# CULTIVATING CLIMATE-SMART DAIRY

## A supplier engagement guide to manure management technologies

Environmental Defense Fund

THE CLIMATE SOURCE

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The complete report is available online at business.edf.org/manure-management-report

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# INTRODUCTION

As the need to tackle climate and environmental impacts of animal agriculture becomes clearer, public and private actors are promoting positive incentives, such as cost-share programs and revenue opportunities, for farmers to transition to climate-smart agriculture practices. The dairy sector in particular has an opportunity, given its meaningful footprint of methane emissions, a potent greenhouse gas (GHG), as well as the industry's demonstrated willingness to drive change. Methane from dairy comes from predominantly two sources – enteric fermentation and manure management. On dairy farms in the U.S., manure management practices lead to nearly 25% of dairy milk supply chain emissions. Thus, governments and corporations are supporting programs focused on manure management systems. For food and agriculture companies engaging with farmers, these programs represent an opportunity for collaborative investment in on-farm infrastructure, strengthen their financial resilience, and improve farm sustainability.

Since a variety of manure management systems are available, it can be difficult for farmers to navigate various manure management programs. To simplify this process, we have created the following actionable guide that covers:

- How to get started with manure management incentive programs
- What management systems exist today and how they fit different operations

This guide is meant for food and agriculture companies to share with their suppliers and support them in making the transition by creating awareness about relevant solutions and potential ways to fund them.

# TYPES OF INCENTIVES AVAILABLE FOR MANURE MANAGEMENT SYSTEMS

TABLE 1.

| | PUBLIC-FUNDED CONSERVATION PROGRAMS | RESEARCH GRANTS | MARKET-BASED INCENTIVES | SUPPLY CHAIN PROGRAMS |
|---|---|---|---|---|
| Description | Federal and state level grants, cost-share, and lending programs | Public and private grants for trial of novel practices and technologies | Credits and commodity premiums for environmental practices | Custom programs designed around corporate marketing and ESG goals |
| Focus audience | Individual farms | Suppliers and larger farms | Individual farms and suppliers | Suppliers and larger farms |
| Key notes | • Key federal programs include the Environmental Quality Initiatives Program (EQIP) and Regional Conservation Partnership Program (RCPP)<br>• Funding applications are ranked according to regional environmental priorities | • Key federal program is the Conservation Innovation Grant (CIG)<br>• Supply chain actors may fund trials on a case by case basis<br>• Participation often requires partnership with a research institution | • Programs include compliance carbon credits (e.g., California's Low Carbon Fuel Standard), voluntary carbon credits, and supply chain inset programs<br>• Supply chain programs vary, including preferred market access, pay-for-practices, and commodity premium structures | • Programs often designed on a case by case basis, based on regional environmental priorities |

## Why public and private investment in novel manure management systems is increasing

Manure has always been a part of the farm ecosystem, serving as a natural fertilizer in the nutrient cycle. As animal agriculture has become increasingly concentrated, farm operations have started to produce larger, more concentrated volumes of manure. Thus, over time, manure management strategies for effective utilization of manure's nutrients have shifted from decentralized to more concentrated treatment methods where cost-effectiveness plays a larger role.

While government policy on manure management has evolved as livestock operations have become more concentrated, often using permitting, cost share and incentive programs to prevent and mitigate the air and water pollution impacts of manure management, increasingly, private actors are also creating positive incentives for certain manure management systems, which they view as a valuable path to reduce their supply chain GHG footprints. Governments have signed on to international agreements, such as the Global Methane Pledge, to reduce their national GHG emissions.  In the private sector, regulatory, investor, and consumer pressures are driving companies to make their own voluntary GHG reduction commitments. Many of these GHG commitments include 2030 reduction goals, and as public and private actors chart their way towards the 2030 deadline, financial incentives available for manure management practices that lead to GHG reductions are expected to grow.

[1] Thoma, Greg, et al. "Greenhouse gas emissions from milk production and consumption in the United States: A cradle-to-grave life cycle assessment circa 2008." International Dairy Journal 31 (2013): S3-S14.

[2] The Global Methane Pledge, signed by over 100 countries in 2021, commits countries to reduce anthropogenic methane emissions 30% by 2030.

# WHAT MANURE MANAGEMENT SYSTEMS EXIST TODAY AND HOW THEY FIT DIFFERENT OPERATIONS

Given that manure management involves all components of farm management– from infrastructure to operations to financials– adopting new manure management practices is a major undertaking. Factors such as size, existing on-farm infrastructure, community infrastructure, and geography will impact what management system is optimal for a given farm. Herd size is often the most significant determinant of what system to adopt, since it drives farm finances, spatial constraints, and the volume of manure that needs to be managed. Geographic factors such as temperature and precipitation will impact the operations of different systems. And finally, funding, offtake opportunities, and equipment options will depend on local availability. In addition to the factors mentioned above, two key considerations should be made when evaluating manure management technologies.

