An Assessment of Technologies for Management and Treatment of Dairy Manure in California's San Joaquin Valley

Prepared by the
San Joaquin Valley Dairy Manure
Technology Feasibility Assessment Panel

December 2005

San Joaquin Valley Dairy Manure Technology Feasibility Assessment Panel

California Air Resources Board	Mike FitzGibbon Stephanie Kato
California Department of Food and Agriculture	Matt Summers Al Vargas
California Energy Commission	***** George Simons Zhiqin Zhang
California Integrated Waste Management Board	Steven Storelli
California Water Resources Control Board	John Menke
Center for Energy Efficiency and Renewable Technologies	John Shears
Natural Resources Defense Council	Diane Bailey
Sustainable Conservation	Allen Dusault
USDA Natural Resource Conservation Service	Mark Cocke
US EPA, Pacific Southwest Region	James Liebman
University of California Cooperative Extension	Deanne Meyer Frank Mitloehner
Western United Dairymen	Paul Martin

Persons indicated with an asterisk (*) have taken other employment since the Panel began its work.

Technical assistance for preparing the report was provided by

Tetra Tech EM, Inc.
Barbara Toole O'Neil

Disclaimer

Views expressed in this report do not indicate endorsement by the Panelists, the Panel, or the organizations they represent of particular companies, products or processes.

Table of Contents

Executive Summary

Dairies are important to California as a source of food and jobs. However, manure from California dairies, especially in the San Joaquin Valley, can degrade air and water quality if the manure is not properly managed. The California dairy industry is facing rapidly increasing state and federal regulation over its role in the pollution of air and water, and there is a critical need to improve the management and treatment of dairy manure to reduce environmental problems, while ensuring the economic viability of this essential agricultural industry.

The Dairy Manure Technology Feasibility Assessment Panel, composed of representatives from government, industry, academia, and environmental and conservation groups, was created in February 2005 to evaluate technologies that have a potential to improve the management and treatment of dairy manure in the San Joaquin Valley. The Panel solicited information from technology vendors and received material on 68 technologies; 44 of these were received by the deadline and were evaluated by the Panel.

The Panel grouped the manure treatment technologies into ten categories: thermal conversion (combustion, gasification and pyrolysis); solid-liquid separation and filtration; composting; anaerobic digestion; aerators/mixers; covers for lagoons and compost piles; microbial cultures, enzymes, and other additives; feed management; nitrification/denitrification; and miscellaneous. The benefits and challenges of each approach are described, and each of the 44 submissions is individually assessed. An appendix is included listing all vendors whose products were assessed by the Panel, as well as some that were subsequently identified but not assessed.

The Panel evaluated each technology for its environmental and economic performance, based on information supplied by each technology vendor. Environmental parameters of most concern were emissions of nutrients (especially nitrogen and phosphorus), air pollutants (especially volatile organic compounds, ammonia, nitrous oxide, methane, carbon dioxide, hydrogen sulfide, and particulate matter), salts, and pathogens. Economic parameters included costs to construct and operate the technology, as well as the value of any products (e.g., fertilizer, compost, energy and fuel). The Panel also considered the quality of supporting data, and the development status of the technology.

Conclusions

There are a great many companies selling products and processes to treat manure. Although the Panel accepted submissions for only 6 weeks, we received 44 submissions, and another 25 after the deadline. We also identified several dozen more companies (Appendix 2) that are marketing technologies that are intended to treat manure, but that did not submit information for review by the Panel. It is apparent that many companies are seeing entrepreneurial opportunities for industrial-scale manure management and treatment, and that these technologies hold promise for potential use as best management practices at dairies.

The Panel was unable to determine the environmental and economic performance of most of the technologies submitted. There are two major reasons:

- **Insufficient Scientific Data.** In this first round of evaluations, only a few companies provided scientific data that allowed the Panel to determine the environmental and economic performance and appropriateness of a technology. Much of the material submitted to the Panel was company marketing claims that were neither adequate nor appropriate for the Panel to use in determining the environmental and economic performance of a technology. Instead, the Panel needs independent, scientific data. Lack of scientific data to support company claims does not mean the technologies are without merit, but does severely limit the Panel's ability to assess the technologies.

  In addition, few of the submissions provided an accounting of the form and fate of all constituents in the manure as it enters, moves through, and exits the processing technology. Of particular concern are nitrogen, phosphorus, carbon, and salts. For example, the Panel could not determine the impact of many of the submitted technologies on converting nitrogen from one form to another (organic nitrogen, nitrate, nitrite, ammonium, ammonia, nitrous oxide, and nitrogen gas). Without knowing the biological and chemical transformations that affect the form and amount of these compounds, it is not possible to determine if there are environmental benefits from the technology.

- **Untested on California Dairies.** Many of the technologies examined by the Panel have never been tested under conditions that occur on dairies in California's San Joaquin Valley. Some have not yet been tried on dairies at all. Although a majority of dairies in the San Joaquin Valley collect at least some of their manure by flushing with recycled wastewater, many of the technologies submitted to the Panel are appropriate for, or have been tested only on, dairies or feedlots where manure is scraped or vacuumed and handled "dry." Some technologies have been tested only on other types of animals such as swine, or on human wastewater, and some are still in the conceptual stage.

Most technologies address only a limited portion of the environmental issues associated with manure. The Panel found few technologies that had been packaged into a whole-systems approach to address all components of the manure stream. Many treat only a portion of the manure. For example, gasification technologies burn manure solids to generate energy, and are not intended to treat the salts and nitrogen that are in the manure wastewater. Anaerobic digestion converts organic carbon to carbon dioxide and methane, which can be burned to generate energy, but does not treat salts and also leaves ammonium-nitrogen in the liquid fraction. Composting can stabilize organic matter, but impacts on air quality from emissions of ammonia, volatile organic compounds, and nitrous oxide, or on water quality from run-off or leaching of ammonium and nitrate, were not reported or addressed by many of the technologies submitted to the Panel. Some technologies intentionally or unintentionally transfer pollutants from one medium to another. For example, technologies that volatilize ammonia reduce the potential for impacts to groundwater but have a negative effect on air emissions and potential subsequent deposition to soils and surface waters. The challenge in evaluating a single component of a system is to understand the net effect on the entire manure stream. Although some submissions were comprehensive packages of technologies, most were not, and the lack of technology packages that comprehensively treat all components of manure remains a challenge for the dairy industry, regulatory agencies, and technology providers.

Treating Manure is Expensive. Some manure processing operations are relatively inexpensive. For example, settling ponds to separate liquids and solids are relatively inexpensive to construct and maintain and have a long operating life. Other operations are considerably more expensive. For example, a system to collect and use biogas (i.e., an anaerobic digester with a methane-powered generator) may have construction costs of $200 per cow (for a simple covered lagoon digester) to more than $800 per cow (for a plug flow digester), and nitrification/dentrification systems can have construction costs of $600 per cow plus operating and maintenance costs of $120 per cow per year. These costs are a significant barrier to wider adoption of manure treatment technology, even when offset by the value of products - such as bedding, compost, fertilizer, and electricity - that result from treatment.

Recommendations

1. **Develop standard test methods so that the environmental and economic performance of technologies can be fairly evaluated and compared.** Panelists believe additional technology assessments will not be worthwhile until the quality of the submitted data can be improved.

   Data submitted by vendors on environmental performance should include results from properly controlled, replicated studies, preferably at commercial-scale dairies, and also should include an accounting of the fate and form of all components of the manure as it is treated. Companies should make their sampling and analysis protocols available to the dairy industry and regulatory agencies.

   Ongoing air quality monitoring research that will take place over the next few years at animal feeding operations in California, and throughout the nation under agreements between the dairy industry and US EPA, will support the development of standardized test methods, particularly for volatile organic compounds (VOCs). Until standardized test methods exist, technology vendors will not be able to accurately claim or compare the impact of their products on reducing emissions of VOCs.

   Data submitted on economic performance should account for the full cost of implementing the technology, including not only the obvious construction and operating costs, but also the costs for land, training operators, infrastructure changes and additional equipment needed to integrate the new technology into the existing dairy, etc., as well as realistic assumptions about the value of any products (fertilizer, soil amendments, energy, etc.).

2. **Conduct applied research on key data gaps.** These gaps include:

   - **Technology Verification.** An independent program to test and compare technologies under controlled conditions in the field would provide the dairy industry, technology providers, and regulatory agencies with a better understanding of the required environmental performance standards, and provide information about the ability of particular products to meet those standards. A program that could assist in this effort is the US EPA's Environmental Technology Verification Program (www.epa.gov/etv), but so far this program has tested only a few manure treatment products, and most were not for cows and were not tested under California conditions. At the state level, the California Environmental Technology Certification Program is no longer funded. A program should be created to test technologies most appropriate for treating dairy manure in California.

- **Salts.** Dairies use large amounts of water and import large amounts of feed from California and from other states. The salts in the water and feed are concentrated in the dairy manure and contribute to the Central Valley's problems with salt accumulation, which is a challenge in all irrigated agriculture systems. Data are needed on the contribution of dairy manure relative to other sources of salts, such as fertilizers, compost, and irrigation water; on the efficacy and costs of technologies that remove salts from manure; and on disposal options, especially the merits of diluting versus concentrating salts for relocation and/or disposal.

- **Volatile Organic Compounds (VOCs).** There are significant questions about the quantities of VOCs emitted from various portions of dairies (animals and housing, liquid and solid manure, lagoons, feed, compost, and land application), and about the chemical species and processes involved in the formation of ground-level ozone. Without this information, it is difficult to assess how various technologies will reduce VOC emissions. Since the research and regulatory communities have not yet reached consensus on how to measure or reduce VOC emissions from processes on dairies, it is not surprising that companies often do not know – and do not know how to determine – the impact of their technologies on VOC emissions. Definitive measurement techniques to adequately characterize VOC emissions are needed.

3. **Establish pilot projects to assess comprehensive technology combinations for treating dairy manure in the San Joaquin Valley.** The Projects should monitor and assess environmental and economic performance, and demonstrate the technologies to the wider community so that the best technologies can be more widely adopted. The dairy industry, private technology vendors, and public agencies and universities may all be expected to participate in funding, siting, monitoring, and publicizing the results of these projects. Key elements of these projects should include:

    - Construction and operation at full-scale commercial dairies
    - Environmental monitoring to determine if the technology reduces or captures emissions of nutrients, salts, volatile organic compounds, ammonia, methane, pathogenic bacteria, and odors
    - Economic analysis to determine the viability for a typical California dairy
    - Education and outreach to the dairy industry so that successful technologies are more likely to be implemented
    - Collaboration with key stakeholders, including dairy industry, technology providers, federal and state agencies, UC Cooperative Extension, environmental NGOs, communities, utilities, irrigation districts, etc.

The pilot projects should combine technologies into packages that comprehensively address all of the environmental concerns associated with manure (excess nutrients and salts, air pollutants, pathogens, odors, etc.), and also utilize the value of manure (compost, soil amendments, fertilizer, energy and fuel). Such a comprehensive system could include some or all of the technology approaches discussed in this report (thermal conversion, solid-liquid separation, composting, anaerobic digestion, aerators/mixers, nitrification/denitrification, covers for lagoons and compost piles, microbial and other additives, and feed management), as well as comprehensive wastewater treatment, and technologies that the Panel has not yet considered.

Introduction

Dairies are important to California as a source of food and jobs. However, manure from California dairies, especially in the San Joaquin Valley, can degrade air and water quality if the manure is not properly managed. The California dairy industry is facing rapidly increasing state and federal regulation over its role in the pollution of air and water, and there is a critical need to improve the management and treatment of dairy manure to reduce environmental problems, while ensuring the economic viability of this essential agricultural industry.

