Onsite Wastewater Treatment and Process Water Recycling Systems for Agriculture Dairy Farms

Final Report

ET23SWE0019

Prepared by:

Derick Baroi AESC

Christopher Rogers AESC

Martin Vu RMS Energy Consulting

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Executive Summary

California dairies face a multitude of challenges, particularly with respect to regulations. New California regulations have significant compliance requirements that result in 1) low milk prices, 2) high energy costs, 3) groundwater usage quotas, 4) reduction of nitrate and phosphorus levels, and 5) reduction of methane emissions.

More specifically, California Senate Bill SB 1383 (Lara, SB 1383 2016) requires the dairy industry to reduce manure methane emissions by 40 percent of 2013 levels by 2030. Accordingly, the dairy industry urgently needs energy efficiency and water reclamation technologies to provide near-term solutions to keep California dairies sustainable and competitive.

The issue is compounded because the economics and complex operations and maintenance of conventional wastewater treatment and process water recycling systems currently available to dairy farmers are particularly challenging for small to midsize dairy farms. In the current configuration, solids contained in settling basins and lagoons biologically decay due to anaerobic digestion, which produces greenhouse gases. Thus, removing the solids before they start decaying will reduce the amount of methane and other greenhouse gases currently produced in the lagoons and settling basins.

This field demonstration project assesses an onsite recycling bead filtration wastewater technology (BFWT) designed to efficiently remove contaminants in dairy farm operations. The bead filtration wastewater technology recycles its backwash water using a small air pump that slowly fills the air chamber below the bead bed. The bead filtration wastewater technology allows facilities to expand their reuse of wastewater in other areas such as drip or flood irrigation or facility maintenance by recycling its backwash water.

The bead filtration wastewater technology exhibits substantial resource, economic, and environmental benefits including electricity and water savings and greenhouse gas emission reduction within California's dairy industry. Benefits also include embedded energy savings in all the energy required for the production, treatment, transport, and any other work needed to bring water to its end-use destination. Using a bead filtration wastewater technology may result in lower demand of water, energy, peak demand, and greenhouse gas emissions, by eliminating the need to pump unnecessary freshwater for dilution from the water table, supporting the state of California's decarbonization goals.

The bead filtration wastewater technology could increase electric reliability and reduce electric ratepayers' costs by significantly reducing the amount of electricity needed to treat dairy farm wastewater while concurrently producing high-quality recycled water for onsite reuse. Accordingly, field testing of the bead filtration wastewater technology was performed to demonstrate a reduction in the amount of potable water and associated embedded energy in the saved water needed for flood or drip irrigation. This field demonstration project goal centers on documenting the electric system impacts both upstream and downstream from the point of technology adoption. If proven successful, the bead filtration wastewater technology has the potential to expand into industrial food processing facilities and municipal water districts.

The field study shows that the floating bead filtration technology has the potential to reduce freshwater usage from 56 to 308 acre feet per year, electric energy usage for pumping from 6.2 to 41.5 megawatt-hours (MWh) per year, anthropogenic carbon dioxide equivalent (CO_2e) from 0.57 to 3.84 metric tons per year and 1.04 metric tons of methane (1.8 percent of baseline) in terms of greenhouse gas reduction from the manure treatment for the project site.

Abbreviations and Acronyms

Acronym	Meaning
AF	acre feet
AMMP	Alternative Manure Management Program
ASABE	American Society of Agricultural and Biological Engineers
AU	animal units
BFWT	bead filtration wastewater technology
BOD	biochemical oxygen demand
CA	California
CARB	California Air Resources Board
CCI	California Climate Investments
CCID	Central California Irrigation District
CDFA	California Department of Food and Agriculture
CDWR	California Department of Water Resources
CFM	cubic feet per minute
Cfs	cubic feet per second
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
COC	constituents of concern
CPUC	California Public Utilities Commission
CSWRCB	California State Water Resources Control Board
CVRWQCB	Central Valley Regional Water Quality Control Board

Acronym	Meaning
DDRDP	Dairy Digester Research and Development Program
EE	energy efficiency
EPA	Environmental Protection Agency
ET	emerging technology
GHG	greenhouse gas
noGpd	gallons per day
Gpm	gallons per minute
ILRP	Irrigated Lands Regulated Program
IPMVP	International Performance Measurement and Verification Protocol
IW	irrigation well
K	potassium
kW	kilowatt
kWh	kilowatt-hour
MAF	million acre feet
MCF	methane conversion factor
$MTCH_4$	metric tons of methane
$MMTCO_2e$	million metric tons of carbon dioxide equivalent
$MTCO_2e$	metric tons of carbon dioxide equivalent
MW	megawatt
N	nitrogen
NH_4-N	ammonium nitrogen
NPDES	National Pollutant Discharge Elimination System

Acronym	Meaning
P	phosphorus
ppm	parts per million
PV	photovoltaic
SA	surface area
SB 1383	Senate Bill 1383
SCE	Southern California Edison
SLCP	short lived climate pollutant
TSB	Total System Benefit
USDA	United States Department of Agriculture
VNEM	Virtual Net Energy Metering
WW	wastewater

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Introduction

The California dairy industry has gained remarkable water use efficiency over the past 60 years by reducing its use of surface and groundwater (blue water) intensity by almost 90 percent (Naranjo et al. 2020). Three types of water are used in US dairy farms: green water or rainwater (81 percent), blue water (8 percent), and gray water or recycled wastewater (11 percent) (Mekonnen and Hoekstra 2012). The breakdown of blue water use in California dairy is 93.4 percent for crops, 5.5 percent for housing and milking, and 1.2 percent for drinking water for the animals (Naranjo et al. 2020). However, climate change and severe drought conditions have created challenges for dairy farms that use blue water. The grey water is a source of nutrients for crops but needs to be diluted with blue water to reduce the concentration of nutrients to avoid soil and ground water table pollution.

This new technology has the potential to reduce the use of blue water in California dairy farms, reduce the manure methane emissions, save grid electric energy used for pumping ground water and reduce greenhouse gas emissions through saving electric energy. The project introduces a sustainable solution that will help farmers stay in compliance using their existing manure capture systems, while satisfying increasingly tougher regulations through the bead filtration onsite wastewater management system.

There were over 732,000 farms housing around 88 million cattle in the United States in 2022. Of these cattle, over 9.3 million were milk cows in more than 36,000 dairy farms. California stood on the top of the leaderboard with 11,759 farms housing more than 5.2 million cattle, of which 1,117 farms house around 1.7 million milk cows (USDA 2022). Figure 1 illustrates the quantity of milk cows in California compared to Wisconsin, Idaho, Texas, and New York. In 2022, California continued to lead the nation in total milk production with 41.8 billion pounds worth $10.4 billion (CDFA 2022).

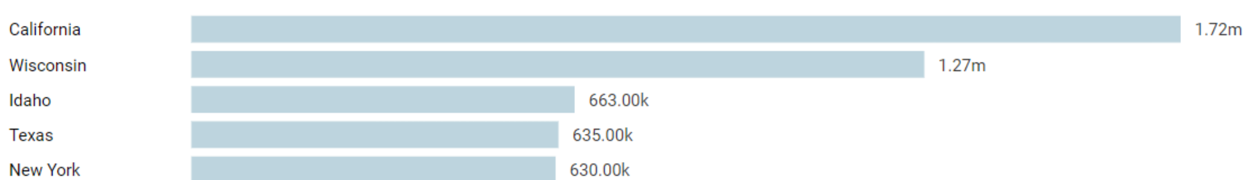

Figure 1: Milk cow statistics 2024.

Source: (USDA 2024)

In 2022, California continued to lead the nation in total milk production with 41.8 billion pounds worth $10.4 billion (CDFA 2022). The recent trend of milk cows, milk production and milk price are shown in Figure 2.

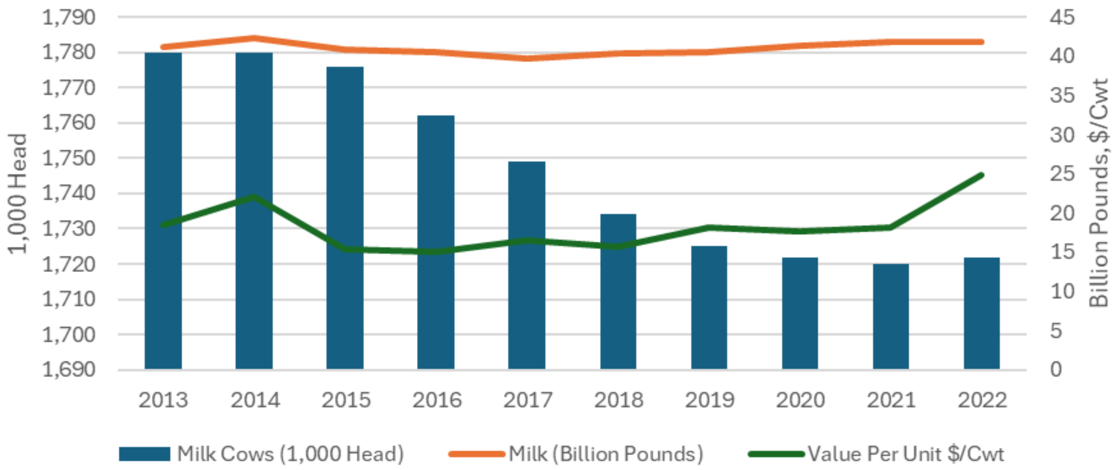

Figure 2: Milk cows, milk production and value, 2013-2022, CA.

Source: (USDA 2024)

Merced County contributes more than 15.3 percent of California's milk production alone. Milk production continued to dominate as Merced County's leading agricultural commodity, with an overall gross value of just over $1.5 billion in 2022 (CDFA 2022).

It is estimated that the average dairy cow produces 12 gallons of fresh manure per day per one thousand pounds of live weight (Chastain and Camberato n.d.). As the industry has evolved, dairy farmers have implemented more efficient manure handling systems to accommodate the enormous amount of manure produced. However, these improved manure-gathering practices have unintended consequences such as greenhouse gas generation, nutrient overloads on croplands and downstream watersheds, and excessive water and energy consumption. To combat these issues, state and federal environmental agencies are adopting new standards that dairy farmers must follow to preserve the environment.

Cattle (dairy and beef) farms in California are generally governed by the National Pollutant Discharge Elimination System (NPDES), the California State Water Resources Control Board (CSWRCB), the California Air Resources Board (CARB), and the California Department of Food and Agriculture (CDFA). Moreover, California is mandated to reduce greenhouse gas emissions by 40 percent below 1990 levels by 2030 (Pavley 2006). This mandate is strengthened by SB 1383, which recognizes the immediate climate benefits of reducing short-lived climate pollutants, i.e. methane (Lara, SB 1383 2016). Figure 3 shows California's greenhouse gas emissions reduction targets and goal through 2050.

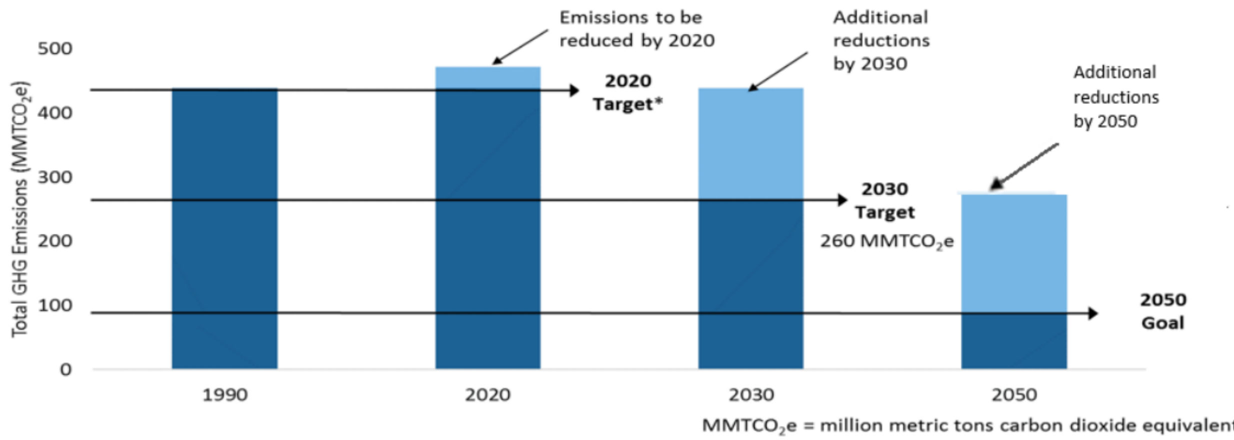

Figure 3: California greenhouse gas (GHG) emissions reduction targets and goal through 2050.

Source: (CARB 2022)

Figure 4 illustrates that methane accounted for 40 million metric tons of carbon dioxide equivalent (MMTCO2e), or approximately nine percent of the state's greenhouse gas emissions in 2013 (CARB 2022).

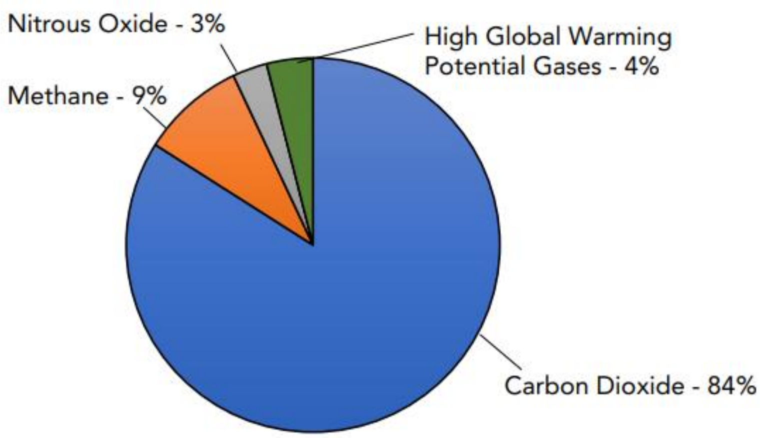

Figure 4: 2013 California greenhouse gas emissions by gas (Total 2013 emissions~460 MMCO2e).

Source: (CARB 2022)

Figure 5 shows the dairy and livestock sectors as the largest source of methane emissions in California, producing approximately 22 MMTCO2e, or about 55 percent of statewide methane emissions (CARB 2022).

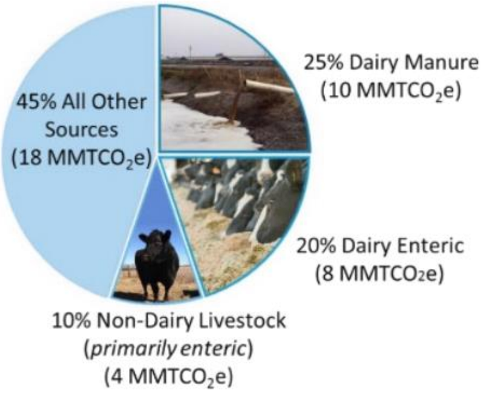

Figure 5: 2013 California methane emissions by source.

