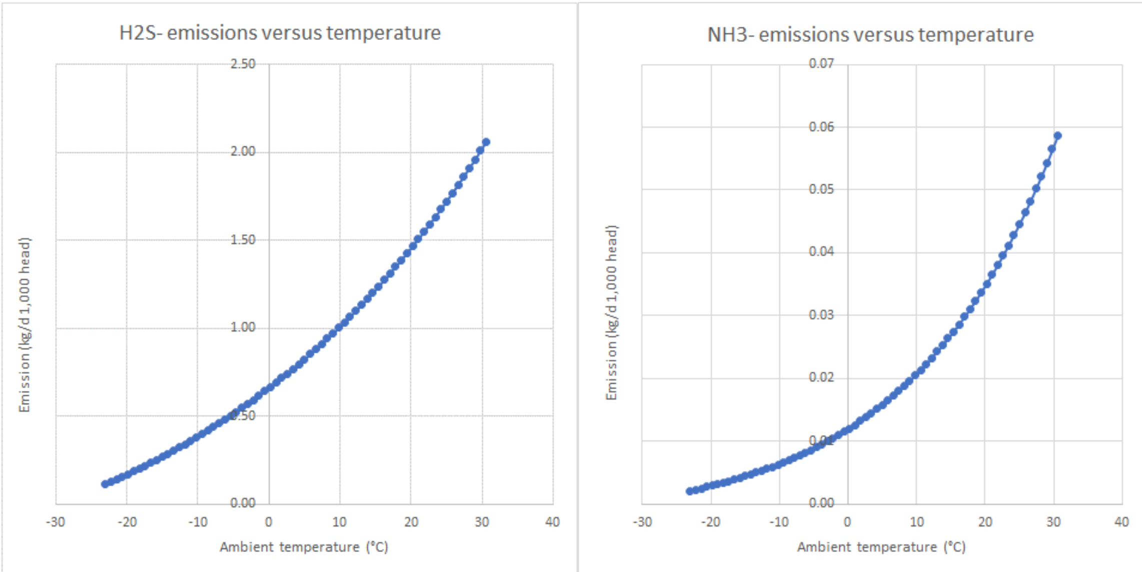

Figure 8-12. Milking center limitation tests for gaseous pollutants.
Visualization of the results for H_2S (left) and NH_3 (right) tests of ambient temperature.

The PM_{10} and $PM_{2.5}$ models (Figure 8-13) do produce negative emission values less than -11°C and -18.2°C for PM_{10} and $PM_{2.5}$ models, respectively, at average relative humidity levels. Additional analysis of 5,390 combinations of temperature and relative humidity values shows the PM_{10} model (Figure 8-14) will produce negative emission estimates when temperatures fall below zero in an increasingly drier environment. That is, the lower the temperature, the lower the relative humidity needed to produce a negative emissions value. For example, the equation for PM_{10} will produce negative emissions at any level of relative humidity when ambient temperature falls just below zero. Similarly, at -21.4°C, the equation can produce negative number when relative humidity is less than or equal to ~60%.

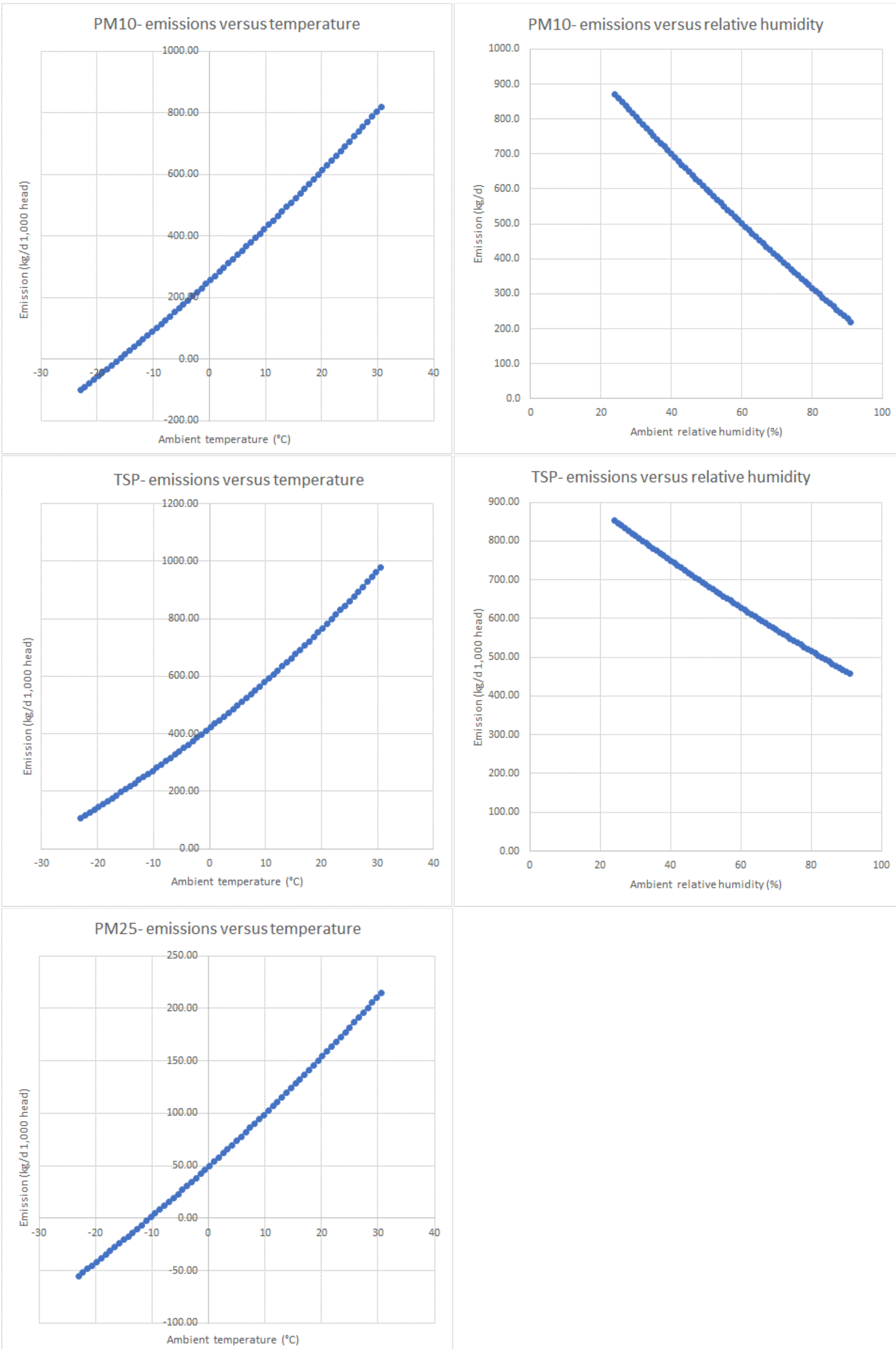

Figure 8-13. Milking center limitation tests for particulate matter.
Visualization of the results for PM10 (top row), TSP (center row), and $PM_{2.5}$ (bottom row) tests of ambient temperature (left) and ambient relative humidity(right).

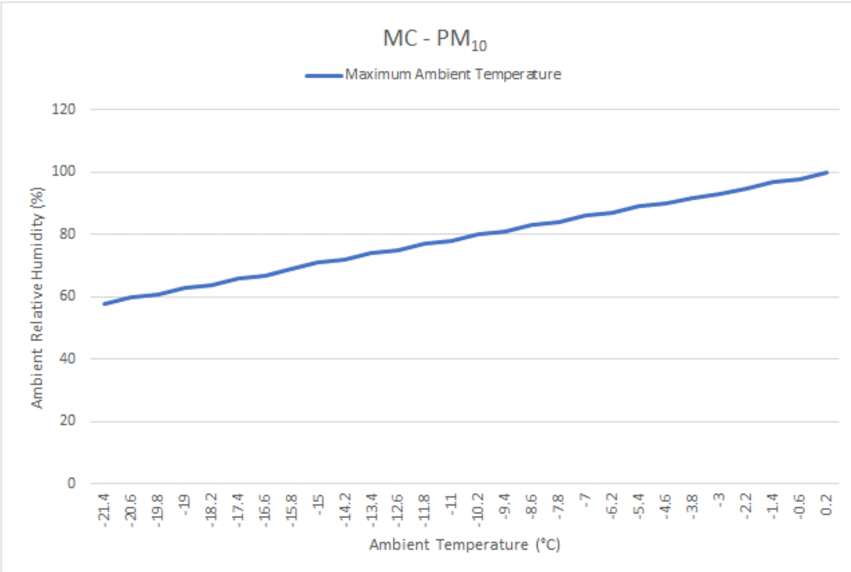

Figure 8-14. Maximum values of relative humidity for each temperature at which the PM10 equation yields negative emissions.

8.2.3.3 Naturally Ventilated Barn

The naturally ventilated barn analysis for gaseous pollutants is presented in Figure 8-15. Analysis for PM_{10}, $PM_{2.5}$, and TSP are presented in Figure 8-17, Figure 8-19, and Figure 8-18, respectively, and particulate matter is presented in Figure 8-13. The H_2S (Figure 8-12) model does not produce negative emissions under average conditions with varying inventory. The NH_3 model will produce negative emission for very small inventories (i.e., less than 70 head) under average conditions. Further testing of 5,548 combinations of wind speed and inventory show at very low wind speeds (< 1 ms^{-1}), an inventory as large as 140 cows will produce negative emissions. As wind speed increases, the corresponding inventory needed to produce a negative number also decreases. These thresholds are demonstrated in Figure 8-16. The sensitivity analysis testing shows rapid increases in NH_3 and H_2S emissions at high inventories. EPA will explore models that predict emissions normalized by inventory, as these models will produce a linear relationship between inventory and emissions (with other factors constant), regardless of the size of the operation.

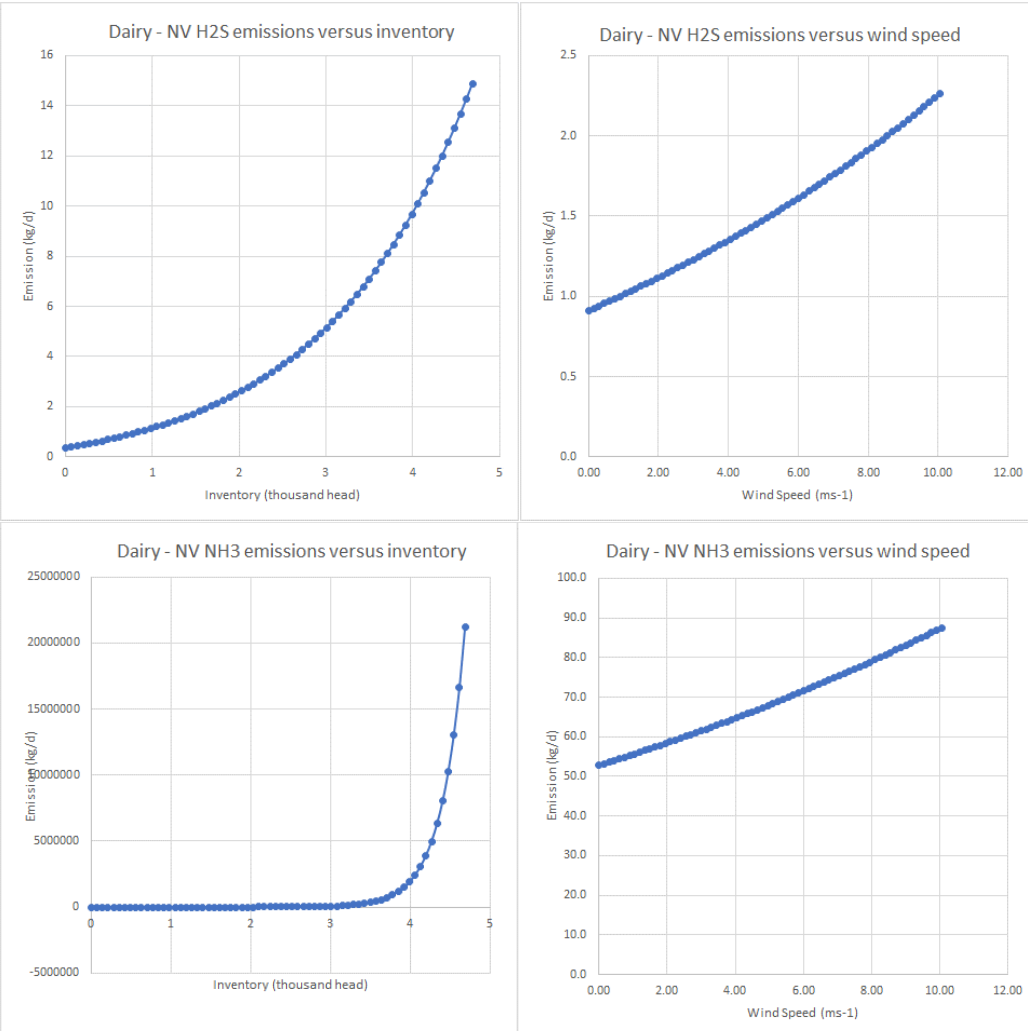

Figure 8-15. Naturally ventilated barn limitation tests for gaseous pollutants.
Visualization of the results for H_2S (top row) and NH_3 (bottom row) tests of inventory (left) and wind speed (right).

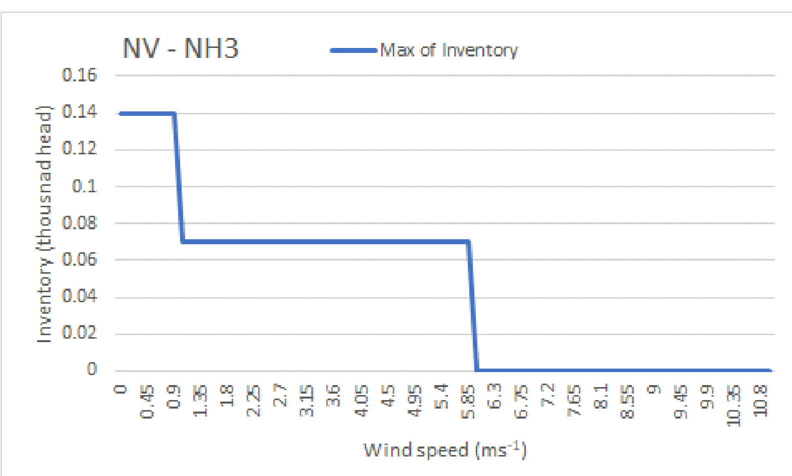

Figure 8-16. Maximum values of inventory for each wind speed at which the NH_3 equation yields negative emissions.

Though it is hard to see on the figures, the PM_{10} and TSP models (Figure 8-17, and Figure 8-18) produce negative values under average conditions for very small inventory levels. Further analysis of 29,903,720 combinations of inventory, ambient temperature, ambient relative humidity, and wind speed show that the models will produce negative values for progressively lower temperatures and winds speeds for increasing temperatures (Figure 8-20). For example, with the PM_{10} model (top graph, Figure 8-20) for an empty barn, the model will produce a negative emission value for temperatures less than 32°C and wind speed less than 9 ms^{-1}. As inventory increases to 1,050 head, negative emissions only occur at temperatures below -30°C and wind speeds less than 1 ms^{-1}. The sensitivity analysis testing shows rapid increases in PM_{10} and TSP emissions at high inventories. EPA will explore models that predict emissions normalized by inventory, as these models will produce a linear relationship between inventory and emissions (with other factors constant), regardless of the size of the operation.

The $PM_{2.5}$ model (Figure 8-19) did not produce negative values under average conditions. However, looking across the combinations of inventory, ambient temperature, ambient relative humidity, and wind speed, the $PM_{2.5}$ model produces negative emission estimates at low wind speeds and temperatures combined with low inventory levels (Figure 8-20). As inventory levels increase, the negative emission estimates can occur at higher values of temperature and wind speed. This is due to the negative relationship between $PM_{2.5}$ and inventory in the model, which will need to be further explored. One option is to explore models that predict emissions normalized by inventory, as these models will produce a positive linear relationship between inventory and emissions (with other factors constant), regardless of the size of the operation.

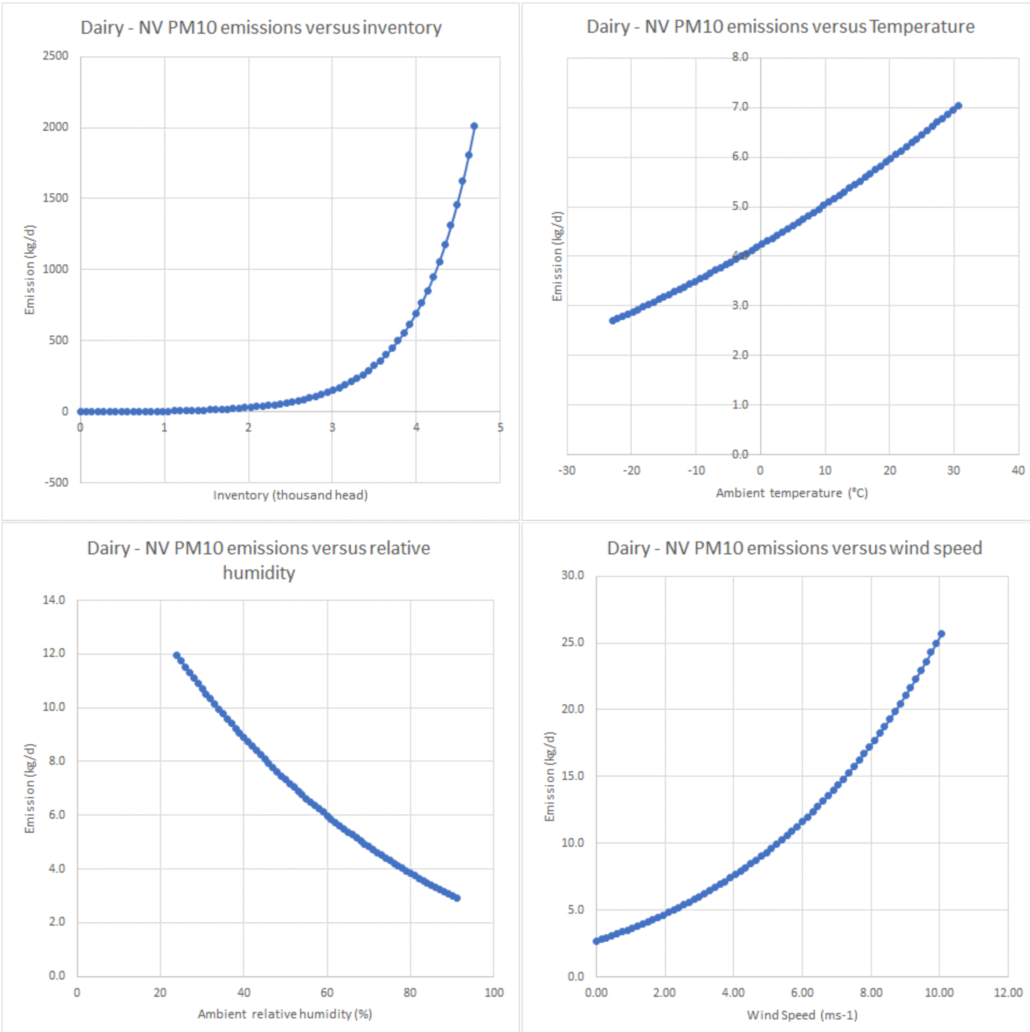

Figure 8-17. Naturally ventilated barn limitation tests for PM_{10}.
Visualization of the results for PM_{10} tests of inventory (top left), ambient temperature (top right), relative humidity (bottom left), and wind speed (bottom right).