## Local pollution concerns:

Proximity of local communities needs to be considered when discussing manure management. Air pollutants of concern that can be emitted from manure include ammonia, which can cause fine particulate matter leading to increased risk of respiratory and pulmonary issues. Ammonia can and should be managed with additional treatment steps. While new manure management technologies are an important tool to address methane emissions, we need thoughtful consideration of frontline communities to protect them from air pollution burdens.

## Trade-offs and combining synergies:

Implementing various manure management technologies involves navigating trade-offs to find the most effective and sustainable solutions. As highlighted in this report, different technologies come with their own set of benefits and challenges. For instance, while anaerobic digestion can generate biogas for energy, it may require significant infrastructure and energy inputs. Composting is a low-cost option but may pose challenges with nutrient run-off. By recognizing these trade-offs, there are opportunities to explore the synergies of combining multiple technologies. For example, by integrating anaerobic digestion with enhanced nutrient recovery systems from the digestate, it becomes possible to maximize energy generation while retaining valuable nutrients for fertilization. This approach underscores the importance of a holistic and adaptable strategy that considers the unique circumstances of each agricultural setting, aiming for a balance that optimizes environmental sustainability, economic viability, and operational efficiency.

While adoption of new manure management technology involves upfront investments and operational changes, some early adopters of alternative practices have developed economical systems that remove some uncertainty from the financial business case. [Annex: Figure 2] depicts three typical manure management systems. Overall, a variety of manure management practices are available. A summary of established and select emerging technologies can be found below in Table 2:

[3] Farm sizes defined as: small: <300 head dairies; medium: 300-999 head dairies; large: 1000-9,999 head dairies; very large: 10,000+ head dairies.

[4] Environmental and social impacts relative to traditional open air anaerobic lagoon management

[5] Wan, Song, et al. “Long-term manure amendment reduces nitrous oxide emissions through decreasing the abundance ratio of AMOA and NOSZ genes in an Ultisol.” Applied Soil Ecology, vol. 184, Apr. 2023, p. 104771, https://doi.org/10.1016/j.apsoil.2022.104771.

[6] Jokela, Bill, er al. “Manure Application Method and Timing Effects on Emission of Ammonia and Nitrous Oxide.” Livestock and Poultry Environmental Learning Community, 5 Aug. 2020, lpelc.org/manure-application-method-and-timing-effects-on-emission-of-ammonia-and-nitrous-oxide/.

# SOLUTIONS APPLICABLE FOR FARMS OF ALL SIZES

TABLE 2.

| TECH OR PRACTICE | FARM SIZE[3] | ECONOMICS | OPERATIONAL CONSIDERATIONS | ENVIRONMENTAL & SOCIAL IMPACTS[4] | FUNDING AVAILABILITY[5,6] |
|---|---|---|---|---|---|
| Advanced field application (soil incorporation and injection) | S Well-suited<br>M Well-suited<br>L Well-suited<br>XL Well-suited | **Upfront costs:** Low to high, depending on equipment<br>**Maintenance:** Medium<br>**Revenue:** None<br>**Savings:** Medium | • Requires application timing and rate planning<br>• Likely needs third-party agronomic support<br>• Regional factors (seasonality, precipitation) impact practice | Potential odor, ammonia, and nutrient runoff reductions if managed well | Conservation Practice Code 590<br>**(EQIP eligible)** |
| Solid-liquid separation | S Well-suited<br>M Well-suited<br>L Well-suited<br>XL Well-suited | **Upfront costs:** Medium<br>**Maintenance:** Medium<br>**Revenue:** Potential to further process separated liquids and solids<br>**Savings:** High | • Technical service often provided by manufacturer<br>• Variety of operational set-ups | Methane reductions<br>Solids and liquids have different chemical fertilizer properties | Conservation Practice Code 632<br>**(not EQIP eligible)**<br>State funding available in California |
| Bedded pack composting | S Well-suited<br>M Well-suited<br>L Feasible for a subset of the farm<br>XL Feasible for a subset of the farm | **Upfront costs:** Medium<br>**Maintenance:** Medium<br>**Revenue:** Low<br>**Savings:** High | • Self-planned or supported by advisor<br>• High per-animal space requirements in barns<br>• Requires availability of carbon-rich bedding | Methane reductions if well managed<br>Health and welfare benefits<br>When field-applied:<br>Improves fertilizer composition<br>Reduces fertilizer runoff impact | Conservation Practice Code 317<br>**(EQIP eligible)**<br>State funding available in California |
| Cap and flare | S Feasible<br>M Well-suited<br>L Well-suited<br>XL Well-suited | **Upfront costs:** Medium to High depending on existing infrastructure | • Use of existing lagoon storage if the shape and size is suitable furthers costs savings.<br>• Likely needs third-party support for installation of gas tight cover<br>• Potential to produce electricity and/or heat to use on farm use if operation is located south of the 40th parallel | Reduced methane emissions<br>Diverts rainwater, preserves freeboard | Conservation Practice Code 366 and 367<br>State funding available in New York |

