Lower Yakima Valley Air Quality Technical Assistance Report

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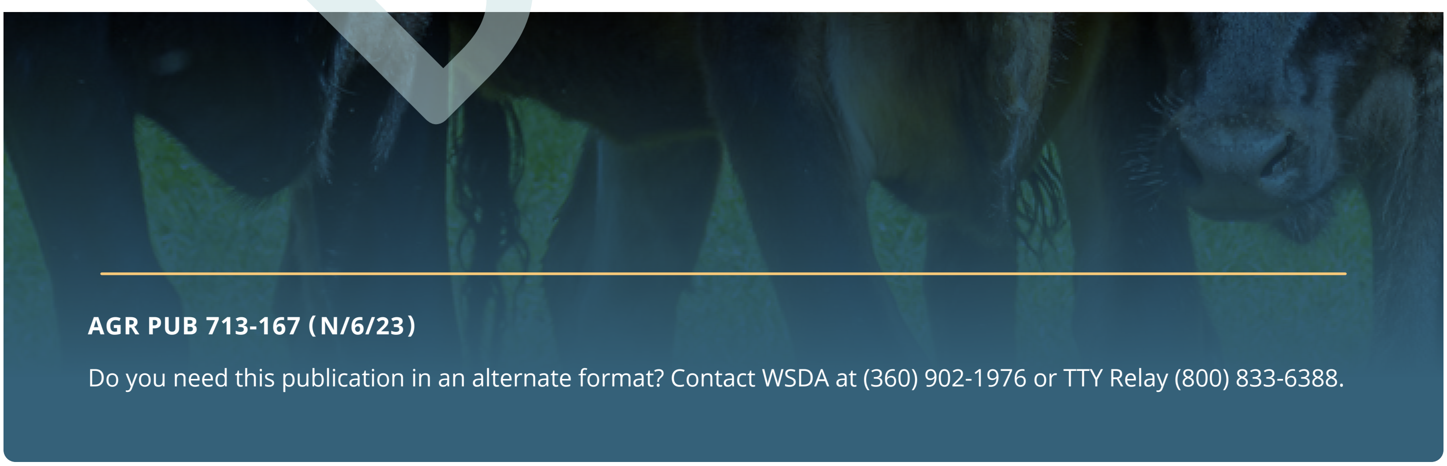

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Introduction and Project Overview

Washington State Department of Agriculture's (WSDA) Dairy Nutrient Management Program (DNMP) conducted on-farm outreach with dairies in the Lower Yakima Valley (LYV) in the spring and summer of 2022. The primary goals of the project were to increase producers' awareness of greenhouse gas (GHG) and other air emissions from their operations and the range of potential best management practices (BMPs) available for emission avoidance or mitigation. This report provides an overview of air quality issues and pollutants, summarizing key findings from this project.

The LYV contains the highest concentration of dairy cows and largest dairy operations within the state. Dairies and large non-dairy livestock farms face growing public pressure to modify practices due to real and perceived environmental impacts to air, water, and public health. Citizen complaints due to impaired air quality and nuisance odors from dairies are common in the LYV. Several studies have linked the negative impact of air pollution in the region to agricultural activities. Other research has identified best management practices dairy producers in the LYV may adopt to mitigate pollutants of concern such as particulate matter (PM) 2.5 and some of its precursors.

Dairy producer participation with this technical assistance project was voluntary. Those who participated took an informal anonymous survey so WSDA could gain a better understanding of attitudes toward emission abatement strategies and potential barriers to implementation. Project leads provided information on carbon capture technologies including anaerobic digestion and carbon markets as strategies to mitigate GHGs and improve local air quality.

Dairies that participated were interested in strategies to reduce air emissions, and the potential interest in BMPs that enabled them to enter carbon markets. Informal survey results showed financial as well as opportunity costs (time needed to learn biogas capture systems that could be spent on other operational objectives) were primary barriers to emission abatement technologies such as anaerobic digesters.

Background of Dairy in the Lower Yakima Valley — Current Challenges

Agriculture in the LYV is a vibrant and diverse industry and plays an important role in the state's economy. Milk is the second largest agricultural commodity in Washington in terms of gross state product (GSP) with total value of production estimated at $1.27 billion annually.[1] Washington remains in the top ten dairy producing states in the nation. Yakima County is home to the largest concentration of dairy cows in the state, accounting for over half of the state's milk production. There are 31 licensed dairy operations in Yakima County regulated by WSDA. There are also approximately nine dairies within the Yakama Nation territory in the LYV. Livestock operations on tribal lands are under the federal Environmental Protection Agency's (EPA) jurisdictional authority.