1.1 Background

A group of some 50 stakeholders representing federal and state agencies, local government, dairies and dairy industry organizations, public-interest non-profit organizations, and private technology providers, met for a conference ("*Waste to Watt's, or What?*") at the Stanislaus County Agricultural Center in October 2004 to identify steps needed to implement new or improved technologies to manage and treat manure. There was broad agreement on the need for a rapid, objective assessment of which technologies were most likely to be successful in California's unique economic, regulatory, and environmental conditions. The group proposed the creation of a San Joaquin Valley Dairy Manure Technology Feasibility Assessment Panel to carry out this work.

The California Air Resources Board agreed to create and host the Panel, and members were drawn from government, industry, academia, and environmental and conservation groups. The Panel was convened in February 2005.

1.2 Importance of Dairies to California

Dairies are an essential component of California's robust agricultural industry. California dairies produced more than 35 billion pounds of milk in 2003 - 21% of the national supply – and made California the nation's leading dairy state. Dairy products and cattle sales are California's most valuable agricultural product, worth more than $6 billion per year and generating $47 billion of economic activity according to the California Milk Advisory Board, September 2005.

Over the last 30 years, the number of milk cows in California has doubled (to over 1.7 million) while the number of dairies has dropped by nearly half (to approximately 2,100). Three-quarters of the state's dairy cows are in the San Joaquin Valley. This concentration of the dairy industry has resulted in a dramatic increase in the average number of animals at new dairies, and a corresponding increase in the amount and geographic concentration of manure.

1.3 Environmental Concerns

Improper management of manure at dairies can result in adverse impacts to water and air. Releases to surface water can result from improper collection and storage of manure or improper application of manure to land. The primary concerns for surface water are ammonia (aquatic toxicity), organic matter (depletion of dissolved oxygen), and nutrients such as nitrates and phosphorus (promotion of algal growth that can adversely affect beneficial uses). Coliform bacteria and other pathogens are a concern if there is human contact with the manure residuals or if manure contacts food or water consumed by humans.

The primary concerns for groundwater are salts and nitrates. Salts are usually measured as total dissolved solids, which includes nitrates. A maximum contaminant level has been established for nitrate because at relatively low concentrations in drinking water it can cause serious health problems, especially for infants. Although improper storage of manure can adversely impact groundwater, the greatest concern is improper application of manure to cropland. Many dairies in California do not have sufficient cropland available to apply the manure at or below agronomic rates (i.e., at rates that maximize nutrient uptake up by the plants and minimize leaching into the groundwater). Rapid population growth in the Valley further restricts the amount of crop land available to utilize manure as fertilizer.

Air emissions of concern from dairies include ammonia (NH_3), nitrous oxide (N_2O), methane (CH_4), carbon dioxide (CO_2), volatile organic compounds (VOC), hydrogen sulfide (H_2S), and particulate matter (PM, PM_{10} and $PM_{2.5}$). The emissions can come from animal housing, storage areas for manure and wastewater, cropland where manure is applied, and directly from the cows.

1.3.1 Regulatory Issues for Air Quality

Until recently, agricultural sources of air pollution in California had maintained a long-standing exemption from local air pollution control and air quality management district (district) permit requirements. This changed with the enactment of Senate Bill 700 (SB 700, Chapter 479, Florez, Statutes of 2003), which removed the permit exemption from the California Health and Safety Code such that minor and major agricultural sources are subject to the permitting requirements and emissions limitations in their respective air districts. SB 700 also required the ARB to develop a definition for large confined animal facilities (CAFs) that would trigger the requirement for an emission mitigation plan. On June 23, 2005, the California Air Resources (ARB) adopted a definition for large confined animal facilities. The local air pollution districts, which are responsible for permitting sources of air pollution, are required to permit CAFs and adopt a rule requiring an emissions mitigation plan. Dairies and other livestock facilities are now subject to emission control requirements that will help to achieve public health-based state and federal ambient air quality standards. Additional information regarding the implementation of SB 700 related to livestock can be found on the ARB's website: http://www.arb.ca.gov/ag/sb700/sb700.htm

Cattle and poultry operations are the main types of CAFs in California. Existing estimates show that dairies are a significant source of VOCs in the San Joaquin Valley. Dairies are also the largest source of NH_3 emissions in California. In addition to VOCs, NH_3 and PM emissions, dairies also emit greenhouse gases including methane (CH_4), carbon dioxide (CO_2), and nitrous oxide (N_2O). On June 1, 2005, Governor Schwarzenegger established aggressive greenhouse gas emission reduction targets for California, to be achieved by years 2010, 2020, and 2050. To meet the targets, the Governor directed the Secretary of the California Environmental Protection Agency to lead a Climate Action Team comprised of representatives from various state agencies to develop and implement global warming emission reduction strategies and report biannually on the progress made toward meeting the statewide targets.

1.3.2 Regulatory Issues for Water Quality

In March 2003, pursuant to the Federal Water Pollution Control Act, the USEPA promulgated National Pollutant Discharge Elimination System (NPDES) permit regulations and effluent limitation guidelines for concentrated animal feeding operations (CAFOs). The regulations are commonly cited as the "CAFO Rule" and were challenged by industry and environmental groups. On 28 February 2005, the United States Second Circuit Court of Appeals issued a judgment on the challenges. The judgment states that only CAFOs that discharge to surface water need an NPDES permit and that the permit must include a Nutrient Management Plan (NMP) prepared for the facility in accordance with the CAFO Rule. Only a small percentage of dairies in the San Joaquin Valley discharge to surface water; consequently, NPDES permits will be issued to relatively few dairies in California. However, it is expected that some of those dairies will not be able to comply with their NMP unless they reduce the rate of nitrogen application to cropland at the facility. Therefore, dairy operators are expected to be interested in waste management technologies described in this report that help prevent discharges to surface water and that reduce nitrogen levels in manure applied to cropland.

Since most dairies in the San Joaquin Valley will not be required to obtain an NPDES permit, it is expected that the Regional Water Boards will use Waste Discharge Requirement (WDR) orders to regulate waste discharges at dairies. The WDRs will apply to all dairies, not just facilities that meet the federal definition for a CAFO based on animal population (more than 700 mature cows). The WDR Orders are expected to require NMPs similar to those required in NPDES permits; however, it is unclear of the NMPs must be included in the WDR orders. In any event, dairy operators operating under WDRs will also be likely to need to reduce the rate of nitrogen application to cropland. Consequently, they will also be interested in new waste management technologies as noted above.

1.4 Goals

The goal of the Panel was to evaluate technologies that have a potential to improve the management and treatment of dairy manure in the San Joaquin Valley and to issue a report that includes:

- A list of technology providers with full contact information
- Descriptions of the technologies evaluated
- An assessment of the environmental and economic performance of each technology
- An assessment of the development status of each technology
- A discussion of knowledge gaps to help identify where additional research is needed
- An assessment of which types of technologies appear to hold the most promise for improving management and treatment of dairy manure in the San Joaquin Valley

The Panel does not endorse any particular company or technology.

1.5 Evaluation Process

To identify and evaluate suitable technologies, the Panel developed and distributed documents describing the Panel's intent and requesting that technology vendors submit appropriate information to the Panel. The documents were distributed widely by email in early February, 2005; at the International Agricultural Exposition held February 8-10, 2005 in Tulare, California; and at the BioCycle Conference held March 7, 2005, in San Francisco. They were also posted on the Panel's website (www.manureproducts.info) and the California Air Resources Board's (CARB) website (www.arb.ca.gov/ag/ag.htm). The Panel set the close of submissions at March 1, 2005 and established a goal of releasing the Panel's summary report in June, 2005. Due to the large volume of material received by the Panel, this date was then moved back to fall 2005.

The Panel met in-person at the CalEPA building in Sacramento on February 1, March 4, April 7, and May 3, 2005. The meetings were posted in advance on the CARB website and were open to the public.

Each technology submitted was assigned a primary and secondary evaluator. Panel members served as primary evaluator on 4 to 6 technologies, but were free to review all submissions. The Panel did not conduct field testing or request an independent verification of company claims. Panel members contacted researchers and users of some technologies to help evaluate each technology's performance.

1.6 Criteria for Evaluating Technologies

The Panel evaluated each technology for its potential to reduce environmental impacts resulting from air emissions and from releases of nutrients, salts, and pathogens to the environment. An initial step was to assess the potential of each technology at preventing – as opposed to only controlling - releases of contaminants. In addition, for each technology the Panel considered its efficacy in reducing environmental impacts, energy production if any, economic performance including saleable products produced by the technology, quality of supporting data, and the development status.

1.6.1 Pollution Prevention or Pollution Control

During the review process, the Panel made an effort to distinguish between pollution prevention and pollution control by defining pollution prevention as waste minimization, recovery, and clean technology, and pollution control as treatment and management of wastes to minimize the effect of the waste on the environment. True pollution prevention reduces the mass of contaminants that are produced, and do not just treat waste after it is generated. For dairies, a technology such as diet modification that reduces the amounts of certain constituents excreted in the manure is generally considered to be pollution prevention. However, the Panel also considered pollution prevention to include waste management technologies that reduce contaminants in emissions and residual wastes compared to conventional waste management practices.

When reviewing the technologies to assess the amounts of emissions and residual wastes they produce, the Panel considered what happens to all the constituents in the manure that was excreted, and did not focus on just the portion of the wastes treated by the technology. If prior to using the technology, or as a result of using the technology, waste constituents are transferred to another fraction of the waste (e.g., from the liquid fraction to a solid fraction), the technology was not considered to have prevented pollution in the treated material. Likewise, if using the technology releases a waste constituent into the atmosphere and the constituent is an air contaminant, then the technology did not prevent pollution even though the amount of the constituent in the original manure was reduced.

Many technology vendors claimed that use of their technology was pollution prevention. However, unless the vendor supplied data that clearly showed that using their technology reduced the mass of a waste constituent prior to the manure being collected and treated, the Panel did not concur that the technology prevented pollution.

1.6.2 Reducing Environmental Impacts

Manure management practices currently utilized by most dairies in California do not adequately protect air, soil, and water from being degraded. Air impacts from dairies are of high concern in California because the San Joaquin Valley has a large number of dairy cows that are believed to contribute to air pollution. Impacts to groundwater are also a concern because of the high density of dairies in certain areas and the continued fertilization of crop land with manure, often at rates greater than what the crop can utilize. The following subsections provide additional information on environmental impacts.

Air Pollutants

The San Joaquin Valley does not meet federal Clean Air Act's National Ambient Air Quality Standards for particulate matter and ozone. Dairies are sources of ammonia (pre-cursor to formation of fine particulate matter) and volatile organic compounds (precursors to formation of both particulate matter and ground-level ozone). Dairies are also sources of methane and nitrous oxide (global warming gases). The dairy industry, crop producers, the environment, and public health will all benefit from implementation of manure management technologies that reduce emissions of these air pollutants.

Nutrients

Nitrogen and phosphorus from dairies have the potential to adversely impact surface water, and nitrates can also impact groundwater. Manure management technologies are needed that will reduce the quantity of nutrients produced at a dairy, prevent off-property releases of nutrients, and/or allow nutrients to be exported from the dairy.

Salts

Salts are a concern primarily because they can leach to groundwater under dairy facilities and cropland where manure is applied. When manure is separated into liquid and solid fractions, most of the nutrients and salts remain in the liquid portion. Although some technologies used to treat manure can produce a solid organic fraction with relatively low salt levels, most technologies have no effect on the total quantity of salts in the various manure fractions. The few technologies that can isolate salts for disposal or reuse usually have high initial and operating costs.

Other Impacts

Other impacts from dairy manure include odors and pathogens. Odors are addressed separately from other air emissions. Pathogens are a concern if manure enters surface water, and in certain circumstances can be a concern for groundwater. In addition, pathogens are a concern if manure solids are sold for use off site where humans may be exposed. Treatment technologies that specifically address odors and pathogens or do so in conjunction with another focus were considered during the review process.