Source: (CARB 2022)

Methane emissions at dairy and livestock operations come from two main sources: the animals themselves, through enteric fermentation (through digestive processes), and through manure management. Both enteric and manure emissions are functions of the cattle population, meaning the more heads of cattle, the higher the methane emissions. The sector has the potential to achieve significant methane emissions reduction from manure management. California Climate Investments (CCI) has funded two California Department of Food and Agriculture grant programs to reduce manure methane emissions; the Dairy Digester Research and Development Program (DDRDP) and the Alternative Manure Management Program (AMMP). These projects are expected to reduce 2.0 $MMTCO_2e$, or 22 percent of the reduction necessary to achieve the 2030 target. Alternative manure management practices can also provide important environmental co-benefits, including improved water quality, nutrient management, and exportable manure solids. Certain alternative manure management practices can remove manure solids, nitrogen, and salt from the manure stream.

Background

California Dairy Farm Water Use Overview

California dairy farms use water to grow crops for the cows, cool the milk through refrigeration, clean milking equipment and milk parlors, provide drinking water for the cows, cool and clean the cows, clean the barn, and to dilute the wastewater before land application. On average, California agriculture irrigates more than 9 million acres using roughly 34 million acre-feet (MAF) of water typically diverted from surface water—rivers, lakes, and reservoirs that deliver water through an extensive network of aqueducts and canals—or pumped from groundwater (CDWR n.d. It can be estimated that the dairy farms in California use 8.7 MAF of blue water from state canals and ground wells. The United States Department of Agriculture (USDA) 2018 Census of Irrigation shows that the source of water for irrigation in California farms is 43 percent from ground water, 9 percent from on-farm surface water and the remaining 48 percent from off-farm water from all suppliers (USDA 2018). California dairy farms presently use an estimated 3.75 MAF of blue water from ground water wells. The expense per irrigated acre for water from wells is $143.76 and for surface water is

$58.17 (USDA 2018). Additionally, California dairies use 256 kg of blue water to produce 1 kg of energy- and protein-corrected milk.

Figure 6 shows that the five leading counties producing dairy milk as of 2022 are Tulare (27.6 percent), Merced (15.5 percent), Stanislaus (11.6 percent), Kings (10.3 percent), and Kern (9.8 percent) and all are in the San Joaquin Vally area under the Central Valley Regional Water Quality Control Board (CDFA 2022). The board controls water regulations for confined animal facilities, operates the Irrigated Lands Regulated Program (ILRP), implements policy for onsite wastewater treatment systems, waste discharge to land and many other programs. Discharge of waste from the confined animal facilities is regulated under four general orders adopted by the Central Valley Regional Water Quality Control Board: Order R5-2013-0122 for existing milk cow dairies, Order R5-2017-0058 for confined bovine feeding, Order R5-2010-0130 for dairies with manure anaerobic digester or co-digester facilities, and Order R5-2016-0087-01 for poultry operations. The orders require facilities to be designed with positive drainage to prevent bonding of waste. Facilities must also have proper waste storage facilities to prevent off-site discharges and new manure ponds must be lined. Manure applied to crops must be done at agronomic rates so that no excess nutrients are added to the soil that the crops cannot use.

Figure 6: California regional water boards map.

Source: (California Water Boards n.d

Irrigation water supply rates vary widely across regions and sources of water. For example, the Central California Irrigation District (CCID) is one of the largest irrigation districts in the Central Valley, serving over 1,600 farms across more than 143,000 acres of prime farmland. Table 1 shows the three-tiered rate schedule of the Central California Irrigation District (CCID 2024). The project site uses Central California Irrigation District canal water at the rates listed in Table 1.

Table 1: Central California Irrigation District Rate Schedule

Tier	Acre-feet/gross acre	$/acre-foot
1	0.00-3.20	18.00
2	3.21 – 3.70	61.00
3	Above 3.70	110.00

Source: (CCID 2024)

Water supplies in the Central Valley are becoming increasingly limited due to a prolonged drought in the region (CSWRCB 2023). As a result, water tables in this area have fallen to record lows (CSWRCB 2023). Agriculture is one of the largest industries in the Central Valley, with dairies comprising a sizeable portion of the activity in the area. Many dairy farmers do not have access to surface water and rely on subsurface water supplies for daily operations. With the increasing scarcity of subsurface water supplies, farmers are forced to drill deeper and deeper to access the water table. As they go deeper, the pump requirements to lift the water to the surface increase. As a result, the energy required to access the water has also increased.

Routine cleaning practices at dairy farms produce a moderate volume of organic wastewater daily. This wastewater is typically recovered and held in large facultative lagoons of four to eight feet in depth, where it is reused repeatedly in other areas of the dairy farm for cleaning purposes. The water carries manure and other debris to primary settling ponds, where the larger particulates are settled out before the water is returned to the facultative lagoon. Due to repeated use, the water contained in these lagoons has elevated levels of nitrogen, phosphorus, and potassium. Many dairy farmers use this wastewater to irrigate crops that are used as a component of the feed given to the herd to subsidize feed costs.

However, due to the high nutrient concentrations of the lagoon water, it cannot be applied to the crops directly. As a result, the lagoon water must be diluted a minimum of five to one with freshwater before irrigation. The amount of freshwater required is further exacerbated due to the "flood and drain" method commonly used for irrigation by dairies. This requires excess water to be used to completely flood a plot of land for irrigation.

Water usage efficiency is only approximately 50 percent using the flood and drain method, and the other 50 percent is assumed to leach back into the water table. Given the increasingly limited water supply, dairies are facing pressures from local regulatory bodies to reduce the amount of water they are consuming.

California Dairy Farm Wastewater Use and Treatment Overview

California's Central Valley dairy farms typically follow the water and waste flow described in Figure 7. This shows the predominant manure pathway where lactating cows are housed in freestalls.

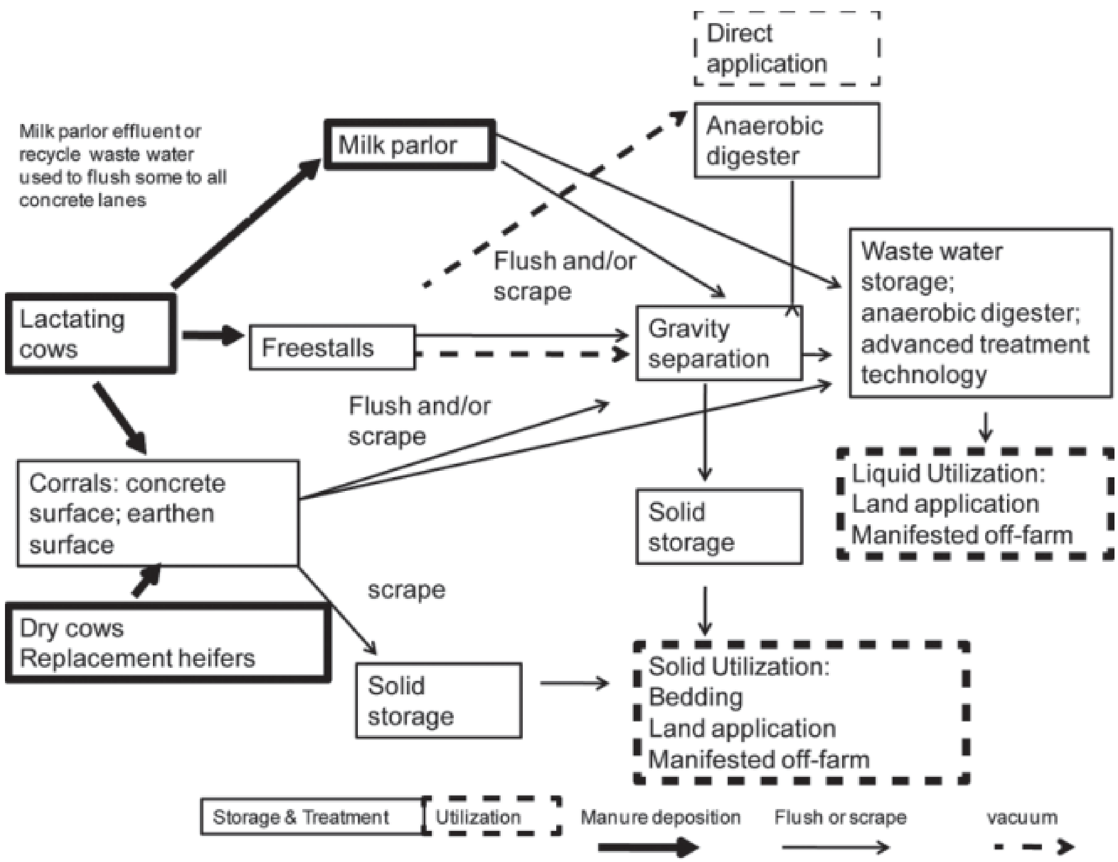

Figure 7: Predominant manure pathway where lactating cows are housed in free stalls.

Source: (Meyer, et al. 2011)

Plant nutrients, especially nitrogen (N), are essential elements for plant growth and food crop production. Soils lack nitrogen after every harvest as plants uptake nitrogen from the soil. Therefore, synthetic or organic nitrogen fertilizers are applied to the soil to help sufficient crop yields. Dairy wastewater is a prime source of nitrogen to grow feed crops. The primary waste constituents of concern, due to discharges of waste from dairies with respect to groundwater are nitrogen in its various forms (ammonia and un-ionized ammonia, nitrate, nitrite, and total Kjeldahl nitrogen, salts, and general minerals (calcium, magnesium, sodium, potassium, bicarbonate, carbonate, sulfate, and chloride). The discharge of waste from dairies must not cause surface water or groundwater to exceed the applicable water quality objectives for those constituents.

High nitrates in drinking water are a public health concern. A University of California study of five dairies in a high-risk groundwater area in the Central Valley during the 1990s found elevated salts and nitrates beneath the production area, wastewater retention ponds and land application areas (CSWRCB, Central Valley 2013). This is why a nutrient management plan and nitrogen balance is needed before applying dairy wastewater to the fodder crop land as a source of nitrogen for the plants. California dairy farms require a waste discharge plan and a nutrient management plan to be submitted to the authority having jurisdiction to use solid manure and wastewater for land application. The plans must be updated every five years and reported yearly. A National Pollutant Discharge Elimination System permit will be required to discharge to surface waters.

Nutrient Management

The University of California Davis's Division of Agriculture and Natural Resources has done in-depth research on California dairy farm nutrient management. 'Managing Dairy Manure in the Central Valley of California' (University of California 2006) 'Principles of Recycling Dairy Manure Through Forage Crops' (Mathews 2005) and 'Dairy Manure Nutrient Content and Forms' (Pettygrove, Heinrich and Eagle 2010) are highly acclaimed works on this topic. The connection between nutrient management and this project is the dilution rate at which dairy lagoon water needs to be diluted with fresh water before applying it to the feed crop field. Nutrient management aims to apply nitrogen, phosphorus, and salt in a way that minimizes the environmental impact while ensuring crop growth. The amount of land required for livestock waste depends on factors such as the cow's diet, crop nitrogen uptake, and soil losses, with nitrogen loss ranging from 20 to 80 percent. Nitrogen application should not exceed 140 to 165 percent of the crop's nitrogen removal. In a synchronized-rate system, 50 to 65 pounds of nitrogen per acre are applied in five to six corn irrigations during peak nitrogen uptake periods. Dairy nutrient water is typically diluted with freshwater at a 10:1 ratio to prevent salt buildup, and ammonia volatilization is minimal because of low ammonium concentration in the irrigation water. For young corn, about 30 pounds of nitrogen per acre may be needed to prevent ammonia toxicity or salt damage (Mathews 2005). "Manure water in the storage lagoon contains from 50 to 1,000 parts per million (ppm) ammonium nitrogen (NH_4-N), with typical concentrations of 200-500 ppm. During irrigations, farmers commonly dilute lagoon water with 5 to 10 parts of fresh source water which results in 20 to 100 ppm NH_4-N in the irrigation water" (University of California 2006).

California Dairy Farm Wastewater Treatment Market Size

As mentioned previously in this report, California has about 1,600 bovine farms (confined animal facilities) of which about 1,117 are dairy farms. Only 124 bovine farms in California have anaerobic digesters as of 2024 (EPA 2024). In the California dairy farms, wastewater resulting from the flushing of manure from concrete feed lanes, free stalls, and the milking facilities typically passes through a mechanical screen where the solids primarily consisting of coarse or fibrous manure particles, spent bedding and spilled or waste forage and feed are separated from the liquid manure. The wastewater is then stored in anaerobic lagoons. Free stalls and feed lanes are typically flushed by recirculating top water from the lagoons. Methane, a short-lived climate pollutant, is generated under anaerobic conditions in liquid manure storage ponds. Onsite wastewater treatment can reduce the methane emission by removing the solids from the wastewater and making the wastewater reusable for flushing before it is sent for land application. This has the potential to reduce the anaerobic condition in the storage pond and reduce the methane generation.

The California Department of Food and Agriculture Dairy Digester Research and Development Program has awarded a total of $214 million for 131 dairy digester projects from 2015 through 2022. Dairy digesters remain one of the most efficient greenhouse gas reduction programs in terms of the cost of each ton of greenhouse gases reduced. These projects will achieve a cumulative estimated greenhouse gas reduction of 2.3 $MMTCO_2e$ annually and equate to 7.26 percent of the methane emissions from manure management in California. Under the Dairy Digester Research and Development Program, the California Department of Food and Agriculture funds up to 50 percent of the total project cost. The average project cost of the Dairy Digester Research and Development Program is $3.27 million.

The California Department of Food and Agriculture has funded $86.9 million for 142 Alternative Manure Management Program projects from 2016 to 2022. Approximately $20 million in matching funds have been contributed by awardees. These projects achieve a cumulative estimated greenhouse gas reduction of 1.3 $MMTCO_2e$ over five years, or 260,164 $MTCO_2e$ annually, and equal to 2.6 percent of the methane emissions from manure management in California. The Alternative Manure Management Program funds a diverse range of manure management practices that provide options to dairy and livestock operations where digesters may not be economically feasible. The Alternative Manure Management Program recognized and incentivized the following manure management practices:

1. Pasture-based management
2. Alternative manure treatment and storage practices, including:
    a. Installation of a compost-bedded pack barn that composts manure in situ; or
    b. Installation of slatted-floor pit storage manure collection that must be cleaned out at least monthly
3. Solid separation-eligible technologies include:
    c. Weeping wall (system must have a minimum of at least two cells)
    d. Stationary screen
    e. Vibrating screen
    f. Screw press
    g. Centrifuge
    h. Roller drum
    i. Belt press or screen
    j. Advanced solid-liquid separation assisted by flocculants or bead filters. This practice must be implemented in conjunction with a primary mechanical separator.
    k. Vermifiltration. This practice must be implemented in conjunction with a primary mechanical separator.
4. Conversion from a flush-to-scrape manure collection system in conjunction with one of the suggested manure treatments or storage systems (CDFA 2024).