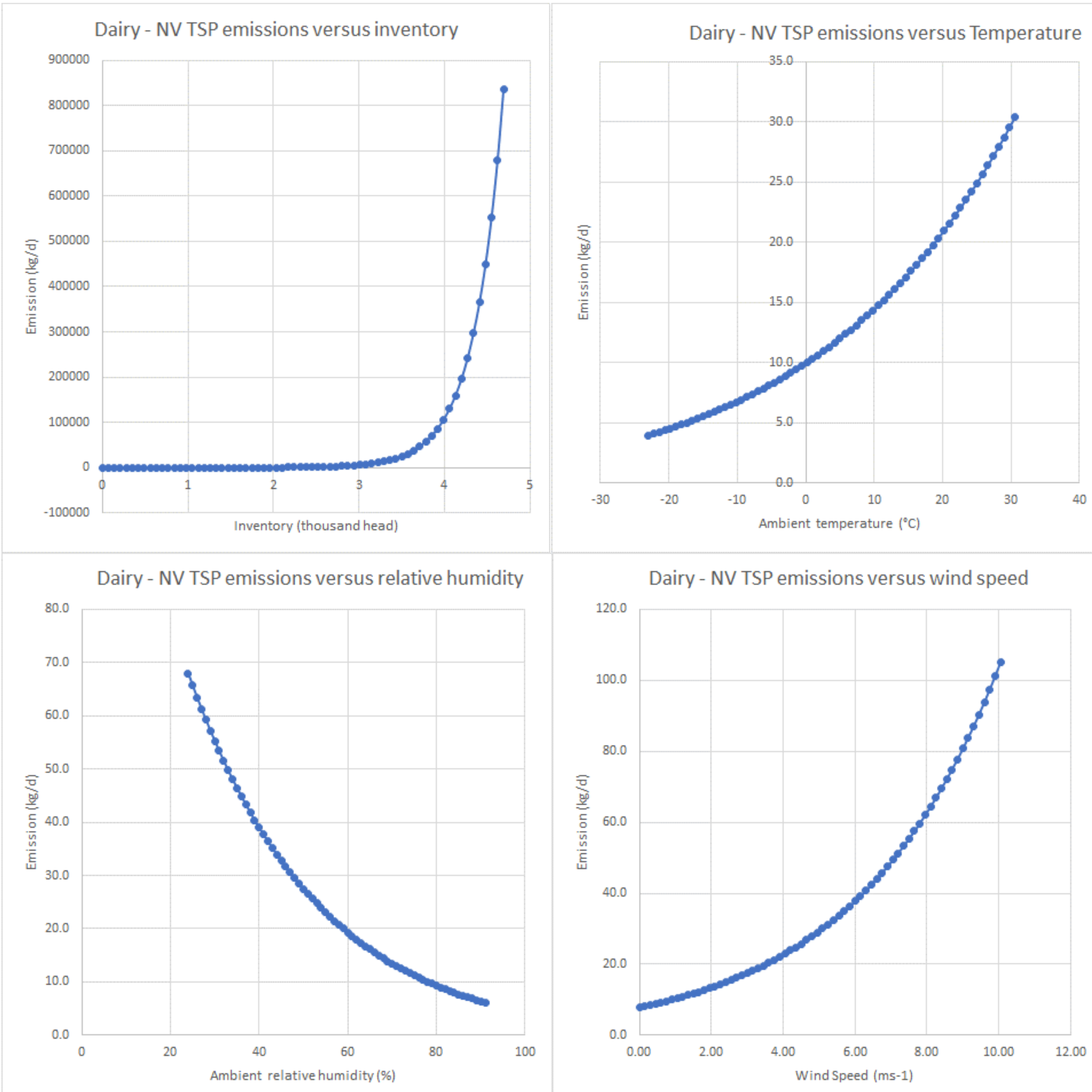

Figure 8-18. Naturally ventilated barn limitation tests for TSP.
Visualization of the results for TSP tests of inventory (top left), ambient temperature (top right), relative humidity (bottom left), and wind speed (bottom right).

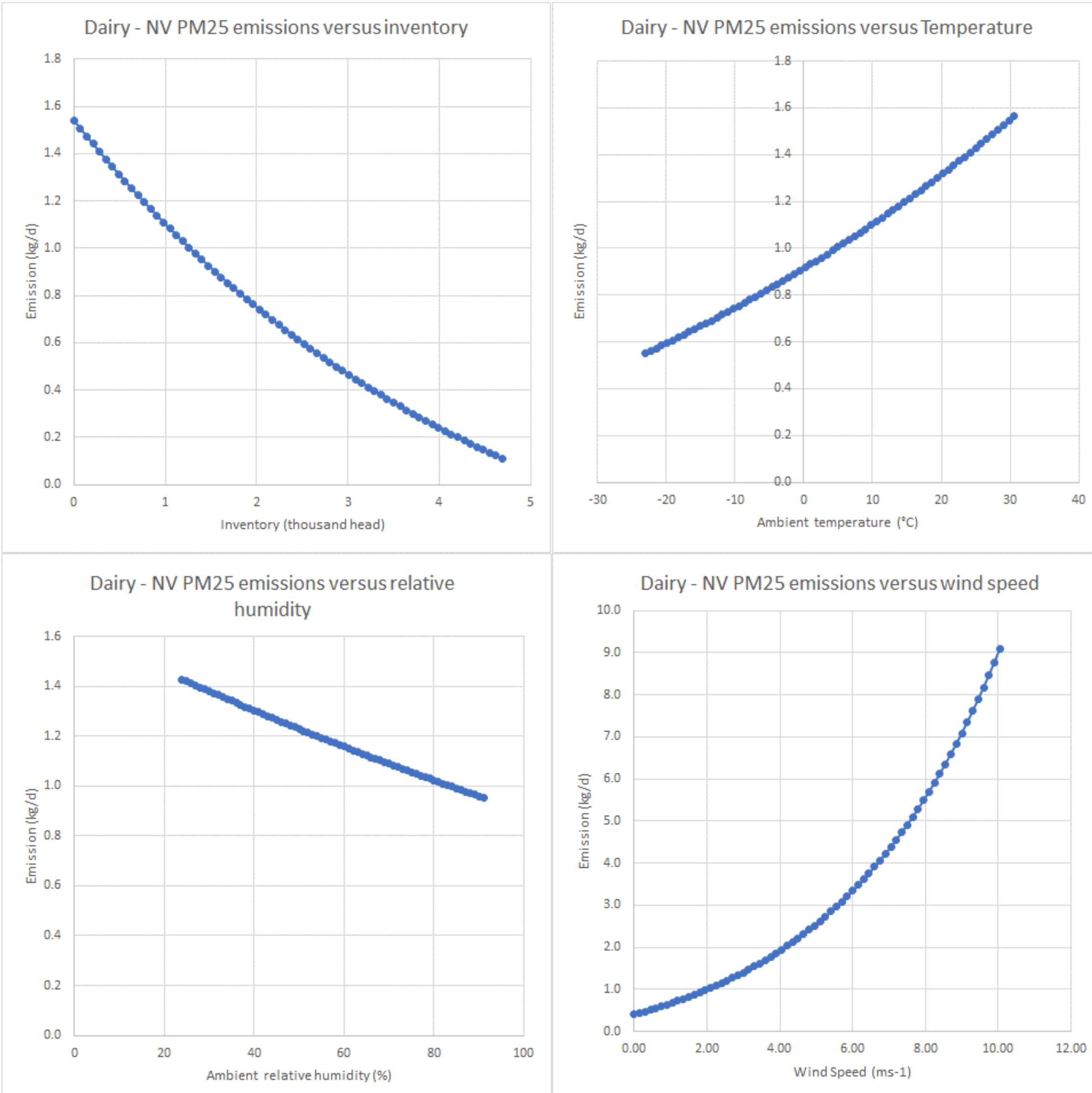

Figure 8-19. Naturally ventilated barn limitation tests for $PM_{2.5}$.
Visualization of the results for $PM_{2.5}$ tests of inventory (top left), ambient temperature (top right), relative humidity (bottom left), and wind speed (bottom right).

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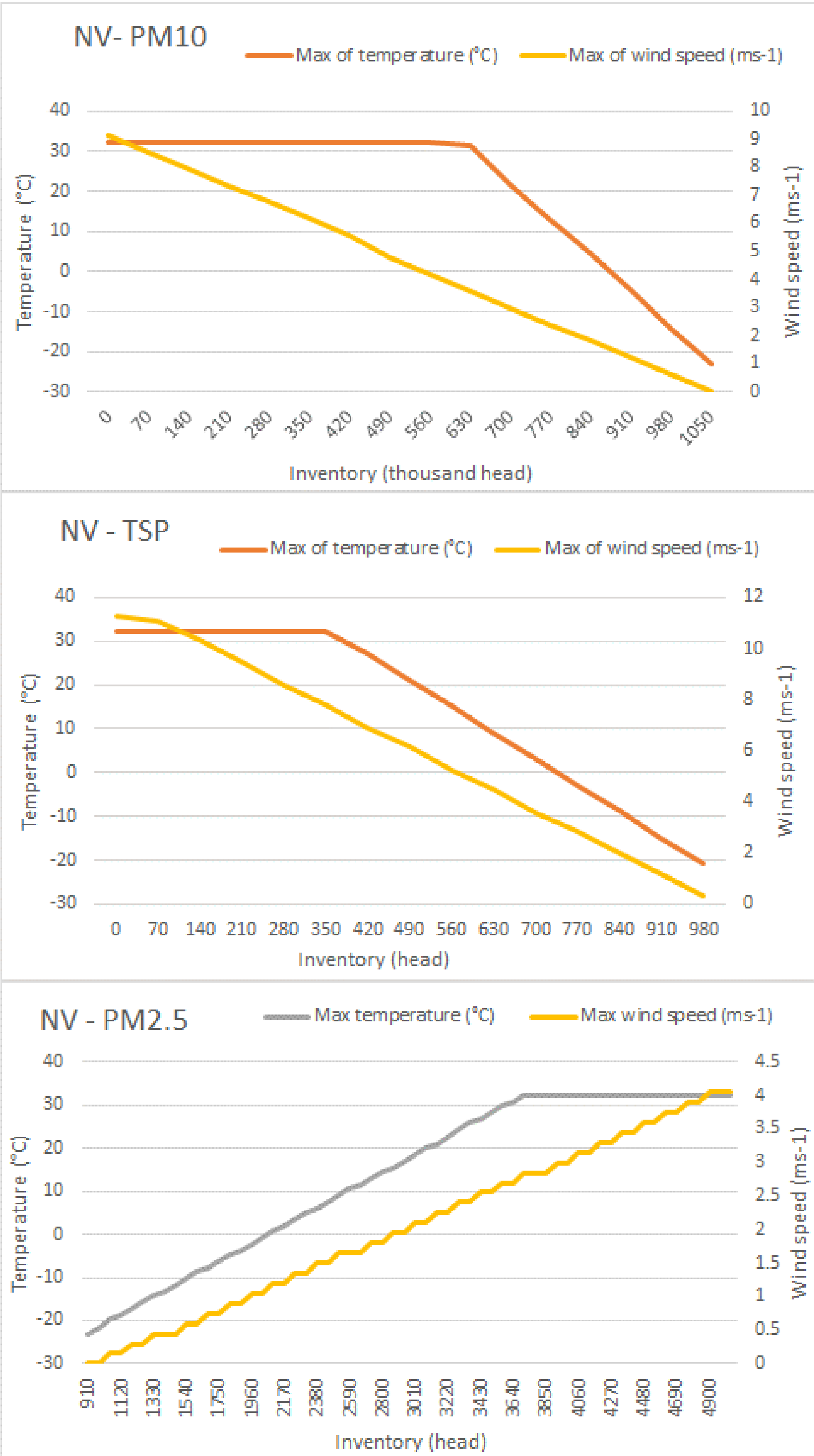

Figure 8-20. Maximum values of wind speed and temperature for each inventory level at which the particulate matter equations yields negative emissions.

Visualizations of the results for PM_{10} (top), TSP (middle) and $PM_{2.5}$ (bottom).

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8.2.3.4 Lagoon

The lagoon analysis for gaseous pollutants is presented in Figure 8-21. Both NH_3 and H_2S will produce negative emission values when temperatures dip below -11.8°C. EPA will evaluate whether the model should include a “floor”, that is past a certain temperature it is assumed the lagoon is frozen and is producing minimal emissions. The relationship between temperature and emissions is positive with no large changes in emission sensitivity.

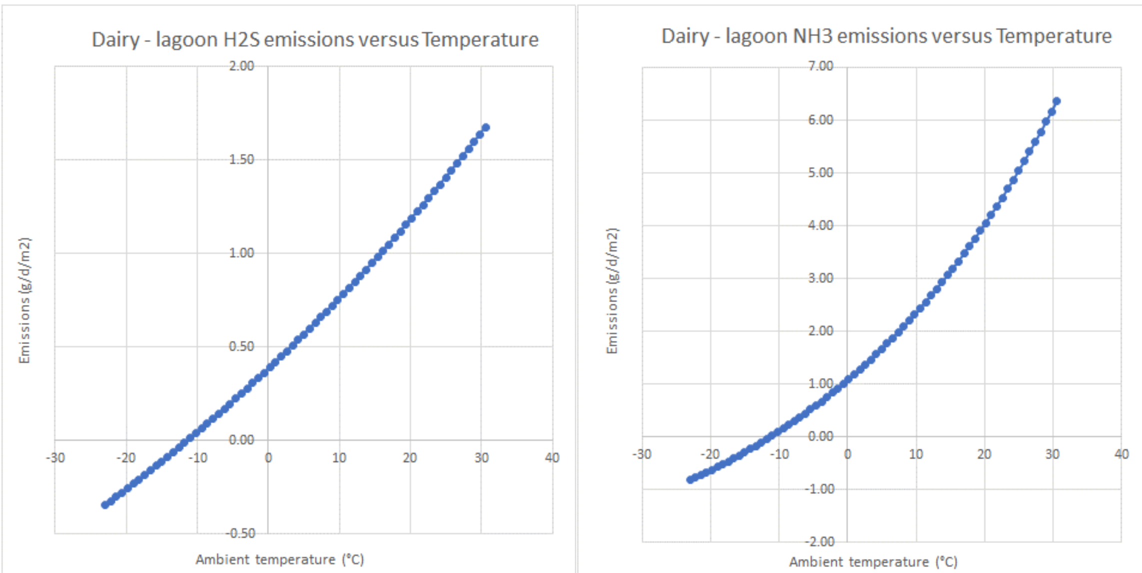

Figure 8-21. Lagoon limitation tests for gaseous pollutants.
Visualization of the results for tests of ambient temperature for H_2S (left) and NH_3 (right).

8.2.3.5 Corral

The corral analyses for H_2S and NH_3 are presented in Figure 8-22 and Figure 8-23, respectively. Neither the H_2S nor the NH_3 model produce negative emissions under average conditions. However, analyzing 397, 936 combinations of temperature, relative humidity, and wind speed, found that the NH_3 model will produce negative emission estimates at low temperatures (<7.8°C) combined with low relative humidities (<46%) and low wind speeds (<3.9 ms^{-1}). Figure 8-24 show that as temperature increases, there is a smaller range of relative humidity and wind speeds that produce negative emissions. Otherwise, the relationships between emissions and predictors do not show any rapid changes in emission sensitivity that are causes of concern.

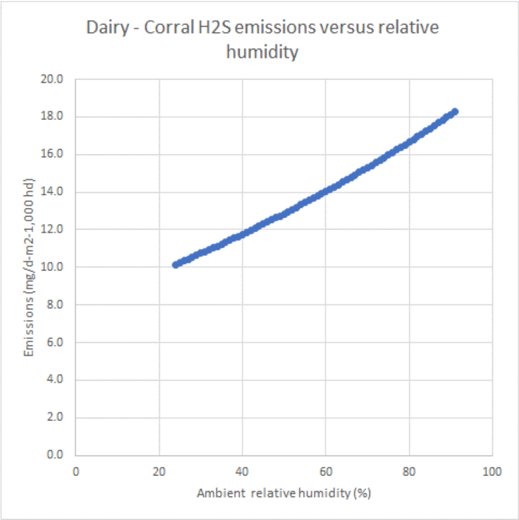

Figure 8-22. Corral limitation tests for H_2S.
Visualization of the results for tests of relative humidity for H_2S.