1.6.3 Generating Energy

Some technologies for managing dairy manure produce energy which can be used at the dairy or elsewhere. Methane gas produced by anaerobic digestion can be used to produce heat or to power an electric generator. With sophisticated additional treatment, the methane also can be purified and used to produce a compressed gas or liquefied gas fuel. Direct combustion of manure can also produce heat that can be used for waste treatment or power production. If electricity is produced, any excess not utilized at the dairy may be sold to offset the costs of manure treatment or to produce income. Power generation for distribution has the additional benefit of reducing California's dependence on conventional energy sources. However, interconnection to the electric grid remains challenging for many dairies, and the price at which dairies sell electricity is often much lower than the retail price at which they purchase it.

1.6.4 Economic Performance

The Panel requested information on the cost of each technology, including construction, operation and maintenance. Where possible, the Panel sought to evaluate costs in a manner that allowed comparison between technologies. The Panel sought to understand how products such as energy, fertilizer, and compost could generate income to offset the cost of manure management and treatment. The Panel also was interested in how the cost of the alternative technologies compared with conventional waste management practices. Conventional waste management practices are those commonly utilized on dairies in California today.

1.6.5 Quality of Supporting Data

The Panel evaluated the sources and quality of the data submitted on each technology. In all cases, the Panel evaluated data submitted by the companies that provide the technology. In addition, where possible and appropriate, the Panel utilized performance evaluations in the academic literature, or at government agencies. The Panel also considered whether the technology is well-known in the engineering world, even if it has not yet been applied to dairy manure in California.

1.6.6 Development Status of the Technology

The Panel asked the technology vendors to provide information on the development status of their technology. The Panel reviewed the information supplied and then classified the technology as belonging in one of the following groups:

- Research (basic research and applied research)
- Development (concept development and prototype development)
- Test and evaluation (product/process development)
- Demonstration (full or field relevant scale)
- Commercial application

A summary of the Panel's assessments of the development status of the technologies is presented in Section 2.2. Detailed assessments of each technology are presented in Appendix 1.

2 Technology Assessments

2.1 Assessment Results

The Panel received 44 submissions for review. A few vendors submitted more than one product, some products were used by more than one vendor, and some of the submissions were treatment packages that utilized two or more products or technologies in series. Most of the technologies submitted came from the United States, but submissions also were received from Israel, South Africa, Korea, and Australia. An additional 25 submissions were received after the March 1 deadline; the Panel did not examine these submissions but has them filed for a possible second round of assessments.

The Panel grouped the manure treatment technologies into 10 categories (see Table 1 for details):

- thermal conversion (combustion, gasification and pyrolysis)
- solid-liquid separation and filtration
- composting
- anaerobic digestion
- aerators/mixers
- nitrification/denitrification
- covers for lagoons, manure storage, and compost piles
- microbial cultures, enzymes, and other additives
- feed management
- miscellaneous

Table 2 presents the apparent focus and apparent effectiveness of the different technological approaches. The benefits and challenges of each approach in terms of both environmental and economic performance are discussed in Section 2.2. Each of the 44 submissions is individually assessed in Appendix 1. The Panel noted that certain technologies are focused on only portions of the wastes produced at a dairy and that the effectiveness of the technologies, as indicated by the information submitted, varies greatly. Appendix 2 is an alphabetical list of company contact information and includes vendors whose products were assessed by the Panel, as well as some that were known to the Panel but not assessed.

Table 1. Components of Technologies Submitted to the Panel for Review

Company	Technology	Thermal conversion, (combustion, gasification and pyrolysis)	Solid--liquid separation and filtration	Composting	Anaerobic digestion	Aerators / mixers	Nitrification / Denitrification	Covers for lagoons and compost piles	Microbials, enzymes, & other additives	Feed management	Miscellaneous
Advanced Concept Technologies LLC	Ethanol from PSRG & Catalytic Reduction	X									
Agricultural Modeling & Training	AMTS.Cattle									X	
Agricultural Waste Solutions, Inc.	Manure to Energy & By-products	X	X				X				
Agrimass Enviro-Energy	Biological Remediation				X	X			X		
Agrimass Enviro-Energy, Inc.	Induced Blanket Reactor				X						
AgSmart, Inc.	The O_2 Solution™					X			X		
Agriventures	Vermi-composting			X							
Air Diffusion Systems	AMTS					X					
Bakersfield, City of;	WoodChips			X							
Baleen Filters	Baleen		X								
Baumgartner Environics, Inc.	Bio-Cap ML							X			
Baumgartner Environics, Inc.	Bio-Curtain™ & ESP Mgt.										X
Baumgartner Environics, Inc.	NDN Mgt. System					X	X	X			
Bencyn West, Inc.	OrTec Biocatalyst								X		
Bigadan	Anaerobic Digestion				X						
Bion Dairy Corp.	Bion		X	X			X				
CH_2M Hill, Inc.	C:N Composting Systems			X							
Coaltec Energy USA	Gasification	X									
Engineered Compost Systems	ASP Composting System			X							
Everstech Consulting & LLC	Everstech ET ™		X		X				X		
FlexEnergy	Flex-Microturbine	X									
Greenfinch Ltd.	Biogas Technology				X						
Haskell Edwards	Water Reclamation Sys.						X				
Hydrolve	Tempest Drying System		X								
ILS-Partners, Inc	Pyromex Gasification	X									
Integrated Separations Solutions	Separators		X								
Jeesung Livestock Engineering Co. Ltd.	JS-2000 Organic Waste Composting Unit		X	X		X					
Kyte Centrifuge	Manure Separator		X								
Lanstar	Carbonisation	X									
Midwestern Bio-Ag Products & Services, Inc.	HumaCal™								X		
Natural Aeration Inc.	CIRCUL8 Systems					X					
Nutrient Control Systems, Inc.	Integrity Nutrient Control		X	X		X				X	
Octaform	Octaform PVC-lined concrete tanks										X
Omnifuel Technologies, Inc.	Rapid Pyrolysis	X									
Organic Waste Management	Wet Composting			X							
Primenergy, LLC	Solids Gasification & Energy	X									
Pro-Act Microbial, Inc.	Pro-Act Microbial Manure Munching Microbes					X			X		
Renewbale Energy Works	Anaerobic Digestion, Biogas Power, Fiber Conditioning			X	X						
Sharp Energy	Anaerobic Digester Lagoons				X						
Sprecher Architects	Solar Drying		X								
Tennessee Valley Authority	ReCiprocating Wetlands ™		X				X				
Waste Technology Transfer, Inc.	Waste Technology Transfer	X									
Western Milling	Aeration & Wet Combustion					X					
Wildcat Manufacturing Co., Inc.	Windrow Composting			X							

Table 2. Expected Effects of Different Types of Manure Treatment Technologies

Type of Technology	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 VOC Emissions	Reduces Methane Emissions	Reduces H_2S Emissions	Reduces Particulate Emissions	Reduces Odors	Produces Carbon Monoxide Emissions	Produces NOx Emissions
Gasification (raw manure or manure solids)																				
For direct combustion	?	?	?	?	N	?	?	?	N	Y	Y	Y	Y	?	Y	Y	?	Y	?	?
With ethanol production	?	?	?	?	N	?	?	?	N	Y	Y	Y	Y	?	Y	Y	?	Y	?	?
Solids Separation for Wastewater																				
Gravity or mechanical	1	2	1	N	N	N							N	N	N	N	N	N		
Chemical precipitation	1	2	Y	N	N	N							N	N	N	N	N	N		
Composting																				
Unaerated Static Pile							N	?	N	Y	Y	Y	N	N	N	N	N	Y		
Aerated Static Pile							N	Y	N	Y	Y	Y	9	9	9	9	9	Y	4	4
Windrows							N	Y	N	Y	Y	Y	N	N	N	?	8	Y	?	?
In-vessel							N	Y	N	Y	Y	Y	9	9	9	9	9	9	4	4
Anaerobic Digestion in Open Ponds																				
	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	3	N	N	Y	N	N	N	?	N	Y	Y	N	Y	Y	Y	Y	N	Y	?	?
Enhanced Mixing of Anaerobic / Facultive Pond																				
Mechanical stirring	N	N	N	Y	N	?							?	?	?	?	?	?	4	4
Air bubblers	N	N	N	Y	N	?							?	?	?	?	?	?	4	4
Aerobic Digestion																				
Stand Alone	Y	Y	N	Y	N	Y							Y	6	6	6	N	N	7	7
With subsequent treatment	Y	Y	Y	Y	5	Y							Y	6	6	6	N	N	7	7
Nitrification-Denitrification																				
	Y	Y	N	?	N	Y							Y	Y	?	?	N	?	7	7
Constructed Wetlands																				
	10	Y	N	N	N	11							Y	Y	Y	Y	Y	Y	7	7
Storage Covers for Wastewater Ponds																				
Bank-to-bank (complete)													Y	Y	Y	Y	N	Y		
Floating (partial)													?	?	?	?	N	?		
Biological Additives for Wastewater Ponds																				
Floating (partial)	3	N	N	Y	N	N							?	?	?	?	N	?		
Desalination (requires pretreatment to reduce particle size)																				
Reverse Osmosis	Y	Y	Y		Y	N							?	?	?	?	N	Y	4	4

Legend

Y = yes N = no ? = unknown

1. Transfers some of the pollutant to the manure solids
2. Releases some of the pollutant to the air
3. May convert some organic-nitrogen to ammonia
4. Minimal effect, if any
5. Reverse osmosis can remove total dissolved solids from wastewater, but resulting brine needs disposal
6. Will increase emissions
7. If diesel motors are used they may produce emissions
8. May increase emissions of particulates
9. Emissions can be reduced through air capture and treatment
10. If wetland plants are harvested
11. Nitrate is available for plant uptake

2.2 Classification of Technologies for Treating Manure

The following subsections provide information on ten categories of treatment technologies that the Panel identified. The following type of information is presented in these subsections:

- Description of how the technology works, including major variations
- Benefits and challenges of the technology
- Implementation status
- Perspective on how the technology applies to California dairies
- Products received and reviewed by the Panel
- Literature cited and references for more information

2.3 Thermal Conversion (including Combustion and Gasification)

2.3.1 Description

Technologies that burn waste to produce energy or treat waste to produce fuels are classified as "thermal conversion" and include direct combustion (burning with excess air to produce heat), pyrolysis (thermal treatment in the absence of air, resulting in the production of pyrolysis oil and a low BTU gas), gasification (thermal treatment at higher temperatures in an oxygen-restricted environment to produce a low to medium BTU gas), and hydrothermal liquefaction (thermal conversion of solids in a liquid stream to oils and char for separation and use as a fuel). Technologies that use an anaerobic digester to produce methane gas are not included here but are discussed in section 2.6. The fuels that are products of pyrolysis and gasification can be used in boilers and engines.

Most of the thermal conversion technologies are not suitable for raw dairy manure because of the high energy cost to dry the manure to acceptable moisture levels. Dairy manure as excreted is 10 to 12% solids; to evaporate the water takes at least two times the energy content of the remaining solids. The problem is worse for flush dairies, since the manure is diluted with water to less than 2% solids. Some 80% of dairies in the San Joaquin Valley use flush systems to clean the stalls. Therefore, this technology may be appropriate only for manure solids that have been separated from the liquid fraction, or solids from the open-lot areas that have reduced moisture content from open air drying. Hydrothermal liquefaction may be applicable to raw manure but was not evaluated here.

2.3.2 Benefits and Challenges of Thermal Conversion

Thermal conversion offers the potential to substitute dairy manure for fossil fuels; stimulate the local economy; reduce the amount of nutrients from manure that have to be managed by land application; and reduce or eliminate pathogens and odors associated with manure solids. The ash byproduct produced in these processes concentrates the phosphorus and salts so that they can be appropriately disposed or utilized for industrial processes, road fill, or other uses.

Thermal conversion technologies have the potential to create air emissions, and these emissions must be addressed. It is feasible to control emissions of pollutants from gasification and combustion systems with various techniques, but these add expense and complexity to the system. Ultimately, these controls make it difficult to apply this technology on a farm scale and will increase the cost of centralized plants. Other challenges exist related to variability in manure quality, the need for a large consistent supply of feedstock manure, the low fuel-density and flame-temperature of manure compared to coal, and the high capital and operating costs.