## Advanced field application

Advanced field application methods include soil incorporation and direct injection (Table 2). Direct injection uses a knife or disk to create a vertical slot in the soil in which the manure is deposited and is currently limited to liquid manure fractions. Incorporation can be accomplished with liquid or solid manure and involves mixing surface-applied manure into the soil profile using some form of tillage implement. This technique is not compatible with growing crops, permanent pastures or hayfields, or no-till cropping systems. Both soil incorporation and direct injection may reduce nutrient runoff and ammonia emissions, though they may increase nitrous oxide emissions. The evidence on manure application enhancement of nitrous oxide emissions is mixed and enhancements seems to be related to soil water saturation as well as the nitrogen balance between nitrogen application rates and N harvested in crops. Implementation windows for both methods are limited, and application involves equipment and labor requirements. Therefore, farms may opt to hire third-parties if they are interested in more advanced spreading practices. Localized circumstances (e.g., seasonality, weather) impact the optimal timing and rate of application.

## Solid-liquid separation

Solid-liquid separation is a flexible add-on technology whereby manure is separated into solids and liquids, which has operational and environmental benefits and makes manure easier to process into valuable byproducts (Table 2). This solution requires increased storage area; however, appropriate separation equipment is available for farms of all sizes. Technologies that remove a higher proportion of fine solids are more expensive.

## Bedded pack composting

Bedded pack composting refers to the process of composting manure directly inside barns with a carbon-rich material such as sawdust and agricultural residues (Table 2). The compost serves as bedding for animals and provides a source of heat during the winter. It does not require complex equipment but does require frequent overturning and dry bedding additions. High per-animal space requirements in the barn make this process easier for smaller farms, though larger farms may consider adopting the practice for a subset of their animals. It can be difficult and expensive to secure continuous access to bedding material. Adoption of this practice is highest in areas with cold winters and abundant sources of carbon-rich waste. Once removed from the barn and cured, compost can be sold as a high-value fertilizer.

[7] Atiyeh, Dennis, et al. "Liquid Manure Injection - Agronomy Fact Sheet Series- Fact Sheet 87." Nutrient Management Spear Program, Cornell University Cooperative Extension, 2015, http://nmsp.cals.cornell.edu/publications/factsheets/factsheet87.pdf.

[8] Endres, Marcia, and Kevin Janni. "Compost-Bedded Pack Barns for Dairy Cows." Extension at the University of Minnesota, University of Minnesota, 2021, https://extension.umn.edu/dairy-milking-cows/compost-bedded-pack-barns-dairy-cows#barn-728460.

[9] Natural Resources Conservation Service CONSERVATION PRACTICE STANDARD ANAEROBIC DIGESTER CODE 366 https://www.nrcs.usda.gov/sites/default/files/2023-08/366_NHCP_CPS_Anaerobic_Digester_2023.pdf

## Cap and flare anaerobic digesters

Covered-lagoon digesters utilize an in-ground lagoon and the installation of a flexible impermeable cover to capture biogas emissions. Typically, farms use a large inflated high-density polyethylene cover. These digesters are not heated, but rather operate at the ambient temperature of the local climate and are much less energy intensive than other types of digesters but sacrifice some efficiency and biogas production due to slowed biological activity within the lagoons during colder temperatures.

These projects tend to have lower capital costs since they typically utilize less equipment and materials, compared to other types of digester technology. The use of existing lagoon storage for the digester if the shape and size is suitable furthers cost savings. Covered lagoon digesters are often seen in more temperate climates. The NRCS Conservation Practice Standard 366 advises that covered lagoon projects are generally suitable in area located below the 40th parallel for system that can generate energy. Covered lagoons north of the 40th parallel could only expect to flare the biogas.