While dairy production is strong in the LYV, producers face a number of challenges including competition for land resources, high production costs, and environmental stewardship pressures. Fertile soils, irrigation water availability, and local processing plants make the LYV well-suited for dairy production. Yakima County leads the nation in apple, sweet cherry, and hop production.[2] Specialty crops such as these increase competition for land resources between producers, including dairy farmers, who require a land base to grow feed for their dairy herd.[2] Many dairies in this region have consolidated business practices, as is the trend nationwide amongst the dairy industry, in order to increase production efficiencies and profit margins.

The topography of the LYV creates unique challenges for air quality. Located east of the Cascade Mountain Range, with tall foothills to the north, east, and south, the LYV lies in a basin making it susceptible to temperature inversions. Inversions cause warm air to rise, trapping cold air and pollution closer to the ground. The trapping of pollutants near the ground's surface creates atmospheric conditions conducive to PM formation. Topography, coupled with prevailing weather patterns, is conducive to fine PM build-up, particularly during fall, winter, and early spring.[3]

Regulatory Challenges Facing Lower Yakima Valley Dairy

$PM_{2.5}$ is a major human health concern and has been identified at unhealthy to hazardous levels the in the LYV. $PM_{2.5}$ formation is the result of many different emission sources ranging from wildfires and wood burning stoves, to a wide variety of agricultural practices, including tillage.[4] In 2013, the Department of Ecology commissioned a study titled "The Yakima Air Wintertime Nitrate Study" with Washington State (WSU) and Central Washington Universities.[27] The study concluded that Yakima County is in attainment for $PM_{2.5}$ for the 24-hour standard set by EPA. However, concentrations were observed close to the federal Clean Air Act standard, primarily during the wintertime. This has prompted consideration of a non-attainment classification.[5] Under non-attainment, EPA would be required to implement regulatory requirements in the region to reduce $PM_{2.5}$ emissions. Widespread voluntary implementation of BMPs to control air emissions leading to $PM_{2.5}$ in the LYV could prevent new regulations in the future from being imposed upon industries in the region. Parts of the country designated in non-attainment by EPA for

$PM_{2.5}$ include California's San Joaquin Valley and Idaho's West Silver Valley.[6]

The existing regulatory framework for air quality protection in the LYV does not drive widespread air quality BMP adoption. The Yakima Regional Clean Air Authority (YRCAA) once required dairy farms to obtain and follow an Air Quality Management Plan, but no longer requires adherence to this policy. In 2021, partners at YRCAA, WSU, and Whatcom Conservation District published an article titled, "Regional Air Emissions Reductions from Dairy Operations via Best Management Practices" in the *Journal of Environmental Protection*.[7] The article details a study the partners conducted for implementation of air quality BMPs specific for dairy operations in the LYV. Best management practices were grouped into tiers with respect to effectiveness, cost, ease of implementation, and compatibility with the state-mandated dairy nutrient management regulations. Tier 1 was the least expensive and easiest to implement BMPs, while Tier 3 was the most challenging and expensive. BMPs focused on reduction of major air pollutants from dairy operations; ammonia, nitrous oxide, hydrogen sulfide, volatile organic compounds (VOCs), odor, PM, and methane. The study notes that properly implemented BMPs do not reduce air emissions to zero, but can significantly lower air emissions leading to improved local and regional air quality.[7]

Dairy producers in the LYV face regulatory pressures and increased threat of environmental lawsuits, incentivizing implementation of BMPs associated with manure nutrient management. The LYV is a groundwater management area under state law, where groundwater nitrate is the primary pollutant of concern. Adoption of innovative nutrient reduction technologies including centrifuges, specialized separators, aeration, and anaerobic digestion are just some of the practices utilized by dairies in the LYV to help meet regulatory requirements. In Washington, dairy producers are required to protect water quality under the Dairy Nutrient Management Act (Chapter 90.64). Dairies undergo regular inspections, are required to obtain a certified dairy nutrient management plan from local conservation districts, and must comply with recordkeeping requirements that include annual soil and manure testing. Dairies under the Dairy Nutrient Management Act may also have a Confined Animal Feeding Operation National Pollutant Discharge Elimination System permit with additional requirements for managing manure and soil testing. Dairy cooperatives, such as Darigold, have committed to sustainability goals to decrease the environmental footprint of the industry. These goals include protecting water quality through agronomic manure and nutrient use, preserving water resources through recycling, and generating and using renewable forms of energy.

Dairy Economics and Carbon Markets

Profitability within the dairy industry depends largely on the price of milk measured in dollars per hundredweight (cwt) and operational input costs. Input costs on a dairy include feed, labor, veterinary, infrastructure, equipment and machinery, electricity, interest, and environmental regulatory expenses such as soil and manure testing requirements.[8] Milk prices in Washington fell by 20 percent from 2011 to 2019 (from $23.18 /cwt in 2011 to $18.60 in 2019) where many dairies either left the market or consolidated.[1]

More recently, milk prices in 2022 saw record highs at nearly $28 /cwt. Despite recent all-time high milk prices, Washington dairies have also faced significant rising input costs from changes to the state minimum wage and economic inflation reflected in fuel, feed, and fertilizer prices, negating overall profit margins. Higher costs of production force producers toward production efficiencies, including efficiencies of scale, meaning larger dairies tend to be the most profitable.[8] Dairy farms are also introducing additional sources of revenue through enterprises such as compost sales, beef cattle breeding and production, food crops, and carbon markets.

