

Manure Treatment Technologies: Anaerobic Digesters

DEANNE MEYER, Livestock Waste Management Specialist, University of California, Davis, Department of Animal Science; **THERESA POWERS**, Junior Specialist, University of California, Davis, Department of Animal Science

Dairy manure treatment technologies are used to modify or stabilize manure components through chemical, physical or biological processes. There is currently a need for technological advancement, with ever-increasing attention to the environmental impacts of manure management and stricter environmental regulations imposed by regulatory agencies. This publication presents an overview of anaerobic digestion, discusses the opportunities for use of anaerobic digesters on commercial dairies in California, provides a technology evaluation process, and identifies key economic considerations to review prior to investing in anaerobic digester technology.

Anaerobic Digestion: the Process

Anaerobic digestion is the biological process in which bacteria digest organic material in the absence of oxygen. “Anaerobic” literally means “no air.” Anaerobic digestion occurs in storage and treatment containment structures where oxygen is absent and methane-producing bacteria (methanogens) are present. Optimal digestion occurs when temperature, pH, nutrient content, and moisture are maintained within acceptable ranges.

Anaerobic digestion results in the formation of biogas, which is primarily methane with some carbon dioxide, water vapor, and minor amounts of other gases. This process serves as a carbon treatment and does not modify salt or phosphorus content. There may be very minor modifications to the form of nitrogen (organic versus ammonium) as a result of anaerobic digestion. Biogas is captured, transported to a point of use, and processed as necessary for the intended use. Biogas has most commonly been scrubbed to remove impurities and used to power a combustion engine-generator unit referred to as a genset. Biogas has also been scrubbed and processed for injection into a natural gas line, or pressurized for use in vehicles that run on compressed gas (CNG). The residual material from the digester is an effluent (liquid to solid in consistency) that contains salts, nutrients, and most of the organic fraction that was present initially in the feedstock. Digester effluent may be used directly or dried prior to use (e.g., as bedding or a soil amendment).





Opportunities for Using Anaerobic Digesters on California Dairies

Anaerobic digesters are designed to optimize the formation and collection of biogas from anaerobic digestion. Digesters are used to treat carbon and may also reduce odors associated with some components of manure storage structures. Using biogas for electricity generation or as compressed gas fuel may offset some energy costs associated with the operation.

The most common anaerobic digester designs currently in use on commercial dairies in California are covered lagoons (for liquid manure) and plug-flow systems (for slurry manure) (California Energy Commission 2010). Both systems require a closed, oxygen-free environment where gases can be collected and conveyed to the gas treatment/ use area. Therefore, design selection is based on method of manure collection.

Evaluating Anaerobic Digesters as a Treatment Technology

The decision to install an anaerobic digester is a complex one. First, identify the management and environmental needs of your particular facility. This establishes the “job description” for the technology. Then determine whether the digester installation and operation will achieve your objectives. Also identify potential management and regulatory hurdles prior to investing in an anaerobic digestion technology. Note that the use of any method or technology that potentially modifies the location, volume, or composition of manure requires submission of a Report of Waste Discharge to the California Regional Water Quality Control Board at least 140 days prior to installation. Facilities operating with a Permit to Operate from their local air district must submit an Authority to Construct and receive direction from the local air district prior to installation.

Potential benefits and challenges (unintended or undesirable consequences) of digesters are outlined in table 1.

Table 1. Potential benefits and challenges of anaerobic digester installation and use on California dairies

Benefits
Stabilize or reduce farm energy costs
Generate income from sale of energy
Less odorous waste products (when complete digestion occurs)
Reduce greenhouse gas emissions to the atmosphere (typically by consuming methane)
Generate income from sale of carbon credits
Reduce pathogen load (anaerobic digestion does not sterilize waste)
Reduce total solids concentration in the waste stream (partial conversion of total solids to gases)
Challenges
Initial installation investment (gas capture, generator and tie-in to existing electric grid, tie-in to existing natural gas infrastructure, gas treatment/cleaning, vehicle conversion to use compressed gas)
Gas treatment and cleaning costs for certain uses or to meet regulatory requirements (scrubbing/purification)
Inconsistent net metering opportunities: local policy determines logistics of interconnect with utility provider and ability to net meter electrical use. Net metering is calculated by subtracting what was used from what was generated. Additional deductions may be made depending on the electric provider.
Unknown affect on management of sludge build up and costs of removal in covered lagoon systems.
Regulatory limitations on gaset emissions in some air districts (must meet NOx emission thresholds in regulated airsheds, particularly important in San Joaquin Valley Air Pollution Control District)
Insufficient technology available to effectively store electricity on farm for future use.
No contribution to manure storage capacity (digester volume does not count in calculations for existing manure storage capacity as the digester is always full and does not have capacity to accept additional material for storage)

Additional considerations

The following management areas must be considered to determine whether an anaerobic digester is a viable waste treatment option at your facility.