Bead filters accomplish the advanced solid-liquid separation that reduces the unavoidable methane emission from the storage pond. It can also decrease the use of freshwater to dilute the wastewater for irrigation, the groundwater pumping energy usage, and the anthropogenic CO_2. These filters also offer a low-cost alternative to other costly technologies. The average cost of an Alternative Manure Management Program project is $0.75 million.

Emerging Technology: Floating Bead Filters

A floating bead filter uses floating media in a submerged, static bed to capture solids by the same mechanism as traditional sand filters. At the same time, the units are designed to operate as a fixed-film bioreactor that oxidizes organics and nitrifies. The media used in floating bead filters are low-density polyethylene beads with a diameter of 1/8 inch and a specific gravity of 0.9-0.95. Figure 8 illustrates an example of the low-density spherical beads. The filters are marketed as clarifiers for the removal of suspended particles, biofilters for the removal of dissolved compounds, or uniquely, as bio-clarifiers that remove solids and dissolved compounds concurrently. Unlike the sand in the sand filter, the lightweight filtration beads rest on top of the filter, rather than on the bottom. These granular beds eventually clog with captured solids and biofilm so they must be periodically backwashed. Figure 9 demonstrates how granular beds can develop biofilm to facilitate biochemical oxygen demand decay and nitrification.

Figure 8: Low density spherical beads.

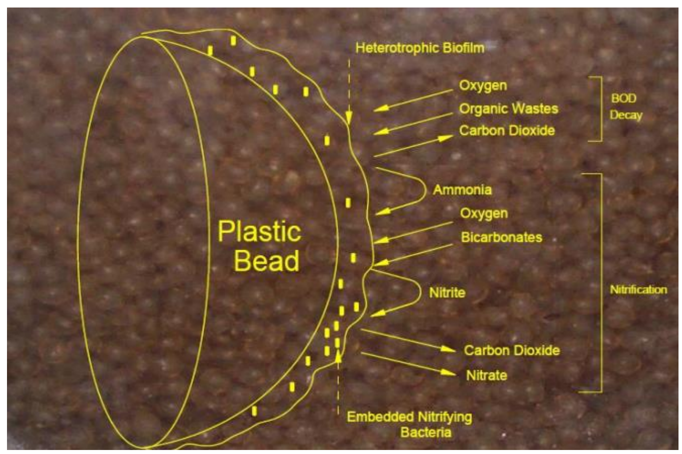

Figure 9: Biofilm development.

Source: (ET Manufacturer).

Floating bead filters or static low-density media filters have been used for the past 25 years to replace clarifiers, sedimentation basins, and sand filters. Since the first filter was used to replace a sand filter in the aquaculture industry, the technology has been used in several industries to improve process operations, remove solids, improve wastewater quality, and reduce water loss all with low head loss and lower operating costs. The filters have been used as primary and secondary clarifiers, tertiary polishers for solids and nitrification, groundwater remediation, and municipal and industrial water reuse projects.

Innovation

Previous bead filter models minimized water loss. However, the bead filtration system for this study takes water conservation one step further by recycling its backwash water rather than draining it. Backwashing is controlled by a small air pump that slowly fills the air chamber below the bead bed.

When the air chamber fills up, a simple nonmechanical triggering device suddenly releases the air, causing the beads and sediments to fall downward. Figure 10 shows the sequences of backwash and sludge storage.

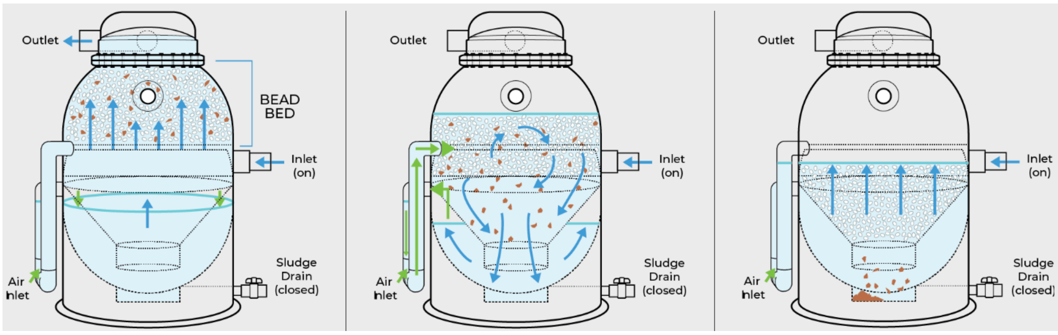

Figure 10: Backwash and sludge storage.

Source: (ET Manufacturer n.d.).

The inflowing water then floats the beads back up to reconfigure the filtration bed, trapping the sediments in a settling zone. The air recharging the charge chamber slowly displaces the settled backwash water, returning it to the circulation loop. Water loss is only incurred when sludge is removed from the hull, usually two to four percent. This process occurs automatically with no moving parts or computer controls. Figure 11 shows the sequence of sludge removal.

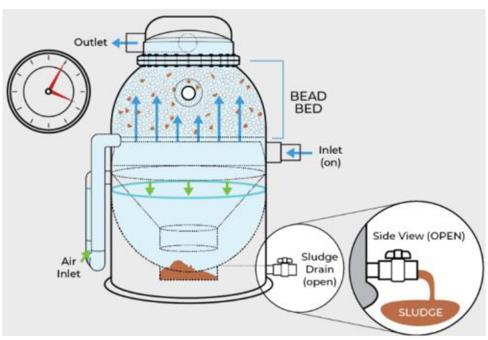

Figure 11: Sludge removal.

Source: (ET Manufacturer).

In addition to building a pathway for bringing new technology to California that can significantly reduce electricity, water, and greenhouse gases attributable to dairy businesses, this project will demonstrate how distributed treatment of dairy farm wastewater and reuse of recycled water also increases public health and safety, increases drought resilience, and reduces the costs of municipal water and wastewater systems.

Figure 12 displays a typical process flow of a dairy farm with a bead filtration wastewater technology.

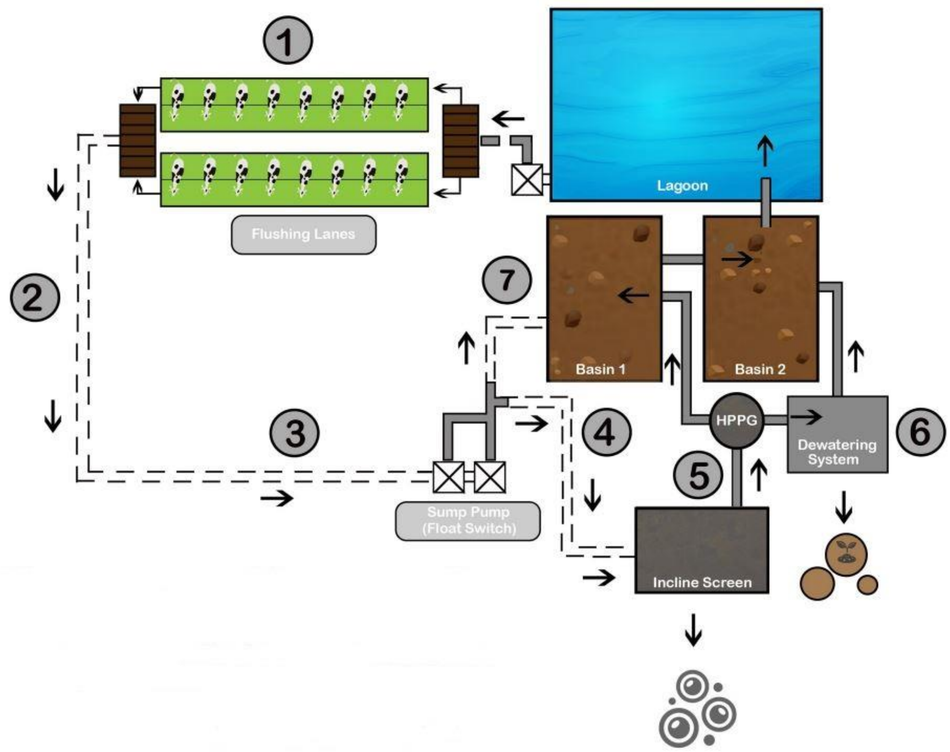

Figure 12: Typical process flow diagram.

Source: (ET Manufacturer n.d.).

1. The process starts in the flushing lanes where waste and uneaten feed is collected.
2. Water is pumped up from the floors, allowing for cow waste and extra feed to be flushed out of the cow pens.
3. The water leaving the cow pens travels to an underground sump pump.
4. The water from the sump is pumped up to the incline screen where it removes most of the large solids. Solids removed from the incline screen are sent to a conveyor where they are piled.
5. The water leaving the incline screen goes through the floating bead filter, the High Profile PolyGeyser (HPPG) filter, to remove most of the remaining solids. The water leaving the filter goes to the solids-settling basins and the sludge goes to the dewatering system.
6. Sludge leaving the filter goes through the dewatering process to remove any remaining solids and the clear effluent is sent to a basin. The remaining sludge is discharged as waste. The process comes full circle and starts again, with the lagoon water being used to flush the cow pens.
7. The sump has a bypass valve that can divert a small amount of its flow to the basins, as needed.

Manure Lagoon Treatment

The floating bead filter offers supplementary filtration capacity, which can be applied to existing livestock manure lagoon treatment systems to reduce the nutrient and organic loading into or out of the lagoon to meet water discharge requirements for irrigation or discharge. Additionally, the filter offers both pretreatment and posttreatment solutions for lagoon systems, to extend the working life of existing systems and reduce greenhouse gas emissions. For pretreatment, the filter can be applied before the lagoon where it decreases the solids and nutrient loading into the lagoon through mechanical filtration. This application lowers the loading into an existing lagoon system, providing a decrease in nitrogen, phosphorus, and greenhouse gas emissions in and from the lagoon.

Removal of additional solid waste before the effluent enters the lagoon will also reduce the frequency of dredging needed, thereby extending the working life of the system. For posttreatment, the filter can be applied to the effluent of the lagoon to biologically and mechanically treat final discharge of the lagoon system, in order to meet strict discharge limits or irrigation requirements. The floating bead filter can also be used for denitrification and aid in the removal of nitrates to reduce nitrogen discharge of the system.

Market Opportunities

Wastewater treatment is generally broken into municipal, industrial and agricultural market segments. The floating bead filter can treat many commonly regulated wastewater contaminants. Additionally, a unique characteristic of the technology is that it is capable of treating a wide range of contaminant concentrations. As a result, this technology is suitable for many municipal, industrial and agricultural wastewater treatment applications. The opportunities of wastewater management systems boil down to cost-effectiveness, as well as environmental benefits. It is more cost-effective to treat water onsite, as opposed to sending it to a wastewater treatment plant. Wastewater disposal costs, once a minor operating expense, have risen dramatically, prompting cost-conscious plant managers to revisit their approach to wastewater treatment. Installing on-site solutions can reduce or even eliminate surcharges incurred by sending wastewater to a municipal treatment plant. On top of that, the technology saves both water and energy in the long run by recycling the water and using the manure as fertilizer, while simultaneously decreasing methane.

The technology has several targets in the agricultural market. One specific target market is enhancing lagoon-based livestock manure management systems. In U.S. animal production, this manure management system approach is mostly used with swine, cattle (dairy and beef) and layer hen production. The national Cattlemen's Beef Association estimates there are more than 700,000 cattle farms, ranches and feedyards in the United States. The USDA estimates there are an additional 60,000 pig and hog farms in the United States. The use of lagoon-based manure management systems is mostly found in regions with warmer year-round climates. While the total number of livestock farms currently using this manure management practice could not be found, it is known that this is a very commonly used practice among dairies in California. California is home to more than 1,100 dairies with a total of 1.7 million dairy cows. It is estimated that if 25 percent of the dairies were to meet the criteria required to use this technology, the California dairy market segment would have a revenue potential of $96 million. This is believed to be a conservative estimate.

Market Barriers

Numerous barriers to widespread adoption of the floating bead filter exist.

LACK OF TECHNOLOGICAL FAMILIARITY: In California dairy farms, solids are typically separated from liquid wastewater using a sand lane or an inclined mechanical screen. However, adding the additional step of a floating bead filter could further improve the water quality. This filter, placed downstream of the mechanical screen, effectively removes the remaining total suspended solids (TSS) and ammonia.

LACK OF CUSTOMER KNOWLEDGE: Federal or state funded programs and local agribusiness shows and events usually introduce emerging technologies to the farmers. Permit and regulatory requirements also act as a driver to adapt to new technology. Lack of adequate knowledge about the source, installation and operation of a new technology act as a barrier to market adoption.

FIRST COSTS: The increasingly higher operating expenses of California dairy farms, compared with the revenue growth, demotivate the farmers to invest in an emerging technology.

ABSENCE OF INCENTIVES: The California Department of Food and Agriculture's Alternative Manure Management Program provided financial assistance for the implementation of non-digester manure management practices on dairy and livestock operations in California. The Alternative Manure Management Program is currently closed.

ADDITIONAL COST: A floating bead filter with a mechanical separator remains an uncommon manure management practice in the dairy industry, due to economic challenges. The significant capital cost of a mechanical separator does not convince the dairy owners to install a filter with added expenses.

Objectives

This technology demonstration project aims to verify the following anticipated benefits essential to achieving California's resource, economic, and environmental project objectives, including:

1. Reducing the quantity of electricity used for treating dairy farm wastewater.
2. Reducing the amount of potable water produced, treated, and delivered by the local water utility,by increasing production and reuse by the dairy farm of high-quality recycled water, and by reducing direct electric use by the water utility and electricity embedded in water.
3. Reducing greenhouse gases by decreasing the amount of electricity that would otherwise have been used to treat dairy farm wastewater.
4. Optimizing the wastewater treatment process by investigating the effectiveness of a filtration technique in removing contaminants from wastewater.
5. Reducing the amount of electricity that would have been used by the local water utility to produce, treat, and deliver potable water to the dairy farm that is met by onsite recycled water.
6. Increasing economic development and creating jobs by accelerating the commercialization of a technology that has the potential to help California achieve its ambitious clean energy, water resilience, and environmental responsibility goals.