A covered lagoon digester allows for the breakdown of unpleasant odors underneath the cover. The cover also diverts rainwater, reducing the volume of manure which must be managed. The covered lagoon digester, like all digesters, does not reduce the amount of nitrogen and phosphorous in the manure stream requiring sufficient cropland or other uses.

# SOLUTIONS APPLICABLE TO SMALL AND MEDIUM SIZED FARMS

TABLE 3.

| TECH OR PRACTICE | FARM SIZE | ECONOMICS | OPERATIONAL CONSIDERATIONS | ENVIRONMENTAL & SOCIAL IMPACTS | PUBLIC FUNDING AVAILABLE |
|---|---|---|---|---|---|
| Thermophilic composting | S Well-suited<br>M Well-suited<br>L Feasible for a subset of manure on farm<br>XL Feasible for a subset of manure on farm | **Upfront costs:** Low<br>**Maintenance:** Low<br>**Revenue:** Low<br>**Savings:** None | • Self-planned or supported by advisor<br>• Some spatial requirements<br>• Variety of operational set-ups | Significant methane reductions if well managed<br>When field-applied:<br>Improves soil health by stabilizing and slowly releasing nutrients<br>Reduces nutrient runoff | Conservation Practice Code 317 **(EQIP eligible)**<br>State funding available in California |
| Pasture-based grazing | S Well-suited<br>M Feasible<br>L Difficult<br>XL Difficult | **Upfront costs:** Low<br>**Maintenance:** Low<br>**Revenue:** Mixed<br>**Savings:** High | • Self-planned or supported by advisor<br>• Significant land requirements<br>• Simplified farm management practices | Significant methane reductions<br>Systems allow for forage diversity<br>Animal health benefits | Conservation Practice Code 528 **(EQIP eligible)**<br>State funding available in California |

## Thermophilic composting

Thermophilic composting refers to aerobic degradation of organic matter in piles in open air, in fields, on concrete pads, or indoors where the compost internal temperature is maintained at 1450 degrees Fahrenheit to adequately kill weed seeds. Space constraints make this process easier to manage for small and mid-size farms, though there are examples of successful composting by large farms. The larger a farm, the more difficult it is to manage a composting operation because larger quantities of manure necessitate more space, solids, time, and specialized equipment. Monitoring the compost moisture content can be cumbersome for larger farms and possibly require more equipment and resources for turning or watering. Dairies with solid separators will have the easiest time commencing a composting operation while dairies without will also need to add other organic dry matters.

Management strategies vary by region, and local water quality permits may be required. Capital and operating costs vary by system type and farm size. Farms also need to find applications for the finished product. Smaller farms will more easily be able to create a closed loop system where they are using the product on their own fields. Closed loop systems are possible for larger farms although the logistics of storing and spreading the compost will be more

## Pasture-based farming

In pasture-based systems, animals deposit manure directly onto fields. Given high per-animal land requirements, small to medium farming operations are best suited for pasture-based systems. Systems have lower infrastructure needs and reduce the need to grow row crops, and therefore have low management costs. Additionally, animals in pasture-based systems may have improved nutritional balance and reduced stress. Given higher acreage requirements for regions with lower rainfall, most pasture dairy operations are found in the U.S. Midwest and Northeast. Additional considerations include setting appropriate stocking rates to avoid overgrazing, use of riparian buffers to keep animals out of waterways and move watering and feed supplements around the pasture to avoid high concentrations of manure which could be washed off the field in runoff.

## SOLUTIONS APPLICABLE TO LARGE AND VERY LARGE FARMS (OR IMPLEMENTED AS COMMUNITY-SHARED INFRASTRUCTURE)

TABLE 4.

| TECH OR PRACTICE | FARM SIZE | ECONOMICS | OPERATIONAL CONSIDERATIONS | ENVIRONMENTAL & SOCIAL IMPACTS | PUBLIC FUNDING AVAILABLE |
|---|---|---|---|---|---|
| Anaerobic digester | S Difficult<br>M Difficult<br>L Feasible<br>XL Well-suited | **Upfront costs:** High<br>**Maintenance:** High<br>**Revenue:** High for renewable natural gas; Mixed for electricity<br>**Savings:** Low | • Technical service often provided by project developer (in the case of renewable natural gas projects)<br>• Variety of operational set-ups | Significant methane reductions, though methane leakage may reduce benefits<br>Can reduce odor; when digested material is stored in a covered tank or lagoon; can further reduce local air quality impacts | Conservation Practice Code 366 **(EQIP eligible)**<br>State funding available in California |

### Anaerobic digester

When manure decomposes under anaerobic conditions, it releases methane as a component of biogas. Anaerobic digesters are gastight bioreactors that capture biogas from decomposing manure, which can be used to produce renewable natural gas or electricity (Table 4). Three common anaerobic digester technologies include covered lagoons, plug flow digesters, and continuously stirred tank reactors (CSTRs).