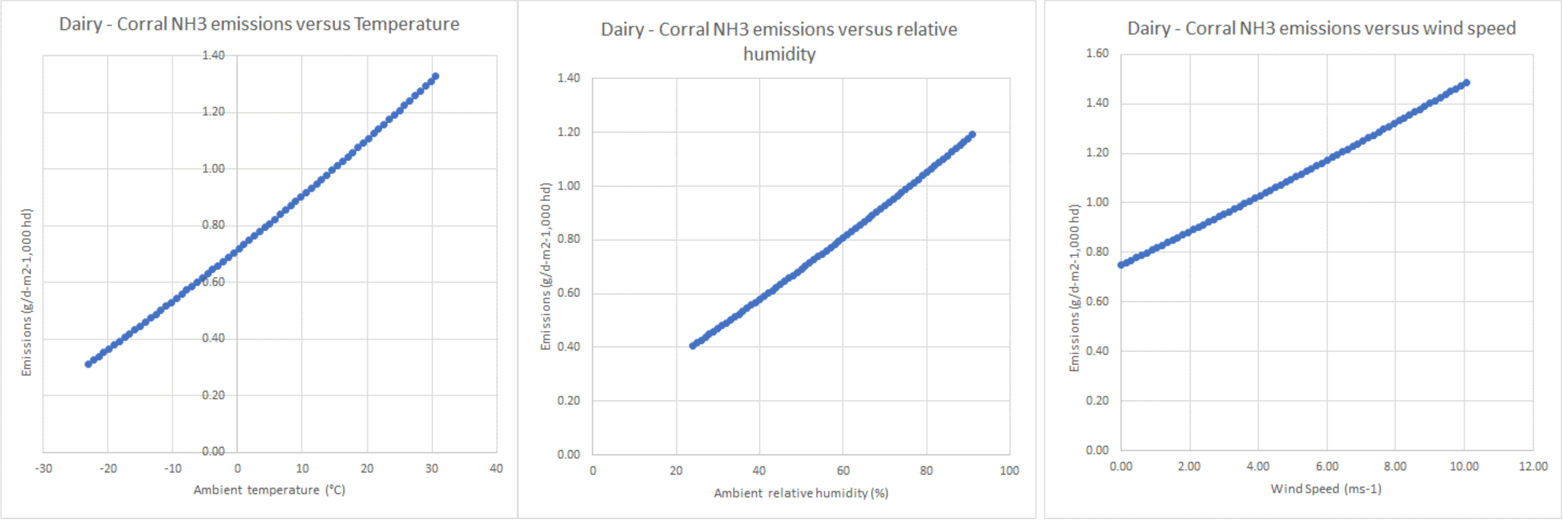

Figure 8-23. Corral limitation tests for NH_3.
Visualization of the results for NH_3 tests of ambient temperature (left), relative humidity (center), and wind speed (right).

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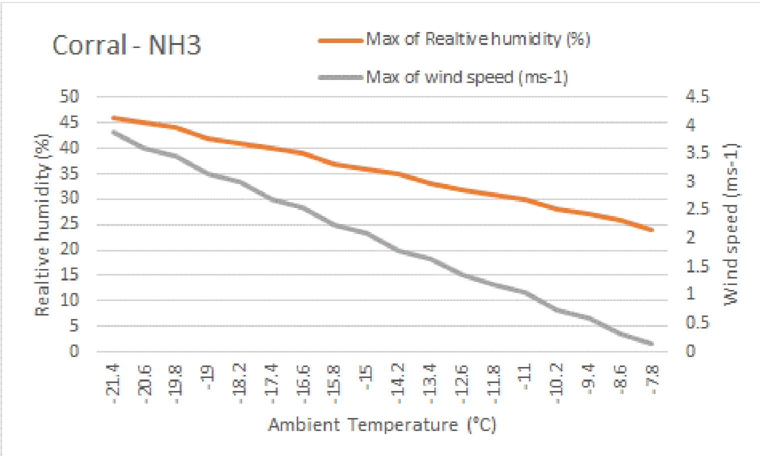

Figure 8-24. Maximum values of wind speed and relative humidity for each temperature at which the particulate matter equations yields negative emissions.

8.3 Comparison to Literature

To further validate the EEMs developed under this effort, EPA compared the results for the emission models to the emissions calculated using emission factors found in literature. EPA scanned the literature for a variety of emission factors for this comparison. EPA selected a variety of recent factors not derived from the NAEMS for comparison, which are summarized separately for barns, lagoons, and corrals in Table 8-15, Table 8-16, and Table 8-17, respectively. There were no emission factors identified for milking centers during the literature review. For the mechanically ventilated barns, the original units provided in Teye, F.K and Hautala, M. (2010) were g m^{-2} hr^{-1}, which were converted to kg hd^{-1} yr^{-1} based on the reported floor area of 774 m^{2} and inventory of 65 head. For naturally ventilated barns, values were converted based on 500 kg AU^{-1}, and an average weight of 635 kg per head, based on the NAEMS farms. For the lagoon and corral sources, surface areas in hectare were converted using the standard factor of 10000 m^{2}/ha. These converted emission factors were then applied to the theoretical farm sources from the previous example calculations. The following sections summarize the results for each source type.

Table 8-15. Emission factors for dairy barns from literature.

Source	Farm Source	Pollutant	mg sec^{-1} hd^{-1}	µg sec^{-1} hd^{-1}	kg hd^{-1} d^{-1}	g m^{2} hr	kg hd^{-1} yr^{-1}
Teye, F.K and Hautala, M. (2010)	Mechanically ventilated barn	NH_3				0.12[a]	12.52
Huang (2017)	Naturally ventilated barn	NH_3	0.98[a]				30.91
Leytem, et al. (2012)	Naturally ventilated barn	NH_3			0.08[a]		29.20
Huang (2017)	Naturally ventilated barn	H_2S		18.5[a]			0.58

[a] as reported in source.

Table 8-16. Emission factors for dairy lagoons from literature.

Source	Farm Source	Pollutant	kg/ha-d	g/m^2-d	kg/m^2-yr
Leytem, A.B., et al. (2011)	Lagoon[a]	NH3		2.0[b]	0.73
Leytem, A.B., et al. (2018)	Lagoon	NH3	43[a,c]		1.57

[a] Identified in the study as a wastewater pond
[b]as reported in source.
[C]rate reported for lagoon associated with a freestall barn (location ID D4)

Table 8-17. Emission factors for dairy corrals from literature.

Source	Farm Source	Pollutant	g/hd-d	kg/hd-d
Leytem, A.B., et al. (2011)	Corral	NH_3		0.13 [a]
Moore, K.D., (2014)	Corral	NH_3	134.2 [a]	0.134
Bonifacio, H.F., et al. (2015)	Corral	NH_3	155 [a]	0.155

[a] as reported in source.

8.3.1 Mechanically Ventilated Barn

Comparisons were made for an inventory of 500 cows and 1,000 cows for both a cold weather location (Wisconsin) and a warm weather location (California). The results for comparing the calculations for NH_3 emissions for mechanically ventilated scrape barns are presented in Table 8-18, and flush barn in Table 8-19. For both inventory levels, the emission factor from Teye and Hautala (2010) produces an estimate that falls just below the estimate produced by the emission models developed in this report. For the flush barns, the estimates based on Teye and Hautala (2010) fall between the estimate for the smaller barn (500 head) and just below the model estimates for the larger barn (1,000). For both manure management types, the models developed in the text represent an increase from previously published literature.

Table 8-18. Comparison of resulting mechanically ventilated scrape barn NH_3 emission from various estimation methods.

Meteorology site	Inventory (hd)	NH_3 Emissions (kg yr^{-1})	
		EPA 2022 models	Teye and Hautala (2010)
WI	500	7,098	6,259
CA	500	8,689	6,259
WI	1000	18,794	12,517
CA	1000	22,657	12,517

Table 8-19. Comparison of resulting mechanically ventilated flush barn NH_3 emission from various estimation methods.

Meteorology site	Inventory (hd)	NH_3 Emissions (kg yr^{-1})	
		EPA 2022 models	Teye and Hautala (2010)
WI	500	6,183	6,259
CA	500	7,597	6,259
WI	1000	16,574	12,517
CA	1000	20,006	12,517

8.3.2 Naturally Ventilated Barn

Like the mechanically ventilated examples, comparisons were made for an inventory of 500 cows and 1,000 cows for both a cold weather location (WI) and a warm weather location (CA). The results for NH_3 are presented in Table 8-20. For the smaller barn (500 head), the estimates for both the cold and warm meteorological conditions fall well below the estimates generated by the factors from literature. The estimates for the larger barn (1,000) the models presented in this work are closer to the estimates provided by emission factors from literature. This reiterates the results from the sensitivity analysis, where the emission estimates from the models increase rapidly with size.

For H_2S (Table 8-21), the estimates based on the models developed in this report are slightly greater for the smaller barn in a cold climate compared to literature. The large inventory examples and the 500 head barn in a warm climate are slightly lower than estimates based on literature.

Table 8-20. Comparison of resulting naturally ventilated barn NH_3 emission from various estimation methods.

Meteorology site	Inventory (hd)	NH_3 Emissions (kg yr^{-1})		
		EPA 2022 models	Huang (2017)	Leytem, et al. (2012)
WI	500	4,194	15,453	14,600
CA	500	3,816	15,453	14,600
WI	1,000	28,137	30,905	29,200
CA	1,000	26,050	30,905	29,200

Table 8-21. Comparison of resulting naturally ventilated barn H_2S emission from various estimation methods.

Meteorology site	Inventory (hd)	H2S Emissions (kg yr^{-1})	
		EPA 2022 models	Huang (2017)
WI	500	310	292
CA	500	289	292
WI	1,000	477	583
CA	1,000	447	583

8.3.3 Lagoon

For lagoons, comparisons were made for both a cold weather location (WI) and a warm weather location (CA) assuming a surface area of 10,000 m^2. The NH_3 results in Table 8-22 show the models developed in this report generate an estimate that falls between the factors from literature.

Table 8-22. Comparison of resulting dairy lagoon NH_3 emission from various estimation methods.

Meteorology site	Surface Area (m2)	NH3 Emissions (kg yr-1)		
		EPA 2022 models	Leytem, A.B., et al. (2011)	Leytem, A.B., et al. (2018)
WI	10,000	8,961	7,300	15,695
CA	10,000	12,525	7,300	15,695

8.3.4 Corral

For corrals, the comparison was made for both cold (WI) and warm (CA) meteorological scenarios. Calculations were also made for a small farm (500 head) and a larger farm (1,000 head), assuming a surface area of 10,000 m^2 for each farm for the method developed in this report. The summary for NH_3 in Table 8-22 shows the estimates based on the EPA 2022 draft methods are comparable to the estimates based on emission factors from literature.

Table 8-23. Comparison of resulting dairy corral NH_3 emission from various estimation methods.

Meteorology site	Inventory (hd)	Surface Area (m^2)	NH3 Emissions (kg yr-1)			
			EPA 2022 models	Leytem, A.B., et al. (2011)	Moore, K.D., et al. (2014)	Bonifacio, H.F., et al. (2015)
WI	500	10,000	23,975	23,725	28,288	24,492
CA	500	10,000	22,551	23,725	28,288	24,492
WI	1000	10,000	47,949	47,450	56,575	48,983
CA	1000	10,000	45,101	47,450	56,575	48,983

8.4 Replication of Independent Measurements

A final test of the developed emission models is to compare the predicted emissions to observed values from an independent study. For this test, EPA was able to obtain some of the data from the Harper, et al. (2009) study of lagoons in Wisconsin. The data available are for NH_3 emissions for two of the three sites, for fall and summer monitoring periods. EPA was also able to obtain data from the Leytem et al. (2013) study, where an open-freestall production facility was monitored in southern Idaho. Measurements were collected for both the open-freestall area and the wastewater ponds. The data from the Idaho open-freestall area was used to test the corral model and data from the Wisconsin lagoons and the Idaho wastewater pond data was used to test the lagoon model.

The data provided included the necessary information to estimate emissions using the developed emission models. These estimates were then compared to the observed values, when available, using the same model performance statistics noted in Section 6 of the main report. Scatter plots were also developed to present the ordered pairs with observations on the x-axis and the model predicted values on y-axis. These plots are useful for indicating trends of either over-, or under-prediction across the range of values. The plots include the 1:1 line (solid line) and the 1:0.5 and 1:2 lines (dashed lines). Points that fall on the 1:1 line were predicted correctly, and points that fall between the 1:0.5 and 1:2 are within a factor of two observations. Good model performance would be indicated by scatter contained within a factor of two of the 1:1 line, that is between the 1:0.5 and 1:2 lines. Looking for scatter confined to within a factor of two of the observation has been used as a model performance metric in air quality modeling by EPA for some time (Chang & Hanna, 2004) and continues to be included in EPA's Atmospheric Model Evaluation Tool (Appel, et al. 2011), which is the current model evaluation platform. The following sections summarize the result for each source type.

8.4.1 Lagoon

The model performance statistics (Table 8-24) indicate an under-prediction of emissions at both sites. Figure 8-25 shows that the largest under-predictions occur for observations greater than 10 g d^{-1} 1000 hd^{-1}, as indicated by the drop below the 1:1.05 line on the plot for the Idaho site. This suggests the current formulation of the model underestimates the highest emissions.

Table 8-24. Model performance evaluation statistics for lagoon NH_3 estimates.

Site	n	LNME[a] (%)	NME[b] (%)	ME[b] (g d^{-1} 1000 hd^{-1})	MB[b] (g d^{-1} 1000 hd^{-1})	NMB[b] (%)	Corr.
ID	23	26.177	69.196	4.800	-4.681	-67.47	0.497
WI	3	20.271	48.388	3.209	-3.209	-48.39	0.999

[a] Based on transformed data (i.e., ln(NH_3)).
[b] Based on back-transformed data.

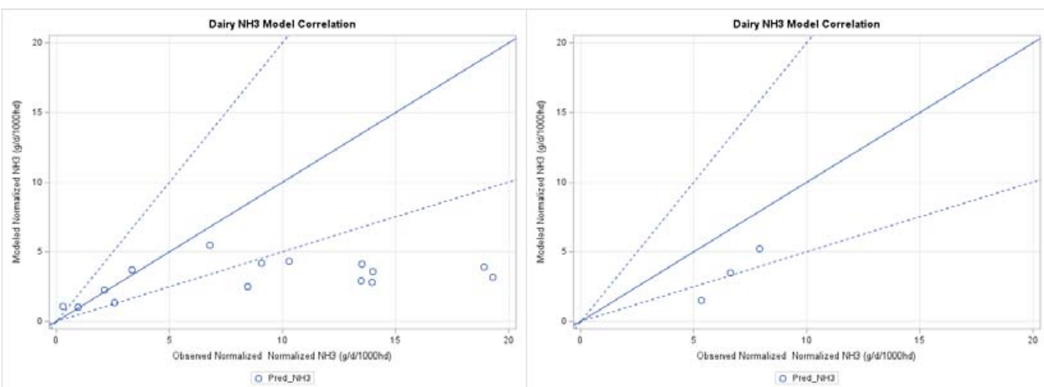

Figure 8-25. Scatter plot of the observed lagoon NH_3 emissions versus the emission model estimates.
Results from the Idaho site (left) and Wisconsin site (right).

8.4.2 Corral

The model performance statistics (Table 8-25) show an under-prediction of emissions from the corral. The plot of observed versus estimated emissions (Figure 8-26) show there are slight overpredictions at low emission levels, as the points fall above the 1:1 line, and an underprediction at higher observed emission levels. As with the lagoon model, this suggests an underprediction of highest emission values in the model.

Table 8-25. Model performance evaluation statistics for corral NH_3 estimates.

Site	n	LNME[a] (%)	NME[b] (%)	ME[b] ($g\ d^{-1}$ 1000 hd^{-1})	MB[b] ($g\ d^{-1}$ 1000 hd^{-1})	NMB[b] (%)	Corr.
WI	18	17.371	70.689	1.316	-0.574	-30.84	-0.351

[a] Based on transformed data (i.e., ln(NH_3)).
[b] Based on back-transformed data.

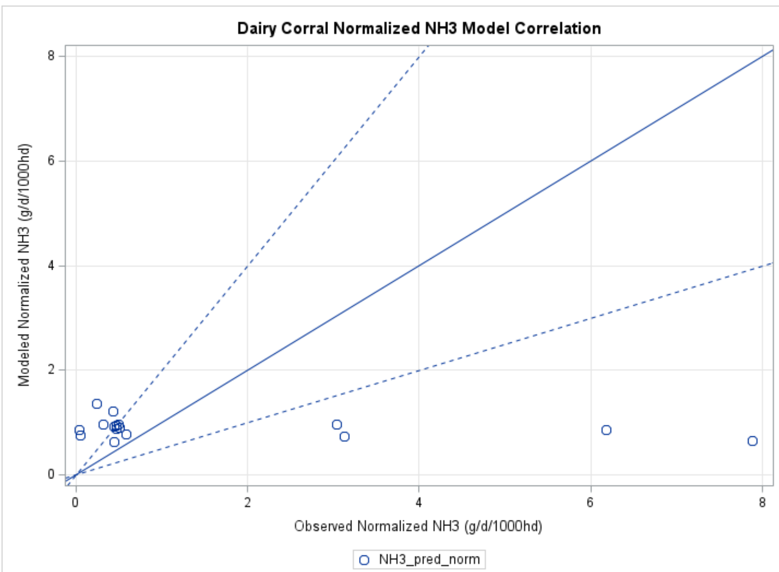

Figure 8-26. Scatter plot of the observed corral NH_3 emissions versus the emission model estimates.

9 CONCLUSIONS

Consistent with the Air Compliance Agreement with the AFO industry, EPA has developed emission estimation methods for NH_3, H_2S, PM_{10}, $PM_{2.5}$, and TSP for confinement and open sources associated with dairy operations. These draft statistical models focus on parameters that have been identified in published peer-reviewed journals as having empirical relationships with emissions. These relationships were evaluated within the NAEMS dataset before selecting parameters for emission model development. EPA also considered which variables could be measured or obtained with minimal effort.

The inventory was identified as a key parameter and is used in all the models as a proxy for the volume of manure generated. Temperature and relative humidity parameters were also identified as important variables for emission rates in the barn emission models. Relative humidity parameters proved to be key for particulate matter prediction, as the higher moisture levels keep barn materials from entraining into the air with mechanical disruptions. Confinement parameters specific to the barn, like exhaust temperature, showed promise as predictive parameters. However, these parameters are not routinely measured at farms and would therefore represent an increased burden to operators should they be required for emissions estimation. As such, all of the draft dairy emission models put forward for potential future use in this document use parameters that are already routinely collected as part of the standard farm operation (e.g., inventory) or are ambient meteorological parameters, which are freely available from public sources such as National Center for Environmental Information (NCEI, https://gis.ncdc.noaa.gov/maps/).