7. Reducing the volume of groundwater used to dilute the recycled water for irrigation.
8. Reducing the electricity used for pumping groundwater.
9. Maintain nitrate and phosphate levels in the crop field using less water.

Expected Project Outcomes

The field demonstration project outcomes include:

1. Quantification of peak kW reduction for the removal of potable water pumping.
2. Quantification of kWh reduction for the removal of potable water pumping.
3. Quantification of greenhouse gas savings for the removal of potable water pumping.
4. Quantification of estimated non-energy benefits, including total nutrient removal and nitrate reduction.
5. Identification of market barriers and recommendations to support broader market adoption.
6. Identification of information necessary for future statewide measure package development or custom solution.

This field demonstration project assesses a bead filtration wastewater technology onsite recycling system for reusing treated processed water at a heifer ranch located in Merced County. The bead filtration wastewater technology proposes to save energy by reducing the freshwater pumping for diluting wastewater used to flood or drip irrigate crop fields. Additionally, the bead filtration wastewater technology avoids electricity pumping use, and the corresponding embedded energy in the water is saved through the treatment process.

Methodology & Approach

The field demonstration phase of the project occurred in four steps:

1. Host site review and inspection
2. Measurement and verification planning and datapoints
3. Monitoring period, and troubleshooting
4. Calculations

Customer Site Baseline Condition

This project was developed in two separate facilities with the same owner, a heifer ranch and a dairy facility, both of which are located in Los Banos in Merced County.

Heifer Ranch

The heifer ranch is located on approximately 15.4 acres of land and is permitted to house 3,501 animals. The facilities include shade structures, two wastewater storage ponds, open corrals, office and storage buildings. The predominant breed of cows housed at the heifer facility is Holstein. The existing facility consists of flush-and-scrape systems that are used to collect and process wastewater and solid manure. Animal wastes from freestalls and other concrete-surfaced areas (such as feed lanes) are flushed with recycled water to an on-site waste management system that consists of two wastewater storage ponds (retention pond) of 3,227,672 gallons of storage capacity. A mechanical solids separator collects solids from the wastewater and returns the liquid to the ponds. Solid manure is removed from wastewater ponds with excavation equipment and is exported to land application areas associated with the adjacent, separate dairy operation.

The wastewater collected in the retention pond is also applied to the same land application areas via irrigation. There are no agricultural wells on the project site. One existing well on the project site which has a two-horsepower pump provides domestic water for the residences and provides drinking water for the herd. 27,100 gallons per day (gpd) of domestic water is needed to water the herd. 24,943 gallons of total process wastewater are generated daily. Figure 13 depicts the existing heifer ranch site map with the wastewater system components. Figure 14 depicts the existing wastewater flow of the heifer ranch (County of Merced 2020) (Sousa Engineering 2019).

The customer participated in CDFA Alternative Manure Management Program and received a grant to install a mechanical screen for solid separation in 2020. The estimated annual greenhouse gas emissions reduction is 240 $MTCO_2e$ (CDFA 2024).

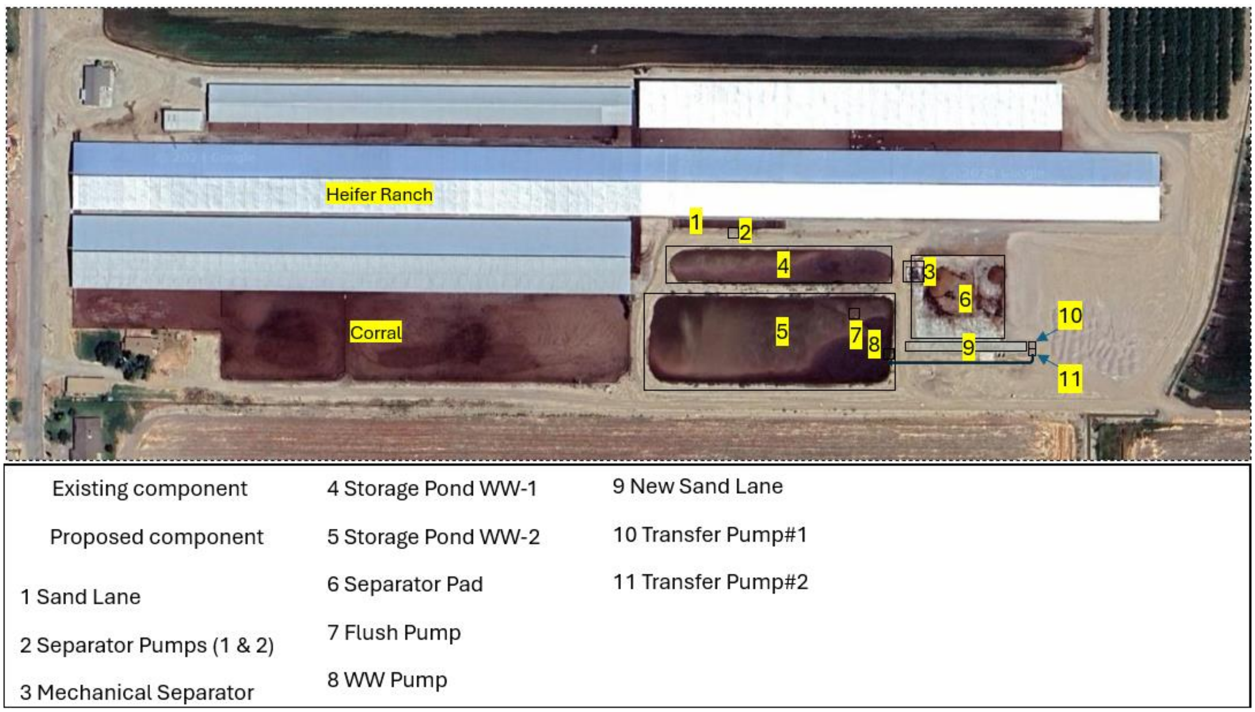

Figure 13: Existing heifer ranch site map.

Source: Project team.

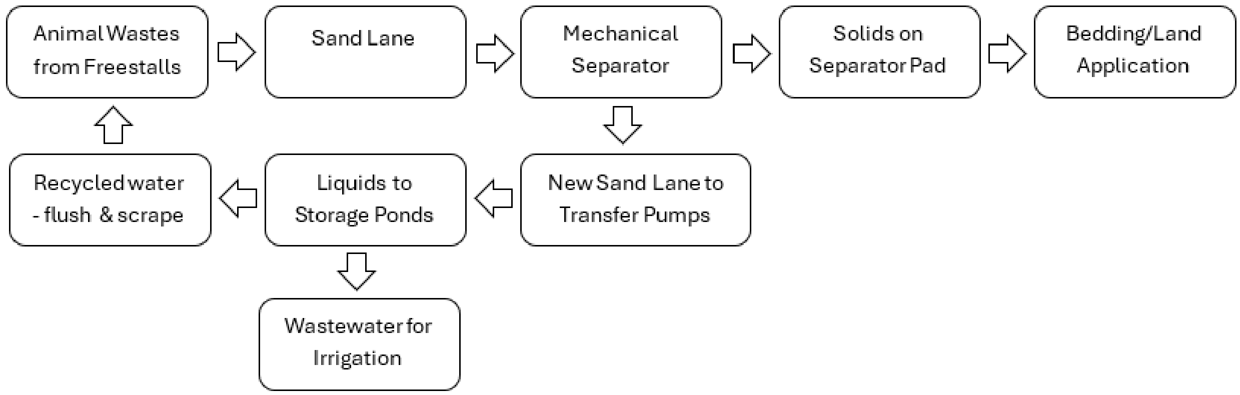

Figure 14: Existing wastewater flow diagram.

Source: Project team.

Dairy Facility

The dairy facility is located on approximately 50 acres of land and permitted to house 4,000 milking cows and 700 dry cows, a total of 4,700 animals. The facilities include free-stall barns, shade barns, a milking parlor, a hospital barn, commodity barns, a feed storage area, open corrals, a manure storage area, an equipment yard, a wastewater storage pond, two settling basins, and a shop. Animal waste from free stalls and other concrete-surfaced areas are flushed to an on-site waste management system, except for solid manure within corral areas, which is scraped. Liquid manure directs to the settling basins and is then treated in the wastewater storage pond. Approximately 1,170 acres of the project area on 17 parcels are currently used for the production of crops and the application of manure process water or solid manure. Domestic water is delivered to the site by four on-site water wells. 178,364 gallons of total process wastewater are generated daily. Table 2 shows the irrigation sources.

Table 2: Irrigation Sources

Irrigation Source Name	Type	Nitrogen (mg/L)	Phosphorus (mg/L)	Potassium (mg/L)	Discharge Rate
CCID Canal	Surface water (canal, river)	0.30	0.00	0.00	5 cfs or, 2,244 gpm
Dairy Well Irrigation Well #1	Groundwater (well)	1.78	0.00	0.00	1,800 gpm

Irrigation Source Name	Type	Nitrogen (mg/L)	Phosphorus (mg/L)	Potassium (mg/L)	Discharge Rate
Dairy Well Irrigation Well (IW) #2	Groundwater (well)	1.00	0.00	0.00	300 gpm
Fahey IW	Groundwater (well)	10.00	0.00	0.00	850 gpm
Fahey IW 2	Groundwater (well)	10.00	0.00	0.00	500 gpm
Freshwater Pond 2014	Groundwater (well) (canal, river)	5.06	0.00	0.00	2 cfs or 898 gpm

Source: Nutrient Management Plan, Waste Management Plan of the Dairy Farm (County of Merced 2018)

Figure 15 shows the existing location of the heifer ranch, the dairy facility, and the water system components of interest.

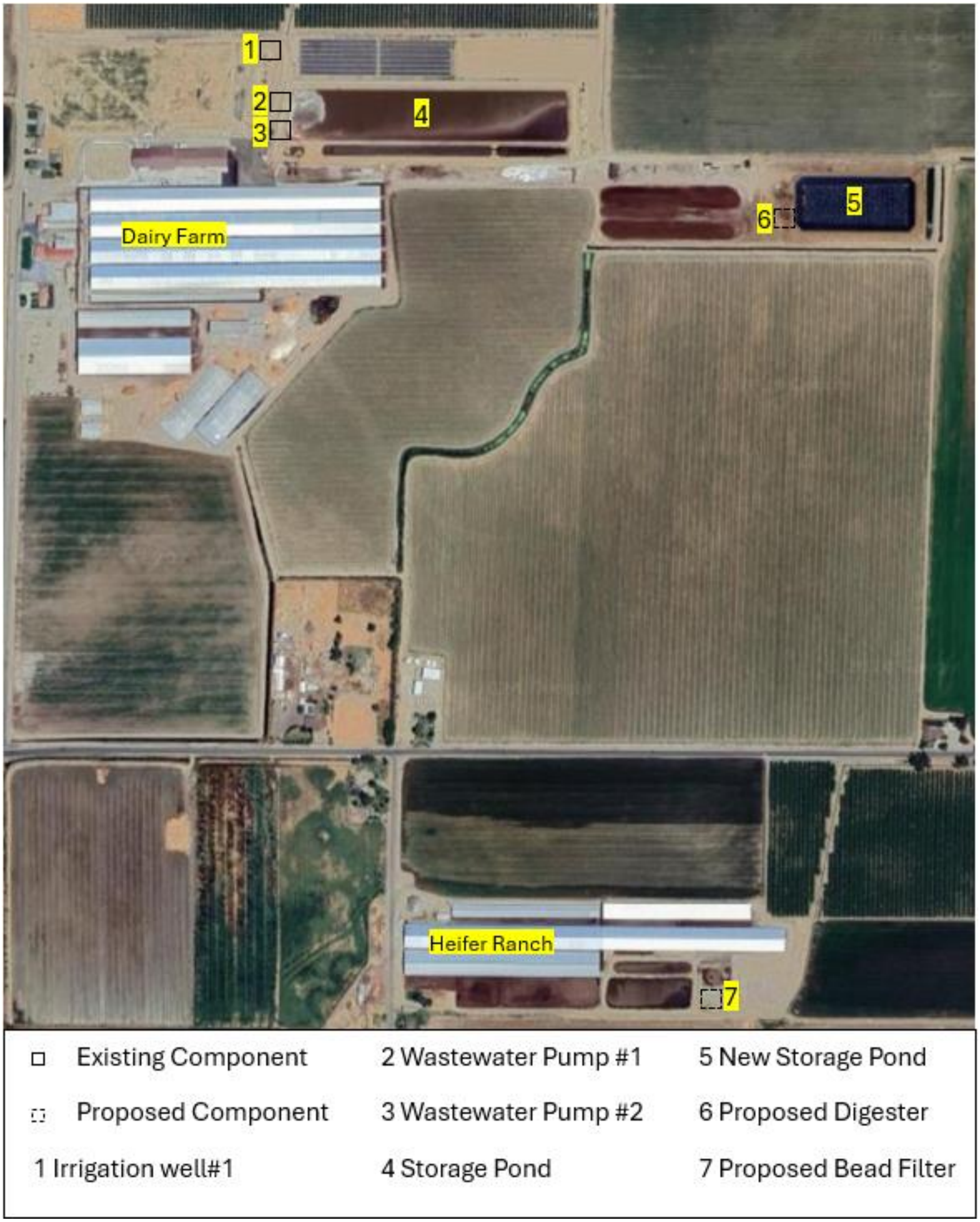

Figure 15: Project site map.

Source: Project Team

The customer participated in the California Department of Food and Agriculture's Alternative Manure Management Program and received a grant to install a 'Compost Bedded Pack Barn', a manure storage method via composting, in 2018. The estimated annual greenhouse gas emissions reduction is 547 $MTCO_2e$ (CDFA 2024).

Proposed Condition

The bead filter has a capacity of 300 gpm. The influent of 300 gpm flow to the filter will come from the 24,943 gallons of total process wastewater generated daily in the heifer ranch. The filtered water with reduced nutrients will be mixed with freshwater (Central California Irrigation District canal surface water, pond water or ground water) and used for crop irrigation during the irrigation season. The rest of the time the bead filter can be bypassed, and the recycled water can be stored in the storage pond for flushing. Figure 16 depicts the proposed wastewater components of interest. Figure 17 illustrates the proposed wastewater flow diagram starting from 'New Sand Lane' and ending at 'Low Nutrient Wastewater for Irrigation'.