- **Manure handling.** Anaerobic digesters are designed to accept semisolid to liquid materials. The method of manure collection will define whether a covered lagoon or plug-flow digester is the best option.
- **Chemical usage.** Chemicals or other additives that may impact methanogenic bacteria reduce biogas yields. It is important to minimize the use of chemicals that could adversely affect a digester (i.e., pesticides, herbicides, copper sulfate, and other potential methanogen inhibiting additives).
- **Odor control.** Odor is typically caused by incomplete digestion due to the presence of low concentrations of oxygen-inhibiting methanogenic bacteria. Maintaining an anaerobic environment is critical for odor reduction within the digester structure.
- **Space.** Sufficient space (land area) in an appropriate location must be available to accommodate the actual digester and associated equipment. Machine houses for systems using a genset are typically located in close proximity to the connection to the electrical line.
- **Digester technical support.** Trained technical support is essential to troubleshoot and make repairs when problems arise.
- **On-farm labor resources.** Daily maintenance of digesters requires from 15 to 30 minutes to update logs, check oil pressure, evaluate production information, and check other necessary components. Regular servicing (oil changes, engine maintenance, etc.) requires additional labor.

- **Safety.** All employees working around the digester must be trained in safe practices relating to its operation, and key employees should be trained specifically to handle emergency situations.
- **Economic resources.** The purchase, installation, and maintenance of all associated manure storage and processing equipment require significant financial resources. Grants, tax incentives, and carbon credits are potential opportunities for financial assistance. Third-party entrepreneurs may provide financial incentives with long-term commitment to energy production. Availability of funds varies.

Technology Evaluation for Anaerobic Digesters

In 2005, the San Joaquin Valley Dairy Manure Technology Feasibility Assessment Panel reviewed technologies used for dairy manure treatment. This panel, composed of representatives from government, the dairy industry, academia, and environmental and conservation groups, was created to evaluate technologies that have the potential to improve the management and treatment of dairy manure in the San Joaquin Valley. A detailed summary of the expectations for anaerobic digesters from that panel includes anticipated effects on manure solids, wastewater, and air emissions (table 2). In summary, anaerobic digestion with the capture and use of methane is effective in reducing pathogens, reducing emissions (methane, hydrogen sulfide, ammonia, and volatile organic compounds), stabilizing manure, and reducing solids. Anaerobic digestion has no effect on phosphorus or salts. In some systems, there may be a small conversion of organic nitrogen into ammonium nitrogen.



Table 2. Technology scorecard for anaerobic digesters on dairies in California as presented in *An Assessment of Technologies for Management and Treatment of Dairy Manure in California's San Joaquin Valley* (p. 17)

Type of Technology	Media																			
	Effects on Wastewater						Effects on Manure Solids						Effects on Air Emissions							
	Reduces organic nitrogen	Reduces ammonia nitrogen	Reduces phosphorus	Dissipates / dissolves solids	Reduces total dissolved solids (TDS)	Forms nitrate nitrogen	Reduces organic nitrogen	Reduces ammonia nitrogen	Reduces phosphorus	Reduces pathogens	Stabilize manure / reduce emissions	Reduce manure volume	Reduces ammonia emissions	Reduces Volatile Organic Compound (VOC) emissions	Reduces methane emissions	Reduces H ₂ S emissions	Reduces particulate emissions	Reduces odors	Produces carbon monoxide emissions	Produces NOx emissions
Anaerobic Digestion Without Methane Capture																				
Uncovered lagoon	N	N	N	Y	N	N							N	N	N	N	N	N		
Anaerobic Digester with Methane Capture & Use																				
Continuous flow	3	N	N	Y	N	N	N	?	N	Y	Y	N	Y	Y	Y	Y	N	Y	?	?
Plug-flow (slurry system)	3	N	N	Y	N	N	N	?	N	Y	Y	N	Y	Y	Y	Y	N	Y	?	?