Cost estimates for these technologies vary widely and do not always include the costs of pretreatment, drying and fuel preparation, or post-treatment, gas cleanup, electrical generation, and emissions controls. In general, it appears the value of the heat and energy alone does not provide sufficient financial incentive for a thermal conversion facility. Additional income streams that might make the technology more economically appealing do not currently exist but could include a combination of tipping fees collected for accepting manure solids, renewable power production tax incentives, and the recovery of value from the ash. There may also be a cost associated with properly disposing of the ash.

2.3.3 Implementation Status and Application to California Dairies

Thermal conversion has been utilized commercially with many organic materials, and there is a base of knowledge for thermal conversion of dry organic fuels that should be applicable to dry dairy manure. However, there are few examples of thermal conversion systems that can use high moisture materials similar to dairy manure, and the Panel is not aware of any commercial thermal conversion facility that utilizes dairy manure. The University of Southern Illinois has a commercial-scale gasification plant that is available to test dairy manure solids and testing with dry poultry and feedlot manure has occurred at some commercial and pilot facilities. A thermal conversion system in Germany that uses sewage sludge and includes moisture removal may be the most similar to processing separated solids from dairy waste. In the San Joaquin Valley, it appears the technology would be most appropriate for a centralized facility with professional operating staff, emissions controls, and sufficient fuel supply.

2.3.4 Technologies Received and Reviewed by the Panel that Include Thermal Conversion

Nine applications were received from technology providers with complete thermal conversion systems or elements related to thermal conversion. Please refer to the following applications and reviews for further information about specific approaches:

Vendor	**Technology**
Advanced Concept Technologies, LLC	Ethanol from PSRG & Catalytic Reduction
Agricultural Waste Solutions, Inc	Manure to Energy & By-products
Coaltech USA	Gasification
FlexEnergy	Flex-Microturbine
ILS-Partners, Inc	Pyromex Gasification
Lanstar	Carbonisation
Omnifuel Technologies, Inc.	Rapid Pyrolysis
Primenergy, L.L.C.	Solids Gasification & Energy Production
Waste Technology Transfer, Inc.	Waste Technology Transfer (bio crude oil)

2.3.5 References

1. Beatty G. and H. Zygmunt, eds. 2005. "Alternative Technologies/Uses for Manure (draft)." United States Environmental Protection Agency, Office of Wastewater Management. Washington, DC. 35 pp. http://www.epa.gov/npdes/pubs/cafo_report.pdf
2. Biomass Technology Group, Europe: http://www.btgworld.com/technologies/gasification.html
3. Hughes, K. and A.C. Wilkie, editors. 2005. Cost-effective and Environmentally Beneficial Dairy Manure Management Practices. National Dairy Environmental Stewardship Council. Sustainable Conservation, San Francisco. 28 pp. http://www.suscon.org/dairies/pdfs/COST%20EFFECTIVE%20AND%20ENVIRONMENTALLY.pdf
4. US Department of Energy, Biomass Program http://www.eere.energy.gov/biomass/thermochemical_platform.html
5. US Department of Energy, Research and Development Reports: http://www.osti.gov/bridge/

2.4 Solid-Liquid Separation (including Dehydration)

Solid-liquid separation removes organic and inorganic matter from dairy manure which is primarily liquid. Objectives for removing solids include removal of nutrients for transport off-site, removal of larger particles to make liquid transfer more efficient, and removal of organic material to reduce volatile emissions. The remaining liquids should have fewer solids that are smaller and less likely to settle. Separation efficiency depends on the particles size distribution in the influent, the characteristics of the treatment technology, and the treatment time.

2.4.1 Description

Separation devices can utilize gravity flow, have few moving parts, and require little management effort, or they can utilize pumps and motors and require intensive management. Mechanical separators include: stationary inclined screen; vibrating screen; rotating flighted cylinder; rotating cone; piston; liquid cyclone; and roller, belt, screw, or filter presses (Reference 1). Gravity separators include settling basins, ponds, and weeping walls. Verley and Miner (Reference 2) identified three parameters that are important for improving solids removal by settling basins: 1) turbulence of the fluid in the settling basin, 2) the settling velocities of the solids being separated; and 3) the detention time of the fluid in each basin.

A standard practice on California dairies includes the reuse of wastewater for flushing animal housing. Flushes use 1,500 to 2,200 gallons per minute of recycled wastewater (i.e., “flush water”). If the flush water is initially collected and stored in a relatively small sump, it will then flow through separation devices at a high volume, thereby minimizing the separation efficiency. If greater interim storage is available and flow rate is reduced, separation efficiency should be enhanced.

The efficiency of separation varies tremendously depending on bedding source and quantity, facility design, and daily parlor water additions. Also, initial facility design and operation can improve separation performance.

Separation efficiency generally decreases during the spring and fall periods when changes in biological activity in the ponds result in increased concentrations of organic material in flush water making separation more difficult. Solids at 85% moisture can “stack” well and allow efficient separation that produces an effluent with low levels of solids. Solids with less than 83% moisture do not stack well and are not separated sufficiently. This non-stackable material results in high amounts of runoff and mess.

Solids are at their largest particle size when excreted from the animal. Any treatment (e.g., storage in an anaerobic pond), will reduce particle size, making it more difficult to remove the particles. Chemical precipitants have been used with other types of waste to precipitate or flocculate specific solids to enhance their removal. Some of these chemical reactions are reversible while others are essentially irreversible. Precipitation or flocculation in a treatment cell where the material can be harvested is beneficial. It is generally not beneficial to have material precipitate or flocculate in a storage lagoon because there is no mechanism to harvest the material.

2.4.2 Benefits and Challenges of Solid-Liquid Separation

- Solid-liquid separation removes large fiber and/or dense particles from flush water. This will:
  - Reduce pumping costs
  - Reduce costs associated with plugged pipes
  - Provide flexibility if a dairy needs to move nutrients within or off the dairy
  - Provide a more uniform distribution of solids in flood or furrow irrigated fields.
- Solid liquid separation may separate out nutrients, which helps isolate nutrients for export.
- During restricted periods in the spring when ponds become more biologically active, "slime" sometimes develops, especially if the dairy is recycling pond water, and can interfere with the efficiency of separation.
- A large concrete slab is needed for storage of solids and to allow for additional dewatering that may occur.
- Additional separation technologies (micro screen) results in more pumping and infrastructure to remove a small fraction of solids.
- The solids from the separator require management (labor and equipment) on a regular basis (daily, weekly, monthly). If separation is done by basins or ponds, solids are managed less frequently, typically 2 or 4 times per year.

They key issue on separation efficiency is particle size and quantity of bedding used for the cow housing area.

2.4.3 Implementation Status

Separators of varying types are found on almost all California dairies. The various separation devices have different infrastructure needs and fixed costs associated with installation. They also differ in maintenance costs well as the ongoing resources needed to collect and manage separated solids. Site-specific parameters will determine what type(s) of separators may be used and the separator location. As parameters change over time, the facility operator should reevaluate separation options and make changes as needed to optimize performance.

2.4.4 Lessons/perspectives on How Solid Separation Applies to California Dairies

Installation cost, maintenance cost, labor costs, and management goals are important parameters that must be considered when selecting a separation technology. Few individuals identify the purpose of installing a separator resulting in a history of failed installations (Reference 3). If the objective is to remove the largest particles any of the standard separation techniques will work. If the objective is to remove large amounts of nutrients for relocation off the facility, current technologies are unable to deliver.

2.4.5 Technologies Received and Reviewed by the Panel that Include Solid Separation

Vendor	**Technology**
Baleen Filters	Baleen
Hydrolve	Tempest Drying System
Integrated Separations Solutions	Separators
Kyte Centrifuge Sales & Consulting	Manure Separator
Sprecher Architects	Solar Drying

2.4.6 References

1. Moore, J. 1989. "Dairy Manure Solid Separation." In: Proceedings from the Dairy Manure Management Symposium, Syracuse, NY. February 22-24. NRAES 31. Northeast Regional Agricultural Engineering Service. Pp.178-192.
2. Verley, W.E. and J.R. Miner. 1974. A Rotating Flighted Cylinder to Separate Manure Solids from Water. *Transactions of ASAE* 17:518-520.
3. Morse Meyer, D., I. Garnett, and J.C. Guthrie. 1997. A Survey of Dairy Manure Management Practices in California. *J. Dairy Sci*. 80:1841-1845.

2.5 Composting

2.5.1 Description

Composting is the aerobic decomposition of organic material by microorganisms under controlled conditions. During composting, microorganisms consume oxygen while breaking the chemical bonds of organic material to obtain energy for growth. In this process, the amount of humus increases, the C:N ratio decreases, pH neutralizes, and the exchange capacity of the material increases.

Composting generates considerable heat and releases large quantities of CO_2 and water vapor into the air. Losses of CO_2 and water can amount to half the weight of the initial materials, and composting significantly reduces both the volume and mass of the starting material. During composting, nitrogen gas and ammonia may also be released to the air. Nevertheless, most nutrients in the starting material remain in the compost as humus and within the bodies of living and dead microorganisms. The final product has a low rate of microbial activity (Reference 1).

Essential factors for composting include aeration, nutrients, C:N ratio, moisture, pile structure, pH, temperature, and time. Aeration provides the large amount of oxygen needed for composting and removes heat, water vapor and other gases from within the composting materials. The required rate of aeration for heat removal can be ten times greater than that for supplying oxygen (Reference 1). The primary nutrients required by the microorganisms involved in composting are carbon, nitrogen, phosphorus, and potassium. An optimal carbon to nitrogen (C:N) ratio will prevent nitrogen loss and ensure rapid composting. A C:N ratio of around 30:1 usually ensures that the other required nutrients are present in adequate amounts. Water is necessary to support the metabolic processes of the microbes and also provides the medium for chemical reactions, transports nutrients, and allows the microorganisms to move throughout the composting material.

Pile structure is a factor of the porosity, structure, and texture physical properties of the starting material. Pile structure affects the composting process by influencing aeration. The composting process is relatively insensitive to pH, within the range commonly found in mixtures of organic materials, largely because of the broad spectrum of microorganisms involved. Composting occurs within two ranges –mesophilic (50 -105° F) and thermophilic (over 105° F). The length of time required to transform manure into compost depends upon many factors including the temperature, moisture, frequency of aeration, and user requirements for the finished compost.

Microorganisms can be classified by the temperature ranges in which they thrive. The major groups of microorganisms that participate in composting are bacteria, fungi, and actinomycetes. Bacteria are small, simple organisms that exist in a wide variety of forms and environmental conditions. In composting, they are the most numerous of the three groups of microorganisms and are generally faster decomposers than other microbes. Bacteria tend to flourish in the early stages of composting, before the easily degraded materials are consumed.

Fungi are larger organisms. Many fungi form networks of individual cells in strands or filaments. They are more tolerant of low-moisture and low-pH conditions than bacteria but are less tolerant of low-oxygen environments. Actinomycetes form filaments like fungi; but because of their small size and cell structure, they are technically classified as bacteria. They tend to become more pronounced after the easily degraded compounds are gone and when moisture levels are low.

There are many types of composting systems from static piles to turned windrows to positive aerated-static-piles to negative aerated-static-piles to enclosed facilities with biofilters and scrubbers, each with their inherent attributes. In general these composting processes are increasingly more expensive to operate but provide greater composting efficiencies and/or environmental protections.

2.5.2 Benefits and Challenges of Composting Dairy Manure

Composting dairy manure reduces odors, kills pathogens, and stabilizes the manure for easier handling. Composted dairy manure can be used as bedding material for dairy cows. Compost or co-compost (compost made from manure and municipal green material) is a value-added soil amendment that can be a source of income. When used as a soil amendment , compost may suppress pests including plant diseases (Reference 2).

While the nitrogen in compost is not as readily available as the nitrogen in fresh manure, the availability of potassium, phosphorus, and micronutrients from compost is similar-to, or higher-than, that from fresh manure. Compost can be applied more uniformly and with better control than manure and can also be stored and applied when convenient. If compost is moved off the dairy site, it removes excess nutrients from the facility.