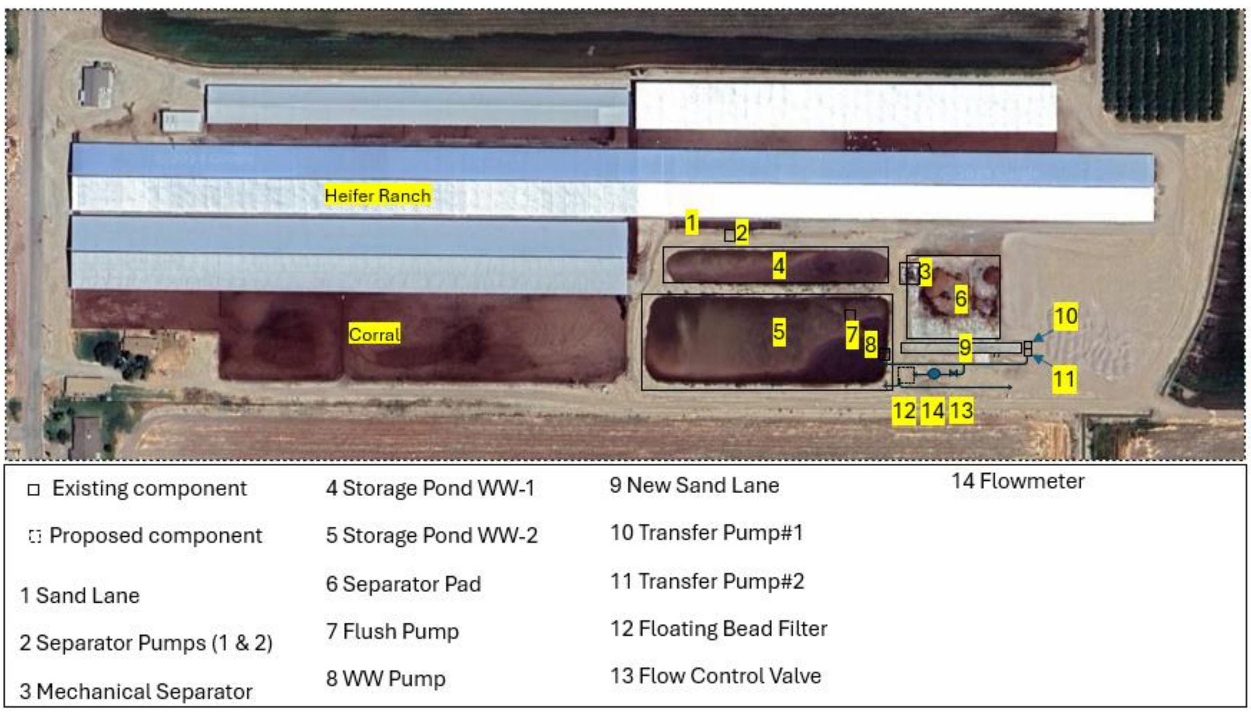

Figure 16: Project site map at proposed condition.

Source: Project Team

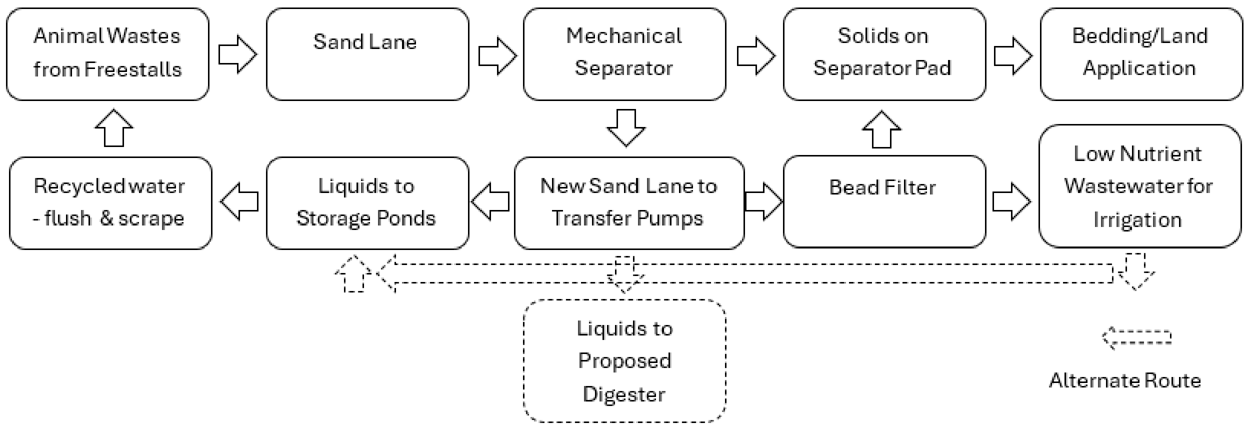

Figure 17: Proposed wastewater flow diagram of Heifer Ranch.

Source: Project team.

Host Site Review and Inspection

Site Selection

Initially, the project team searched for a dairy farm with 200 to 300 cows in the Central Valley region that would fit a 300-gpm bead filtration system since August 2023, but the search was not successful. After a series of searches, three prospective farm owners were selected for a full-scale (1500 gpm) deployment of the bead filtration system. None of the farm owners agreed to invest in the full-scale deployment of the emerging technology. In February 2024, the heifer ranch at Los Banos was selected as the project site for this project with a 300-gpm bead filtration system. The project team inspected the site with Southern California Edison representatives on April 10, 2024.

The host site, the heifer ranch, has one settling pond, two separator pumps, one mechanical separator, two sand lanes, two transfer pumps, one retention pond, one flush pump and one wastewater pump. During the initial site inspection, none of the equipment was selected for baseline monitoring, as their functionality did not relate to the project's goal. The installation contractor provided one groundwater pump and two wastewater pumps (WW#1 and WW#2) from the dairy facility to estimate the groundwater pumping power and wastewater pumping power for a typical condition. While interviewing, the installation contractor informed the project team that the pumps are operated manually during the irrigation season and according to the nutrient management needs. Different factors influence the groundwater and wastewater pumping needs, such as irrigation needs, nutrient needs, type of crops, seasonality, weather conditions, canal water availability, freeboard height of lagoon water, etc. The installation contractor also informed us that the mixing of the freshwater with the wastewater is visually monitored by the facility personnel dedicated to controlling the irrigation system. All pumps were equipped with high-quality magnetic flowmeters which record the amount of water used and are reported in the nutrient management and waste management reports to the county. Historical groundwater and wastewater flow data (if available) should be useful to normalize and annualize the field-logged data.

Electric Utility Data

The owner of the heifer ranch and the dairy farm has 1 MW of photovoltaic(PV) solar power generation located at the dairy farm site. The PV generation has virtual net energy metering (VNEM) connected with around 20 utility meters of the same owner. The interval data of the meter to which the groundwater pump is connected was collected. Due to the missing VNEM component, the utility data analysis could not be completed.

Test Plan

International Performance Measurement and Verification Protocol Option B (Retrofit Isolation: All Parameters Measurement) was used for the savings determination. Option B was selected because the technology is installed on the dairy farm as a side stream filtration with existing pond treatment system. The energy use of the filter affected by the technology can easily be separated from the energy use of the rest of the facility.

The parameters to be monitored included groundwater pump power, wastewater pump power, air compressor power, and influent flow to the filter. Baseline and post-installation data were collected using the equipment in the Table 3 below.

Table 3: Measurement and Verification Data Points and Logging Instrumentation Details

Data Point	Measurement	Instrument	Accuracy	Frequency	Period
Groundwater pump (Irrigation Well#1)	Power in kW, Runtime in minute	DENT power logger	+/- 1% of full scale	1 min average	Baseline
Lagoon Pump-1 (WW#1)	Power in kW, Runtime in minute	DENT power logger	+/- 1% of full scale	1 min average	Baseline
Lagoon Pump-2 (WW#2)	Power in kW, Runtime in minute	DENT power logger	+/- 1% of full scale	1 min average	Baseline
Groundwater pump (Irrigation Well#1)	Flow in gpm or AF	Seametric AG2000	+/- 1% of full scale	Initial and Final	Baseline
Lagoon Pump-1 (WW#1)	Flow in gpm or AF	McCROMETER DM10-1SMB	+/- 1% of full scale	Initial and Final	Baseline
Lagoon Pump-2 (WW#2)	Flow in gpm or AF	Seametrics AG2000	+/- 1% of full scale	Initial and Final	Baseline

Data Point	Measurement	Instrument	Accuracy	Frequency	Period
Air Compressor	Power in kW, Runtime in minute	DENT power logger	+/- 1% of full scale	Initial and Final	Post Install
Bead Filter	Flow in gpm	Seametrics iMAG4700	+/- 1% of full scale	Initial and Final	Post Install

Source: Project team.

During the baseline period, pump power and flow data were logged to create a pumping energy profile for the test site.

Monitoring Period and Troubleshooting

The baseline monitoring period started soon after the recruitment of the site and followed the schedule stated in Table 4. Initially HOBO state loggers were installed with the Seametrics and McCrometer flowmeters to log the flow of groundwater and wastewater measuring in terms of pulses. Due to some technical reasons, the pulse loggers were removed from the flowmeters later and the flowmeter start-and-end data were used in the calculations.

Table 4: Monitoring Period in 2024

Data Point	Measurement	Start	End
Groundwater pump (Irrigation Well #1)	Power in kW, Runtime in minute	May 1	September 4
Lagoon Pump-1 (WW#1)	Power in kW, Runtime in minute	May 30	June 27
Lagoon Pump-2 (WW#2)	Power in kW, Runtime in minute	May 30	September 4
Groundwater pump (Irrigation Well#1)	Flow in gpm or AF	May 30	July 19
Lagoon Pump-1 (WW#1)	Flow in gpm or AF	Jan 01	Nov 20
Lagoon Pump-2 (WW#2)	Flow in gpm or AF	May 30	July 19
Air Compressor	Power in kW, Runtime in minute	Nov 04	Nov 20

Data Point	Measurement	Start	End
Air Compressor	Power in kW, Runtime in minute	Nov 04	Nov 20
Bead Filter	Flow in gpm	Nov 04	Nov 20

Source: Project team.

Findings

Overview

The project team evaluated the system's performance monitoring baseline and post-installation data. The baseline and post-installation monitoring describe the system components, measurement and verification procedures, system flowmeters, and the system's power and flow logged results. Data analysis and calculations use the runtime results of the system's power and flow to find energy, demand, emission savings, and more.

Results

Baseline Monitoring:

The measured data was used to evaluate the systems' performance.

GROUNDWATER PUMPING (IRRIGATION WELL#1):

The groundwater pump (Irrigation Well#1) is a Fairbanks Morse turbine pump, driven by a 150-HP electric motor made by BMR Electric and controlled by a variable-frequency drive made by Fuji Electric. The pump has a Seametrics AG-2000 magnetic flowmeter installed on the common header and discharges to four directions namely 'Field', 'CCID', 'Lagoon', and 'Main'. There are butterfly valves on each branch line to direct the flow as needed. During the site visits only 'Main' valve was found in the open position and the rest were in the closed position. The logged data showed that the pump was manually operated for a limited period at different flowrates during the monitoring period of three months. It pumped around 50 acre-feet in three months and consumed an average 140 kWh/acre-foot. Figure 18 displays the site's groundwater pump. Figure 19 shows the project team's measurement and verification efforts with real power logging. Figure 20 illustrates the flowmeter at irrigation Well#1. Figure 21 demonstrates a three-month observation period of the groundwater pump power (kW) and flow (gpm) with some inactivity of the pump.

Figure 18: Irrigation well #1 groundwater pump.

Figure 19: Real power logging.

Figure 20: Irrigation well #1 flowmeter.

Source: Project Team

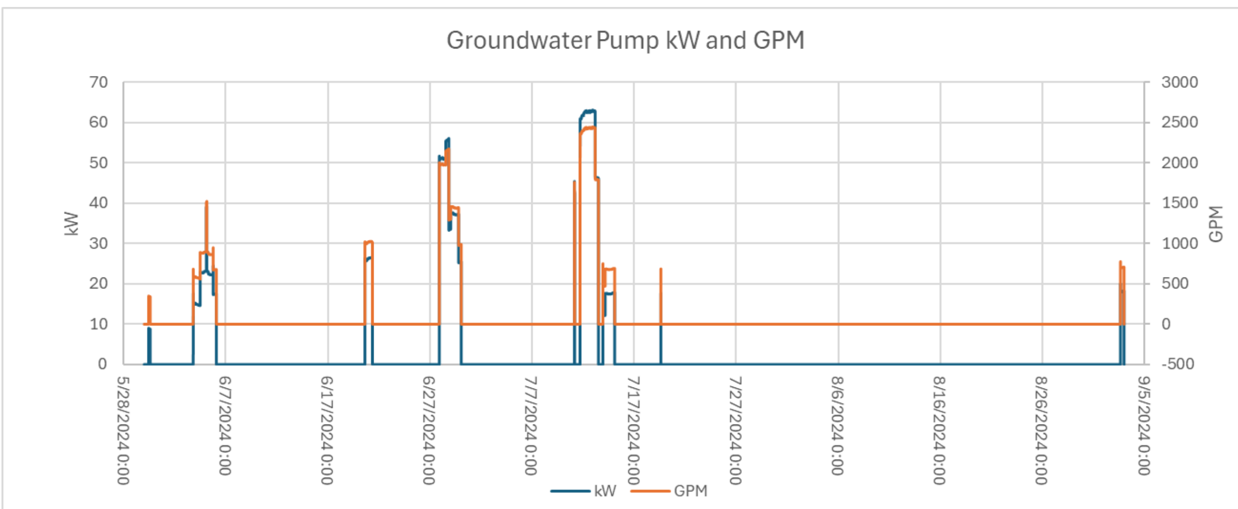

Figure 21: Groundwater pump power and flow.

Source: Project team.

WASTEWATER PUMPING (LAGOON PUMP-1 WW#1 AND LAGOON PUMP-2 WW#2):

The wastewater pump #1 (WW#1), shown in Figure 22, is a turbine pump driven by a 50-HP electric motor made by WEG Industries and controlled by a variable-frequency drive made by Frenic. The pump has a McCrometer Duramag DM-10-1SMB magnetic flowmeter, as shown in Figure 24, installed on the discharge line to the irrigation canal. The project team installed real power monitoring equipment on the pump as shown in Figure 23 but could not log useful data due to power issues and inaccessibility during the monitoring period. The project team downloaded 12-hour interval flow data for the last eleven months from the flowmeter, which was analyzed and used in this report.

The wastewater pump #2 (WW#2), shown in Figure 26, is a turbine pump driven by a 40-HP electric motor made by WEG Industries and controlled by a variable-frequency drive made by Frenic. The pump has a Seametrics AG-2000 magnetic flowmeter as shown in Figure 28 installed on the discharge line to the irrigation canal. The project team installed real power monitoring equipment on the pump as shown in Figure 27.