Existing and developing opportunities in carbon markets position LYV dairies to take measures to address air quality concerns while introducing additional revenue streams. Such revenues may help farms increase their profit margins in the face of volatile milk prices and rising input costs. Anaerobic digestion technology is not yet widely adopted by Washington dairies, but is one of the most common biogas technologies a dairy may use to capture methane produced from its manure lagoons where it can then be flared off, or converted to a renewable fuel source. Previous reports by WSDA and EPA have identified the LYV as an area well suited for widespread adoption of anaerobic digestion technology at dairies. In 2010, EPA's AgStar program estimated that 125 dairy farms in Washington had the potential to capture biogas on farms where positive financial returns appear to be most likely at dairies with 500 or more cows.[3]

Public funding for biogas captures systems on dairy farms is vital, as shown by California's dairy digester boom, as well as policies at the state and federal level that increase demand for renewable fuels from these systems. Washington has just recently implemented climate laws and policies that both provide funding for dairy digester projects and will increase demand for renewable fuels over the coming decades.

Washington Climate Commitment Act Cap-and-Invest and Lower Carbon Fuel Standards Programs: Washington Dairy Industry

In 2021, Washington's legislature passed the Climate Commitment Act (CCA) (RCW 70A.65.260), establishing a market-based program to reduce carbon pollution and achieve GHG reduction goals set by the state.[10] The market-based program created under the CCA is called the Cap-and-Invest program, which commenced January 1, 2023. The program regulates, or "caps," the state's largest designated emitters of carbon emissions, requiring them to obtain allowances equal to their covered GHG emissions.[10] Dairies in the state are not regulated under the CCA, but may act as generators of carbon "offsets" that "capped" industries can purchase to offset their regulated emissions or go toward their emission allowance. Coupled with the cap-and-invest market, Washington also established its own Low Carbon Fuel Standard (LCFS) program. Under Washington's LCFS, targets are set by the state that require transportation industries to meet renewable energy targets in their overall portfolio of energy sources in order to decrease carbon emissions.[10]

The diversification of energy portfolios by industry as mandated by the state will increase demand for renewable forms of energy, such as biogas, that can be captured on dairies. California and Oregon are the only other two states currently with LCFS programs. There is also a Federal Renewable Fuel Standard (RFS) program that requires transportation fuel sold in the U.S. to contain a minimum volume of renewable fuels.[11] Under these programs, dairies can earn carbon credits for their GHG reductions, or "offsets," they generate and may refine biogas captured through anaerobic digester technology to renewable natural gas (RNG), providing low carbon fuels and feedstock to these growing markets. Demand for renewable fuels is scheduled to increase at both the state and federal levels over the coming decades, lowering uncertainty for livestock producers considering entering carbon and low carbon fuel markets. Carbon credits generation may serve as an additional revenue source for farms while providing an incentive for outside parties to provide project funding for AD/biogas systems.[12]

In 2006, California enacted statewide policy targeted to reduce GHG emissions to 1990 levels by 2020, implementing the country's first "Cap and Trade" market to help meet these goals.[13] California required their state's dairy industry participate due to their estimated contribution to the state's total GHG emissions. Dairies in California reportedly contribute 32% of total GHG emissions from the agricultural sector, accounting for 2.4% of the state's total GHG emissions.[14] Dairies were required to reduce their emissions to 1990 levels by 2030 either through voluntarily efforts, or face threat of future regulation.[15]

In 2016, California passed Senate Bill (SB) 661, directing nearly $195 million in public funds (revenue from their Cap-and-Trade program) toward dairy digester and development and "alternative manure management programs" to support the state's dairy industry in achieving its GHG reduction targets.[15] Of the $195 million that has gone toward dairy digester projects, approximately $392 million was provided in matching funds by private developers and the dairies involved.[14] California Department of Food and Agriculture (CDFA) reports that 117 dairy digesters were installed at California dairies between 2015 and 2021.[14] In addition to emissions reductions through dairy digester installation, California is planning to meet their 2030 methane target reduction levels through widespread implementation of feed additives in order to reduce methane generated by the enteric fermentation process.[15]

Ensuring dairies in California would not incur excessive costs for digester installation was of major to concern for policymakers, as it would likely cause dairies to exit the market in California to states without such regulation, negating any potential GHG reductions.[15] Systems such as covered lagoons and other types of anaerobic digesters require high capital start up costs to implement, maintain, and operate, particularly if the biogas captured is then converted to RNG and/or electricity as an end-use. In order for a dairy or other livestock operation to then enter these cap and trade markets voluntarily, there must be a clear advantage the operation's bottom line.