California on-farm and co-composting regulations do not pose a barrier for dairy farmers. A dairy in California that sells or gives away less than 1,000 cubic yards of compost annually made exclusively from on-farm materials is not subject to the California Integrated Waste Management Board's (CIWMB's) permitting requirements. Dairies that sell or give away more than 1,000 cubic yards of such compost must notify the local enforcement agency that regulates waste disposal activities, but no permit is required. However, the State's minimum standards and annual inspections apply as described in the California Code of Regulations, Title 14, Section 17856.

CIWMB regulations allow a considerable amount of municipal green material to be brought on the dairy for composting. If less than 1,000 cubic yards of compost is sold or given away, there is no limit on the amount of municipal green material that is used. If the 1,000 cubic yards limit is exceeded, the dairy can compost up to 12,500 cubic yards of green material on-site at any one time. Under both of these scenarios, the dairy would be required to notify the local enforcement agency and comply with the State's minimum standards and annual inspections.

Composting dairy manure does pose challenges. Composting manure generally requires dewatering (solids separation) as a pre-treatment, which means that a significant portion of the nutrients and salts do not enter the composting process and must be managed separately. Composting transforms nutrients in manure, but does not remove phosphorus or all the nitrogen present in the manure. Other disadvantages of composting include potential odors during composting, significant land requirement for composting activities, costs for protecting compost piles from rainfall and managing runoff, expense of equipment and labor, long processing times, and the need to develop a successful marketing plan for compost.

Composting emits ammonia and volatile organic compounds (VOCs); therefore, emissions from the composting area may need to be controlled. Dairy manure composted in open windrows will emit less ammonia and VOCs compared to manure that is naturally degraded. Biofilters can be incorporated into the compost process and can reduce emissions of ammonia and VOCs by 90 to 95 percent (Reference 8). Manure composted in an uncovered negative-aerated static pile, where variable speed blowers maintain a continual negative pressure on the compost pile and discharge the air for secondary treatment in a biofilter, can also achieve a high emission reduction. However, composting using negative aerated static pile with a biofilter will require more labor and energy inputs. Also, the biofilter must be maintained for optimal efficiency.

2.5.3 Cost of Composting Dairy Manure

The direct cost to the dairy operator of composting dairy manure will be greater than the cost of directly applying manure to land, or hauling the manure off-site. Composting on a dairy requires equipment, labor, and management. An on-farm composting system could easily exceed $100,000, depending on the equipment purchased. A large, enclosed, aerated static pile (ASP) composting system with a biofilter could cost several million dollars.

Depending on the composting system utilized, composting may still be one of the lower-cost manure management technologies available. To improve the economics of a compost operation, a "tip fee" could be generated by bringing municipal green material and/or manure from other dairies on-farm for composting. However, concerns about the ability of the market to absorb large increases of commercially-produced compost from dairy manure are well founded. Because of the increasing cost of transportation, the typical maximum practical haul-zone for compost is about 50 miles.

In California, 170 green-waste compost and processing facilities processed 10 million tons of material in 2003 and produced more than 18 million cubic yards of organic products (Reference 3). A composting operation located at two dairies in Tulare County annually sells between 80,000 to 100,000 tons of compost made from dairy manure and dairy wastewater. The operation pays $1.00 to $1.50 per ton for the manure, and the operator is able to sell his entire production each year to farmers located within 50 miles of the operation.

2.5.4 Implementation Status

Composting has been widely applied on farms as a form of manure management in California.

2.5.5 Lessons/perspectives on How Composting Applies to California Dairies

Composting is a management alternative that can reduce or prevent environmental impacts from storage and use of manure produced at dairies. Composting provides a method to capture nitrogen as organic nitrogen in the compost which can be exported rather than applying the nitrogen to cropland at the dairy facility. Although composting manure and selling it to markets outside of the dairy industry reduces nutrient loading, it also diverts desirable organic matter from cropland. A dairy should consider using some compost on cropland to maintain the soil-building benefits of organic material.

2.5.6 Summary

Composting dairy manure on-farm or at a regional facility may be part of the solution for reducing environmental impacts from dairy manure. Actual costs will depend on the composting method used and whether or not co-composting with green material can enhance the economics of the operation.

2.5.7 Applications Received and Reviewed by the Panel that Include Composting

Vendor	Technology
Agriventures	Vermi-composting
Bakersfield, City of; Solid Waste Div.	WoodChips
CH_2M Hill, Inc.	C:N Composting Systems
Engineered Compost Systems	ASP Composting System
Jeesung Livestock Engineering Co.Ltd.	JS-2000 Organic Waste Composting Unit
Nutrient Control Systems, Inc.	Integrity Nutrient Control System
Organic Waste Management	Wet Composting
Renewbale EnergyWorks	Anaerobic Digestion and Biogas Power Generation and Fiber Conditioning
Wildcat Manufacturing	Windrow Composting

2.5.8 References

1. *On-Farm Composting Handbook*, Natural Resource, Agriculture, and Engineering Services (NRAES) Cooperative Extension, Ithaca, NY, 1992.
2. *Economic and Environmental Manure Solutions*, Cornell University, Department of Biological and Environmental Engineering, Ithaca, NY. Web Page: http://www.bee.cornell.edu/extension/manure/composting.htm
3. *Second Assessment of California's Compost-and Mulch-Producing Infrastructure*, State of California, California Integrated Waste Management Board, May 2004. http://www.ciwmb.ca.gov/Publications/default.asp?pubid=1074
4. *Field Guide to on-Farm Composting*, Natural Resource, Agriculture, and Engineering Service (NRAES) Cooperative Extension, Ithaca, New York, 1999.
5. *Soil Biology Primer,* Soil and Water Conservation Society, USDA Natural Resources Conservation Service, 2000.
6. *Alternative Technologies/Uses for Manure,* U.S. EPA Office of Wastewater Management, 1999
7. *Understanding Alternative Technologies for Animal Waste Treatment*, Waterkeeper Alliance, 2005
8. South Coast Air Quality Management District, Technology Assessment for: Proposed Rule 1133: Emission reductions from composting and related operations, Appendix C – Biofilters in operation at composting facilities in the United States, March 22, 2002.

2.6 Anaerobic Digestion

2.6.1 Description

Anaerobic digestion is a natural biological process by which bacteria break down organic matter in an oxygen-free environment with moisture content of 85% or higher. The process produces "biogas," inorganic salts, and residual organic material. The biogas consists of CH_4, CO_2, and trace amount of other gases including hydrogen sulfide (H_2S). Biogas can be burned to produce heat or to power an electric generator. The amount of biogas produced and the percentage of residual organic matter depends on the duration of the anaerobic digestion process and factors such as temperature, moisture, nutrient content, and pH. The residual organic material can be used for animal bedding or as a soil amendment.

As discussed below, most dairies in California use to control odors during storage and as part of their system for using manure to fertilize cropland. Some dairies have also constructed systems to capture biogas and use it to produce heat and energy.

2.6.2 Using Anaerobic Digestion to Manage Manure

Most dairies in California store manure in ponds. The surface of the pond is exposed to the atmosphere and contains some dissolved oxygen. Oxygen content decreases rapidly with depth, and anaerobic digestion occurs in the lower level. Since the majority of the odoriferous materials are in the lower layer and the primary gaseous emissions are methane and carbon dioxide, which are odorless, these ponds generally produce fewer odors than some other storage methods for manure.

Because anaerobic digestion breaks large organic molecules into smaller molecules, facultative lagoons "break up" manure solids and make more of the nutrients in manure available for plants when the lagoon effluent is applied to cropland. The solid material that accumulates at the bottom of facultative lagoons over several years generally has relatively high levels of phosphorus and may need to be carefully managed to avoid excessive application of phosphorus on cropland. Proper construction and lining are necessary to prevent leaching, especially of nitrates, from lagoons to groundwater.

Facultative lagoons do not reduce the amount of inorganic salts in manure discharged to the lagoons. The inorganic salts, measured as total dissolved solids, are primarily in the liquid fraction and build up to high levels as a result of recirculating lagoon effluent for flushing of animal housing. There are a number of additives available that are claimed to reduce odors from facultative lagoons, enhance the break-up of solids, and improve animal health in housing flushed with lagoon effluent. Two of these additives were reviewed by the Panel.

2.6.3 Anaerobic Digesters for Biogas Production

Anaerobic digesters can be divided into two classifications depending on the temperature at which they operate. Mesophilic anaerobic digestion occurs at a temperature range of 20 to 40°C, and thermophilic anaerobic digestion occurs at 40 to 60°C. Mesophilic digestion is more common, but thermophilic digestion is faster and can therefore use a smaller digester. The types of anaerobic digesters include:

- Covered lagoon
- Plug-flow digester
- Completely-stirred tank reactor (CSTR)
- Upflow anaerobic sludge blanket (UASB), and
- Anaerobic sequencing batch reactor (ASBR).

The covered-lagoon, plug-flow digester, and CSTR are three types of digesters recognized by the USDA's Natural Resource Conservation Service (NRCS) in their national guidance. Covered lagoons are typically earthen impoundments fitted with a floating cover that contains the biogas that is produced. The cover is typically an impermeable industrial fabric that rests on solid floats laid on the surface of the lagoon. The cover can be placed over the entire lagoon or over the part that produces the most methane. Covered lagoons are best suited for organic wastes with 0.5 to 3% solids.

Capital costs for covered lagoons can be less than for plug-flow and CSTR digesters. Furthermore, compared to plug-flow and CSTR digesters, operation and maintenance of covered lagoons is simple and straightforward. Covered lagoons are generally not heated externally. Since digestion is dependent on temperature, biogas production varies seasonally (i.e., methane production is greater in summer than in winter). Average daily biogas production in summer can be 35% higher than in winter. The fluctuations in gas production may make end-use applications more problematic than with plug-flow and CSTR digesters.

The basic plug-flow digester design is a long linear trough, often built below grade, with an airtight expandable cover. Organic waste is added to one end of the trough, and each day a new "plug" of wastes is added, slowly pushing the material through the trough. Plug-flow digesters are usually operated at the mesophilic temperature range with a solids range of 11 to 13% and a HRT from 20 to 30 days.

The CSTR digester is typically a large circular container made of poured-concrete or steel. CSTR digesters can handle organic wastes with a solids range of 3 to 10%. CSTR digesters can be operated at either the mesophilic or thermophilic temperature range; the hydraulic retention time can be as low as 10 to 20 days at thermophilic temperatures.

2.6.4 Biogas to Energy

Four basic technologies for the utilization of biogas are listed below:

Generating Heat with Biogas

Biogas can be used directly in a number of ways as a medium-BTU gas. Typically, after condensate and particulate removal, the biogas is compressed, cooled, and then transported by pipeline to a nearby location for use in a burner or boiler. Natural-gas-burners require minor modifications to use biogas because of its lower heating value. When biogas is used to generate steam in a boiler, the steam must be used nearby since high-pressure-steel insulated pipe is expensive and heat is lost during transport.

Generating Electricity

Biogas can be used to generate electricity using a reciprocating engine, gas turbine, or steam turbine. Condensate and particulates must be removed from the biogas before use in an engine or gas turbine, and biogas must be compressed before use in a gas turbine. Using a steam turbine requires generating the steam first as described above. The Panel reviewed five technologies for using biogas in a reciprocating engine to generate electricity.

Microturbines can be used to generate electricity at a capacity as small as 30 kW. However, the technology for using biogas in microturbines has not been extensively commercialized because of the high cost for gas clean up and lower running times.

Injection into an Existing Natural Gas Pipeline

Biogas can be upgraded into high-BTU gas and injected into a natural gas pipeline. Because carbon dioxide and other impurities must be removed, the capital cost for pipeline-quality gas is high compared with other power-generation alternatives. Also, upgraded gas needs a significant amount of compression to conform to the pipelines pressure at the interconnect point. However, the advantage of pipeline quality gas technology is that all the biogas produced can be utilized. No technologies using gas pipelines were received by the Panel.