The pumps are in parallel, and site personnel manually operate and control flow, as per the irrigation requirement. Generally, the pumps run on duty-standby mode. During the site visit, either WW#1 or WW#2 was found in operation, or both pumps were in off position. The logged data supports that the pumps were manually operated for a limited period at different flowrates during the monitoring period of one to three months. Field data shows that the WW#1 pumped around 394 acre-feet in eleven months. The WW#2 pumped around 36 acre-feet in two months and consumed an average 37 kWh/acre-foot. Figure 25 and Figure 29 demonstrate a time series of WW#1's and WW#2's power (kW) and flow (gpm), correspondingly. The project team assumes that both pumps have similar overall energy consumption of 37 kWh/acre-foot.

Figure 22: Wastewater pump #1.

Figure 23: Real power logging.

Figure 24: Wastewater pump #1 flowmeter.

Source: Project Team

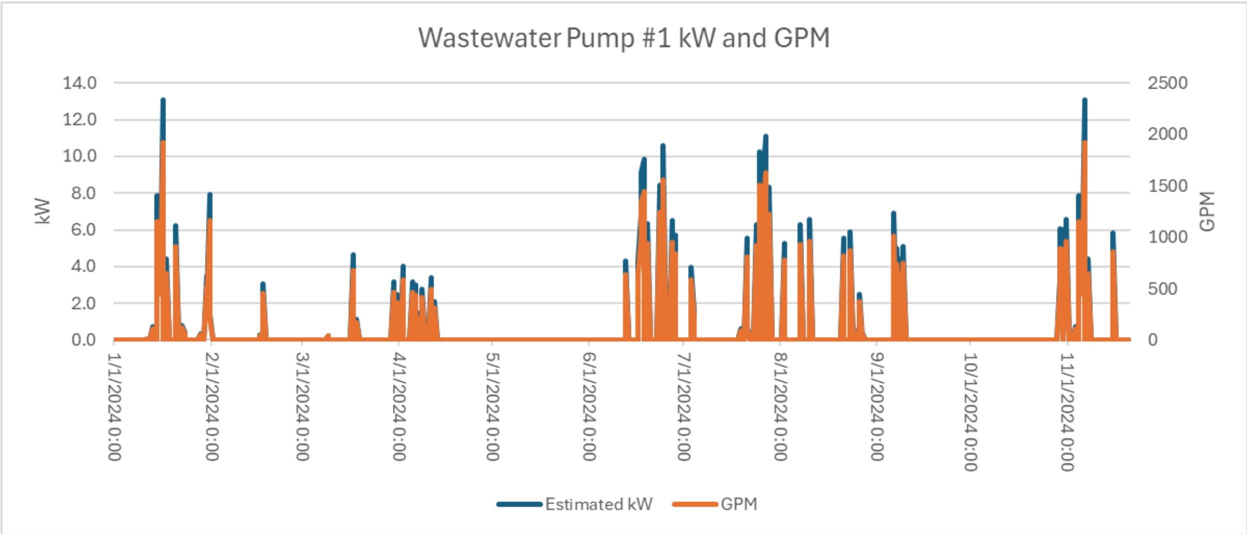

Figure 25: Wastewater pump #1 power and flow.

Source: Project team.

Figure 26: Wastewater pump #2.

Figure 27: Real power logging.

Figure 28: Wastewater pump #2 flowmeter.

Source: Project Team

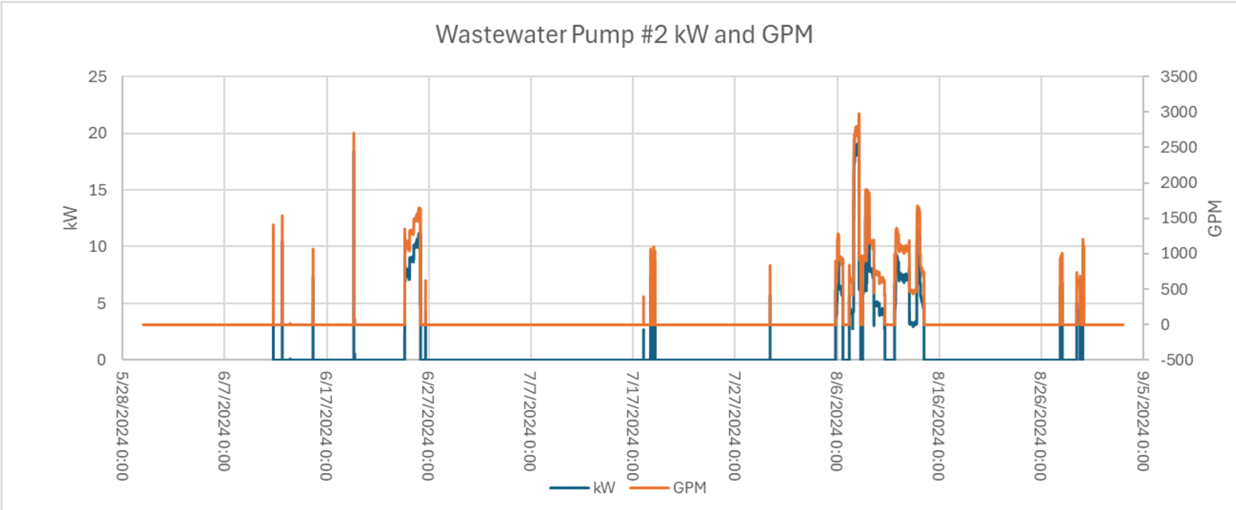

Figure 29: Wastewater pump #2 power and flow.

Source: Project Team

Post-Installation Monitoring

AIR COMPRESSOR:

The floating bead filter consumes roughly 2.5 cubic feet per minute (CFM) of air at 24 pounds per square inch, gauge (PSIG) to facilitate backwash. The air is being supplied via a branch line with a pressure reducer and a flowmeter from a 5-HP Mattei brand rotary vane air compressor operating at 100 PSIG to supply 21 CFM of air to the mechanical screen, which is the air compressor's primary load. The air compressor's power consumption for the floating bead filter is estimated to be 0.18 kW. Figure 30 shows the components of the air compressor and Figure 31 shows post-install real power monitoring. Figure 32 and Figure 33 display the pressure gauge for the filter and the filter flowmeter respectively. The logged real power data shows the compressor's power consumption and operational time. Figure 34 shows the run time and power consumption of the air compressor during the post-install period.

Figure 30: Air compressor.

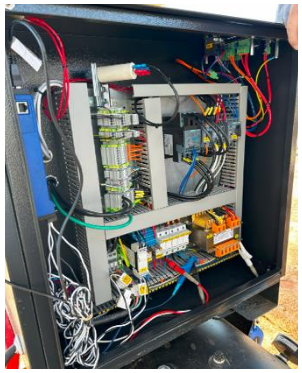

Figure 31: Real power logging.

Figure 32: Pressure gauge for filter.

Figure 33: Filter flowmeter.

Source: Project Team

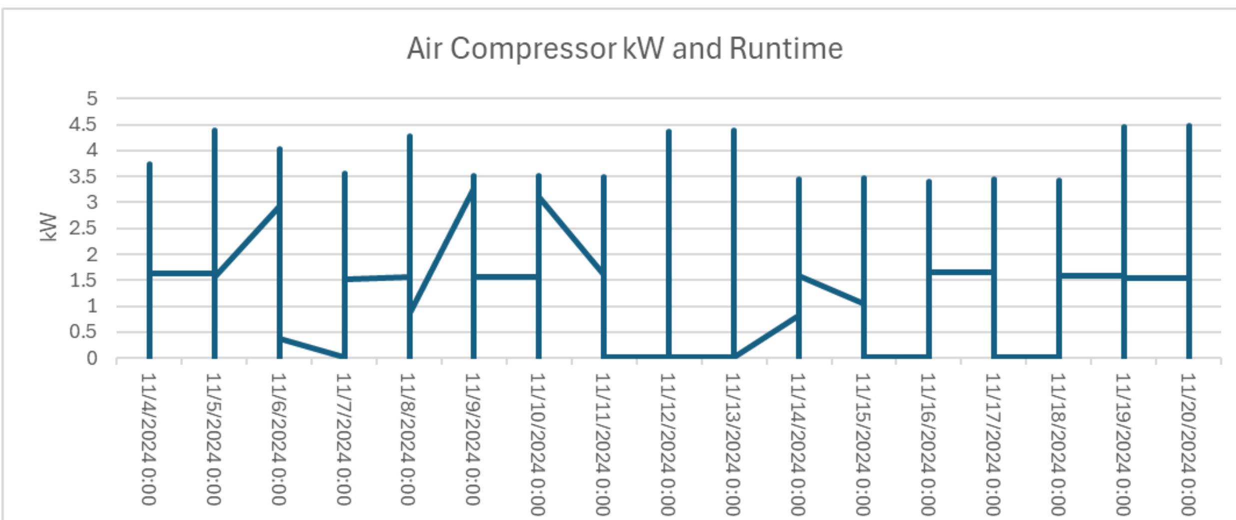

Figure 34: Air compressor power consumption.

Source: Project Team

TRANSFER PUMP:

Two submersible transfer pumps operated on a duty-standby mode to supply wastewater from the new sand lane sump to the WW-2 wastewater storage pond. 300 gpm of this flow was taken to the filter, and the rest of the flow went to the WW-2 wastewater storage pond. An ultrasonic level sensor installed in the pump triggered the pump's start and stop. The filter will work as long as the pumps run, until no more filtration is required. The logged data in Figure 35 shows that the transfer pumps consumed an average of 8.7 kW.

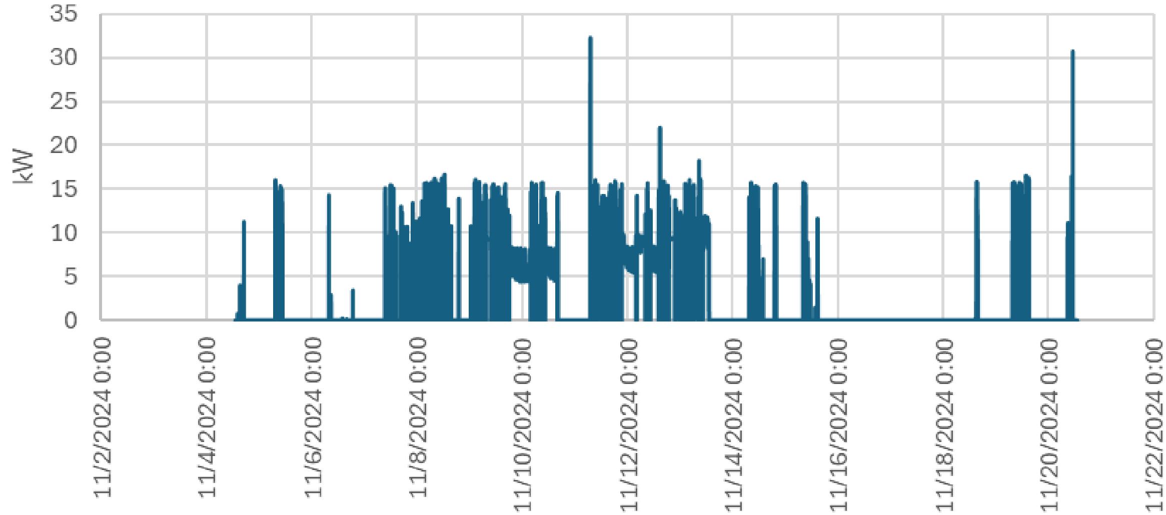

Figure 35: Transfer pump kW and runtime.

Source: Project team.

FLOATING BEAD FILTER:

Figure 36 and Figure 37 show the installed floating bead filter on the bank of the WW-2 storage pond of the heifer ranch. It has a rated flow capacity of 300 gpm. The technical specifications can be found in Appendix A.

Figure 36: Floating bead filter, front view.

Figure 37: Floating bead filter, rear view.

Source: Project team.

The filter has no electric power consumption. The filter has a Seametrics AG3000 magnetic flowmeter installed on the inlet to the filter to measure the influent flow. The logged data showed that the filter operated for around 11 hours and filtered around 191,000 gallons of wastewater during the monitoring period.

Data Analysis

An analysis of the data presented in the next sections includes the floating-bead filter runtime examination, total system energy use, electric demand, groundwater savings, and greenhouse gas emission savings.

Calculations:

The estimation of nutrients in manure and lagoon water and typical dilution rates of lagoon water for irrigation are based on the given references.

Table 5: Maximum Permitted Herd Size

Dry Cows	Bred Heifers (15-24 mo.)	Heifers (7-14 mo.)	Calves (4-6 mo.)	Calves (0-3 mo.)	Total Animals	Animal Units (AU)
471	1,262	354	882	532	3,501	2,125

Source: (County of Merced 2020)

AU = Animal Unit. An animal unit is 1,000 pounds of animal weight.

Manure contains important nutrients for plant growth, most notably nitrogen (N), phosphorus (P), and potassium (K). Due to variations in animal diet and manure handling and storage procedures, nutrient concentrations in both liquid and solid manure vary significantly between dairies and over time within the same dairy. The quantity of manure and nutrients in the manure excreted by an animal can be estimated using a procedure developed and published by the American Society of Biological and Agricultural Engineers (ASAE Standard D384.2, ASABE 2005).

American Society of Agricultural and Biological Engineers (ASABE) method: (County of Merced 2008)

Total manure produced: 2,531 cubic feet/day

Total manure produced: 41,351 lbs/day

Total nitrogen in manure: 854 lbs/day

Total Nitrogen to the pond: 598 lbs/day

The dairy lagoon water physical and chemical characteristics are referenced from the University of California's Cooperative Extension Manure Technical Bulletin (University of California Cooperative Extension Manure Technical Bulletin Series 2010) and shown in Figure 38.

Dairy Lagoon Water (Tables 5 and 6)

Table 5. Physical and chemical characteristics for lagoon water collected from same dairies as samples in Table 4 (Heinrich, 2009)

Dairy	9	3-2	10	11	12	8-2	13	Mean
pH	7.6	7.9	7.5	7.3	8.2	8.2	7.2	**7.7**
EC (mS/cm)	10.9	4.2	7.8	7.8	5.7	6.9	0.0	**6.2**
TS (g/L)	10.2	3.0	7.7	6.1	4.0	5.8	22.9	**8.5**
TSS (g/L)	3.4	0.8	2.8	1.6	0.7	2.2	21.1	**4.7**
TKN (mg N/L)	1010	320	770	730	410	630	810	**670**
NH_4-N (mg N/L)	600	200	440	480	270	360	170	**360**
Dissolved Org N (mg N/L)	150	20	120	90	60	120	50	**90**
TSS-N (mg N/L)	230	70	180	120	50	140	580	**200**
Total C (mg C/L)*	3580	1080	2660	2250	1200	1950	8430	**3020**
Dissolved Org C (mg C/L)	540	160	290	430	220	270	250	**310**
TSS-C (mg C/L)	1820	440	1340	900	390	950	7630	**1920**
Total C:TKN	3.5	3.4	3.5	3.1	2.9	3.1	10.4	**4.5**
Total C:Org N	8.8	9.1	8.2	9.1	8.9	7.0	13.1	**9.8**
TSS-C:TSS-N	8.0	6.0	7.3	7.5	7.1	6.7	13.2	**8.0**
TSS <28 µm and >0.3 µm (%)	87	98	82	94	100	98	43	**86**

*Total C = Total suspended solid C + dissolved organic C + dissolved inorganic C

Abbreviations in Table 6. TS=total solids, TSS=total suspended solids, TKN=total Kjeldahl N,

Figure 38: Physical and chemical characteristics for lagoon water.