Overall, the method used to develop the emission models allows for the incorporation of additional emissions and monitoring datasets from other studies, should they become available to EPA after the release of the emission models. Revised emission models for any individual farm type could be issued once significant additional data becomes available. Similarly, if monitoring options for barn parameters become more widespread as automation options grow, future evaluations could assess whether emission models should be developed to include these parameters.

EPA recognizes the scientific and community desire for process-based models. The data collected during NAEMS, and the emission models developed here lay the groundwork for developing these more process-related emission estimates. EPA supports the future development of process-based models which account for the entire animal feeding process. While the interim statistical models allow estimation of emissions from barns and open sources at dairy operations across the U.S., process-based models would allow producers to estimate the impacts of different management practices to reduce air emissions, helping to incentivize change.

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Guidelines for Calculating Emissions from Dairy and Poultry Operations

December 2016

The dairy and poultry farms are required to report to the SCAQMD their emissions of Volatile Organic Compounds (VOC), Particulate Matter (PM) and Ammonia (NH_3) that result from the handling of livestock waste. For poultry operations, there are additional PM emissions from bird feed.

1. PROCEDURES

Facilities can estimate their VOC, PM, and NH_3 emissions using the equation:

$$\mathbf{E = Q * EF * (1 - CE)}$$

Where,

E = VOC, PM or NH_3 emissions, expressed in pounds per year (lbs/yr)

Q = Throughput is the number of animals per reporting year by animal category. For poultry farms, the throughput is also expressed in tons of bird feed when estimating PM emissions from bird feed.

EF = Uncontrolled emission factors from Table 1 based on the animal categories and materials.

CE = Control effectiveness listed in Table 2 based on the types of manure disposal practices.

Table 1: Uncontrolled Emission Factors

Animals/Operations	**VOC lbs/head**	**PM**		**NH_3 lbs/head**
		lbs/head	**lbs/ton**	
Dairy Farms:				
Milking Cows	12.8	3.56	---	74.0
Dry Cows	8.7	3.56	---	45.4
Heifers (4-24 months)	6.1	3.56	---	27.8
Heifers (4-24 months)*	4.4	3.56	---	27.8
Calf (under 3 months)	4.5	3.56	---	23.6
Mature Cows*	6.3	3.56	---	74.0
Poultry Farms:				
Manure	0.02565	0.0616	---	0.096
Feed	---	---	0.108	---

*Emission factors for dairy operations with flush lanes that are flushed with water to a holding pond.

- *Milking cow is a cow raised to produce milk*
- *Dry cow is a cow of approximately 2 weeks from calving and in between lactation, hence, is not giving milk and is usually kept separately for different feeding*
- *Heifer is a young female calf under 3 years old and has not borne a calf*
- *Calf is a young cow or bull in its first year*
- *Mature cow is a cow that has had one or two calves and which may be more than 3 years old*

Table 2- Control Effectiveness

Type of Disposal	**(VOC & NH_3) Control Effectiveness**	**(PM) Control Effectiveness**
No Disposal	---	---
Best Management Practices	---	0.20
Manure Sent out of Basin	0.50	---
Composting (open window)	0.385	---
Composting (enclosed)	0.475	---
Digester (plug & complete mix)	1.0	---
Land Application	0.115	---

- *Best Management Practices are Class One Mitigation Measures defined in Rule 223, Appendix A, Table 1, subsections E & F, and Table 2, subsections C & D.*
- *Land Application is the use of methods such as tilling, injecting, or plowing that covers animal waste in accordance with NRCS Agricultural Waste Management Field Handbook Chapter 10, Section 651.1102.*

2. HOW TO REPORT

VOC, PM, NH_3 emissions must be reported separately for each animal category (i.e., milking cows, dry cows, heifers, birds, etc.). This can be done through the following steps:

1. Determine the annual average number of animals, (Throughput, Q):
    - For a dairy farm, take the annual average number of animals for each annual category from the annual report submitted to the Santa Ana Regional Water Quality Control Board (SARWQCB).

- For a poultry farm, take the annual average number of birds using your annual recordkeeping report. In addition, the total amount of bird feed used for the same time period is also needed.

2. Select proper emission factors listed in Table 1, (EF):
   - Note that the VOC emission factors are different based on the animal category (e.g., milking cows versus dry cows) and whether the dairy farm has lanes that are flushed with water to a holding pond.
   - Note that the PM emission factors are different based on the source of emissions (bird's manure or feed). There are no VOC or NH_3 emissions associated with bird feed.
3. Select appropriate control effectiveness (CE) from Table 2 based on the type of emissions (i.e., VOC, PM, or NH_3) and manure handling method.
4. Enter the information into the AER Reporting Tool.

EXAMPLE 1:

Last year, a dairy farm facility has reported to the Santa Ana Regional Water Quality Control Board 900 milking cows, 300 heifers (17-14 months) and no calves. The manure is sent out of the basin. This dairy does not have any lanes that are flushed with water to a pond.

<u>STEPS TO REPORT THE EMISSIONS</u>

Image 1: Click **<u>Emission Sources (ES)</u>**. The reporting tool displays existing permitted units (emission sources) as shown at bottom of the image below. If livestock waste handling is not listed, it must be added to the list by clicking <u>Add New Emission Source</u>. In this example, this farm is operated with a permit. Click on the hyperlink <u>Open</u> for ES#1 which will take user to image 2 below.

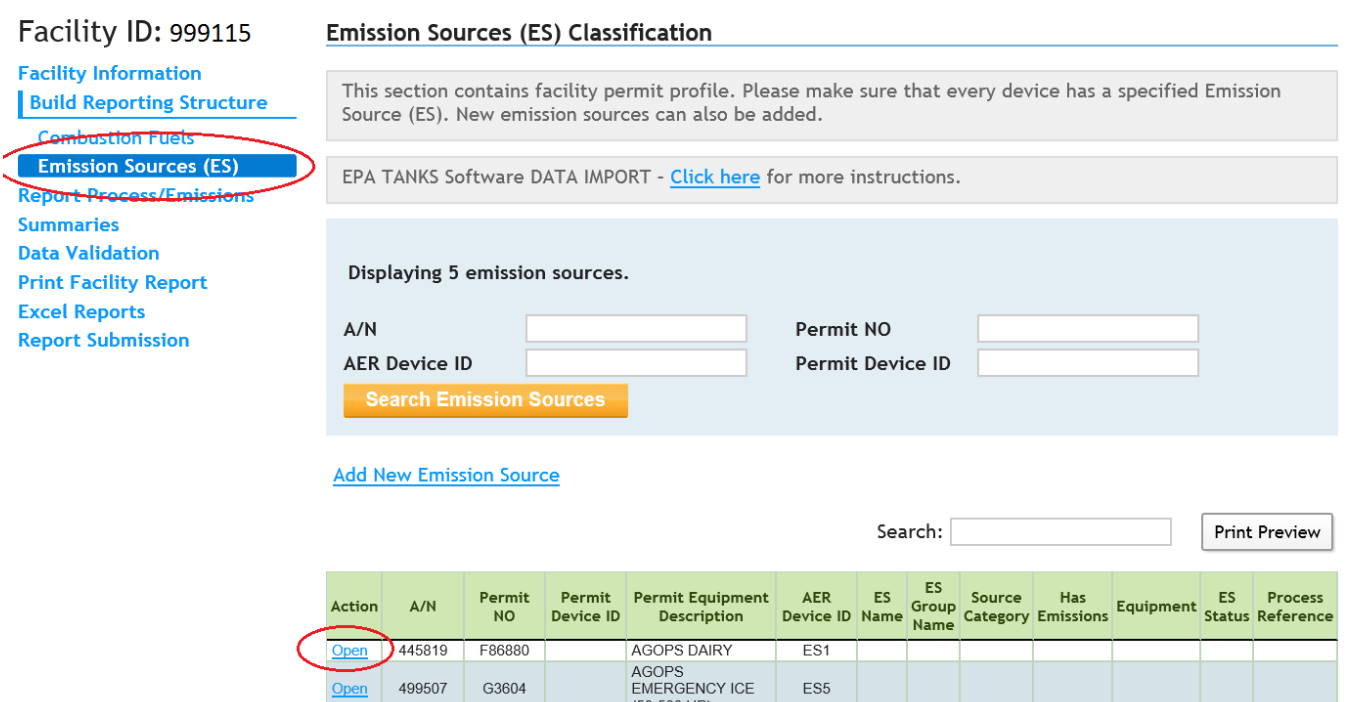


Image 2: Fill out relevant information to the Emission Source by identifying ES Name (example, Animal Waste Handling) and selecting the Operating ES Status (i.e., Normal Operation) from the drop-down menu. After selecting the appropriate Operating ES Status, the **Categorize Emission Source** button will appear. By clicking this button, the tool will take the user to the next screen (image 3 below) for categorizing this emission source.

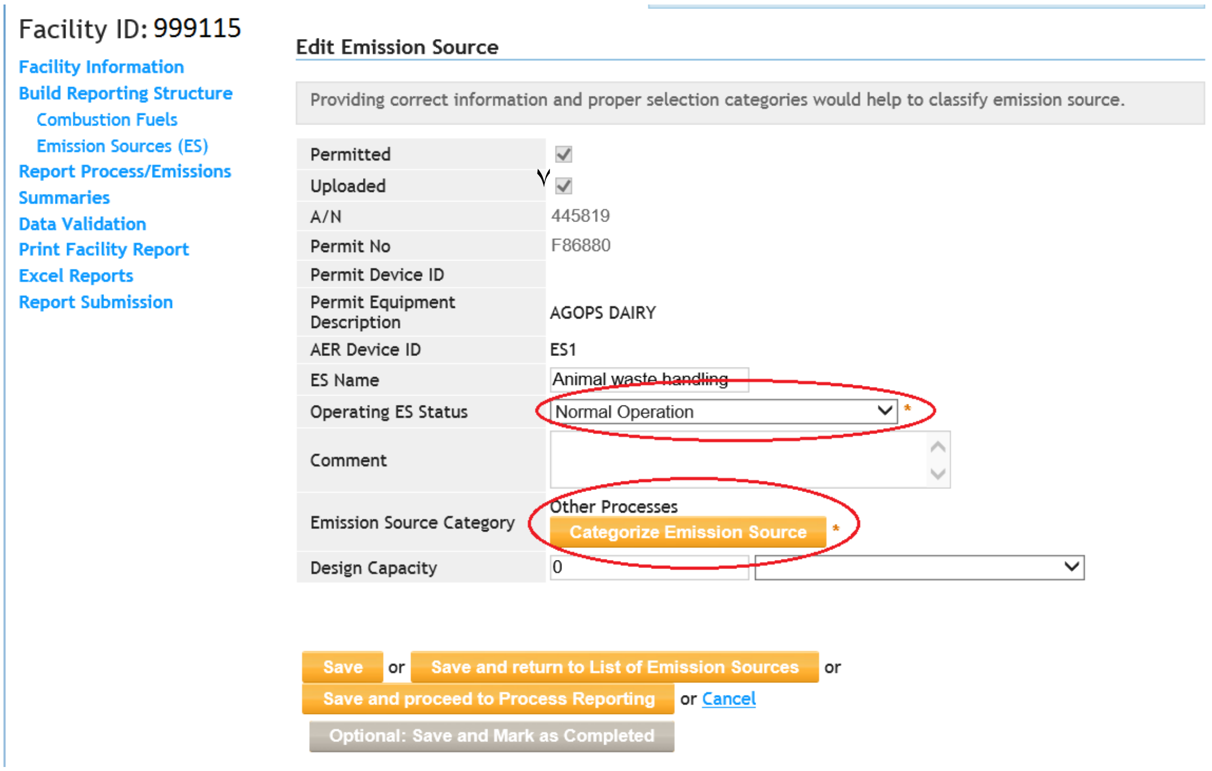
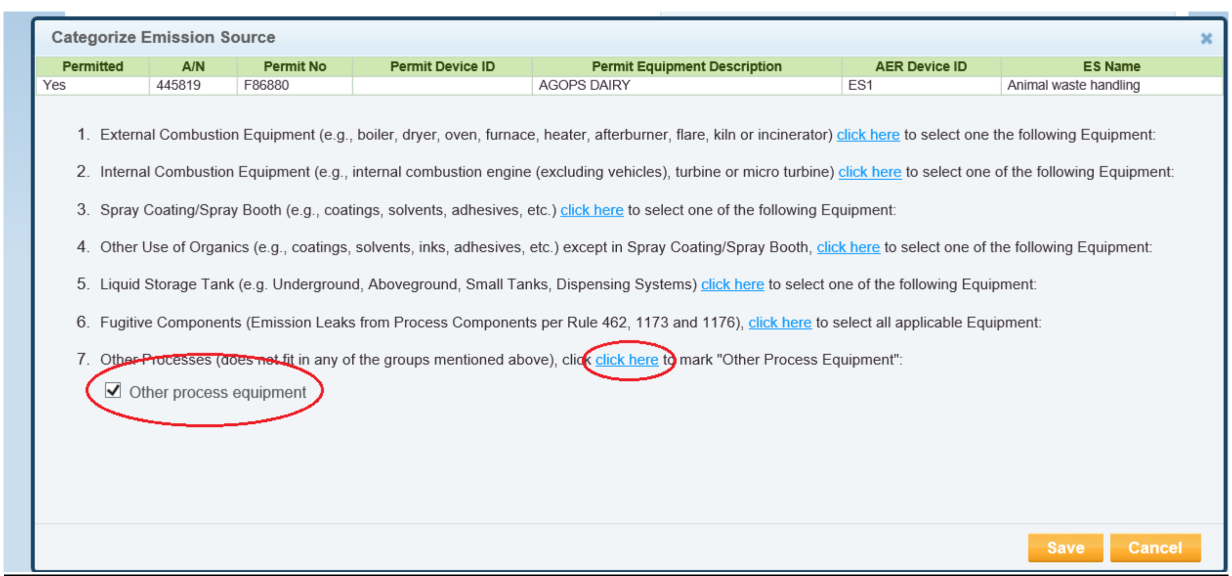


Image 3: In this example, user selects No. 7 by clicking on any part of the selection. Click the box designated as "Other process equipment", and click **Save** button.



Item A 000247

After saving, the program return user to Image 2. Click "**Save and proceed to Process Reporting"** which will take the user to the screen shown in Image 4 for reporting emissions for this emission source.

Image 4: The reporting tool adds a new Process (P1). Click the hyperlink "Open" for entering process information such as throughputs, emissions, emission factors, and TACs as shown in Image 5.

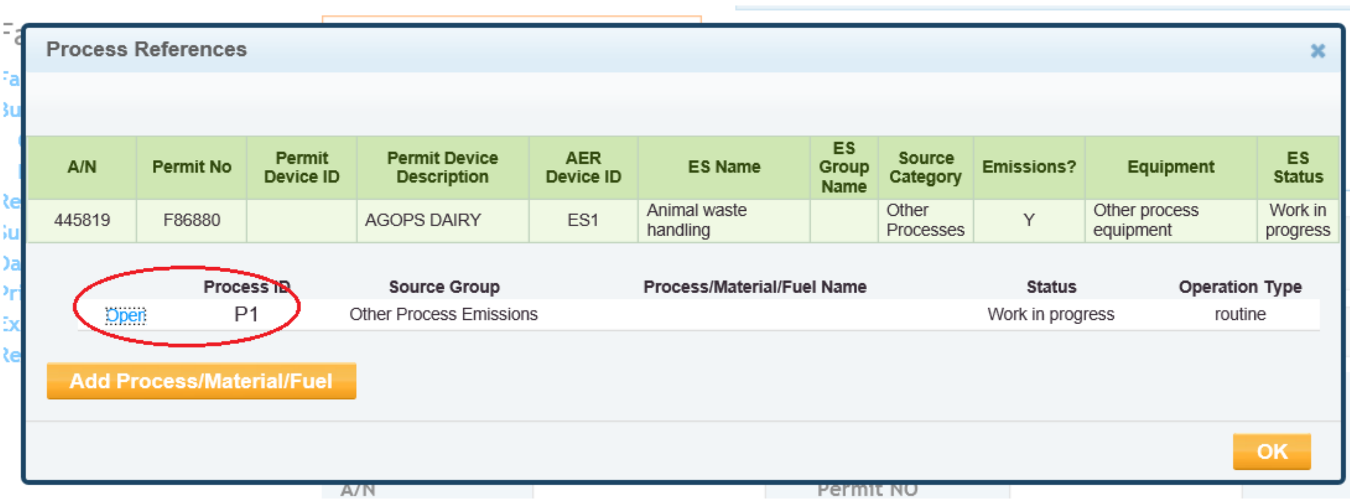


Image 5: The hyperlinks "Open" are designated for data entry to each section. The first one is for process information as shown in Image 6 below.