Conversion to Other Chemicals

It is possible to convert biogas to methanol, NH_3, or urea. Of these three options, conversion to methanol is the most economically feasible. In order to convert high CH_4 content gas to methanol, water vapor and CO_2 must be removed. In addition, the gas must be compressed under high pressure, reformed, and catalytically converted. This tends to be an expensive process, which results in about 67% loss of available energy. No technologies using biogas to produce other chemicals were received by the Panel.

2.6.5 Benefits and Challenges

Additives for facultative lagoons

Additives, typically microbes and enzymes, are sometimes used in facultative lagoons with the intention of enhancing microbial decomposition of organic matter, reducing odors, and enhancing methane production. The challenge is to obtain data that clearly show that the products are effective. Most of the products have only anecdotal evidence of their effectiveness.

Using biogas to generate electricity

The benefits to using anaerobic digestion to produce biogas and generate electricity include better control over air emissions from lagoons, reduction in the amount of electricity that must be purchased, and possibly income from sale of excess electricity. There are several challenges. The primary challenge is assessing the long-term reliability of the system and the associated operating and maintenance costs. There is also the high initial cost if there are no financial incentives such as were provided for recently-constructed systems funded by Senate Bill 5x and administrated by the California Energy Commission's Dairy Power Production Program through Western United Resource Development, Inc. Another challenge is dealing with the local electrical supplier if the intent is to connect the generator to the power grid so that excess electricity can be sold. An additional challenge is managing the effluent that is produced in a plug-flow or CSTR digester. The nitrogen and phosphorus content may be greater than in effluent from a facultative lagoon or a covered lagoon. This is a problem if there is limited cropland available for using the nutrients.

2.6.6 Implementation Status

Biogas from anaerobic digesters has been used to produce heat and power for decades. However, facilities constructed during the last several years are most likely to have better efficiency and reliability. There are approximately 70 biogas energy production facilities operating at animal feed operations in the United States, and many more overseas, especially in Denmark. Information on the systems operating in the United States and in California can be obtained from US EPA AgSTAR program, California Energy Commission's Dairy Power Production Program, and Western United Resource Development, Inc. (see References and Notes section below).

2.6.7 Lessons / Perspective on How Anaerobic Digestion Applies to California Dairies

With respect to additives for facultative lagoons, data provided by vendors generally do not meet scientific research standards. In particular, more data are needed to document mass balances and to demonsrate reductions in air emissions. Without adequate performance data it is difficult to equate the technology costs to the benefits.

With respect to technologies that utilize biogas to produce heat or electricity, the capital investment costs, initial setup costs, and ongoing operational costs need to be carefully reviewed relative to the expected life of the equipment and the benefits for implementing the technology. Particular emphasis should be given to claimed value of the organic material that is a byproduct of digester operations. Also, the expected composition of the digester effluent should be considered relative to the nutrient needs of available cropland. If the technology produces an effluent that has higher nutrient concentrations than expected from conventional facultative lagoons, additional cropland may be needed to utilize the extra nutrients. Since digesters do not affect inorganic salts, the need to manage salts in digester effluent must also be addressed.

2.6.8 Applications Received and Reviewed by the Panel that include Anaerobic Digesters

Some of the applications reviewed by the Panel included anaerobic digestion as part or all of the technology. Where anaerobic digestion is part of the technology and some other type of technology is used before or after anaerobic digestion, the technology vendor will appear in the listing below and also in the listing(s) for other technology (technologies).

<u>Additives for facultative lagoons:</u>

Vendor	**Technology**
Agrimass Enviro-Energy	Biological Remediation
Bencyn West, Inc. (dba BWI Solutions, Inc.)	OrTec Biocatalyst
Pro-Act Microbial, Inc	Pro-Act Microbial Manure Munching Microbes

<u>Digester systems using biogas to generate electricity:</u>

Vendor	**Technology**
Agrimass Enviro-Energy, Inc	Induced Blanket Reactor
Bigadan	Anaerobic Digestion
Everstech LLC	Everstech ET Process

Greenfinch Ltd.	Biogas Technology
Renewbale EnergyWorks	Anaerobic Digestion and Biogas Power Generation and Fiber Conditioning
Sharp Energy	Anaerobic Digester Lagoons

2.6.9 References and Notes

1. US EPA's AgSTAR program (http://www.epa.gov/agstar/) has information on digesters and power production. See especially "Documents, Tools and Resources" at http://www.epa.gov/agstar/resources.html. Contact for more information: Kurt Roos, telephone 202-343-9041; email: roos.kurt@epa.gov. The AgSTAR program is a voluntary effort jointly sponsored by USEPA, the United States Department of Agriculture, and Department of Energy. The program encourages the use of biogas technologies at animal feeding operations. AgSTAR holds conferences, publishes specifications and information on the performance for methane digesters operating in 16 states, and provides technical assistance to programs run by the states and other federal agencies.
2. "Understanding Alternative Technologies for Animal Waste Treatment - A Citizen's Guide to Manure Treatment Technologies" February 2005, published by Waterkeeper Alliance, Tarrytown, New York. (http://www.waterkeeper.org/mainarticledetails.aspx?articleid=174)
3. Sustainable Conservation has a map of digesters used for power production on dairies in California (http://www.suscon.org/dairies/pdfs/methanedigestersmap.pdf).
4. The California Energy Commission's Dairy Power Production Program (http://www.energy.ca.gov/pier/renewable/biomass/anaerobic_digestion/index.html) encourages development of biogas energy production projects on California dairies. The program has provided buy down grants and incentive payments to assist dairies in the design and construction of the biogas systems, and also provides technical assistance to dairies that installed biogas systems under the program.
5. Western United Resource Development Corporation, Inc. (http://www.wurdco.com/) is a non-profit organization formed to work with the California Energy Commission to implement biogas energy production projects on California dairies.

2.7 Aeration

2.7.1 Biology of Dairy Lagoons

Dairy wastewater lagoons are generally designed for storage and not for treatment, and therefore organic loading often exceeds treatment capacity. Influent 5-day Biological Oxygen Demand (BOD_5) concentrations in dairy wastewater lagoons can exceed 5,000 to 10,000 mg/L. Under these conditions, oxygen is depleted and the lagoons become anaerobic.

Anaerobic degradation of organics is a two-step process. In the first step, acidogenic bacteria convert organic materials to intermediate products such as organic acids, amino acids, aldehydes, mercaptans, alcohols, and other volatile compounds. In the second step, methanogenic bacteria convert the intermediate products to methane, carbon dioxide, hydrogen sulfide, ammonium, and water. Under certain temperatures, as may occur in late spring (Reference 1), acidogenic bacteria produced odiferous intermediate products at rates that exceed their transformation by the rate-limiting methanogenic process. In this circumstance, the odiferous compounds accumulate and are then emitted to the atmosphere where odor episodes may occur.

Dairy wastewater lagoons may also undergo anoxygenic photosynthesis by a host of bacteria that use reduced sulfur or organic compounds as electron donors and release an oxidized form of sulfur such as elemental sulfur or release sulfate and oxidized organic compounds. This process has the benefit of reducing the emissions of odiferous hydrogen sulfide. Among the bacteria that promote anoxygenic photosynthesis are the photoautotrophic purple sulfur bacteria. Lagoons with large populations of purple sulfur bacteria have a red tinge of varying hue depending on the purple sulfur bacteria densities. Reductions of odor, hydrogen sulfide and ammonia emissions have been documented in swine lagoons that were phototrophic as determined by red coloration (Reference 1). In another study, Chen et al. (Reference 2) found lower ammonia concentrations in lagoons containing purple sulfur bacteria.

There has been much interest and speculation on the role of purple sulfur bacteria in reducing odors and gaseous emissions form dairy lagoons. The conditions that support and promote purple sulfur bacteria propagation are unknown, and therefore it is difficult to artificially create the conditions to promote the propagation of purple sulfur bacteria. Recently, Chen et al. (Reference 2) found a correlation between oxygen reduction potentials in lagoons prior to spring algal blooms and the blooming of purple sulfur bacteria in the lagoon. Lagoons that had oxygen reduction potentials in the range of –16 to –57 millivolts (mV) had algal blooms, whereas those with lower oxygen reduction potentials did not. Generally, dairy wastewater lagoons have oxygen reduction potential in the order of –200 to –300 mV. They also found that salinity levels above 6 decisiemens per meter (dS/m) inhibited purple sulfur bacteria colonization.

2.7.2 Overview of Aeration Systems

Oxygen may be introduced into dairy lagoons to assist in the digestion and stabilization of organics and minerals and/or to reduce odors and, potentially, to reduce nitrogen. The products of aerobic digestion are carbon dioxide, water, nitrate and sulfate.

Aeration has been routinely utilized in the municipal wastewater industry. The engineering principles are well defined. The goal is to reduce the BOD and suspended solids to permit requirement levels for discharge to surface water. More recently, aeration is being used to convert ammonia to nitrate (nitrification) for subsequent denitrification to eliminate nitrogen from the wastewater (Reference 6). Generally 1.5 to 2.5 pounds of oxygen is required to digest 1 pound of BOD. Nitrification requires more oxygen, generally 5 pounds of oxygen per pound of ammonia.

Dairy wastewater may be treated in a similar fashion to municipal wastewater. Most dairies, however, have cropland available where some or all of their wastewater can be used for irrigation and fertilization. When properly managed, the soil system can treat and stabilize manure, thus eliminating the need for expensive aeration systems.

The Central Valley Regional Water Board recently found that food-processing wastewater at high organic loading can alter the redox and pH environment of soils, resulting in degradation of soil quality and of groundwater. These changes result in the mobilization of iron, manganese, calcium, magnesium, and in some cases, arsenic. Although the appropriate organic loading has not been developed or evaluated in relation to dairy wastewater management practices, aeration may be needed to reduce organic loading at some dairies.

The interest in aerating dairy lagoons in California has been primarily to provide an economical way to control odors (Reference 10). Various aeration strategies have been used in swine production for the control of noxious odors that may be applicable to controlling odors in dairy production. Such practices have included continuous and intermittent aeration, combination of aerobic and anaerobic reactors, mixed lagoons, and shallow surface aeration to form a bio-blanket (Reference 9). A "bio-blanket" works on the principle that a shallow aerated surface layer intercepts surface migrating odiferous gases, which are subsequently digested to innocuous products (Reference 14). Zhang et al., 1997 (Reference 11) found that continuous low-level aeration to maintain dissolved oxygen in the surface layer at 0.5 to 2.5 mg/L was effective at controlling odors. However, the aeration resulted in high ammonia volatilization. Potentially, less aggressive aeration could achieve odor control. Schulz and Barnes, as cited in Reference 10, note that effective odor control may be achieved by maintaining redox potential at greater than –76 mV E_h.

2.7.3 Aeration Design Considerations

Aeration of wastewater is accomplished by using submerged air diffusers to force air or pure oxygen into the wastewater, or by using mechanical means to disperse atmospheric air in the wastewater. The introduced air maintains solids in suspension and provides mixing that keeps solids in suspension within the area of influence of the aerators. Submerged diffusers are generally located on the bottom of the tank and produce air bubbles of varying diameters from fine (2 mm) to coarse [upper limits not provided]. There are three types of mechanical aerators: surface and submerged-turbine, and venturi aerators. In the first two types, air is introduced through agitation and, for submerged-turbine type, air or pure oxygen may be supplemented from the bottom of the lagoon. In the venturi type, air or oxygen is entrained into the wastewater, which is pumped through a pipe and later dispersed into the lagoon

Two parameters are used to evaluate the performance of aerators: 1) oxygen transfers rate (kg O_2/hr), and 2), the aeration efficiency (kg O_2/kW-hr). Oxygen transfer rate is the quantity of oxygen transferred to wastewater per unit of time per aerator. Oxygen transfer efficiency is also used for compressed air diffusion aerators, which is the quantity of oxygen transferred to wastewater per unit of air introduced by submerged diffusers. For fine-bubble diffusers, the efficiency varies between 10 and 30 percent, whereas for coarse-bubble diffusers, the efficiencies are only 4 to 8 percent. Aeration efficiencies for submerged or surface mechanical aerators range from 1 to 2 Kg O_2/kW-hr (Reference 10). Additional parameters that can be used to evaluate performance include the circulating efficiency, which is the volume of wastewater circulated per unit time, and the size of the area where the minimum velocity of the wastewater is 1 foot per second. At that velocity, the solids are maintained in suspension (Reference 7) and are the area of influence of the aerator.