Source: (University of California 2010)

The ratio of lagoon water to fresh water is dependent on the concentration of the target nutrient, usually nitrogen, in the undiluted lagoon water, the total amount of water being applied, and the desired application rate of the nutrient. Figure 39 shows the ratio of lagoon water to fresh water needed to supply a target nutrient application rate for an irrigation rate of three acre-inches/acre. The chart can be found for six and nine acre-inches/acre from the same source. It shows that the dilution rate of lagoon water by fresh water can vary from 1:1 to as high as 1:40.

Ratio of lagoon water to fresh water needed to supply a target nutrient application rate						
total water applied acre-inches/A	desired application rate (lbs/acre)	lagoon concentration in mg/L	lagoon concentration in lbs/ac inch	acre inches/A LW needed to supply rate	% lagoon water in blend	ratio lagoon to fresh water
3	50	200	45	1.1	37%	1:2
3	50	400	91	0.6	18%	1:4
3	50	600	136	0.4	12%	1:7
3	50	800	181	0.3	9%	1:10
3	50	1000	227	0.2	7%	1:13
3	100	200	45	2.2	73%	1:0.4
3	100	400	91	1.1	37%	1:2
3	100	600	136	0.7	24%	1:3
3	100	800	181	0.6	18%	1:4
3	100	1000	227	0.4	15%	1:6
3	200	200	45	4.4	-	-
3	200	400	91	2.2	73%	1:0.4
3	200	600	136	1.5	49%	1:1
3	200	800	181	1.1	37%	1:1.7
3	200	1000	227	0.9	29%	1:2.4
6	50	200	45	1.1	18%	1:4
6	50	400	91	0.6	9%	1:10
6	50	600	136	0.4	6%	1:15
6	50	800	181	0.3	5%	1:21
6	50	1000	227	0.2	4%	1:26
6	100	200	45	2.2	37%	1:2
6	100	400	91	1.1	18%	1:4
6	100	600	136	0.7	12%	1:7
6	100	800	181	0.6	9%	1:10
6	100	1000	227	0.4	7%	1:13
6	200	200	45	4.4	73%	1:0.4
6	200	400	91	2.2	37%	1:2
6	200	600	136	1.5	24%	1:3
6	200	800	181	1.1	18%	1:4
6	200	1000	227	0.9	15%	1:6
9	50	200	45	1.1	12%	1:7
9	50	400	91	0.6	6%	1:15
9	50	600	136	0.4	4%	1:23
9	50	800	181	0.3	3%	1:32
9	50	1000	227	0.2	2%	1:40
9	100	200	45	2.2	24%	1:3
9	100	400	91	1.1	12%	1:7
9	100	600	136	0.7	8%	1:11
9	100	800	181	0.6	6%	1:15
9	100	1000	227	0.4	5%	1:19
9	200	200	45	4.4	49%	1:1
9	200	400	91	2.2	24%	1:3
9	200	600	136	1.5	16%	1:5
9	200	800	181	1.1	12%	1:7
9	200	1000	227	0.9	10%	1:9
1 mg/L = 1 ppm = 0.2268 lbs/ac-in						

Figure 39: Ratio of lagoon water to fresh water.

Source: (Designing Dairy Liquid Manure Transfer Systems for Nutrient Management n.d

Alternatively, California Central Valley Dairy Waste and Nutrient Management has a ‘Liquid Nutrient Application Estimator’ tool, that can be used to find out the dilution rate (California Central Valley Dairy Waste and Nutrient Management).

To figure out the reduction of freshwater usage for dilution at a desired application rate, the project team used data from Figure 39 creating a trend profile for a three acre-inches/acre-irrigation rate with 50-, 100-, and 200-lb/acre nutrient application rates, as shown in Figure 40.

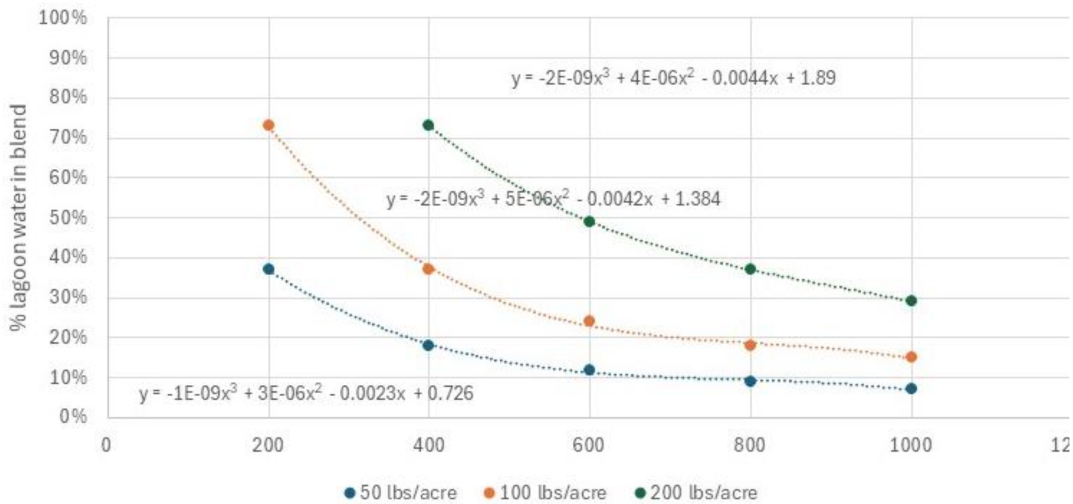

Figure 40: Lagoon water blend rate for three acre-inches/acre.

Source: Project team.

Figure 41 shows the typical blending of lagoon water to freshwater for a field irrigation of three acre-inches/acre and a nutrient application rate of 50 lbs/acre.

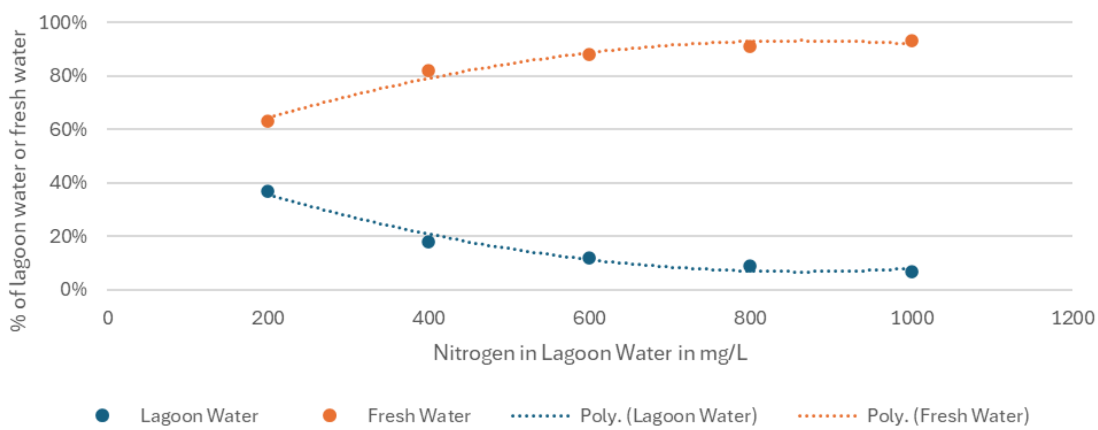

Figure 41: Blend rate for three acre-inches/acre and application rate of 50 lbs/acre.

Source: Project team.

The freshwater savings potential of the heifer ranch is shown in Figure 42. The filter has the potential to save freshwater ranging between 50,000 to 275,000 gallons per day for the heifer ranch.

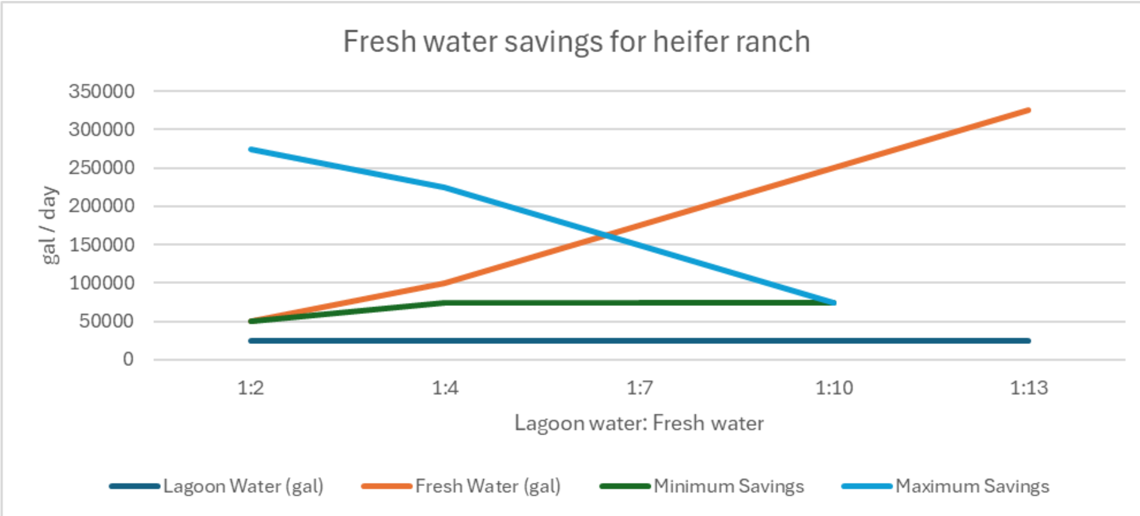

Figure 42: Freshwater savings potential of the heifer ranch.

Source: Project team.

The filter uses no electric power except 0.18 kW for compressed air for backwash, which can be estimated at 1619 kWh/yr. Groundwater pumping energy savings can be estimated using the groundwater pump's pumping energy of 141 kWh/acre-ft.

A minimum change in dilution rate would result in yearly net savings from 6,200 to 10,100 kWh.

A maximum change in dilution rate would result in yearly net savings from 21,900 to 41,500 kWh.

Savings

The floating bead filter can generate savings for a dairy farm in different setups. Central Valley dairy farms use five to 10 percent groundwater in a normal year, and 25 percent in a drought year except for a few dairies that use 100 percent groundwater to meet the demand for blue water. Savings depend on different scenarios:

DAIRY FARM WASTEWATER FLOW: To use the full flow, a bigger capacity of the filter is required at a high first cost. The savings on water, electric energy for pumping, and embedded greenhouse gases will also be higher.

TOTAL NITROGEN IN THE MANURE: Nitrogen content in dairy manure varies widely, as per Figure 38. Dairies with a high nitrogen content may need a larger filter to enhance nutrient removal, matching the irrigation need, and the nutrient application rate.

DILUTION RATE: Studies show that Central Valley dairies typically use a 1:5 to 1:10 dilution rate for wastewater to freshwater. Farms with a higher dilution rate will save more.

Savings are anticipated in terms of:

GROUNDWATER SAVINGS: Farms with a high use of groundwater can reduce the groundwater pumping for reduced total nitrogen in the wastewater. The site has the potential to reduce groundwater pumping between 56 to 308 acre-feet per year using the floating bead filter.

ELECTRIC ENERGY SAVINGS: Farms with high use of groundwater can save on the electric energy bill by reducing pumping. The site has the potential to reduce electric energy for groundwater pumping between 6.2 to 41.5 MWh per year using the floating bead filter.

ANTHROPOGENIC CO2 EMISSION REDUCTION: The facility uses most of the electricity from onsite solar photovoltaic generation and the rest from Pacific Gas and Electric. Pacific Gas and Electric has a greenhouse gas pollutant intensity factor of 203.983 lb CO_2/MWh. The site has the potential to reduce anthropogenic CO_2 emissions reduction between 0.57 to 3.84 metric tons per year using the floating bead filter. The California Emission Estimator Model (Caleemod 2022) is used for this estimation.

METHANE EMISSION REDUCTION: The sludge from the filter, which contains around 2% solids, directly reduces methane emission from the liquid manure treatment. The project site is located in California Climate Zone CZ-12 with an average temperature of 62°F with a range of 28°F to 108°F. The filter system has the potential to reduce 1.04 metric tons of methane or 28 metric tons of carbon dioxide equivalent greenhouse gas reduction (a 1.8-percent reduction from the baseline) assuming one percent of additional volatile solids removal. Capturing and Destroying Methane from Manure Management Systems (CARB n.d is used to estimate the greenhouse gas emission reduction.

Environmental Benefits

The treatment system will have several environmental benefits in addition to energy and water savings including nitrate reduction, and nutrient removal.

Nitrate Reduction

Current flood and drain practices require excess water to be added to completely flood the crop plot. As a result, only about 50 percent of this water is taken up by the plants. The rest either evaporates or leaches back into the water table. One of the constituents in the lagoon water is ammonia. After irrigating, nitrifying bacteria found in the soil convert the ammonia to nitrate. Given the fact that it takes a minimum of a 1:5 dilution with freshwater to reduce the nutrient concentrations in the lagoon water to tolerable levels, nitrates are being added through irrigation at a rate that is a minimum of two times higher than what the crops are capable of consuming. As a result, nitrates accumulate in the soil and can be transferred to the water table as the excess irrigation water leaches back. This has many underlying consequences. For example, nitrate concentrations in many domestic wells in Merced County exceed safe drinking water standards as they are known to cause reproductive issues such as methemoglobinemia, or 'blue baby disease'. In fact, Cropland is responsible for 96 percent of total nitrate contributions to groundwater, primarily from synthetic fertilizer (54 percent) and animal manure (33 percent).

By using a drip irrigation system, water usage efficiencies can be increased to over 90 percent. As a result, significantly less water is required to irrigate.

More precise dosing with a lower concentration of lagoon water will reduce the amount of excess nitrate being added to the crops, significantly decreasing the nitrates available to leach back into the water table. The volume of water used for drip irrigation is low enough that excess water is more likely to evaporate than it is to leach back into the water table, which will result in a considerable reduction in the amount of nitrate polluting subsurface water supplies.