The solids content of digester feedstocks and regional temperatures impact the optimal digester choice. Installation costs ($400+ per working cow equivalent) and operational costs ($300+ per working cow equivalent per year) are high, but revenue can be generated through the sale of renewable natural gas or electricity and the acquisition of renewable energy premiums.

# EMERGING SOLUTIONS

TABLE 5.

| TECH OR PRACTICE | FARM SIZE | ECONOMICS | OPERATIONAL CONSIDERATIONS | ENVIRONMENTAL & SOCIAL IMPACTS | PUBLIC FUNDING AVAILABLE |
|---|---|---|---|---|---|
| Vermicomposting | S Well-suited<br>M Feasible<br>L Difficult<br>XL Difficult | **Upfront costs:** Low<br>**Maintenance:** High<br>**Revenue:** Limited commercial implementation with potential high-value applications<br>**Savings:** Low | • Requires consultation with technical advisor<br>• Requires manure pre-treatment<br>• Significant practice variation by region<br>• Large spatial requirements | Significant methane, nitrous oxide, and ammonia reductions<br>Care required to prevent earthworm damage to local ecosystems<br>When field-applied:<br>Increases bioavailable nutrients, microbial populations, and soil carbon storage<br>Reduces nutrient runoff | Conservation Practice Code 317 **(EQIP eligible)**<br>State funding available in California |
| Ammonia Recovery | S Difficult<br>M Difficult<br>L Feasible<br>XL Well-suited | **Upfront costs:** High<br>**Maintenance:** High<br>**Revenue:** Limited commercial implementation but a valuable product is produced<br>**Savings:** Low | • Self-planned or supported by advisor<br>• Significant land requirements<br>• Simplified farm management practices | Significant ammonia and nitrous oxide emissions reductions<br>Reduces local pollution risks | Conservation Practice Code 629 **(not EQIP eligible)** |

## Vermicomposting

Vermicomposting is a type of aerobic composting that uses earthworms. The practice has relatively low adoption today. High space constraints make it ideal for small and mid-size farms. The practice requires specific chemical and climate conditions to be maintained inside the manure worm bed. A skilled technician is required to operate the system. Additionally, vermicomposting is easier to adopt on farms that already have some form of manure treatment (solids separation, anaerobic digestion, or aerobic composting) and have access to a low-value carbon source.

## Ammonia recovery

Ammonia recovery is a practice that is being explored for commercial-scale implementation on farms with anaerobic digesters). The process manipulates the pH of a digested manure feedstock to enable extraction of ammonia, though newer approaches use alternate capture mechanisms (e.g., permeable membrane tubes). Implementation is capital intensive and economics depend on yield management, with improved economics for larger farms. Development of these management processes reduce ammonia pollution and nutrient runoff associated with anaerobically digested manure, while producing commercial-grade fertilizer, a valuable product.

[10] Cao, Y., Tian, Y., Wu, Q., Li, J., & Zhu, H. (2021). Vermicomposting of livestock manure as affected by carbon-rich additives (straw, biochar and nanocarbon): A comprehensive evaluation of earthworm performance, microbial activities, metabolic functions and vermicompost quality. Bioresource Technology, 320, 124404

[11] Renewable Nutrients, https://www.renewablenutrients.com/

[12] Darestani, M., Haigh, V., Couperthwaite, S. J., Millar, G. J., & Nghiem, L. D. (2017). Hollow fibre membrane contactors for ammonia recovery: Current status and future developments. Journal of Environmental Chemical Engineering, 5(2), 1349–1359

# HOW FOOD AND AGRICULTURE COMPANIES CAN ENGAGE FARMERS TO GET STARTED WITH MANURE MANAGEMENT INCENTIVE PROGRAMS

FIGURE 1.

## 1


**Companies should engage farmers in their supply chains to take a baseline assessment of the GHG emissions in their milk pools.**

- Baseline assessments are usually a prerequisite for incentive program participation, since they help program funders understand projectreduction potential
- Tools such as the National Milk Producers Federation's FARM Environmental Stewardship Calculator help farmers understand the sources of their footprint
- Random sampling methodologies and use of field surveys can improve the data available for GHG calculators
- Aggregating and anonymizing data will minimize farm data privacy risks
- Such baseline assessments should also review issues beyond GHG emissions, such as water quality, community impacts, etc., to maintain a system-wide view.