In municipal wastewater systems, tank shape and dimensions are engineered to optimize aerator performance. Dairy lagoons do not provide the optimum characteristics to maximize aerator performance.

2.7.4 Benefits and Challenges

Two aeration schemes have been proposed for dairy lagoons: large scale and low level. These schemes are discussed below.

Large-scale Aeration

Large-scale aeration involves treatment of the entire wastewater stream to stabilize the wastewater and reduce the BOD as much as 95%, thereby eliminating odors and greatly reducing solids content and lagoon maintenance. The downside to this process is the partial conversion of nitrogen to nitrate, which may be more difficult to contain in the lagoon or manage for the fertilization of cropland. A larger obstacle is the high-energy costs. Consider a 1,000-cow dairy with an influent BOD of 5,000 ppm, and a daily water usage of 150 gallons per cow. This translates to a daily oxygen need of 5,700 Kg. Based on an assumed aerator efficiency of 1.5 Kg O_2/kW-hr, the daily power needs would be 3800 kW-hrs. At $0.10 per kW-hr, the costs appear to be prohibitive. Similarly, Zhang, 2005 (Reference 13) estimates a cost of $0.59/cow-day or $214/cow-year based on 2.4 pounds of oxygen per cow-day for complete removal of Biological Oxygen Demand (BOD_5) and 3 pounds of oxygen per cow-day for oxidation of 70% of the nitrogen.

Although stabilization of the entire wastewater stream at a dairy does not appear to be economically desirable, it may be a viable option if insufficient cropland is available to utilize all of the nitrogen that is produced. This problem may be acute at the regional level (Reference 3) and may become more apparent as nutrient management programs are implemented. Since the export of nutrients from a dairy may be limited by the use of liquid handling systems, high density of dairies in a region, and limited markets for manure solids, some treatment to remove nitrogen may be necessary.

Treatment of dairy wastewater to remove nitrogen presents an opportunity for a dairy producer to maintain stock levels without exceeding nitrogen assimilation capacity of his associated cropland. A two-step process of nitrification and denitrification can achieve nitrogen removal. For nitrification, a portion of the wastewater is aerated to oxidize organic N and ammonia to nitrite and nitrate. Nitrification is followed by denitrification, in which the nitrite and nitrate are converted to inert N_2 gas and returned to the atmosphere (which is already composed of 78% N_2 gas), thereby reducing the nitrogen remaining at the dairy facility. Denitrification could be accomplished by using the aerated wastewater for flushing and re-introducing it back into the lagoons, where reducing conditions would cause denitrification. This process removes the N fertilizer value of the manure, but may be desirable to a dairy operator whose only alternative for balancing nitrogen is to reduce herd size.

Low-level Aeration

Low-level aeration of dairy lagoons has recently been receiving considerable attention as a result of regulatory agency concerns about the emissions of reactive organic gases, odors, and ammonia (a PM_{10} precursor). A number of companies are marketing mechanical surface aerators in the Central Valley and claiming control of odors and gaseous emissions, solids reduction, and enhanced solids-separation performance. A variety of mechanism have been proposed to explain the claimed benefits including reduction in BOD and ammonia as a result of aeration, photochemical and biological degradation of the wastewater during circulation, and creation of environments favorable to Purple Sulfur Bacteria. Data to support these hypotheses have not been presented.

Likewise, the claimed benefits have not been supported by scientific data and have been largely testimonial. Basic aerator performance information has also not been developed. Not knowing the mechanisms by which the technology functions, nor having aerator performance information, calls into question how these systems are being designed.

Zhang et al., 2003 (Reference 12) conducted an evaluation of mechanical aerators at a 3,000 milking-cow dairy. In this study, two lagoons were bifurcated, one portion equipped with aerators and the other serving as the control. A total of 28 aerators were needed to treat half of the wastewater stream. Standard oxygen transfer rates and aeration efficiency were evaluated and found to be one-half to one-fourth of the performance generally observed for aerators used in the industrial and municipal wastewater industry. The performance of five aerators being marketed to dairies in the San Joaquin Valley had Standard Aeration Efficiencies ranging from 0.35 to 0.7 Kg/kW-hr (Reference 13). Recall that the performances of typical wastewater aerators are in the range of 1 to 2 Kg/kW-hr.

The aerated portion of the lagoons had a 20 to 40% reduction in odors, and reduced solids build-up relative to the control, but no reduction of the existing sludge layer was noted.

Rumberg et al. (Reference 8) also evaluated a mechanical surface aerator system at a 350-cow dairy. They found no change in ammonia before and after treatment and no measurable nitrate or Dissolved Oxygen before or after treatment. Those findings indicate that the aerator system did not change the oxygen status or enhanced the mineralization of organic nitrogen. They also found limited mixing; in fact, the operation of the aerators caused solids to build up around the aerators minimizing their effectiveness.

2.7.5 Implementation Status

No information is available regarding implementation of large-scale aeration on dairies in California. It is likely that is not being adopted due to the high-energy requirements and the high energy costs in California as well the fact that many dairies have sufficient cropland available for nutrient assimilation.

No statistical information is available on the adoption of low-level aeration; however, there are many vendors of this technology, and the technology is being actively being marketed.

Additionally, dairy producers are under public and regulatory pressure regarding air quality and nuisance issues that are motivating the adoption of this technology. As noted, mostly only testimonials and anecdotal information are available regarding the benefits.

2.7.6 Lessons/Perspectives on How Aeration Applies to California Dairies

Large-scale aeration of dairy wastewater is unlikely in California due to the high-energy costs and the available cropland to assimilate a large part or all of the nutrients generated at a dairy facility. There is, however, the potential to use aeration to treat a portion of the waste stream followed by denitrification. This process will allow a dairy producer to reduce the nitrogen load in situations where nutrients are being produced in excess of the available land to assimilate those nutrients and when other alternatives may not be available other than to reduce the herd size to achieve nutrient balance. This process could be made more economical by integrating other technologies such as anaerobic digestion and stabilization ponds. Anaerobic digestion could substantially reduce the BOD while capture of methane produced by anaerobic digestion could provide some of the needed energy. Aeration may become more widely used as nutrient management is implemented and land deficiencies for nutrient assimilation are revealed at the farm and regional level (Reference 3). However, aeration is unlikely to have much effect on salts and other nutrients. Researchers at the University of California Davis have developed a two-stage sequencing batch reactors system to treat dairy wastewater (Reference 5).

Low-level aeration has promise in reducing odors and some gaseous emissions from dairy lagoons. It also has the potential to reduce solids build up in ponds when used in conjunction with an effective solids separation system. Much work is needed with this technology to decipher the mechanisms at work so that system designs can be improved. Additionally, the impacts on ammonia emissions need to be studied further. Aeration mechanisms need to be developed that provide for gentle aeration without driving ammonia from the lagoon. The mixing performance of mechanical aerators needs to be evaluated further. Potentially, a benefit of this type of system is the mixing of the lagoon to assist in nutrient management and application. However, data obtained to date indicate that some commercial mechanical aerators evaluated provided incomplete mixing (Reference 8). For dairies that are mainly concerned with reduction of air emissions, surface aeration of lagoons could be an effective approach.

When evaluating aerators for their operations, dairy producers should consider performance information, including the Aeration Efficiencies, Standard Oxygen Transfer Rates, and any information regarding the area of mixing influence. This information should be evaluated in relation to known performance information for aerators with established performance histories, which are routinely used in the domestic and industrial wastewater treatment industry. A producer contemplating the implementation of this technology should carefully calculate the cost and benefits of implementing this strategy, as well as alternative means to achieve the same benefits.

Further, a producer should consider that much is unknown regarding the optimum operating parameters for such a system if the desired goal is odor and volatile gas emission reductions. Work with swine production showed a 90% reduction in odors in lagoons with a 30% reduction in BOD_5. Recent work suggests that a 70% reduction in BOD_5 may reduce selected volatile gas emissions by 70% (Reference 13). Additional research is needed on the sources and mechanisms of odor and gas emissions at dairies and optimum control strategies.

2.7.7 Technologies Received and Reviewed by the Panel that Include Aeration

Vendor	Technology
Agrimass Enviro-Energy	Biological Remediation
AgSmart, Inc.	The O2 Solution™
Air Diffusion Systems	AMTS
Natural Aeration Inc.	CIRCUL8 Systems

2.7.8 References

1. Byler, Jason, D. Schulte, R. Koelsch. 2004. Odor H2S, and NH3 Emissions from Phototrophic and Non-Phototrophic Anaerobic Swine Lagoons. 2004 ASAE/CSEA Annual Meeting. Ottawa, Ontario, Canada, August 2004.
2. Chen, T., D. Shulte, R. Koelsch, and A. Parkhurst. 2003. Characteristics of Phototrophic and Non-Phototrophic Lagoon for Swine Manure. *Transactions of the ASAE* 46(4):1285-1292.
3. Kellogg, R. L. C. Lander, D. C. Moffitt, N. Gollehon. 2000. Manure Nutrients Relative to the Capacity of Cropland and Pastureland to Assimilate Nutrients: Spatial and Temporal Trends for the United States. United States Department of Agriculture. www.nhq.nrcs.usda.gov/land/index/publication.html
4. Li, X., R. H. Zhang. 2004. Integrated Anaerobic and Aerobic Treatment of Dairy Wastewater with Sequencing Batch Reactors. *Transactions of the ASAE* 47(1):235-241.
5. Li, X., R. H. Zhang. 2005. Aerobic treatment of Dairy Wastewater with Sequencing Batch Reactor Systems. Submitted for publication to *Water Research*.
6. Meyer, M., J. Mullin, A. Mazzei, I. Diaz, M. Grundvig. Dairy Wastewater Management by Aerobic Digestion. Mazzei Injector Corporation, Bakersfield, California. Internal Report.
7. Moore, L. W. 2001. Performance of Floating Horizontal Aerators in Aerated Lagoons and Oxidation Ditches. Texas Water 2001 Annual Conference, April 4, 2001.
8. Rumberg, B., N. Manjit,m, G. H. Mount, D. Yonge, J. Filipy, J. Swain, R. Kincaid, K. Johnson. 2004. Liquid and Atmospheric Ammonia Concentration from a Dairy Lagoon During Aeration Experiment. *Atmospheric Environment* 38:1523-1533.
9. Stanton, T.L. W. R. Wailes, S. Reynolds, D, Johnson and J. Davis. The effect of algae and bacterial additions to a CAFO lagoon on the conversion from anaerobic to aerobic fermentation. AgSmart Corporation, Strasburg, Colorado.
10. Westerman, P. W., and R.H. Zhang. 1997. Aeration of Livestock Manure Slurry and Lagoon Liquid for Odor Control: A Review. *Applied Engineering in Agriculture* 13(2):245-249.
11. Zhang, R. H., P. N. Dugba, and D. S. Bundy. 1997. Laboratory Study of Surface Aeration of Anaerobic Lagoons for Odor Control of Swine Manure. *Transactions of the ASAE* 40(1):185-190.
12. Zhang, R. H., P. Yang, C. A. Collar, and L. Ham. 2003. Treatment of Flushed Dairy manure by Solid-Liquid Separation and Lagoon Aeration. Ninth International Symposium of Animal, Agricultural and Food Processing Wastes. October 2003, Raleigh, North Carolina.
13. Zhang, R. H. 2005. Personal Communications – Presentation of November 9, 2005, Dairy Manure Energy Program – Efficiency of Aerator for Manure Ponds. Edison Ag TAC, Tulare, CA.
14. Zhil, J. 1998. A Laboratory Study of an Aerated Lagoon Bio-Blanket for Swine Manure Odor Control. *Engineering Technology* 19:1085-1093.