Source: San Joaquin Valley Dairy Manure Technology Feasibility Assessment Panel 2005, p. 17.
 KEY
 Y = Yes
 N = No
 ? = Unknown
 — = Not applicable
 3 = May convert some organic nitrogen to ammonium

Part of evaluating a potential technology includes careful consideration of existing technology to determine whether the new technology will work at a specific location with specific resources. In other words, Will this work for me? In considering installation of an anaerobic digester, first define the job description. What is expected of the anaerobic digester? Identify the specific manure management needs and challenges of the facility and expectations for treatment effectiveness. How much methane per unit material must be generated for the project to be a success? Alternatively, what percentage of the volatile solids must be removed for the project to be deemed a success? Next, identify the path of manure through the treatment technology and where data and samples can be obtained. Finally,

determine how the performance of the technology will be measured to compare it with desired goals. Remember to consider unintended consequences and other potentially valuable resources (reduced pathogen load, carbon credits, energy, etc.).

Do your homework before signing contracts with potential vendors, contractors, and installers. Be sure you have detailed information available prior to project initiation. The following list serves as a good start to be sure your project has potential for success.

- Identify other producers who have already installed a similar technology and make site visits to better understand the issues associated with the design and installation of a successful project. Contact these operators and include the following in your questions:



- » *Are you satisfied with the technology?*
 - » *Are you still using it? (What is the daily operation commitment?)*
 - » *How much did you pay (direct expenses, labor, equipment use)?*
 - » *Were there financial incentives (grant funds, tax incentives, etc.)? What were they worth?*
 - » *Would you do it again?*
 - » *What would you do differently?*
- Identify a vendor with a positive track record from design through installation.
 - Have the vendor provide references for both attempted and completed projects in your geographic area in the last 5 years.
 - Check vendor references to be sure you understand how the vendor works.
 - Identify the specific responsibilities of each party, including subcontractors if they are used. Particularly, assign responsibility for the permitting work with various regulatory agencies, including the county, the local regional water quality control board, and the local air district.
 - Have the vendor provide an estimated time for project completion, including the

permitting, construction, installation, and operation phases.

- Try to identify potential pitfalls at the beginning and get estimates of how they may affect the project finish date.

If the technology is not already being used in California, be sure there is adequate information available to determine whether compliance with California regulations may be achieved. If data are available from dairies located outside California, make sure similar management practices for manure collection and handling are used.

Key Economic Considerations

Installation and maintenance costs for an anaerobic digester are substantial. The estimated cost of equipment installation can range from \$350,000 to \$3,000,000 depending on herd size (range 500 to 5,000 cows) and method of digestion. General cost analysis equations as well as summary costs for two dairies of different size are provided from the U.S. Environmental Protection Agency (EPA) AgSTAR computer analysis program available for use from the website provided with tables 3 and 4.

Table 3. Formulas to determine the fixed cost associated with complete mix and plug-flow digesters, in 2008-equivalent dollars

Digester type	Capital costs	Capital cost per cow
Complete mix 700 to 2,300 cows	$\$615 \times (\text{cows}) + \$354,866$	$\$12,331 \times (\text{cows}) - 0.362$
Plug-flow 650 to 4,000 cows	$\$563 \times (\text{cows}) + \$678,064$	$\$12,960 \times (\text{cows}) - 0.332$

Source: AgSTAR 2010.

Table 4. Fixed costs of covered lagoons for two dairy farms of different sizes, in 2008-equivalent dollars

Number of cows	Capital costs	Capital cost per cow
496	\$798,699	\$1,610
1600	\$1,241,395	\$776

Source: AgSTAR 2010.

Note: Regulatory requirements for Tier 1 and Tier 2 lagoon liners for dairies located in the Central Valley and operating under General Order for Existing Milk Cow Dairies will increase costs.



The equations and calculations in table 3 account only for fixed costs associated with the installation of an anaerobic digester; they do not include costs associated with permitting, maintenance, management, and economic considerations. Installation of an anaerobic digester requires large capital resources, and therefore, as herd size increases, the cost of using the technology on a per-cow basis decreases, making the technology more attractive to producers with larger herds. Maintenance costs vary. A previous study reported that routine maintenance (not equipment replacement) ranged from \$4,000 to \$25,000 annually (Morse et al. 1996). Daily labor (15 to 30 minutes) is required to attend to system needs. Additionally, scheduled maintenance for oil changes and other engine needs are done per manufacturer's recommendations (monthly or more frequently). Replacement of parts (spark plugs, catalytic converters, sulfur scrubbing equipment, and the genset) incur additional costs.

A potential positive economic result may be the ability to participate in an international carbon market through the generation of greenhouse gas (GHG) credits. To this end, California dairy operations using anaerobic

digesters are urged to register and adhere to the voluntary CCAR (California Climate Action Registry) Livestock Project Reporting Protocol (also known as the Manure Digester Protocol) available at the California Environmental Protection Agency Air Resources Board Web site, <http://www.climateregistry.org/resources/docs/protocols/project/livestock/CCARLivestockProjectReportingProtocol2.1.pdf>.