Capital startup costs and the long-term maintenance of an anaerobic digester are key considerations prior to on-farm installation. In California, subsidies coupled with private developers are reportedly the biggest drivers to anaerobic digester development.[16] Prior to public funding, dairies reported low levels of adoption following the state's mandate, prompting the state to pass legislation to subsidize dairy digester development.[15] Third party developers and operators of anaerobic systems are standard in California due to the financial costs and complexity of the system. This is particularly so for efforts involving gas refinement technology at dairies.

Conducting a cost-benefit analysis for a dairy can be useful to determine the amount of short- and long-term costs required for anaerobic digestion start-up and potential revenue generation through biogas sales and carbon credit generation. Dairy operators who are unsure about adding methane capture technologies on farm should assess their ability to operate, manage, and maintain such systems or consider working with a third party to manage the system. EPA's AgStar program has many resources and tools available online for anaerobic digester project development.[12]

Other factors to consider when considering when weighing anaerobic digester technology on farm include regulations that may apply:

- Dairy nutrient management plan update to account for changes in the facility and nutrients on farm.
- Solid waste permitting (if dairy receives greater than 30% non-dairy manure/imports).
- Local planning regulations including building and zoning codes.

Rules for the protocol a dairy, or other livestock facility, must follow in order to generate carbon offsets and participate in Washington's Cap-and-Invest program are listed in Washington's CCA, labeled the "Livestock Offset Protocols."[17]

Washington's CCA is designed to allocate revenue from the state's cap-and-invest market toward funding for dairy digester development and alternative manure management practices within the Climate Commitment Account.[10]

The Climate Commitment Account's proceeds are intended to focus "on projects that support Washington's transition to a low-carbon economy, improve air quality, and increase access to clean energy for Washington residents."[10] In addition to potential funding opportunities at the state level, the federal government recently passed the Inflation Reduction Act which includes more than $20 billion in direct incentives for climate-smart agriculture, including dairy farms.[15]

The CDFA requires that dairy digesters receiving grant funding be composed of at least 80% dairy manure.[18] Washington has yet to establish guidelines for proposals for grant funding for dairy digesters. However, much of its framework has been modeled directly after California's. While there are other on-farm practices that reduce GHGs such as feed additives that inhibit enteric fermentation and aerobic management of manure. These methods of reducing GHGs are not established offset protocol as defined under the CCA. In other words, only established protocols that quantify GHG reductions based on the implemented practice are allowed to generate offset credits under the CCA. The four current adopted protocols include: livestock projects (Livestock Offset Protocols), U.S. forestry projects, urban forestry projects, and ozone-depletion projects.[10]

"The prospect of a deep pool of offset projects providing a potentially low-cost supply of reductions creates an effective cap on allowance prices in a cap-and-trade-system…. For firms and individuals outside of sectors that might fall directly under a cap, such as the U.S. agricultural sector, an offset mechanism offers a potentially lucrative new source of revenue." –Bushnell J.[19]

Government subsidies for implementation of climate-smart technologies at dairies can have dual benefits in addressing environmental concerns in overburdened communities such as the LYV while supporting the state's dairy economy.

Common Emissions From Dairy Facilities

GHG emissions can form from multiple areas of production on a dairy. These areas include: directly from cows (enteric fermentation) and their confinement areas, cropping, feed management, manure storage, and application of both manure and commercial fertilizers. Local climate and weather features, as well as on-farm management practices, may exacerbate certain emissions and the overall magnitude of their effects.

The most common GHGs and nuisance emissions formed on dairies are listed below in **Table 1**:

Table 1: Common Emissions From Dairy Facilities

Emission type	Formula / Abbreviation	Description
Methane	CH_4	Methane is emitted via enteric fermentation and manure storage under anaerobic conditions. Livestock diet composition and manure storage system operation, diet, and bedding are major contributors to CH_4 production at a dairy.[20]
Ammonia	NH_3	Main sources of ammonia emissions on dairies include fresh manure, anaerobically stored manure, and the land application of manure.[21] Ammonia emissions carry negative impacts to human health and the environment and may contribute to eutrophication and acidification of aquatic ecosystems. The level of ammonia emissions on farm varies depending on the time of year and weather conditions.[22]
Nitrous oxide	N_2O	A highly volatile GHG that is formed through microbial processes during denitrification of nitrate (NO_3) to nitrogen gas (N_2). Nitrous oxide can form via manure storage, land application, and in small amounts via the rumen.[22]
Volatile organic compounds	VOCs	A class of chemical that when reacted with oxides of N and sunlight contribute to ozone formation. VOCs may be emitted from dairy waste, slurry wastewater lagoons and feedstuffs (silage). Some common VOCs include methanol, acetone, propanol, and dimethylsulfide.[22]
Carbon dioxide	CO_2	CO_2 is largely regarded as an anthropogenic GHG contributing most to climate change and is a byproduct of both cellular respiration and fossil fuel combustion. CO_2 emitted from dairy animals is not considered a net contributor to climate change because the animals consume plants that collected atmospheric CO_2 via photosynthesis. Fossil fuel combustion for on-farm use is the largest contributor of CO_2 on a dairy.[22]
Particulate matter	PM	Most particulate matter forms in the atmosphere as a result of complex reactions of chemicals such as sulfur dioxide and nitrogen oxides, pollutants emitted from automobiles, power plants, and agriculture.[6] Dairy operations emit compounds that are precursors to particulate matter formation such as ammonia.[21] $PM_{2.5}$ is of major concern in the LYV.

The GHG that receives the most attention from dairy and livestock production is methane. Methane derived from enteric fermentation and manure storage are areas where abatement strategies can be most easily implemented to control methane emissions. In well-managed confinement areas, enteric emissions contribute nearly half (45%) of total GHG emissions from the full dairy farm system.[21]

Liquid manure storage (lagoons) has been the main area of focus for controlling methane emissions on dairies because abatement strategies tend to be more feasible for manure storage than inhibiting substantially reducing methane formation from enteric fermentation. However, various feed additivities are a method under exploration as ways to mitigate emissions from enteric fermentation. There remain barriers to widespread adoption, including a lack of proven, commercially available, and cost-effective additives.[15]

Existing Best Management Practices for Emission Reductions and Controls

Table 2: Existing BMPs for Emission Reductions and Controls

More BMPs for emissions reductions exist that are not mentioned below. The ones discussed tend to be most applicable for dairies situated in the LYV and may not apply to dairies outside of this area.

BMP category	Description
Animal nutrition and feed management	Diet manipulation has many potential possibilities to mitigate enteric emissions through alterations to nutrition strategy and composition. Methane emissions from dairy animals represent a gaseous loss of their dietary energy intake.[21] When formulating diets for cows, meeting and not exceeding cows' requirements for nitrogen and sulfur can decrease excess of these compounds in the resulting manure, resulting in less gaseous emissions overall. Selectively choosing feed can measurably reduce emissions. This occurs by either limiting feeds known to increase emissions or adding specific supplements to emissions. Strategies such as limiting corn distiller grain, which known to increase NH_3 emissions, can be taken into consideration.[22]
	Feed storage and management practices also play a crucial role in controlling gaseous emissions on farm. Creating and implementing a feed handling plan can reduce shrink, or loss, of purchased feed. Covering feedstuffs and managing feed mixing can reduce airborne losses of feed products, especially in high- or frequent-wind environments. Other management strategies include mixing feed in a covered area, using covers on feed mixer wagons, and adding higher moisture content ingredients to mixers first in order to minimize the amount of dry ingredients becoming airborne.

Table 2: Existing BMPs for Emission Reductions and Controls	
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Animal housing type and management	Open lot systems, or a hybrid of free stalls and open lots for animal housing, tend to be more prevalent in arid climates, such as the LYV. Maintenance of pens in an open lot system housing on dairies can vary from covered systems like free stall barns to open lots, or a combination of the two. In covered systems, daily manure removal, whether through harrowing, scrape, vacuum, or flush systems, will be effective in reducing emissions. Daily management in open lots using harrowing will reduce emissions compared to management practices that infrequently mix and aerate manure. Daily removal of manure from housing is known to reduce ammonia emissions overall. Facility design also plays a large role in effective management of air emissions. Covered systems should include slopes and grooved concrete floors that favor draining urine away from feces. Mechanical ventilation should be incorporated, when possible, to disperse emissions away from high-traffic areas. In open lot systems, shade structures can encourage cattle to spread out, dispersing waste throughout the lot. Open lot systems can also benefit from high carbon surface amendments such as including wood chips that promote aerobic activity.
Manure management	Manure management represents a substantial opportunity for controlling gaseous emissions on farm. Manure can be handled aerobically (with oxygen) or anaerobically (oxygen limited). Waste storage ponds, or lagoons, are the most common liquid waste storage facilities on dairies. Anaerobic lagoons are the largest source of emissions on many dairies other than emissions from enteric fermentation in cows. In the process of manure management, there are several types of technologies that can be deployed between manure collection and storage to reduce overall emissions. The three primary strategies are contained, anaerobic digestion, the separation of solids from the liquid waste stream, and the composting of solids. Once manure is in storage, strategies to reduce emissions include: aeration, lagoon or tank covers, and managing pH and bacteria.
Land application and cropping	Manure serves as a valuable and cost-effective resource for crop fertilization on dairies. Methods of liquid manure application that best control emissions are immediate incorporation through injection, near surface application, ideally followed by immediate irrigation. The use of sprinklers generates greater levels of emissions, but even sprinkler system emissions can be reduced if followed by irrigation to incorporate the manure into the soil. Systems that rapidly incorporate manure into the soil after land application will reduce ammonia emissions while increasing nitrous oxide emissions.[23] Other important factors when trying to reduce and control emissions include application timing and adjusting to environmental variables including air temperature and wind speed. BMPs suggest applying manure during low wind and temperature conditions as much as possible in order to minimize ammonia volatilization and reduce odor. Cropland can produce N_20 via nitrogen transformations in the soil. The N_20 produced by these transformations is an important contribution of total farm GHG emissions on farm.[21]