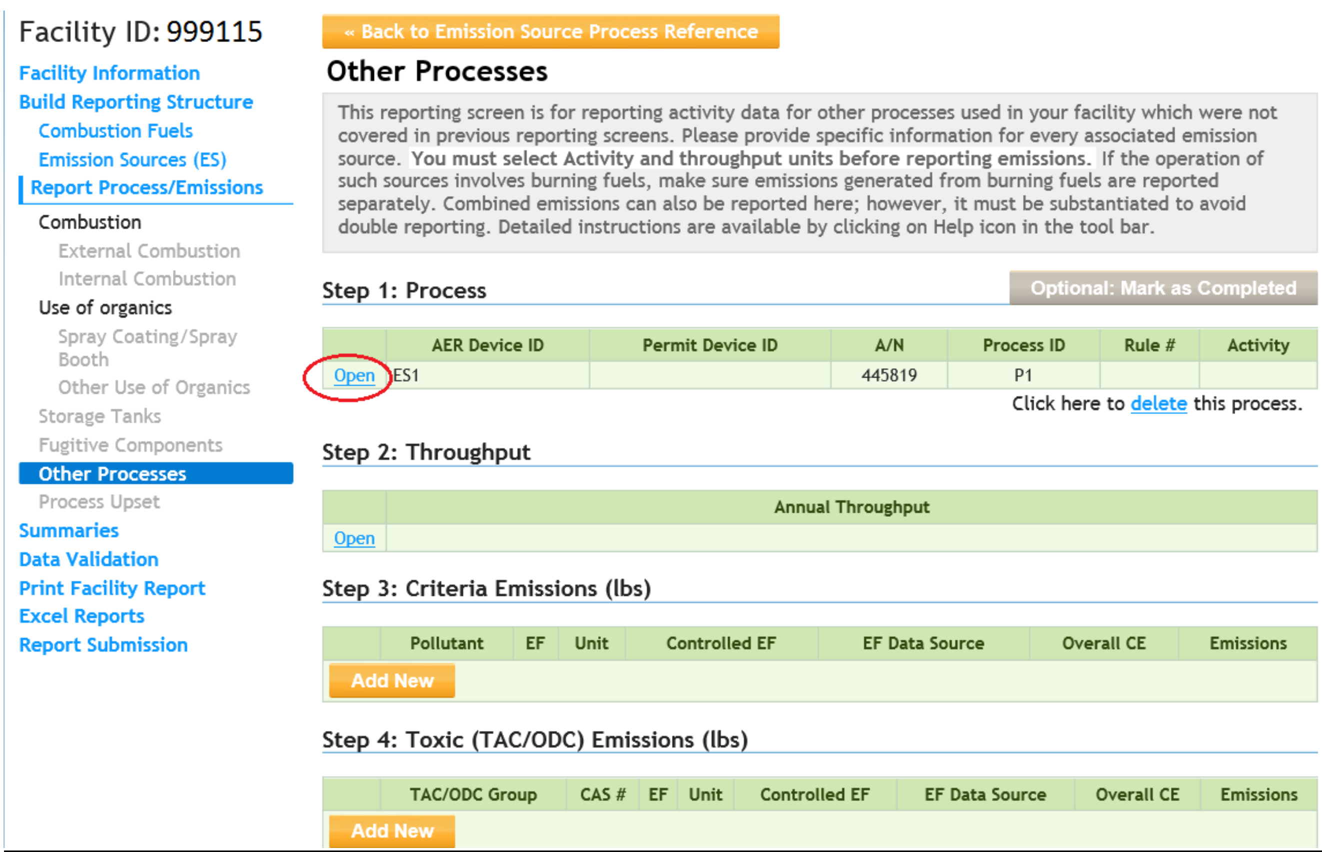


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Image 6: After clicking Open, this image will pop-out. Identify the Process Name for the first process P1 and fill out the Activity Code by selecting the appropriate information from the drop-down menu from each box. Example shows correct sector, industry, operation, process, and rule for the milking cows. Click **Save** button.

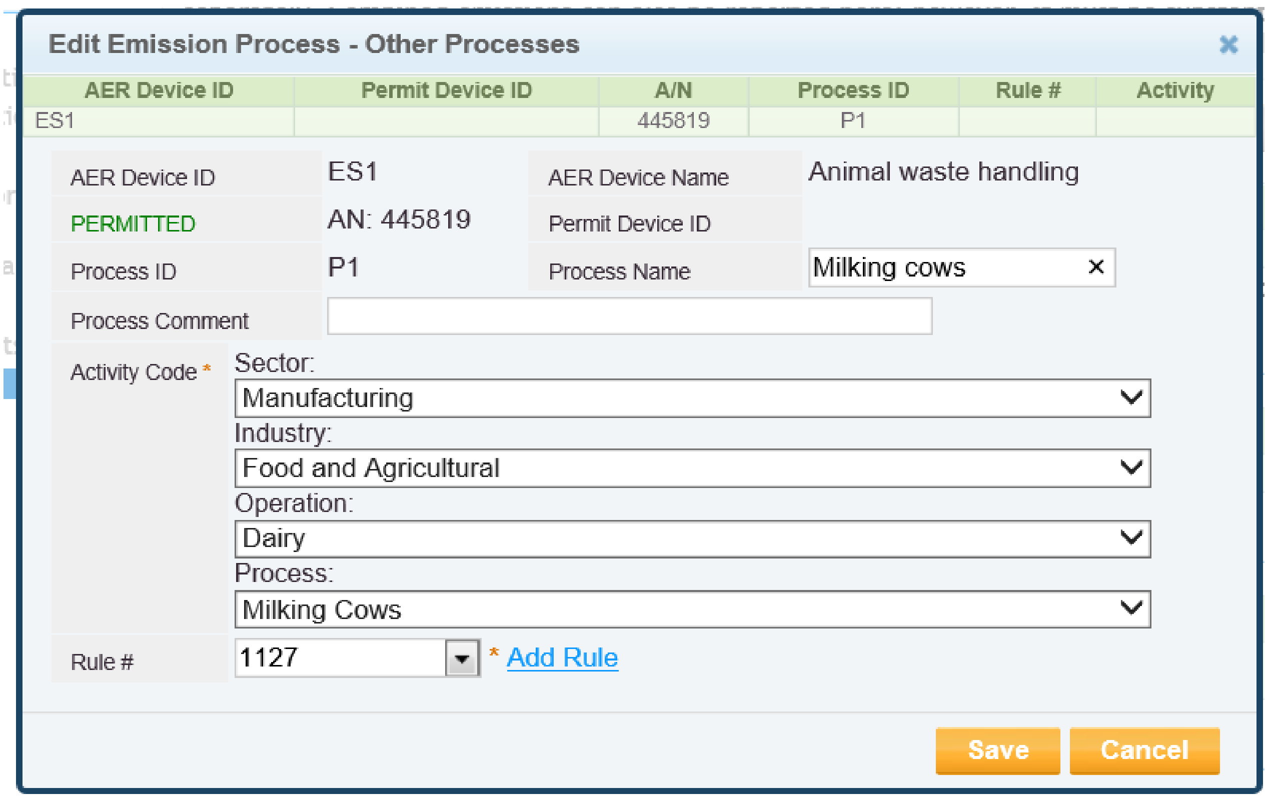

Image 7: After saving, the program returns to Image 5. This time, open the **Throughput** section (see Image 5) to enter the Annual Throughput, Type and Comment for the Process, as shown below. Click the **Save** button.

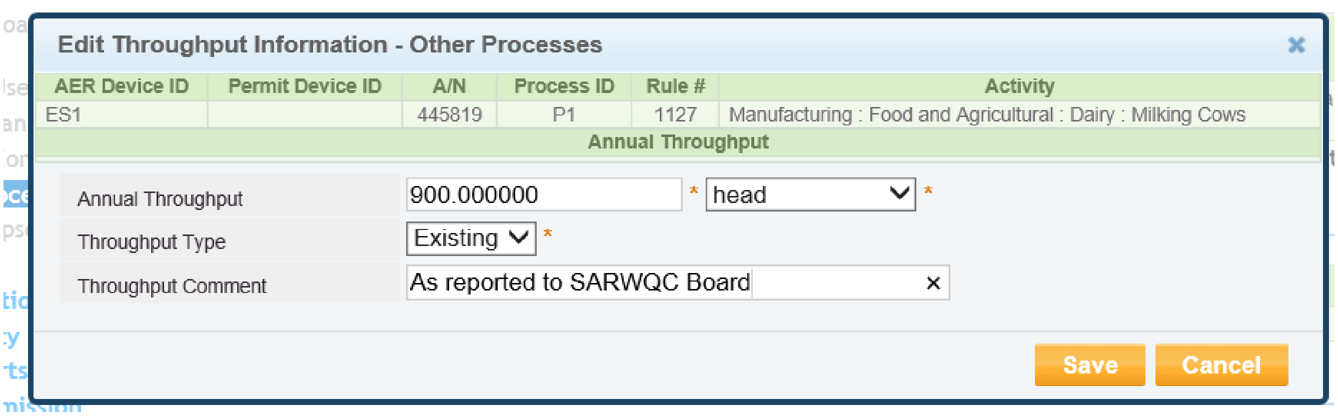

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Image 8: After saving, the program returns to Image 5. Add the Criteria Emissions generated by the Process by clicking "**Add New"** (yellow button)" under **Criteria Emissions** section.

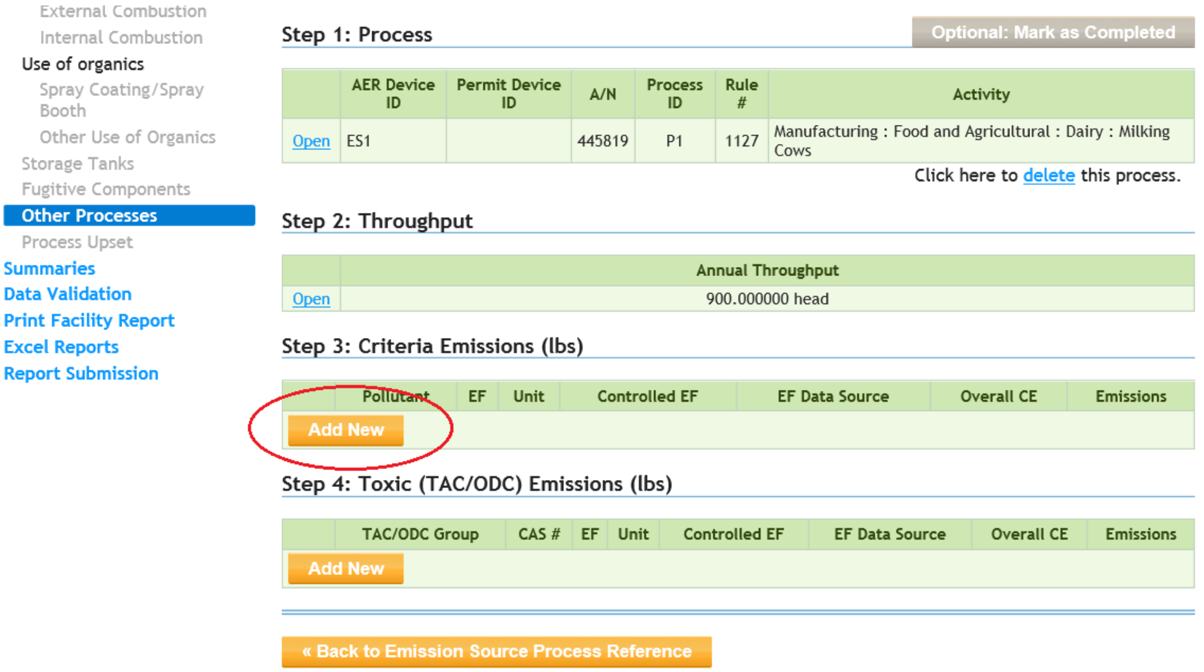
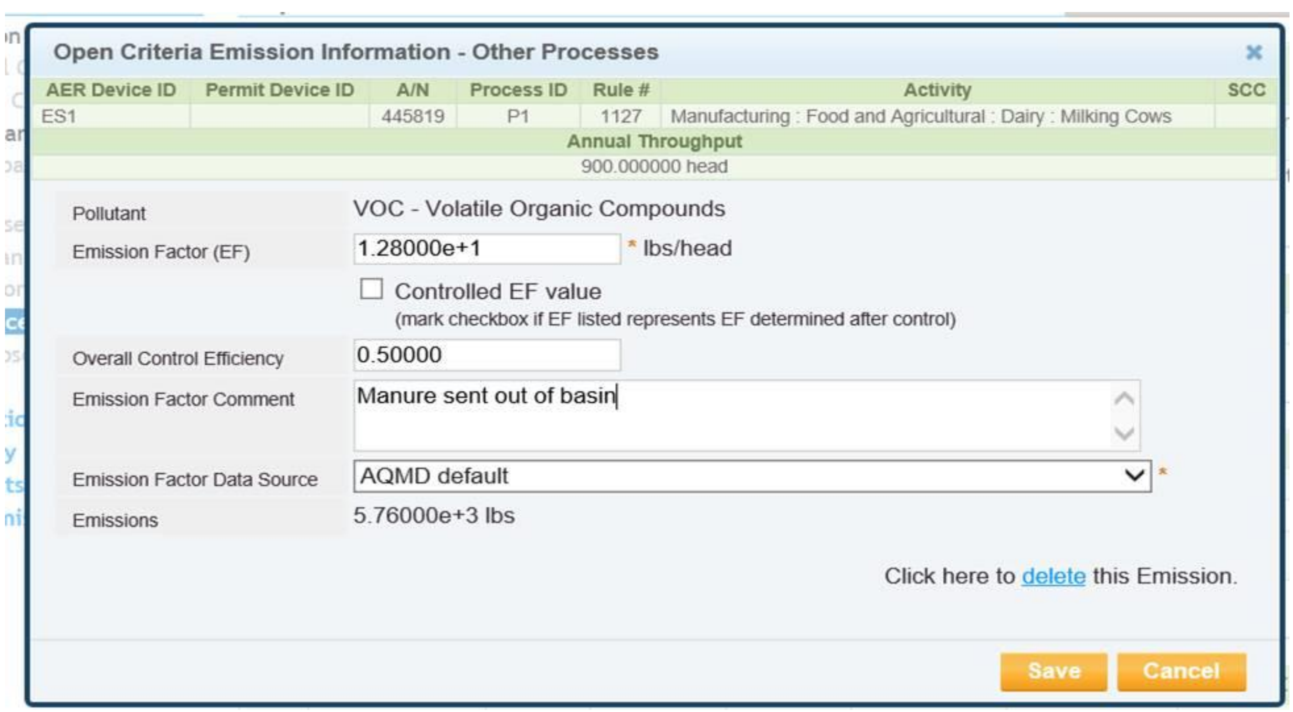
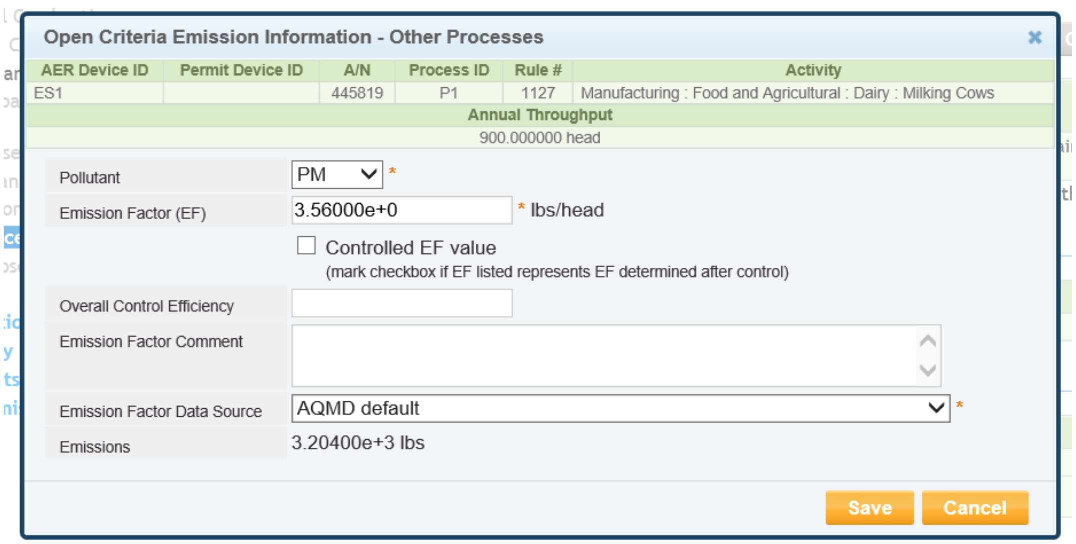


Image 9: Select the type of pollutant, (i.e., VOC, etc.) from drop-down menu, enter the applicable emission factor (from Table 1), control efficiency (from Table 2), emission factor comment and the emission factor data source for the Process. Click **Save** button.



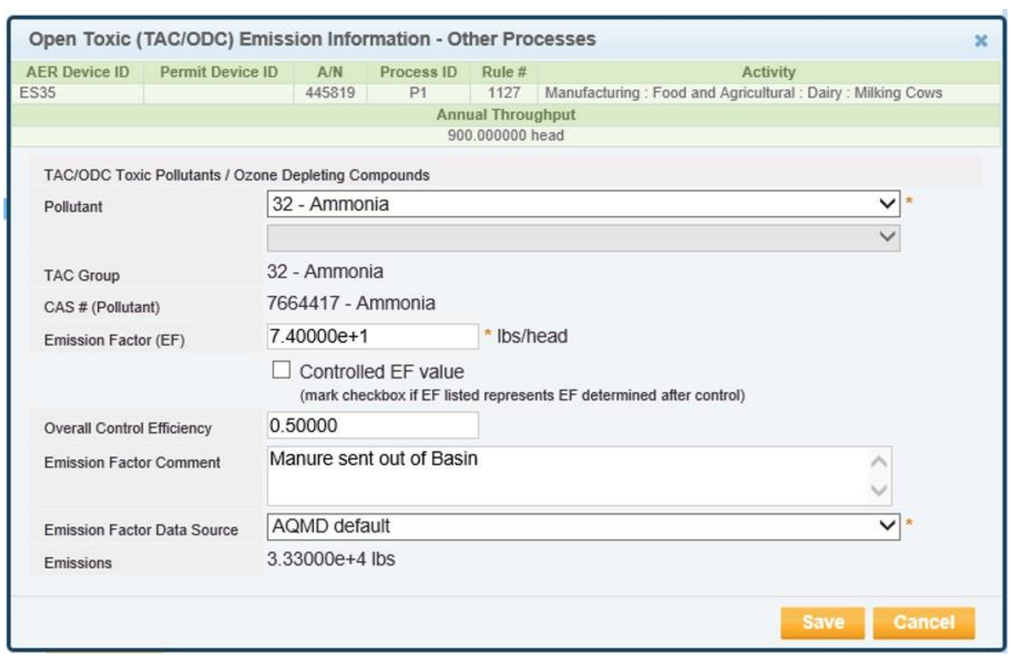
Item A 000250

Image 10: After saving, the program returns to Image 5. To add the next pollutant type (PM) for the same Process P1, click the **Add New** button under **Criteria Emissions** section, Select PM from the drop-down menu, enter the applicable emission factor (from Table 1), control efficiency (from Table 2), emission factor comment and emission factor data source and enter them in the appropriate boxes. Click the **Save** button.