Registration allows producers to quantify their greenhouse gas emission reductions in order to recapture their value as GHG credits.

Conclusion

Anaerobic digesters have been in use for decades, but they are used on only a small number of dairy facilities in California. Digesters have the potential to reduce odor from manure treatment, stabilize energy costs, and provide an income through carbon credits. However, they do little to aide in nutrient management. The greatest hurdles in California include complying with permitting requirements of the regulatory agencies and attaining interconnection with utility companies. Capital and operational costs are high. Labor and equipment must be available for operation and maintenance requirements.

References

- AgSTAR Program. 2010. Anaerobic digestion capital costs for dairy farms. U.S. EPA AgSTAR Program Web site, http://www.epa.gov/agstar/documents/digester_cost_fs.pdf.
- CCAR (California Climate Action Registry). 2008. Livestock project reporting protocol. Version 2.1 CCAR Web site, <http://www.climateregistry.org/resources/docs/protocols/project/livestock/CCARLivestockProjectReportingProtocol2.1.pdf>.
- California Energy Commission. 2008. PIER Final project report. Project 3.1: Co-digestion of manure/food processing wastes and biosolids/food processing wastes to energy. CEC Web site, <http://www.energy.ca.gov/2007publications/CEC-500-2007-015/CEC-500-2007-015.PDF>.
- . 2010. Renewable energy research: Overview. CEC Web site, http://www.energy.ca.gov/research/renewable/biomass/anaerobic_digestion/index.html.
- Leggett J., R. Graves, and L. Lanyon. Anaerobic digestion: Biogas production and odor reduction from manure. Pennsylvania State University Agricultural and Biological Engineering Web site, <http://www.abe.psu.edu/extension/factsheets/g/G77.pdf>.
- Midwest Plan Service. 1985. Livestock waste handbook. 2nd ed. Ames: Iowa State University.
- Morse, D., J. Guthrie, and C. Mutters. 1996. Anaerobic digester survey of California dairy producers. *Journal of Dairy Science* 79:149–153.
- San Joaquin Valley Dairy Manure Technology Feasibility Assessment Panel. 2005. An assessment of technologies for management and treatment of dairy manure in California's San Joaquin Valley. California Air Resources Board Web site, <http://www.arb.ca.gov/ag/caf/dairypnl/dmtfaprprt.pdf>.

For Further Information

To order or obtain ANR publications and other products, visit the ANR Communication Services online catalog at <http://anrcatalog.ucdavis.edu> or phone 1-800-994-8849. You can also place orders by mail or FAX, or request a printed catalog of our products from

University of California
Agriculture and Natural Resources
Communication Services
1301 S. 46th Street
Building 478 - MC 3580
Richmond, CA 94804-4600
Telephone 1-800-994-8849
510-665-2195
FAX 510-665-3427
E-mail: anrcatalog@ucdavis.edu

©2011 The Regents of the University of California
Agriculture and Natural Resources
All rights reserved.

No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without the written permission of the publisher and the authors.

Publication 8409

ISBN-13: 978-1-60107-733-2

The University of California prohibits discrimination or harassment of any person on the basis of race, color, national origin, religion, sex, gender identity, pregnancy (including childbirth, and medical conditions related to pregnancy or childbirth), physical or mental disability, medical condition (cancer-related or genetic characteristics), ancestry, marital status, age, sexual orientation, citizenship, or service in the uniformed services (as defined by the Uniformed Services Employment and Reemployment Rights Act of 1994: service in the uniformed services includes membership,

application for membership, performance of service, application for service, or obligation for service in the uniformed services) in any of its programs or activities.

University policy also prohibits reprisal or retaliation against any person in any of its programs or activities for making a complaint of discrimination or sexual harassment or for using or participating in the investigation or resolution process of any such complaint.

University policy is intended to be consistent with the provisions of applicable State and Federal laws.

Inquiries regarding the University's nondiscrimination policies may be directed to the Affirmative Action/Equal Opportunity Director, University of California, Agriculture and Natural Resources, 1111 Franklin Street, 6th Floor, Oakland, CA 94607, (510) 987-0096. For information about ordering this publication, telephone 1-800-994-8849. For assistance in downloading this publication, telephone 530-754-3927.

An electronic copy of this publication can be found at the ANR Communication Services catalog Web site, <http://anrcatalog.ucdavis.edu>.



This publication has been anonymously peer reviewed for technical accuracy by University of California scientists and other qualified professionals. This review process was managed by ANR Associate Editor Chair Joseph Grant.

web-4/11-SB/RW