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Grazing	The majority of dairy operations in the LYV have transitioned to intensive systems where cattle are not grazed on pastureland. If grazing is still part of the operation, a grazing plan should be used to optimize pasture performance to improve soil health and soil carbon storage. A good grazing plan will include management of stocking density to match pasture availability, irrigation water management, plan, grazing management (i.e. e.g., intensive rotational), and use of improved appropriate grass species selection to help promote soil carbon sequestration.[24]
General practices	An easy strategy to help prevent the spread of airborne pollutants, including dust and odor, is the adoption of windbreaks around farms. Trees and shrubs around the perimeter of the property will slow down and can capture a portion of overall emissions before they disperse. Livestock windbreaks also help reduce mortality from cold weather, animal stress, and feed consumption, all of which lead to increased weight gain and milk production".[25] Anaerobic digesters are recognized as an important tool and strategy to capture methane from manure waste streams. Other technologies such as vermifiltration are also effective at reducing GHGs and odors from manure collection.

Lower Yakima Valley Air Quality Project

Project Summary

WSDA's Dairy Nutrient Management Program conducted a five-month voluntary air quality technical assistance project with dairy producers in the LYV to survey what is already being done to protect air quality on farms and what prevents adoption of new air quality BMPs. The project goals are outlined below:

- Encourage voluntary adoption of BMPs for reducing air emissions on dairies through technical assistance.
- Identify opportunities for producers to sequester carbon with current or new BMP adoption.
- Continue efforts previously done in the area to address air quality and dairy production.
- Build the knowledge base of the agency to support the dairy industry and protect the public and the environment.

Between March and July 2022, DNMP staff conducted site visits with producers in the LYV who volunteered for this technical assistance project. DNMP met with 14 dairy producers, representing nearly half of all licensed dairies under WSDA's jurisdiction, in the LYV. Each dairy conducted a National Air Quality Site Assessment Tool (NAQSAT) and an informal BMP adoption survey. NAQSAT is a tool created by the U.S. Department of Agriculture (USDA), which allows producers to visualize on farm emission sources based on facility design and management practices. While the NAQSAT does not identify every source, it gives an inventory of the primary on-farm sources. The NAQSAT simultaneously collects and maintains results that are not tied to a specific producer or facility, maintaining the anonymity of producers. Following completion of the NAQSAT, producers and DNMP staff met reviewed a list of air quality BMPs and discussed their potential applicability and effectiveness on each farm. At the end of each visit, producers completed an informal survey to identify barriers to the successful adoption of new BMPs on their farm. Finally, the survey asked producers to identify air-quality-related issues for which supplemental information and technical assistance is desired.

In addition to technical assistance provided on farm, DNMP co-hosted a workshop in Sunnyside, Washington with Washington State Dairy Federation and WSU's Department of Animal Sciences for dairy producers on air quality and carbon markets. The goals of the workshop were to educate producers in making informed decisions on air quality BMPs and to connect dairy producers and associated industries with government agencies and academic institutions. Attendees learned about BMPs targeting ammonia emission reduction and future opportunities with carbon capture. The ammonia session covered BMPs related to open lot dairy systems while the carbon-focused session covered existing and upcoming opportunities for dairy producers to enter carbon markets.

NAQSAT Results Overview

Based on the NAQSAT, many operators were already implementing BMPs across their farm to mitigate emissions.