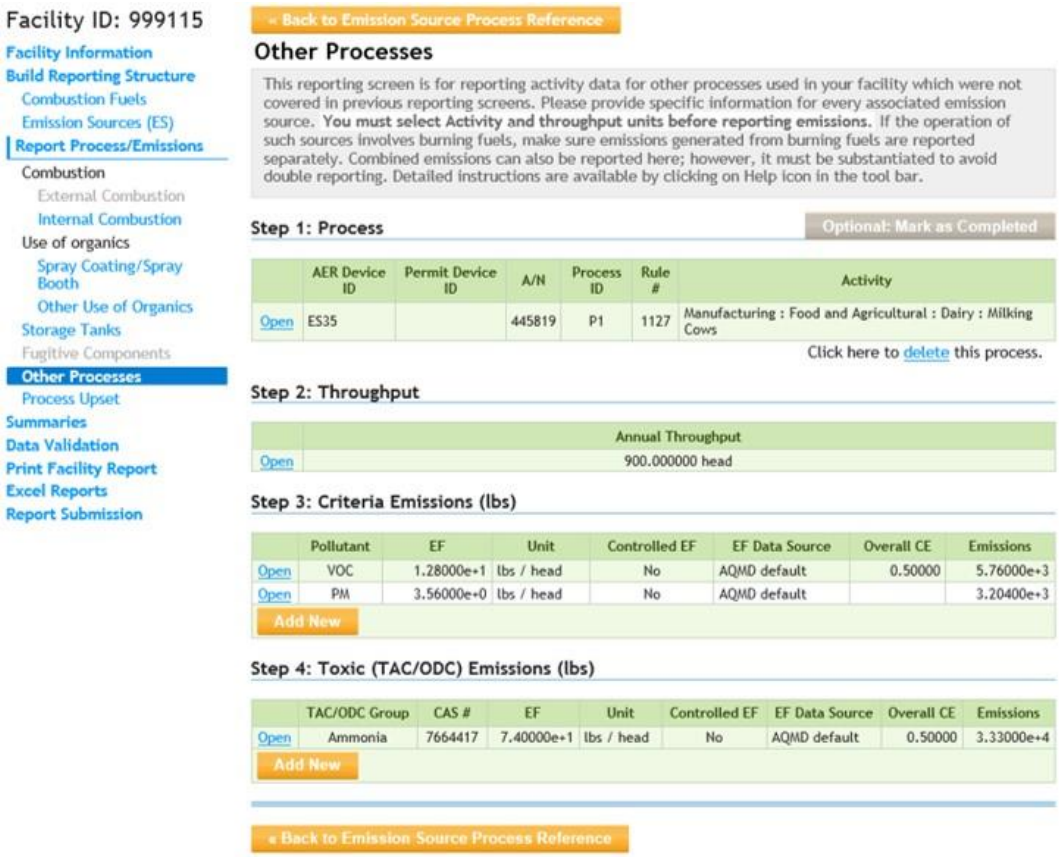
STEPS TO REPORT NH_3 (TAC/ODC)

Image 11: After saving, the program returns to Image 5. To add TAC/ODC emissions from the same Process P1, click the **Add Toxic (TAC/ODC)** Emissions under **Toxic Emissions** section (NH_3 emissions in this example). Select NH_3 (Ammonia) from the drop-down menu and select the applicable Emission Factor (from Table 1) and Control Efficiency (from Table 2) and enter them in the appropriate boxes. Click **Save** button.



Item A 000251

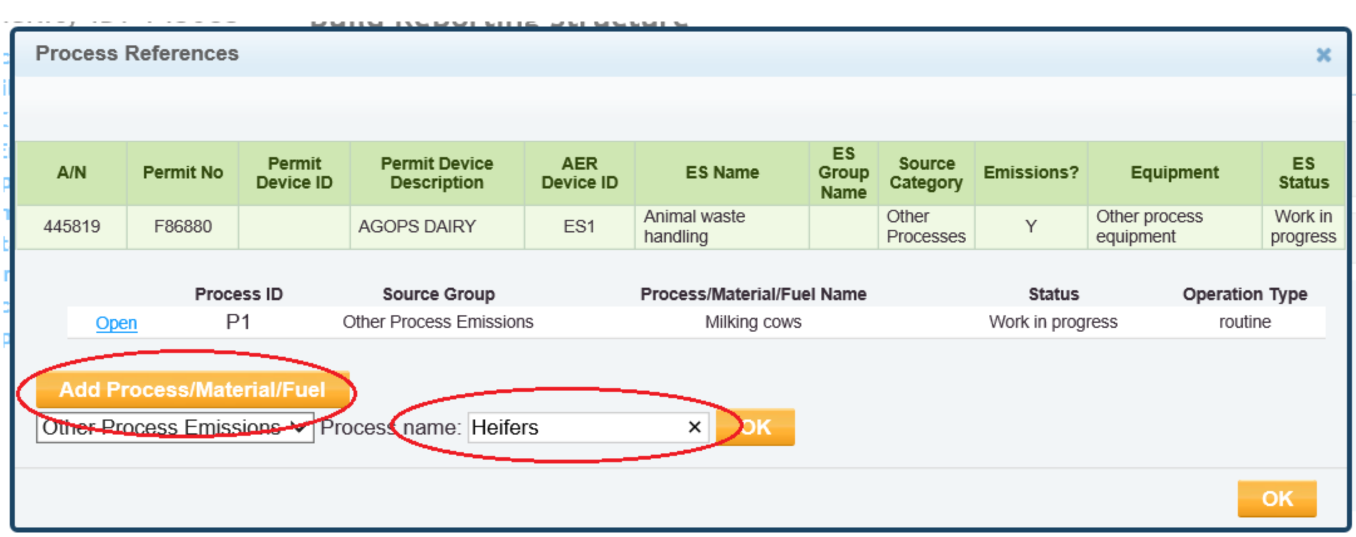
After saving, the program returns to Image 5. The emissions from the 900 Milking Cows have been reported as shown below.



STEPS TO REPORT THE NEXT PROCESS

Image 12:

1. To add the next Process (Heifers), click "**Add Process/Material/Fuel"** button as shown below.
2. Name the Process (i.e. Heifers) in the box and click the OK button next to it.



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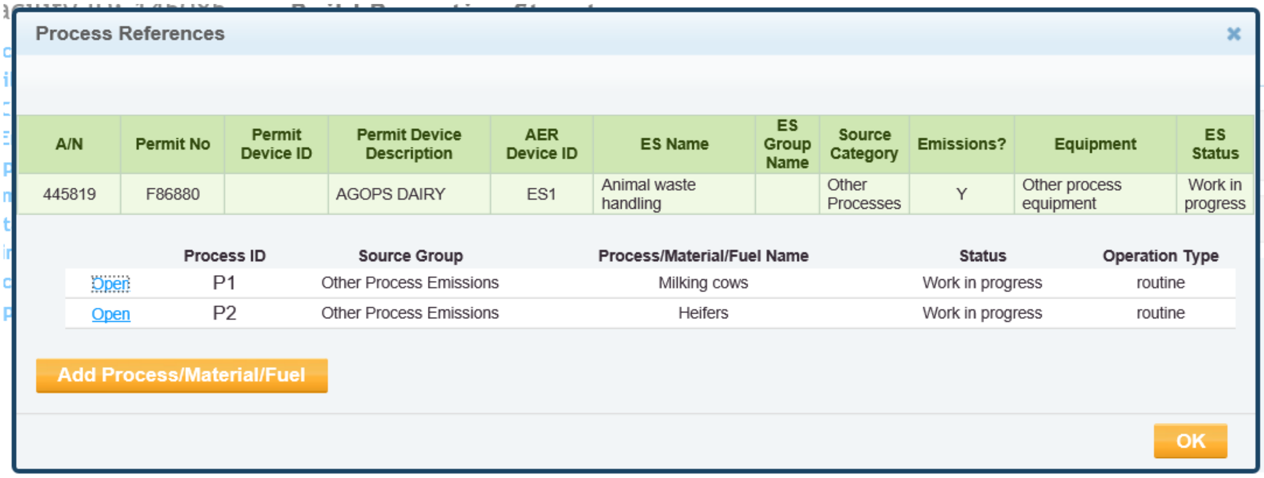
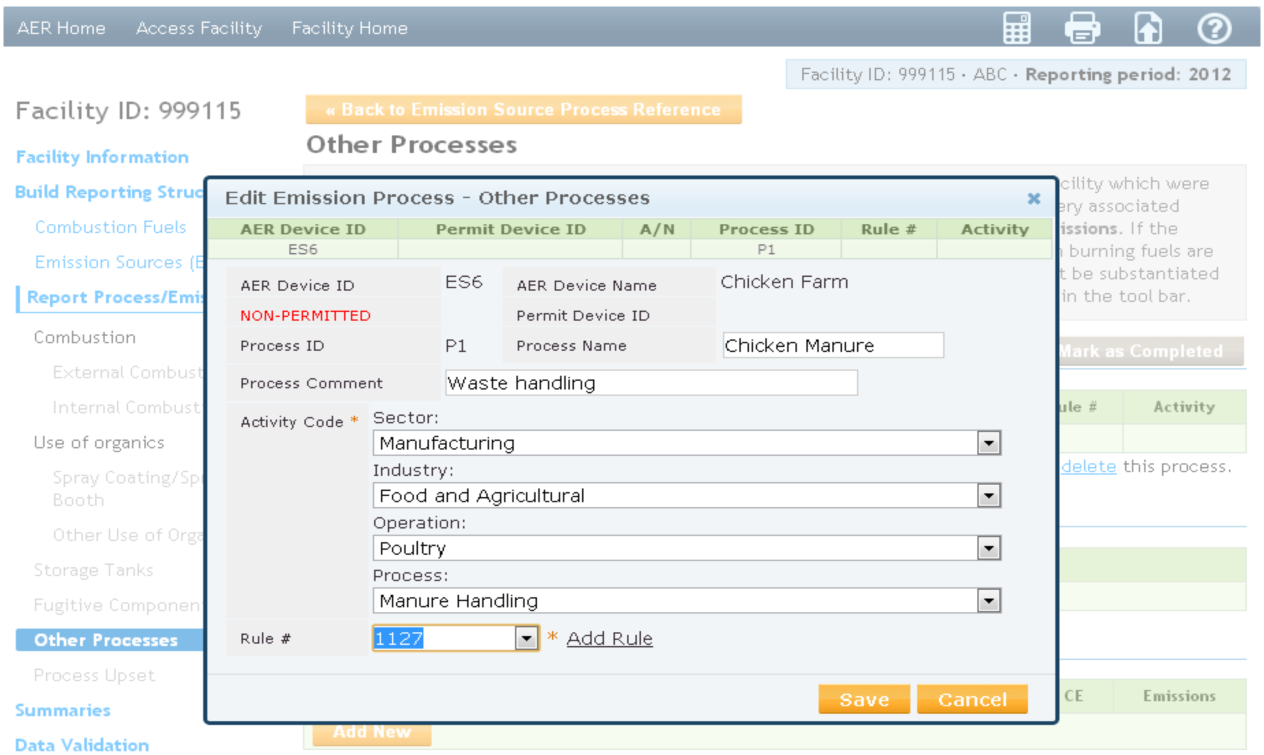
REMINDER:
To report the VOC, PM, and NH_3 emissions from the 300 Heifers, repeat the procedures as illustrated in Image 5 and follow the steps leading to Image 11.



EXAMPLE 2:

Last year, a poultry farm facility raised 5,000 chicken on 100 tons of feed. The manure is sent out of the basin. This poultry does not have any lanes that are flushed with water to a pond.

Since this poultry farm does not possess an operating permit, the user must add this emission source by clicking on the hyperlink "Add New Emission Source". Follow the procedure illustrated in Images 1-5 of Example 1 and fill in the information for Chicken Farm as shown in the following image. Click the **Save** button.



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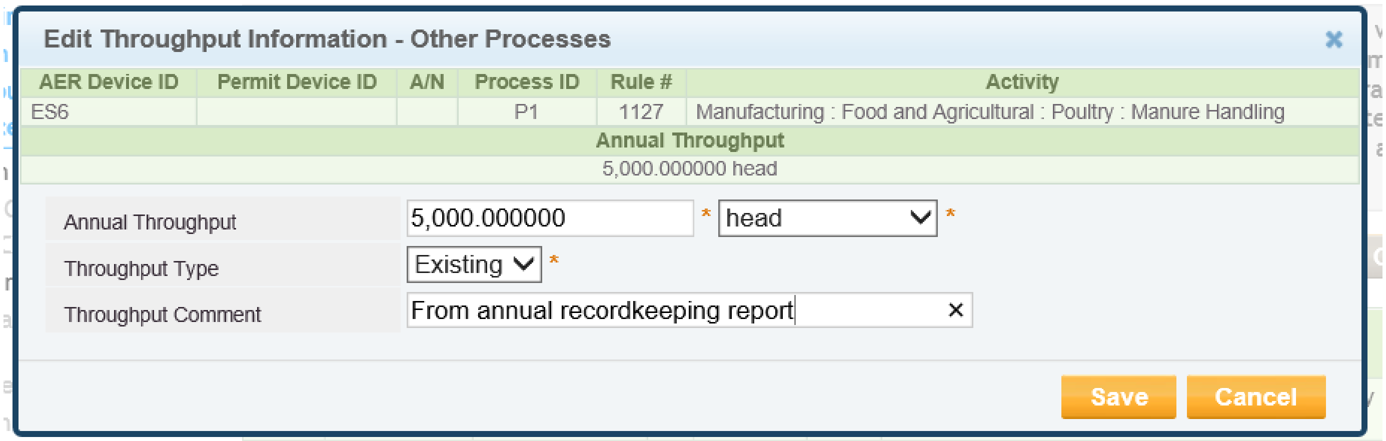
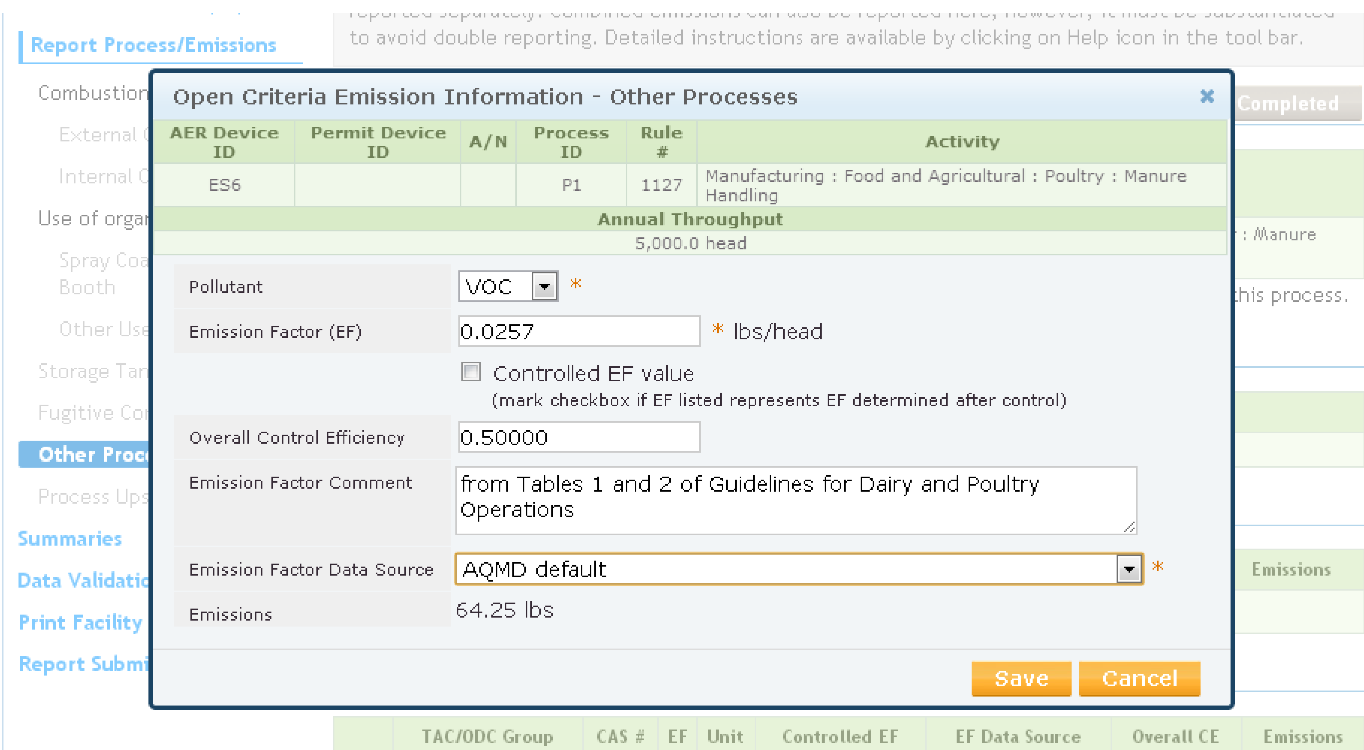
After saving, the program returns to Image 5. Open the **Throughput** section to enter the amount, as shown below. Click **Save** button.



After saving, the program returns to Image 5. Open the **Criteria Emissions** section (by clicking **Add New**) to enter the criteria pollutant (i.e., VOC) and its emission factor information, as shown below. Click **Save** button.