Nutrient Removal

In addition to nitrate, phosphorus and potassium are currently found at elevated levels in the lagoon. Both are important components found in most fertilizers. If these nutrients somehow get into surface water sources, they can lead to algal blooms, which can have devastating consequences for local aquatic and plant life. Removing the solids from the water upfront prevents the sludge from breaking down and releasing these nutrients into the water.

Discussions and Conclusions

This field study has certain limitations and findings that need to be addressed. A summary of the findings is listed below:

- A small-scale project will not be an option for a dairy farmer to experience the benefit unless it is completely subsidized or incentivized.
- Dairy farmers typically have narrow profit margins, which leaves them less interested in investing in a project which does not have direct and perceived benefits.
- The emerging technology works independently for aquaculture system filtration. The emerging technology only works in a dairy farm if installed with a mechanical separator.
- The filter does not consume energy itself. But the influent needs pumping. The most energy-efficient way to install the filter is a gravity-fed arrangement.
- Though the backwash air requirement seems low, it needs an air compressor to be installed, powered, and automated.
- The backwash airflow requirement varies depending on the charge chamber volume of the filter and the frequency of backwash. The higher the total suspended solids in the wastewater, the more the solids to be removed and the more frequent the backwash. For a 300-GPM dairy wastewater flow with an average total suspended solids flow rate of 300 mg/L, backwash can be carried out between 30-minute to two-hour intervals.
- The rule of thumb for sludge removal rate is three minutes for every one hour of filter operation. Usually, sludge contains two percent of solids. The sludge volume lies between one twentieth to one tenth of the flow volume depending on the dairy wastewater constituents.
- The amount of sludge removed through the filtration process, though small, is an added step to removing nutrients which has added advantage to reducing unavoidable greenhouse gas emissions from the storage pond. The sludge from the filter needs to be conveyed to the dry sludge storage which is an additional step in the process.
- It is suggested to install the filter with gravity feed, avoiding the use of a transfer pump.

The following limitations were identified in this study:

- The project site was much bigger in comparison to the smaller scale of the ET. The project was initially scoped for a 200 to 300 cow dairy farm, but the actual farm used in this study is for 3,500. A full-flow study cannot be performed.
- The enormous size of the project site creates an issue of unavailability of information. For example, the business owner has a 1 MW solar PV generation VNEM connected with 20

utility meters. The site's peak demand reduction (if any) and energy savings on the grid could not be analyzed due to the lack of electric utility data and solar PV production data.

- The site has four groundwater pumps as mentioned in the Dairy Farm Nutrient Management Plan report. Only one can be located and logged for pumping energy and groundwater flow. Nutrient management plan report data are used for irrigation water usage.
- An annualization of the baseline and proposed system was targeted initially but due to the short time for pre- and post-install measurement and verification, the annualization is not deemed necessary.
- The field study was delayed primarily due to the lack of interest of a dairy owner to install this emerging technology on the farm. The project team struggled to find a suitable site and at last convinced the fourth candidate (dairy farmer) after trying for almost a year.
- The manufacturer and the installation contractor tried to deploy a cost-shared full-size deployment but could not find an interested dairy owner.
- The filter needs to be installed after a mechanical screen that removes usually 55 to 60 percent of solids from the dairy wastewater. The performance of the filter without a pre-screening has not been tested in this study.
- If a pump is required to feed the filter, the pumping energy will need to be considered.

Dairy farmers are facing new challenges to meet state and federal regulations. They need to maintain the nutrient management plan report and the waste discharge plan report yearly to avoid any violation and financial surcharges or penalties. Maintaining the nitrogen level and other constituents in the groundwater is becoming a challenge for them. The filter can act as a remedy for them. The cost of blue water is a burden to the dairy farmers. The filter has the potential to reduce the use of blue water from the canal or pumping from the ground aquifer. The California State Water Resources Control Board (CSWRCB) may fund a project to incentivize dairy farmers to install filters with mechanical separators.

Stakeholder Feedback

Feedback was gathered as part of this project on an ongoing basis. A couple of dairy farmers, agricultural equipment installation contractors, agricultural equipment suppliers, agronomists, and wastewater engineers were encountered. The technology is more predominant in the aquaculture filtration process, and it is a new entity for the agricultural sector. Dairy farmers from Kings County, Madera County, and Merced County were proposed as the project site. The dairy farmers showed interest initially but were found less interested in co-financing the project. As a result, emerging technology faces challenges without incentive. Agricultural equipment installation contractors and agronomists were familiar with and knowledgeable about this technology.

Recommendations

The California Department of Food and Agriculture updated the list of manure management practices incentivized through the Alternative Manure Management Program in October 2024, where 'advanced solid-liquid separation assisted by flocculants and/or bead filters' is added as an incentive-eligible solid separation technology. This practice must be implemented in conjunction with a primary mechanical separator.

The following next steps are recommended for the adoption of this emerging technology in other energy efficiency programs:

- Continue the California Department of Food and Agriculture’s Alternative Manure Management Program project.
- Incentivize relatively small dairy farms to adopt emerging technologies.
- Develop deemed and custom measures to incentivize dairy farmers installing a mechanical separator with a floating bead filter.
- Develop projects to incentivize dairy farmers using mechanical separator with floating bead filter who are found to be net exporters to the grid.
- Encourage a floating bead filter to treat the effluent from the dairy digester. The California Department of Food and Agriculture’s Dairy Digester Research and Development Program can incentivize the relatively smaller cost of a filter to increase energy savings and emission reductions.
- A full-scale deployment of the floating bead filter with real-time monitoring in a dairy farm set up is recommended to demonstrate the full potential of energy savings and emission reductions.

Additionally, the dairy currently uses a “flood and drain” method of irrigation on crops grown on the property. This method of irrigation requires an amount of water above what can be used by the crops. If drip irrigation is implemented, the total amount of water required for irrigation should be reduced significantly.

As described in this paper, onsite recycling and reuse wastewater technologies and systems have a significant potential to reduce both water, energy, and greenhouse gas emissions. The technologies identified in this study suggest that onsite recycling and reuse wastewater systems can immediately transfer into the current custom incentive programs. However, the current customized energy efficiency incentive programs’ cost effectiveness test must consider other benefits beyond energy efficiency for technology adoption to succeed. Therefore, there are some foundational activities that must occur before the technology can successfully migrate into the customized incentive programs.

Strategic and Intelligent Outreach and Education Partnerships

Many of the challenges related to moving forward with wastewater ideas is the level of customer knowledge. As on-site wastewater is relatively new, it is important to spend time educating potential customers on the benefits of adopting on-site wastewater. However, even though education is a major issue, the customers also need to be informed of the different funding opportunities that are available to them if they choose to adopt on-site wastewater technologies.

Promoting participation through programs such as Strategic and Intelligent Outreach and Education Partnerships could help. These custom incentive programs aim to maximize outreach efforts by educating decision makers and to facilitate market acceptance through existing relationships that have been established from a wide food processor contact base. This base includes food producers, processors, and integrators, where promoting the understanding and selling value proposition of the program can occur. Southern California Edison must strengthen this customer base to draw interest and increase awareness.

Eliminating Market Barriers

Therefore, Southern California Edison must focus its attention on reducing and eliminating market barriers by:

- leveraging data analytics,
- understanding the specific criteria in targeting the right candidate customer, and,
- accounting for their respective drivers, including production, competitiveness and compliance with various regulations and understanding the economics and associated financing strategies.

By doing so, California investor-owned utilities (IOU) can tailor its incentives and technical support to encourage this customer segment in adopting onsite recycling and reusing wastewater systems, by developing new customer-focused and innovative models and concepts and help serve its customers' energy and water need and support their desire to participate in a clean energy future.

Providing Technical Assistance and Tools

Additionally, Southern California Edison should focus on providing applicable technical assistance and tools that support the adoption of onsite recycling and reuse wastewater solutions. Investor-owned utilities are currently refocusing their goals to consider greenhouse gas emissions reduction benefits as part of a holistic cost-benefit analysis, and in response, to encourage the implementation of energy efficiency and flexible demand response-capable technologies and systems that also have the capability to provide onsite generation and for certain applications.

The deployment of onsite water recycling and reuse systems will achieve a more comprehensive approach in supporting California's vision of a 100 percent renewable and decarbonized clean energy future. California investor-owned utilities could gain significant traction with its customers by customizing technical assistance and tools to each customer segment's unique needs by exploring behavioral energy savings. In practical terms, this could be done by collecting, quantifying, and translating 1) smart interval metered data, 2) benchmarking data, and 3) dynamic pricing data into relatable valuation terms that are relatable to key decision makers.

Leveraging All Applicable Financial Solution Resources

The main barriers and struggles experienced with the California Central Valley dairy community engaged for this project centered on the cost of the onsite wastewater recycling system. The cost for these onsite wastewater recycling systems can push towards half a million dollars or more. By introducing on-site wastewater technologies, it can help replace conventional primary solutions such as dissolved air flotation (DAF), as well as traditional aerobic and anaerobic treatment systems. Most importantly, these new wastewater systems can help eliminate the use of dairy lagoons, which are a driving factor for greenhouse gas emissions. Furthermore, for dairies using a lagoon-based manure management strategy, the best practice recommendation centers on installing a liquid separator, followed by filtration units in combination with adding a dewatering process to treat the sludge produced by the unit.

However, in order to alleviate this significant financial barrier, California investor-owned utilities need to find creative ways to assist its customers by leveraging all applicable financial solution resources, including 1) traditional custom energy efficiency incentives and rebates, 2) integrated demand side management or non-resource utility funding, 3) utility on-bill financing or on-bill repayment 4) other utility or grant funding mechanisms or 5) demand response time-of-use rates and dynamic pricing (where applicable).

Additionally, to significantly reduce greenhouse gas emissions and nutrient concentrations and achieve more energy and water savings, an onsite wastewater recycling system used in conjunction with sprinkler or drip irrigation system would achieve more benefits that could reduce the short-term payback period requirements for customers. By doing so, it has the potential for significantly reduce energy and water consumption while addressing a lot of the new environmental regulatory pressures dairies are facing. The concentrated slurry produced by the units can be dewatered and sold as fertilizer offering dairies a new potential revenue stream. The units are designed to operate with very little oversight so there should not be a significant increase in labor costs.

Additional Best Practice Recommendations for Dairy Farm Customers

The new onsite wastewater recycling and reuse system must have the following attributes:

- Be installed at an existing agricultural dairy farm within California investor-owned utility service territory.
- Be used in conjunction with existing liquid fiber or where appropriate dry scraping mechanical separator system.
- Reduce nitrogen levels to comply with the Central Valley Salinity Alternatives for Long-Term Sustainability (CV-SALTS) program's nitrate water quality objectives. The existing nitrate water quality objective for the protection of drinking water supplies in the Central Valley is 10 mg/L (nitrate measured as nitrogen).
- Thicken slurry material and reduce digestor size from three to eight percent within a 21-day period if system is connected to a digestor.
- Reduce organic levels minimizing methane generation and greenhouse gas emissions.
- Mechanically remove and concentrate fine suspended solids forming a concentrated slurry with a minimum total suspended solids concentration of 1.5 percent.
- Reduce reject water volumes due to high efficiency pneumatic backwash (if system employs backwash as part of operation).
- Consistently reduce total suspended solids concentration by a minimum of 50 percent.
- Reduce nutrient concentrations of effluent.

Appendix A: Technical Specification of the Filter

Characteristics	Values
Bead volume (ft^3)	200
Flow (gpm)	300
Denitrification flow (gpm)	25
Peak Hull Pressure	<20
Oxygen Delivery (kg/day)	54
Bead SA (m^2)	6,520
Nitrification Ammonia @0.5 ppm (kg/day)	5.1
Nitrification Ammonia > 2 ppm (kg/day)	10.2
Denitrification (kg/day)	5.66
Length (ft)	10
Width (ft)	10
Height (ft)	11.5
Bead Weight/Hull Weight/Operating Weight (lb)	5,500/12,200/49,000

Source: Manufacturer.

Appendix B: Different Installation Methods

The filter was initially intended to be placed directly downstream from the inclined separator. Water from the separator would run through the filter, removing residual fine particulate still present in the waste stream. The effluent coming off the filter would feed back to the main transfer line feeding the anaerobic digester. Concentrated sludge would also periodically be transferred to the anaerobic digester via the same main transfer line.

Pros

- A floating bead filter removes solids from the liquid manure or slurry before it goes to the storage pond. This practice results in reduced manure in liquid storage, leading to reduced methane emissions. The portion of manure that is moved from liquid storage to solid storage produces fewer methane emissions because solid storage is not as anaerobic as liquid storage.
- Anaerobic digestion is the best way to capture methane from manure. Facilities without anaerobic digesters will be able to reduce methane emissions using floating bead filtration. The collection of predigested solids will indicate the value the sludge can offer as a supplemental fertilizer source for crops.

Cons

- Creates small liability issues with digester energy production posing a potential risk of lowering revenues if the facility has an anaerobic digester.
- The addition of digesters is becoming increasingly popular for dairy owners in the region. As a result, there will be fewer facilities where the benefits of the technology applied in this way will be relevant.
- Concentrated sludge coming directly off the separator cannot be assessed for its potential value as a direct feedstock to anaerobic digesters.
- All outputs from the treatment will be returned to the main transfer line; any local effects on the facility can only be assessed through sampling and lab data. No changes to the facility's water quality can be studied.

Outcomes from placing the filter downstream from the anaerobic digester are also assessed. Typically, water discharging from the anaerobic digester feeds a lift station where it is transferred to the wastewater retention pond.

A slipstream from the pump will feed the filter inlet. Effluent from the filter will be returned to the main transfer line feeding the wastewater retention pond. The unit will be in place to remove residual solids still present after anaerobic digestion. Captured sludge can either be pumped to the transfer pond or returned to the anaerobic digester as a recovered concentrated feedstock.

Pros

- The digester's performance is unaffected.
- As digesters become more prevalent, placement of the filter technology after the anaerobic digester is becoming increasingly applicable to facilities in the region.
- Based on datasets provided by digester companies in the region, the digestion of volatile solids is nowhere near complete. As a result, the fundamental problems resulting from solids

being transferred to the retention ponds still exist. Moving the unit to this location allows assessment of the filter's capabilities to reduce effects caused by the underlying problems the technology originally aimed to resolve, while also demonstrating potential ancillary benefits for the digester. Data can be collected on the potential value of reintroducing partially digested solids back into the digester in a concentrated form, and how this might improve the overall digester efficiency in terms of energy capture and greenhouse gas emission reductions.

Cons

- Treating water post-digestion does not allow any data to be collected on the potential use of sludge generated from solids removal coming directly off the separator.
- The technology has the potential to produce a concentrated form of the feedstock currently being used. If the concentrate can be fed to the digester directly, there is a potential to reduce the amount of water transferred to and from the digester, which could be another area of energy savings.

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