Table 3: NAQSAT Results	
Feeding and nutrition	**Pen management**
Efforts to reduce emissions through feeding and nutrition include tailoring diets to animal requirements (i.e., reducing nitrogen intake), optimizing starch in cow diets, covering feed storage, and strategically loading feed mixing equipment. Dairies were typically working with a nutritionist to optimize their feeding program to help reach production goals (pounds per hundredweight, percent fat and protein) while prioritizing cow health. All producers noted they are making conscious efforts when creating their rations in their mixers by putting dry, dustier ingredient on the bottom or between high moisture feedstuffs.	Almost every participant is doing pen maintenance in the winter and summer to manage moisture content. In the winter, producers add straw to pens to absorb excess moisture and improve bedding. In the summer, pens are harrowed at least once a week, up to daily, to expose wet manure to the sun to encourage drying and decrease overall pen emissions. Producers are taking steps to slow emissions from leaving other areas of their facility by employing dust abatement strategies such as water or chemical treatment on dirt roads and the planting and maintenance of tree windbreaks.
Manure storage and management	**Land application**
Most dairies in the LYV have begun investing in multi-stage manure separation technology in order to optimize nutrient management. Centrifuges, slope-screens, and screw-presses are common separation systems deployed at LYV dairies. Reducing solid manure in lagoons decreases the amount of reactive material that can become an air emission.[23] Separated solids are either typically composted or reused for bedding. Only one producer has adopted advanced technology like anaerobic digesters and, and another was experimenting with surface lagoon aeration to transform and capture additional pollutants. Other abatement strategies such as covered lagoons to capture methane have not yet been adopted at dairies in the LYV.	New technologies such as manure injection and other precision agricultural techniques are increasingly growing in used for the cropping portion of a dairy system in the LYV region. A double crop rotation of corn and triticale is practiced commonly in the LYV to maximize land productivity, protect the soil from erosion, and reduce feed costs. Alfalfa is the other predominant crop rotation used by dairies in the LYV, which also contributes to carbon storage increases and reduced erosion on the landscape. Practices that keep a crop in place for most of the year (corn-triticale rotation) or on a multi-year perennial cycle (alfalfa) promote carbon storage and protect against erosion. On some operations this practice is combined with no-till cropping which helps promote soil carbon storage that is often released via high-tillage farming.

Note: NAQSAT survey results were not collected by WSDA in order to preserve producer autonomy.

Dairy producers in Washington must apply manure (solid and/or liquid) to their crop fields at agronomic rates. Many have adopted incorporation of manure applied through injection or disking to minimize nitrogen loss in ammonia volatilization. Retaining nitrogen in the soil promotes crop growth and reduces losses to both groundwater and surface waters, as well as the atmosphere. Many producers have adopted BMPs on farm that increase cow health and proper nutrient management, which results in lower air emissions. Measures still exist that can be implemented on dairies in the area to further reduce emissions. In Emberston et .al. (2021), practices such as lagoon covers and enclosed housing for cows are listed as a Tier 3 BMP - the most effective at reducing emissions but also the most costly.

Survey Results Overview

- Each question was composed of a part A and B.
- In part A, producers were asked to indicate "Yes," "No," "Maybe," or "Fine" with current program" in response to the survey question.
- In part B, producers were asked to identify what factors prevent adoption of the BMP associated with part A and could select from: "Cost of implementation," "Labor," "Knowledge," "Time," and "Not a priority for my operation."'
- The majority of producers responded to part A of each question. Not all producers who answered part A also answered part B.

Table 4: Survey Questions and Answers

	Informal survey question	Yes (%)	No (%)	Maybe (%)	Fine with current program (%)	Barriers to implementation responses (% who responded)
1	Would you adopt new BMPs in nutrition? (e.g. adjust diets to exclude excessive N, higher quality starch, less sulfur-based products)?	64	0	29	7	Cost of implementation: 100%
2	Would you adopt new BMPs in feed storage (e.g. mixing times, storage facilities, feed processing, spoilage/ spillage)?	50	0	43	7	Cost of implementation: 83% Knowledge : 20% Labor: 20%
3	Would you adopt new BMPS in open lot design?	29	0	42	29	Cost of implementation: 67% Knowledge: 33% Time: 17%
4	Would you adopt new BMPs in open lot management?	43	0	43	14	Cost of implementation: 67% Knowledge: 33%

Table 4: Survey Questions and Answers						
	Informal survey question	**Yes (%)**	**No (%)**	**Maybe (%)**	**Fine with current program (%)**	**Barriers to implementation responses (% who responded)**
5	Would you adopt new BMPs in free stall barn construction and design?	20	0	30	50	Cost of implementation: 67% Labor: 67% Knowledge: 67% Time: 33%
6	Would you adopt new BMPs in free stall barn manure removal?	20	0	30	50	Cost of implementation: 50% Knowledge: 100%
7	Would you adopt new BMPs in waste storage and treatment (e.g. lagoon covers, anaerobic digesters, additives, solids separation)?	50	7	29	14	Cost of implementation: 80% Knowledge: 60%
8	Would you adopt new BMPs in land application (e.g. application technique, cover crops, tillage, timing)?	29	7	35	29	Cost of implementation: 67% Labor: 33% Knowledge: 50% Time: 17% Not a priority for my operation: 7%
9	Would you adopt new BMPs in composting?	43	7	29	21	Cost of implementation: 20% Labor: 20% Knowledge: 75% Time : 20% Not a priority for my operation: 20%