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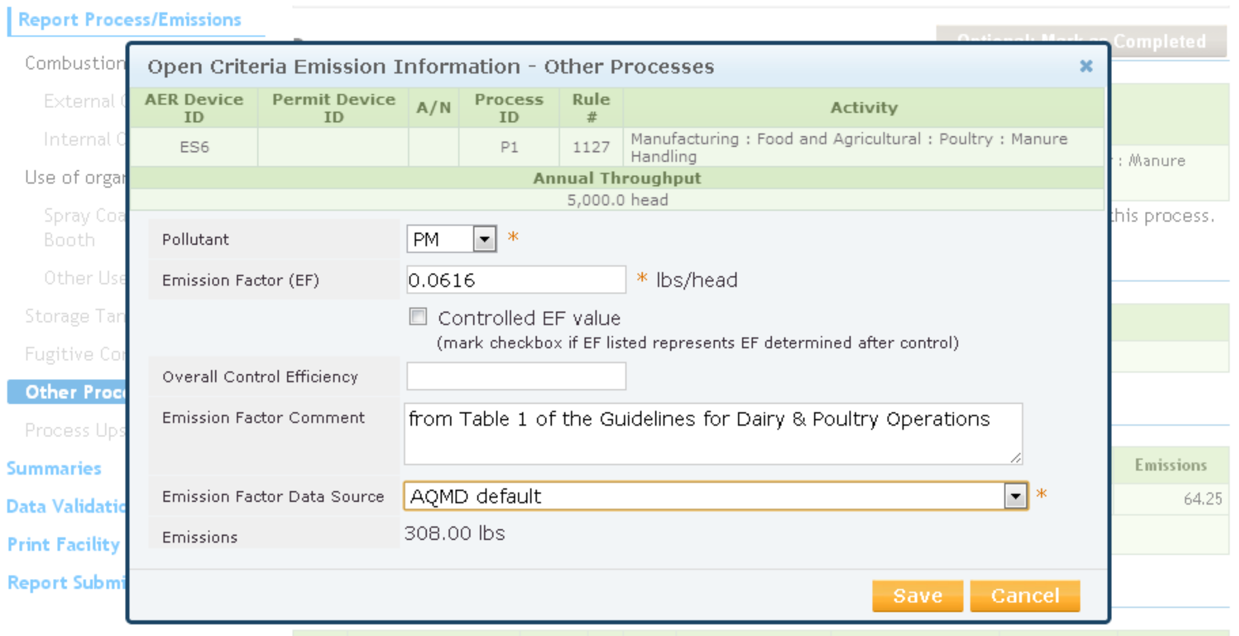
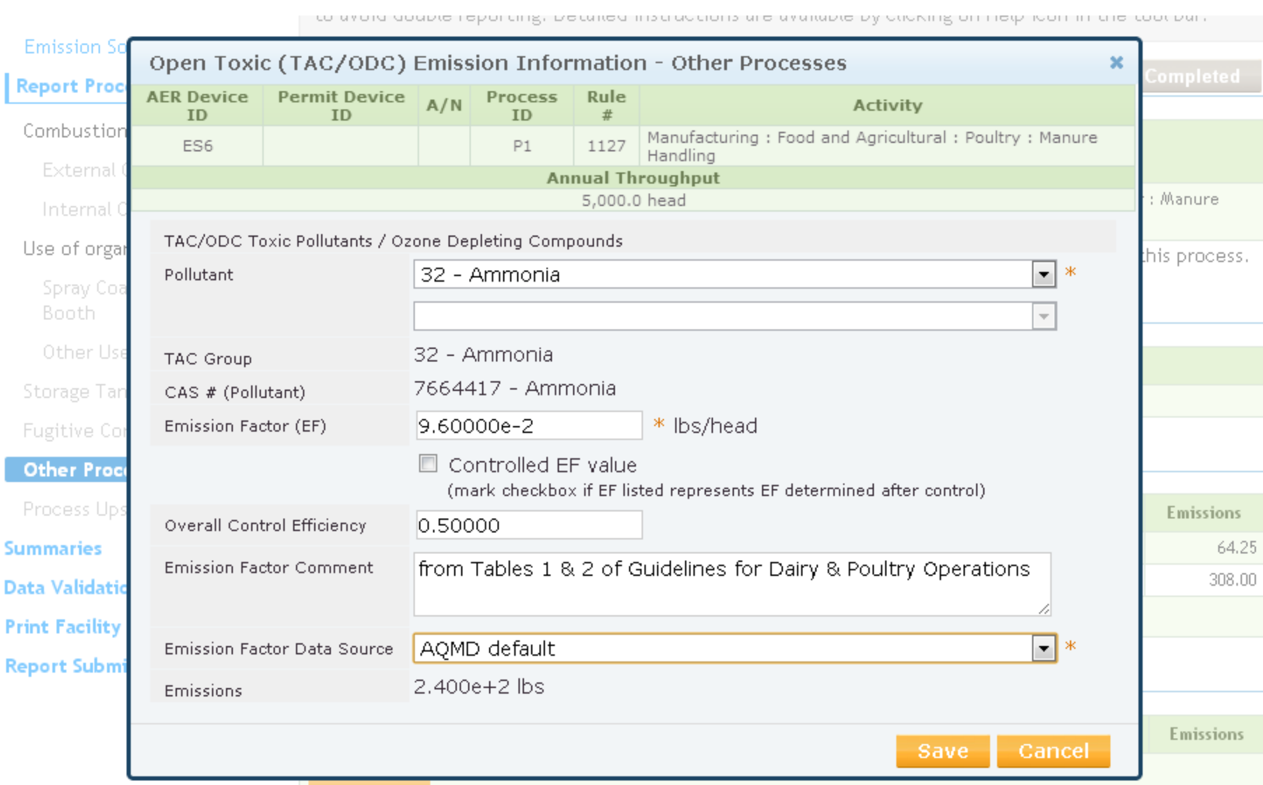
After saving, the program returns to Image 5. Open the **Criteria Emissions** section again by clicking **Add New** to enter the next criteria pollutant (PM) and its emission factor information, as shown below. Click the **Save** button.



After saving, the program returns to Image 5. Open the **Toxic Emissions** section by clicking **Add New** to enter the TAC/ODC (i.e. NH_3) and its emission factor information, as shown below. Click **Save** button.



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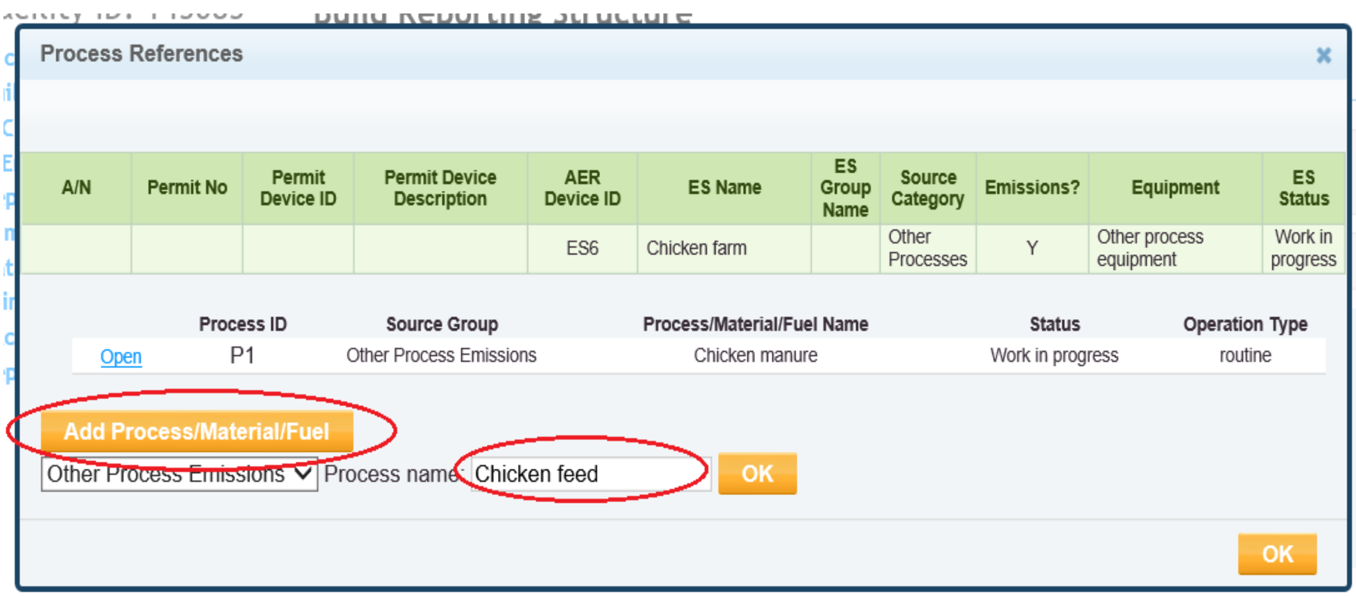
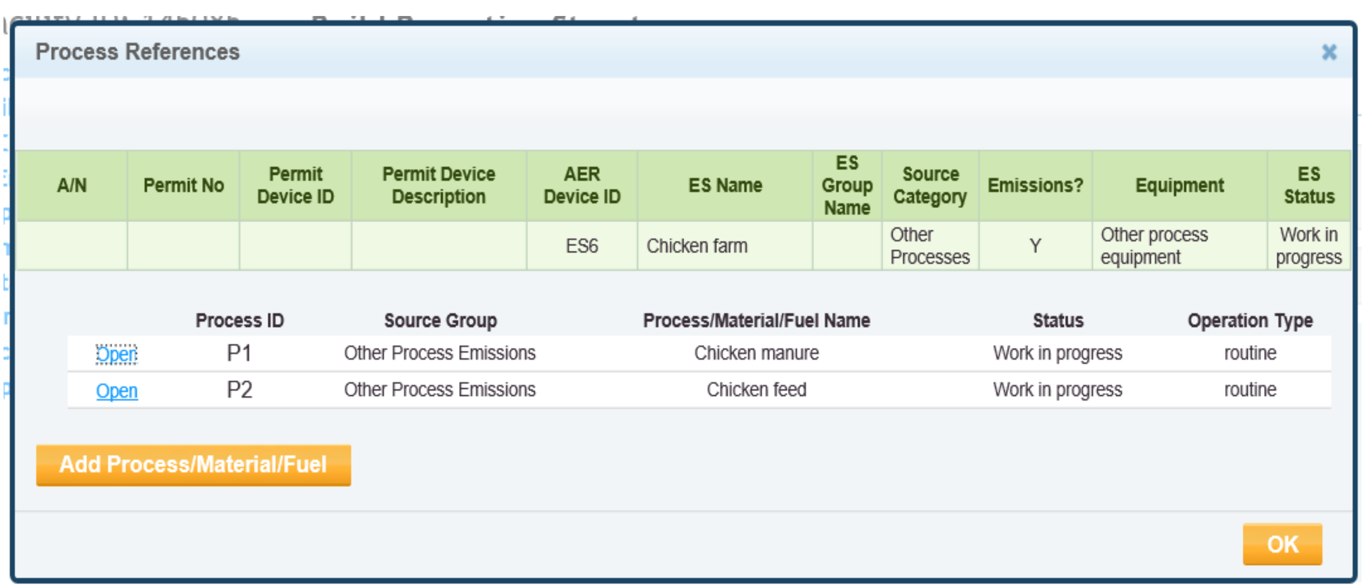
STEPS TO REPORT THE NEXT PROCESS FOR PM EMISSIONS FROM FEEDS.

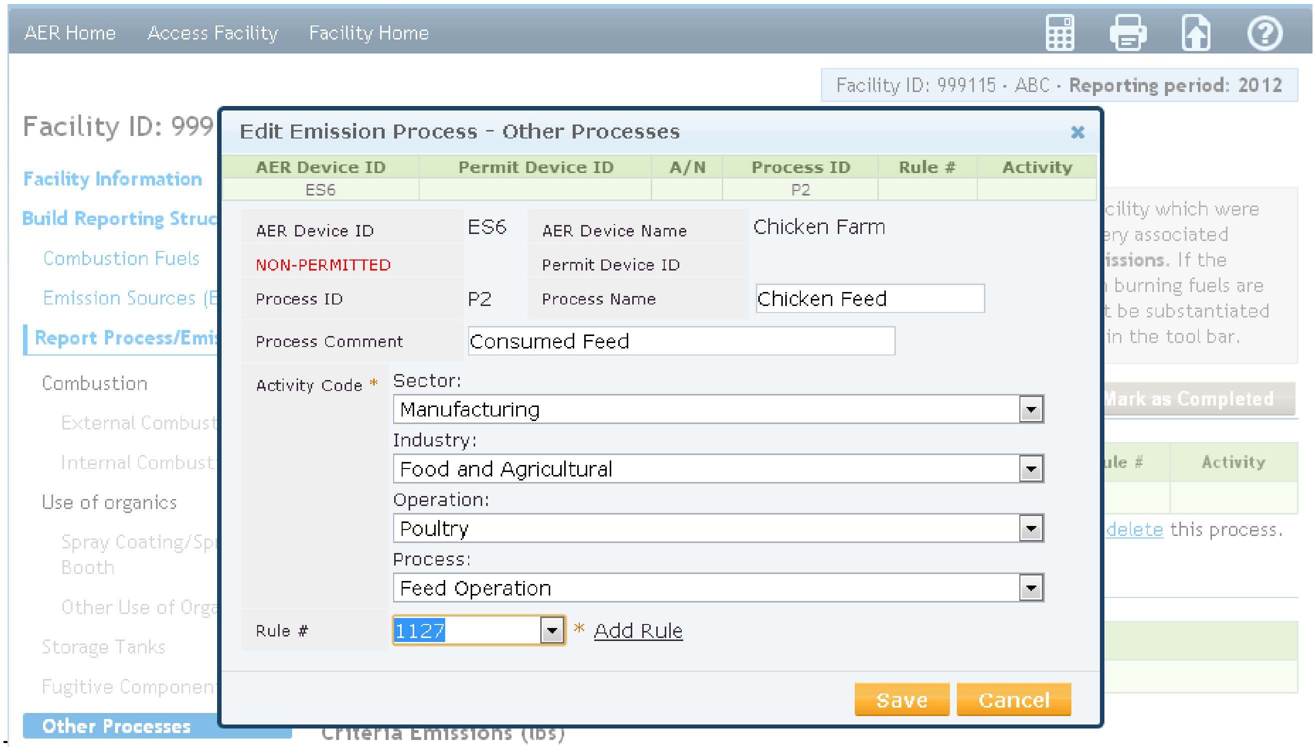
The following images will illustrate how to report emissions from handling of chicken feed. After saving, the program returns to Image 8. By clicking the **"Back to Emission Source Process Reference"** button at the bottom, the tool will pop up a screen (shown below) for user to add another process. Click "**Add Process/Material/Fuel"** button, name the process (i.e. Chicken Feed), and click OK button next to it.



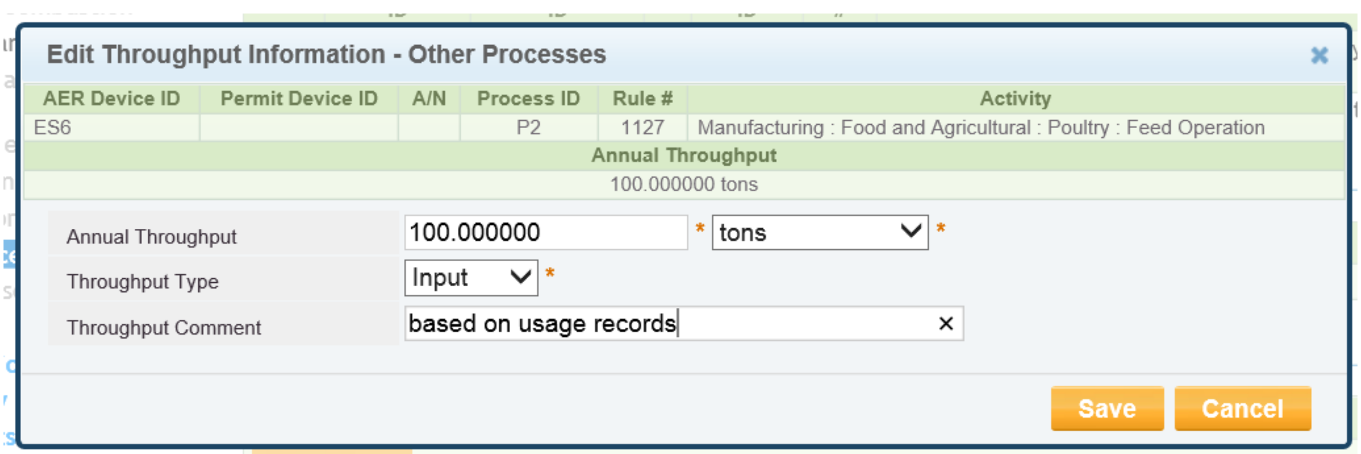
After clicking OK, process P2 is added for chicken feed operation as shown below. Click on "Open" for P2 and start entering the information for that process.



After clicking P2, the tool will present to user a process data entry screen similar to Image 5 where user can enter information for the steps as shown in the following screens. Use the drop-down arrow at the right of each box to report information for this process as shown below. Click the **Save** button.



After saving, the program returns to Image 5. Open the **Throughput** section to enter the amount, as shown below. Click **Save** button.



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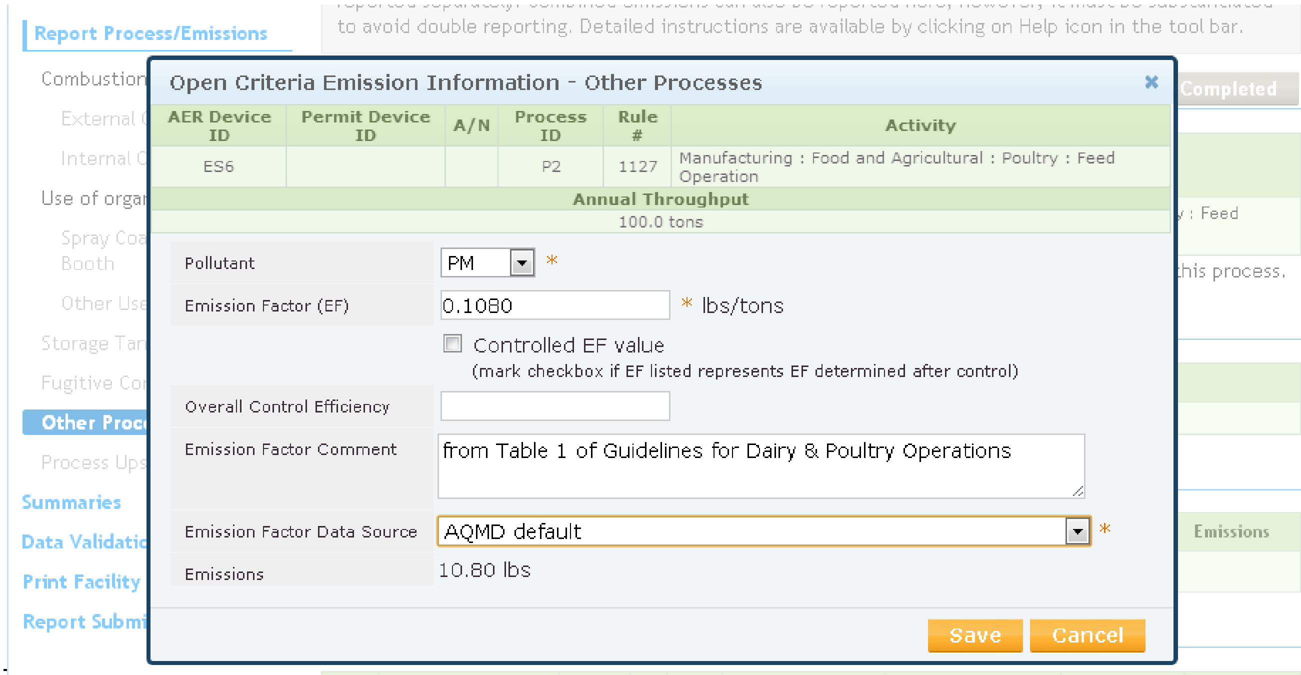
After saving, the program returns to Image 5. Open the **Criteria Emissions** section (by clicking **Add New**) to enter the criteria pollutant (i.e., PM) and its emission factor information, as shown below. Click the **Save** button.