## 2

**Companies should engage their farmers and suppliers to understand what practices are compatible with and build upon their existing manure management systems.**

- Operational considerations, such as farm size, geographic factors, and community infrastructure are the primary factors influencing optimal management system choice. See appendix for three models of farm size-geography-based manure systems.
- Technical best practices will vary based on geography; local farmers who have already experimented with novel practices, local manufacturers, and the local NRCS office are critical sources of technical expertise
- Understanding local context could help identify solutions that can maximize co-benefits for the community

## 3

### Companies should partner with their farmers and suppliers to develop the economic business case for implementation

- Important factors to consider are the upfront costs, maintenance costs, on-farm savings, revenue opportunities, and available funding for system adoption
- On-farm savings can take many forms, including reduced costs for external manure management solutions, fertilizer substitutes, lower labor requirements, and more
- Offtake options for manure byproducts, such as fertilizers and biogas, are localized; some offtake requires additional infrastructure, such as transportation, pipelines, and electric grid network
- Public and private grants and incentives for practice adoption tend to be localized; USDA grants are administered by local NRCS offices, and applications are typically ranked according to local and state priorities

## 4

### After new practices and technologies are identified, companies should support their suppliers to determine which public and/or private programs to engage with and design program implementation

- Public programs tend to be competitive and application-based, with clear qualification and compliance structures
- Companies may have existing programs including incentives, farmer education, etc. that they can on-board farmers in their supply chain onto. Successful pilot programs can be scaled.
- Private programs (voluntary carbon markets, corporate supply chain programs) generally involve an upfront feasibility study and are custom designed on a case-by-case basis.
- Program participation often requires third-party measurement, monitoring, reporting and verification (MMRV) activities
- Farms should consider community engagement before putting their plans into action, preferrable during the project design stage. Companies can support farmers here.
- Farms should establish a continuous improvement process to ensure that they are best positioned to take advantage of emerging program and market opportunities.


Photo credit

# CONCLUSION

The evolving landscape of manure management systems presents a critical opportunity for the dairy sector to align with sustainability goals, reduce greenhouse gas emissions, and fortify the resilience of farming operations. The commitment of governments and corporations to incentivize these practices underscores the urgency of addressing environmental concerns in agriculture.

The increasing investment in novel manure management systems reflects a paradigm shift from traditional methods towards more sustainable practices. The emergence of diverse technologies provides flexibility for farms of varying sizes and operational capacities. While this report laid out a few technologies, there are others like biogas fuel cells and composting with additives like biochar, that are gaining traction. This diversification allows farmers to tailor solutions that align with their unique circumstances, fostering a more holistic and adaptive approach.

The report recognizes the significance of trade-offs in implementing different technologies and emphasizes the potential synergies when combining these approaches. While each technology has its benefits and challenges, the holistic strategy aims for a balanced integration that optimizes environmental sustainability, economic viability, and operational efficiency.

As farmers navigate the complexities of participating in incentive programs, the importance of baseline assessments, understanding compatible practices, and developing robust economic business cases cannot be overstated. The collaborative engagement of local communities, farmers, and public and private entities is essential for the success and sustainability of these initiatives.

In essence, the dairy sector stands at the nexus of environmental responsibility and agricultural innovation. The actionable guide provided serves as a roadmap for farmers to embark on this transformative journey. By embracing manure management practices that work for farms, farmers can not only contribute to mitigating climate change but also unlock economic opportunities, improve farm sustainability, and ensure a healthier future for our planet and communities.