Table 4: Survey Questions and Answers						
	Informal survey question	**Yes (%)**	**No (%)**	**Maybe (%)**	**Fine with current program (%)**	**Barriers to implementation responses (% who responded)**
10	Would you adopt new BMPs in grazing management?	15	8	15	62	Cost of implementation: 33% Labor: 33% Knowledge: 100% Time: 33% Not a priority for my operation: 33%
11	Would you install windbreaks?	35	14	14	29	Cost of implementation: 75% Labor: 25% Knowledge: 50% Time: 50% Not a priority for my operation: 25%
12	Would you adopt new BMPs in vehicle and equipment management?	43	0	29	29	Cost of implementation: 75% Labor: 50% Knowledge: 25% Time: 25% Not a priority for my operation: 25%
13	Would you adopt certain air quality or carbon sequestration BMPs if they enabled you to generate carbon credits/sell offsets/ participate in carbon markets (e.g. anaerobic digesters, covered lagoons for biogas capture, no-till farming, biochar, cropping rotation)?	64	0	36	0	Cost of implementation: 80% Labor: 20% Knowledge: 40% Time: 20%

The informal survey included several more descriptive questions where producers could elaborate on specific concerns or areas of attention they felt their individual facility and the industry needed to address air quality.

- When asked if they would be interested in educational opportunities around air quality mitigation and carbon markets, 67% of producers said they were interested in both air quality mitigation and carbon markets, 8% said they were only interested in carbon markets, 8% said they were only interested in air quality concerns, and 8% indicated they were interested in neither.
- Producers were then asked if adopting air quality BMPs would benefit their production goals financially, environmentally, and socially. 46% indicated yes, 8% indicated no, and 46% indicated that they do not know.
- When asked what resources producers needed in order to help the dairy industry's goal of net zero carbon emissions by 2050, nearly all producers indicated that more research, education, and collaboration was needed both by industry and government in order to move forward.

Nutrition, feed storage, waste storage, and carbon markets generated the greatest farmer interest in BMP adoption. BMPs that reduce feed costs and feed shrink are advantageous to farmers' economic success as feed is the most expensive input on the dairy. Survey results showed the most hesitancy to adopt BMPs in relation to restructuring their animal containment type (open lot versus barns).

The largest hindrance to adopting new BMPs across all categories is the cost of implementation, reported as the primary factor preventing adoption across all survey questions. Dairy producers are subject to fluctuating milk prices and high operating costs, which can make investing in new technologies financially risky. New technologies on farm also tend to have high input costs and often require infrastructure changes. To make such changes, dairy operators generally need a financial justification such as increased efficiency and/or lower operating costs.

All producers surveyed said they would adopt or would consider adopting air quality or carbon sequestration BMPs that enabled them to generate carbon credits or participate in carbon markets. Financial barriers are common with adoption of BMPs that may generate carbon credit such as anaerobic digesters. Nearly all producers expressed hesitancy or were uncertain about the financial returns associated with participation in carbon markets. Only one dairy in the LYV currently has an anaerobic digester and produces renewable natural gas.

Conclusion

A range of technologies and practices exist that dairy producers may adopt to mitigate air emissions from their facilities. Growing environmental pressures in Washington's LYV as well as growing opportunities in carbon markets are driving dairy producers to consider adopting emission abatement practices. If no action is taken by dairy or other industry, Yakima County risks "non-attainment" of $PM_{2.5}$ under the Clean Air Act, potentially prompting EPA to require a state implementation plan under the Clean Air Act.[26, 27] Some of the technologies that trap and reduce GHGs and other air pollutants on dairy farms may also position dairies to participate in carbon markets. Funding for the implementation of dairy digesters and alternative manure management practices, that both reduce GHGs and improve local air quality for Washington dairies, is expected through Washington's Climate Commitment Account that generates revenue from the Cap-and-Invest program.

Air quality benefits associated with biogas capture technology, such as anaerobic digesters, can extend beyond reductions in GHGs. Some biogas capture technologies, such as lagoon covers, and can potentially improve local air quality by reducing odor and emissions, such as ammonia, which serves as a precursor to PM formation while enabling producers to participate in carbon markets.

Demonstrated by California's dairy industry, producers without financial assistance may be hesitant to implement carbon capture technologies due to high levels of capital required for startup and ongoing maintenance, as well as the daunting task of running a multi-enterprise entity. In Washington, participation in carbon markets by the dairy industry is voluntary; therefore, low financial risk is likely a necessary factor for both for individual farmer and industry participation. Producer interest exists within Washington's dairy industry, particularly the LYV to implement climate-smart technologies that may both improve air quality while achieving sustainability goals set by the industry.

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