After saving, the program returns to Image 5. Emissions from process P2 are reported. Complete the report by validating the entries.

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Dairy VOC and NH3 Emission Factors

Breakdown of Dairy VOC Emission Factor by type of Cow & Housing				
Type of Cow	**VOC EF (Corral Housing)**	**NH3 EF (Corral Housing)**	**VOC EF (Freestall Housing)**	**NH3 EF (Freestall Housing)**
Milking Cow	19.3*	74.0	21***	74.0
Dry Cow	11.9**	45.4	12.9**	45.4
Heifer (15-24 mo)	8.3**	31.8	9**	31.8
Heifer (7-14 mo)	7.2**	27.8	7.9**	27.8
Heifer (4-6 mo)	6.6**	25.1	7.1**	25.1
Calf (under 3 mo)	6.2**	23.6	6.7**	23.6

*This emission factor is from "APCO's Determination of VOC Emission Factors for Dairies" report.

**This emission factor was developed by taking the ratio of manure generated by the different types of cows to the milk cow and multiplying it with the emission factor obtained in the "APCO's Determination of VOC Emission Factors for Dairies" report.

***This emission factor was developed in a District document entitled "Breakdown of Dairy VOC Emission Factor into Permit Units", however, the basis of the emission factor was taken from the "APCO's Determination of VOC Emission Factors for Dairies" report.

Breakdown by Permit Unit

Open Corral Flush dairy****		
Dairy Emissions	**Emissions (lb/hd-yr)**	**NH_3 Emissions (lb/hd-yr)**
Cow Housing (enteric)	7.6	0
Cow Housing (manure)	4.8	32.3
Cow Housing (Total)	12.4	32.3
Milk Center (Enteric)	0.7	0
Milk Center (Manure)	0.2	1.3
Milking Center (Total)	0.9	1.3
Liquid Manure Handling	2.3	15.5
Solid Manure Handling	N/A	N/A
Land Application	3.7	24.9
Total	**19.3**	74

Freestall Flush dairy****		
Dairy Emissions	**Emissions (lb/hd-yr)**	**NH_3 Emissions (lb/hd-yr)**
Cow Housing (enteric)	7.6	0
Cow Housing (manure)	4.8	28
Cow Housing (Total)	12.4	28
Milk Center (Enteric)	0.7	0
Milk Center (Manure)	0.2	1.2
Milking Center (Total)	0.9	1.2
Liquid Manure Handling	2.7	15.7
Solid Manure Handling	N/A	N/A
Land Application	5	29.1
Total	**21**	74

Breakdown per type of cow of Permit Unit

Cow Housing Permit Unit - Enteric and Manure****				
	Open Corral Housing		Freestall Housing	
Type of Cow	(lb-VOC/cow-yr)	(lb-NH_3/cow-yr)	(lb-VOC/cow-yr)	(lb-NH_3/cow-yr)
Milk Cow	12.4	32.3	12.4	28
Dry Cow	8.2	20.6	8.2	17.9
Heifer (15 to 24 months)	5.7	14.4	5.7	12.6
Heifer (7 to 14 months)	5	12.6	4.9	11
Heifer (3 to 6 months)	4.5	11.4	4.5	9.9
Calf (under 3 months)	4.3	10.7	4.3	9.3

Cow Housing Enteric Breakdown****		
Type of Cow	(lb-VOC/cow-yr)	(lb-NH_3/cow-yr)
Milk Cow	7.6	0.0
Dry Cow	4.8	0.0
Heifer (15 to 24 months)	3.4	0.0
Heifer (7 to 14 months)	2.9	0.0
Heifer (3 to 6 months)	2.6	0.0
Calf (under 3 months)	2.5	0.0

Cow Housing Non-Enteric (Manure) Breakdown****			
Type of Cow	(lb-VOC/cow-yr)	(lb-NH_3/cow-yr) (Freestall)	(lb-NH_3/cow-yr) (Open Corral)
Milk Cow	4.8	28.0	32.3
Dry Cow	3.4	17.9	20.6
Heifer (15 to 24 months)	2.4	12.6	14.4
Heifer (7 to 14 months)	2.1	11.0	12.6
Heifer (3 to 6 months)	1.9	9.9	11.4
Calf (under 3 months)	1.8	9.3	10.7

Lagoon/Storage Pond Emission Factors for Dairy Cows****				
	Open Corral Housing		Freestall Housing	
Type of Cow	(lb-VOC/cow-yr)	(lb-NH_3/cow-yr)	(lb-VOC/cow-yr)	(lb-NH_3/cow-yr)
Milk Cow	2.3	15.5	2.7	15.7
Dry Cow	1.4	9.5	1.7	9.6
Heifer (15 to 24 months)	1	6.7	1.2	6.7
Heifer (7 to 14 months)	0.9	5.8	1	5.9
Heifer (3 to 6 months)	0.8	5.3	0.9	5.3
Calf (under 3 months)	0.7	4.9	0.9	5

Land Application Emission Factors for Dairy Cows****				
Type of Cow	Open Corral Housing		Freestall Housing	
	(lb-VOC/cow-yr)	(lb-NH_3/cow-yr)	(lb-VOC/cow-yr)	(lb-NH_3/cow-yr)
Milk Cow	3.7	24.9	5	29.1
Dry Cow	2.3	15.3	3.1	17.9
Heifer (15 to 24 months)	1.6	10.7	2.1	12.5
Heifer (7 to 14 months)	1.4	9.3	1.9	10.9
Heifer (3 to 6 months)	1.3	8.5	1.7	9.9
Calf (under 3 months)	1.2	7.9	1.6	9.3

****The emission factors for milk cows are based on an internal draft document entitled "*Breakdown of Dairy VOC Emission Factor into Permit Units*". The emission factors for the other cows were developed by taking the ratio of manure generated by the different types of cows to the milk cow and multiplying it by the milk cow emission factor.

Appendix F

Environmental Justice Report – Morrow County

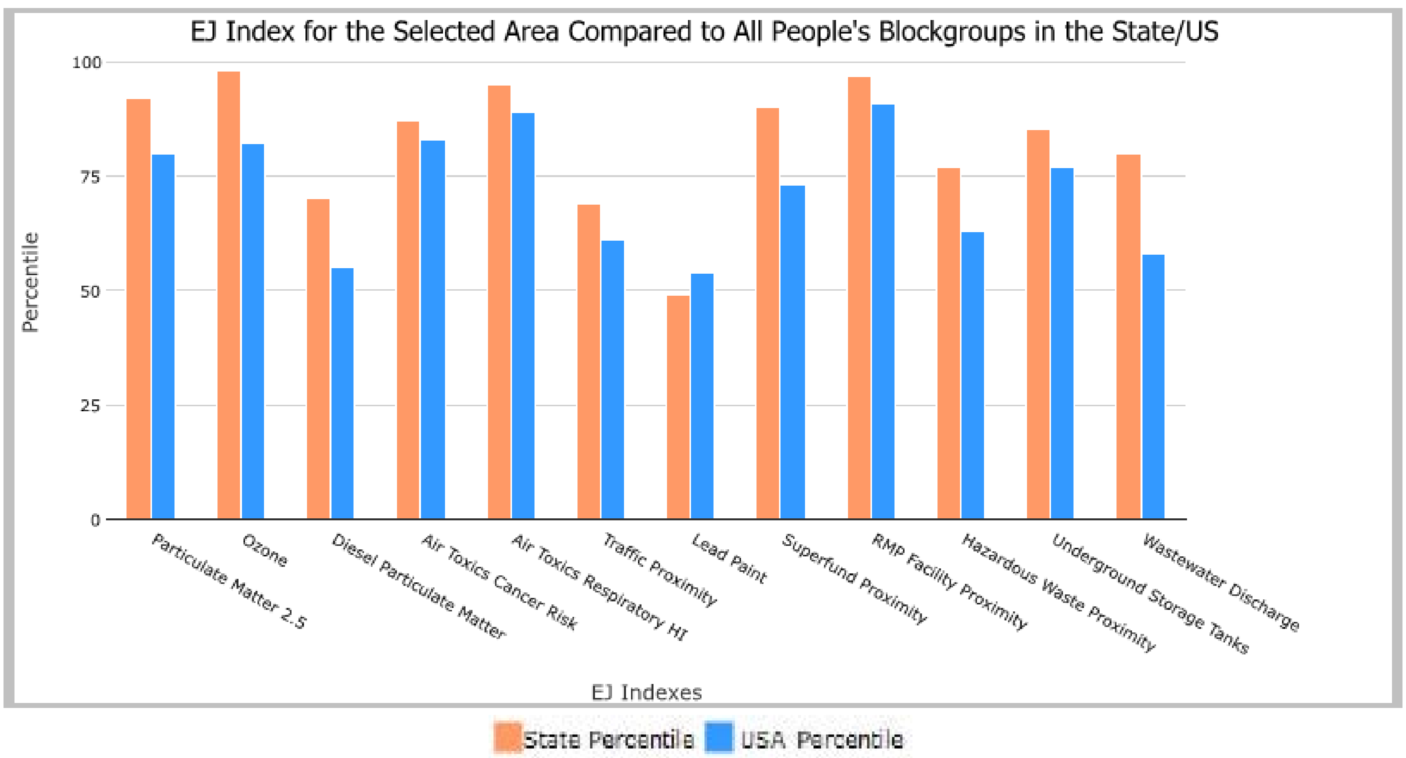
EJScreen Report (Version 2.1)

City: Morrow, OREGON, EPA Region 10

Approximate Population: 3,538

Input Area (sq. miles): 4.43

Selected Variables	State Percentile	USA Percentile
Environmental Justice Indexes		
EJ Index for Particulate Matter 2.5	92	80
EJ Index for Ozone	98	82
EJ Index for Diesel Particulate Matter*	70	55
EJ Index for Air Toxics Cancer Risk*	87	83
EJ Index for Air Toxics Respiratory HI*	95	89
EJ Index for Traffic Proximity	69	61
EJ Index for Lead Paint	49	54
EJ Index for Superfund Proximity	90	73
EJ Index for RMP Facility Proximity	97	91
EJ Index for Hazardous Waste Proximity	77	63
EJ Index for Underground Storage Tanks	85	77
EJ Index for Wastewater Discharge	80	58



This report shows the values for environmental and demographic indicators and EJSCREEN indexes. It shows environmental and demographic raw data (e.g., the estimated concentration of ozone in the air), and also shows what percentile each raw data value represents. These percentiles provide perspective on how the selected block group or buffer area compares to the entire state, EPA region, or nation. For example, if a given location is at the 95th percentile nationwide, this means that only 5 percent of the US population has a higher block group value than the average person in the location being analyzed. The years for which the data are available, and the methods used, vary across these indicators. Important caveats and uncertainties apply to this screening-level information, so it is essential to understand the limitations on appropriate interpretations and applications of these indicators. Please see EJSCREEN documentation for discussion of these issues before using reports.

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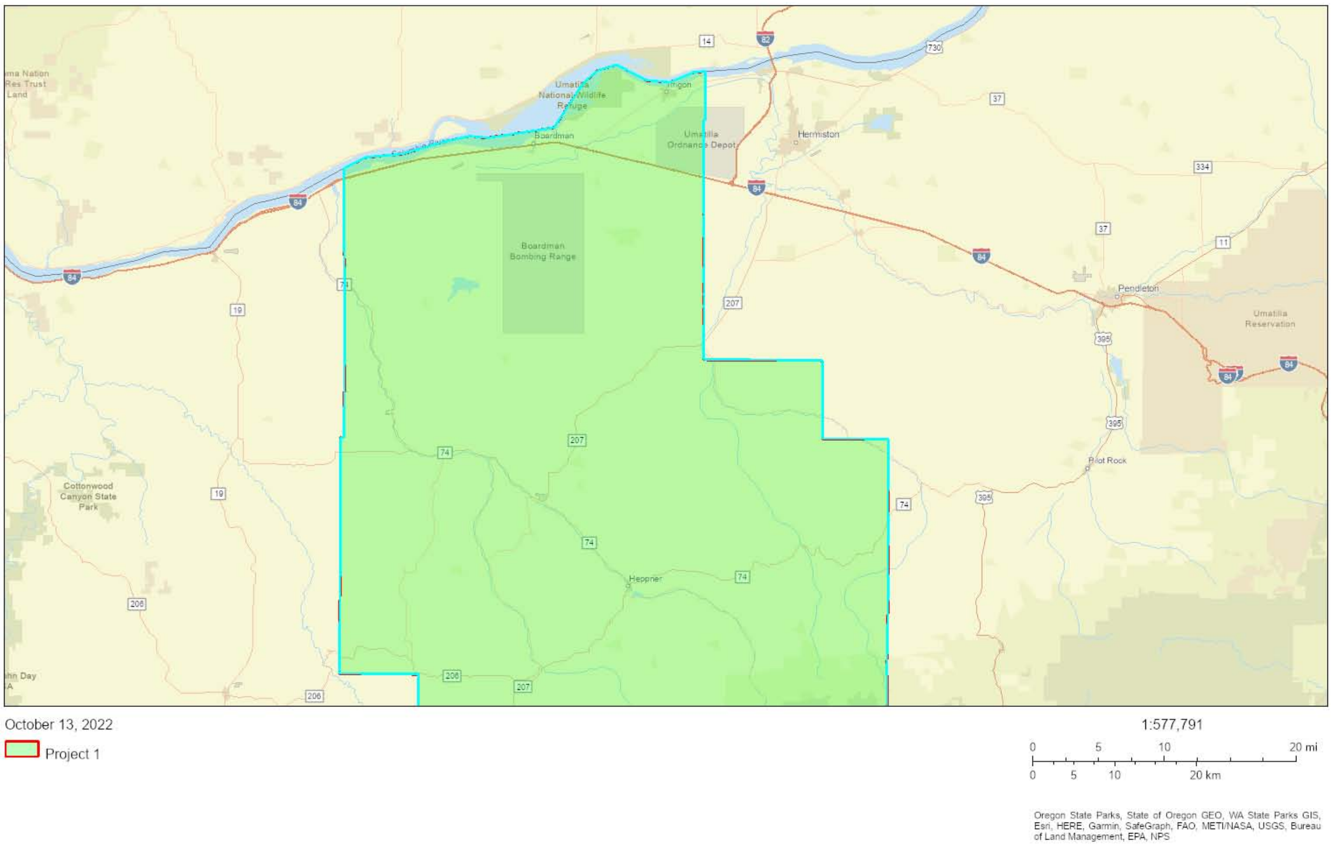
EJScreen Report (Version 2.1)

City: Morrow, OREGON, EPA Region 10

Approximate Population: 3,538

Input Area (sq. miles): 4.43



Sites reporting to EPA	
Superfund NPL	0
Hazardous Waste Treatment, Storage, and Disposal Facilities (TSDF)	0

United States Environmental Protection Agency

EJScreen Report (Version 2.1)

City: Morrow, OREGON, EPA Region 10

Approximate Population: 3,538

Input Area (sq. miles): 4.43

Selected Variables	Value	State Avg.	%ile in State	USA Avg.	%ile in USA
Pollution and Sources					
Particulate Matter 2.5 (µg/m^3)	8.87	8.69	57	8.67	58
Ozone (ppb)	42.8	37	86	42.5	55
Diesel Particulate Matter* (µg/m^3)	0.141	0.337	31	0.294	<50th
Air Toxics Cancer Risk* (lifetime risk per million)	30	32	59	28	80-90th
Air Toxics Respiratory HI*	0.5	0.47	73	0.36	95-100th
Traffic Proximity (daily traffic count/distance to road)	110	660	36	760	35
Lead Paint (% Pre-1960 Housing)	0.042	0.24	20	0.27	24
Superfund Proximity (site count/km distance)	0.051	0.081	52	0.13	44
RMP Facility Proximity (facility count/km distance)	2.4	0.78	91	0.77	92
Hazardous Waste Proximity (facility count/km distance)	0.22	1.6	37	2.2	33
Underground Storage Tanks (count/km^2)	1.7	3.8	52	3.9	56
Wastewater Discharge (toxicity-weighted concentration/m distance)	5.2E-05	0.0046	40	12	27
Socioeconomic Indicators					
Demographic Index	57%	27%	96	35%	81
People of Color	65%	25%	97	40%	76
Low Income	50%	29%	85	30%	79
Unemployment Rate	3%	5%	42	5%	45
Limited English Speaking Households	18%	2%	97	5%	92
Less Than High School Education	33%	9%	97	12%	93
Under Age 5	11%	5%	92	6%	89
Over Age 64	9%	18%	17	16%	21

*Diesel particular matter, air toxics cancer risk, and air toxics respiratory hazard index are from the EPA's Air Toxics Data Update, which is the Agency's ongoing, comprehensive evaluation of air toxics in the United States. This effort aims to prioritize air toxics, emission sources, and locations of interest for further study. It is important to remember that the air toxics data presented here provide broad estimates of health risks over geographic areas of the country, not definitive risks to specific individuals or locations. Cancer risks and hazard indices from the Air Toxics Data Update are reported to one significant figure and any additional significant figures here are due to rounding. More information on the Air Toxics Data Update can be found at: https://www.epa.gov/haps/air-toxics-data-update.

For additional information, see: www.epa.gov/environmentaljustice