# APPENDIX

## THREE MODELS OF MANURE MANAGEMENT SYSTEMS

*Diagrams authored and owned by Concord Ag Partners and Jennifer Bockhahn*

FIGURE 2A. Model 1: Small New York 100 head dairy

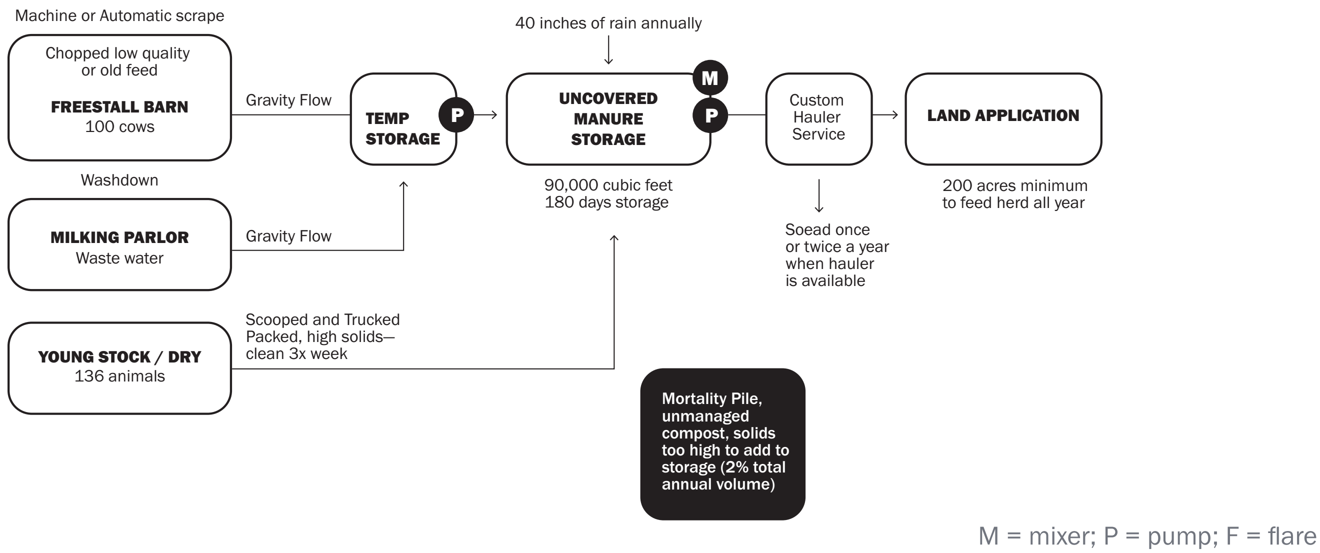



FIGURE 2B. Model 2: Medium Wisconsin 400 head dairy

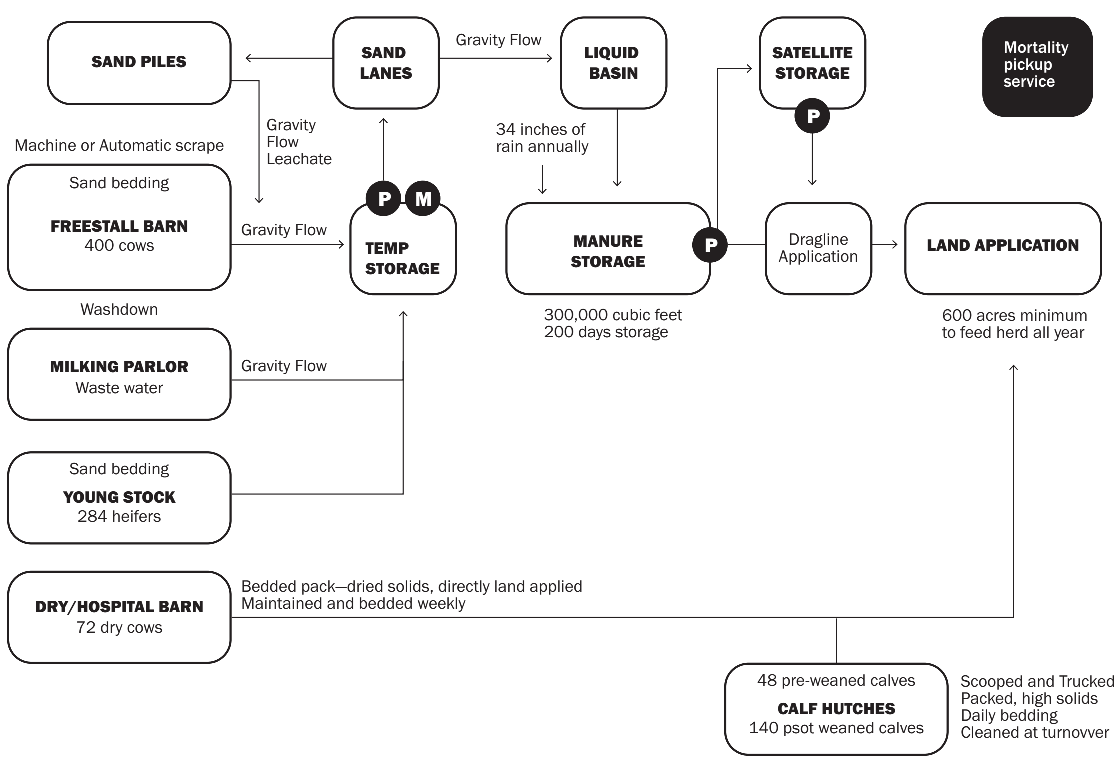
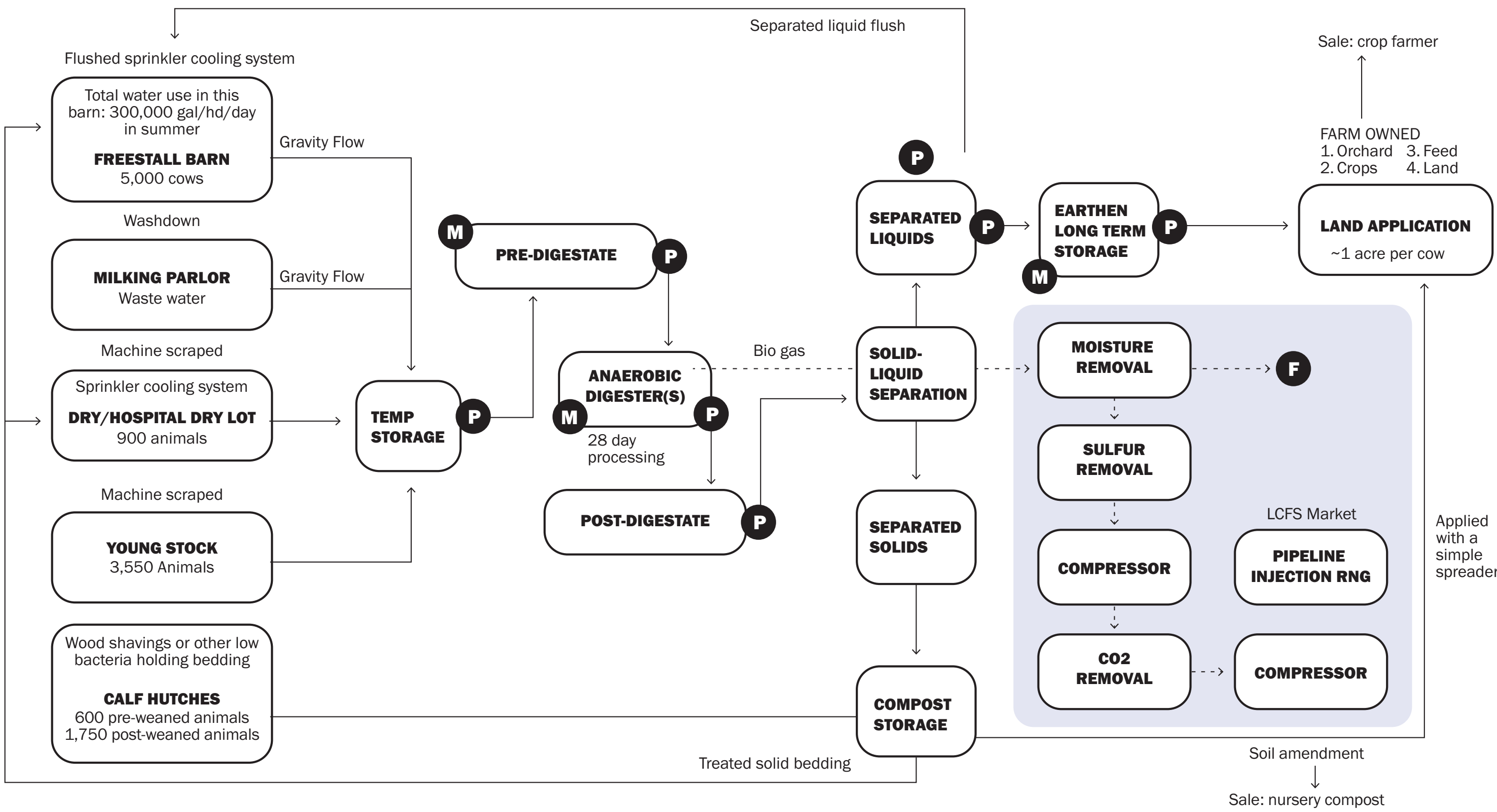


FIGURE 2C. Model 3: Large California 5,000 head dairy




# SPECIAL THANKS

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| Cavanaugh & Associates | Brantly Braswell, Ben Cauthen, Steve Cavanaugh, Andrew McCarthy, Gus Simmons |
| Michigan Milk Producers Association | Sarah Michalek |
| Tillamook | Casey Storey |
| Chobani | Roberta Osborne |
| Hilmar | Patrick Robinson |
| Danone | Caitlin Dillon |

| ORGANIZATION | PERSON |
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| Stonyfield | Dana Bourne |
| McDonalds | Jordan Sabine |
| Starbucks | Nichole Embertson |
| Dairy Management, Inc. | Karen Scanlon |
| Newtrient | Chris Kopman |
| International Dairy Foods Association | Mike Aquino |
| Vanguard Renewables | David Darr |
| Concord Ag Partners | Jennifer Bockhahn |
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