2.8 Nitrification/denitrification Systems

One of the greatest challenges facing dairies is avoiding the uncontrolled release into the environment of the nitrogen present in dairy manure (Reference 1). Conventional manure management practices result in much of the nitrogen in dairy manure being converted to ammonia (NH_3),which exists as the ammonium ion (NH_4^+) when in solution, and to other nitrogen compounds. The various forms of nitrogen can volatilize into the air (Reference 2), provide fertilizer for crops, or pollute surface water and groundwater (Reference 3). One method for addressing the "nitrogen problem" is to convert all of the reactive nitrogen compounds that can be found in the dairy waste into the harmless and chemically inert form of nitrogen, nitrogen gas (N_2). The process used to make that conversion is referred to as "nitrification/denitrification." Within the dairy context, the process of nitrification/denitrification is best applied to the liquid waste-stream, usually after the bulk of the solids have been removed from the manure slurry. Removing the solids greatly reduces the cost of energy needed to adequately mix the manure during the nitrification/denitrification process. The solids should be appropriately handled as described elsewhere in this report, in order to minimize or avoid the pollution problems that may result from the excess nutrient loads that this part of the dairy waste stream can generate.

2.8.1 Description

Nitrification/denitrification converts nitrogen present in manure into an inert gas known as diatomic nitrogen (N_2) that accounts for roughly 78% of the Earth's atmosphere. The Panel received six submissions for technologies that involve such conversions. The unifying approach employed in these systems is the use of multiple conditions in combination in order to nitrify and then denitrify the dairy waste-water (Reference 4).

Nitrification under Aerobic Conditions

The first step for conversion of reactive nitrogen is to create highly aerobic conditions to facilitate the oxidation of the NH_3 first into nitrite (NO_2^{-1}) and then into nitrate (NO_3^{-1}) (Reference 5). This process of converting NH_3 into NO_3^{-1} is known as nitrification. The nitrification conversion steps are typically carried out by soil bacteria of the genera *Nitrosomonas* and *Nitrobacter*, but species from other genera may also be involved, depending upon the conditions.

	Nitrosococcus spp *Nitrosospira spp.*		*Nitrococcus spp* *Nitrospira spp.*	
$NH_3 \longrightarrow$		$\longrightarrow NO_2^{-1} \longrightarrow$		$\longrightarrow NO_3^{-1}$
	Nitrosomonas spp *Nitrosorobia spp.*		*Nitrobacter spp* *Nitrosoeystis spp.*	

Denitrification Under Anaerobic Conditions

In a second step, conditions are altered to ensure that anaerobic conditions are present, and the NO_3^{-1} is reduced and converted to N_2. This process is known as denitrification and involves the action of another suite of bacterial organisms, including members of the genera *Achromobacter, Acinetobacter, Agrobacterium, Alcaligenes, Arthrobacter, Bacillus, Brevibacterium, Corynebacterium, Enterobacter, Flavobacterium, Hypomicrobium, Moraxella, Lactobacillus, Micrococcus, Neisseria, Paracoccus, Paracalobactrum, Propionibacterium, Proteus, Pseudomonas, Rhizobium, Rhodopseudomonas, Spirillum, and Vibrio* (Reference 6).

$$NO_3^{-1} \text{— bacterial } \textit{spp.} \rightarrow NO_2^{-1} \text{— bacterial } \textit{spp.} \rightarrow NO \text{— bacterial } \textit{spp.} \rightarrow N_2O \text{— bacterial } \textit{spp.} \rightarrow N_2$$

The denitrifying bacteria require an adequate supply of carbon compounds as an energy source. However, the presence of too much carbon leads to conditions that inhibit denitrifying bacteria.

System Performance

Thus, these systems can convert nitrogen from any of its reactive forms (NH_3, NO_2^{-1}, NO_3^{-1}, NO, and N_2O) into its non-reactive form (N_2). This conversion avoids the air and water pollution problems that would otherwise result from the abundance of these compounds in dairy manure and wastewater.

The challenge for the dairy owner is to balance the need to avoid the environmental impacts that can result from the release of the reactive forms of nitrogen, against the need to maintain some nitrogen in manure for application at agronomic rates to the land used to generate forage and feed for the dairy (Reference 7).

While the nitrification/denitrification approach has the advantage that it can help address the problem of surface water and groundwater pollution through the removal of nitrogen, the application of this treatment processes to dairy manure must be conducted carefully in order to avoid contributing to the degradation of air quality and to global warming: N_2O, which can be produced during denitrification, is a potent green house gas. In addition, nitrification/denitrification does not remove other nutrients and salts from the dairy waste (Reference 8), and does not necessarily reduce the pathogens present in the manure (Reference 9).

Cost of Implementation

While the environmental benefits that can be gained from the use of nitrification/denitrification are significant, this process destroys the manure's value as a source of N fertilizer and does not allow the dairy to create any value-added materials for sale or use elsewhere on the farm, unless a market exists for the sale of the treated water. In addition, the dairy must incur some expense in order to implement a nitrification/denitrification system.

The costs associated with those submissions that presented cost-data to this panel vary widely. Some data were provided on a per installation basis without regard to the size of the dairy. This made it difficult to determine how the cost would scale with dairy size and/or number of cows. Installation costs per cow before annualization would range from a few tens of dollars to several hundreds of dollars. While there is little doubt that many of these technologies will work, a dairy owner should focus on how effective each technology is likely to be for a given dollar investment in helping to manage/address the nitrogen nutrient-load on the dairy.

Data provided for some of the technologies included the cost of operation and maintenance, but only one of the submissions spoke to the issue of what training and/or staffing would be required for the technology. The submission by Everstech USA indicated that their personnel would have to run the process. No cost was given for the required staffing.

2.8.2 Benefits and Challenges of Nitrification/Denitrification

Benefits include:

- Nitrification/denitrification is a well established technology that has long been used in municipal sewage treatment systems (Reference 10) and can be applied to dairy operations
- Provides for the treatment of wastewater to make it suitable for irrigation at dairies where cows produce more nitrogen than needed by crops grown at the facility
- Controls nitrogen to reduce potential impacts to air and water quality.

Challenges include:

- Destroys the N-fertilizer value of the manure and does not by itself provide a revenue stream for the dairy through the production of a other value-added products
- May require additional lagoons or other containment facilities for the proper maintenance and control of the process
- Additional expense for both the equipment and energy (electricity, diesel, etc.) to maintain high levels of aeration during the denitrification stage (Reference 11)
- The proper temperature regime must be maintained in order to ensure the efficient conversion of the nitrogen compounds
- May require monitoring and careful balancing of carbon content, with possible supplementation of carbon compounds in the denitrifying lagoon/reactor. Methanol, ethanol, acetic acid, molasses, high fructose corn syrup, and cellulosic material have been used to provide additional carbon in waste water at a municipal sewage treatment plants (Reference 12).
- Dairy staff may need to be trained, or the dairy may need to hire additional staff dedicated to operating the nitrification/denitrification process
- Failure to ensure that the conversion process is completed allows reactive nitrogen compounds to remain and potentially impact air and water
- Does not eliminate pathogens present in dairy manure
- Does not remove other problematic compounds from the waste stream (e.g., salts, trace metals, etc.)

2.8.3 Technologies Received and Reviewed by the Panel

The following technologies that include nitrification/denitrification were received and reviewed by the Panel:

Vendor	**Technology**
Agricultural Waste Solutions, Inc.	AWS Technology
Baumgartner Environics, Inc	NDN Mgt. System
Bion Dairy Corporation	Bion
Everstech Consulting (UK) / Everstech LLC (USA)	Everstech ET ™
Haskell Edwards	Water Reclamation System
Tennessee Valley Authority	ReCiprocating Wetlands ™

The submissions received by the panel represented a breadth of approaches to nitrification/ denitrification. They ranged from:

- traditional approaches or approaches based on municipal wastewater treatment, or multiple lagoons/reactors designed for dairies (Agricultural Waste Solutions, Inc., Bion Dairy Corp., Everstech Consulting/Everstech LLC, and Haskell Edwards)
- a lagoon cover that provides surface area for growth of a thin film of anaerobic bacteria under conditions for nitrification (Baumgartner Environics, Inc.)

- artificial wetlands (Tennessee Valley Authority).

2.8.4 Implementation Status

All of these technologies would appear to have potential for use at dairies in California. Some are mature technologies (Agricultural Waste Solutions, Inc., and Baumgartner Environics, Inc.), meaning that they have been installed and are operating in dairies somewhere within the USA. Other technologies are either near mature (Bion Dairy Corp.), or have been used extensively to handle the waste water from other types of confined animal facilities (Tennessee Valley Authority). Still others appear to have not yet been applied to the dairy waste stream and need to undergo testing and/or demonstration (Everstech Consulting/Everstech LLC, and Haskell Edwards). Significant data necessary for the panel to determine the validity of many of the environmental benefits resulting from the use of these technologies and claimed by the vendors were not provided in many of the submissions.

2.8.5 Lessons/perspectives on How Nitrification/denitrification Applies to California Dairies

A problem for dairies throughout the country and within California is that there is often insufficient cropland and pasture available to use of all of the nutrients in the manure produced at the dairy (Reference 13). The resulting challenge facing dairy owners is to remove excess nutrients but ensure that sufficient nutrients are retained for sustainable and efficient crop production.

A dairy owner has limited opportunity to remove nutrients from the dairy site. Although nitrogen can be removed by exporting the nitrogen-containing waste or by using a nitrification/denitrification technology, those actions require careful planning. Exporting manure and operating a nitrification/denitrification system can be very expensive, and regardless of which method is used, care must be taken to remove only that nitrogen which exceeds the amount that can be supported by the dairy's associated crop and pasture land. Failure to retain adequate nitrogen will result in the need to purchase nitrogen fertilizers for the farm.

2.8.6 References and Notes

1. Burton, C.H., and C. Turner. 2003. Manure Management: Treatment Strategies for Sustainable Agriculture. 2nd edition. Silsoe Research Institute, Silsoe, UK. 451 pp.
2. National Research Council. 2003. *Air Emissions from Animal Feeding Operations: Current Knowledge, Future Needs.* The Ad Hoc Committee on Air Emissions From Feeding Operations, Committee on Animal Nutrition, Board on Agriculture and Natural Resources, Board on Environmental Studies and Toxicology. National Academies Press. 286pp. http://books.nap.edu/books/0309087058/html/51.html

   Akiyama, H. and H. Tsuruta. 2003. Nitrous Oxide, Nitric Oxide, and Nitrogen Dioxide Fluxes from Soils after Manure and Urea Application. *J. Env. Quality* 32:423-431.
3. USGS National Water-Quality Assessment Program (NAWQA). Water quality and nonpoint sources in agricultural watersheds. http://water.usgs.gov/nawqa/informing/agriculture.html

   USGS, NAWQA Program, Nutrients National Synthesis, Publications about Nutrients. http://water.usgs.gov/nawqa/nutrients/nspubs.html

   Nitrate in Farmland Streams and Groundwater. In: The State of the Nation's Ecosystems. The John H. Heinz Center for Science. http://www.heinzctr.org/ecosystems/farm/indicators.shtml

Nolan, Bernard T., Barbara C. Ruddy, Kerie J. Hitt, and Dennis R. Helsel. 1998. A National look at Nitrate Contamination of Ground Water. *Water Conditioning and Purification* 39(12):76-79. http://water.usgs.gov/nawqa/wcp/

4. To see a schematic of the Nitrogen Cycle in Nature go to: University of Florida, Department of Botany, Introduction to Ecology, Nutrient Cycling and Regeneration. http://ecology.botany.ufl.edu/ecologyf02/Art/CH07/JPG/figure%2007-11.jpg, (Graphic taken from Robert E. Ricklefs. 2001. The Economy of Nature. W. H. Freeman; 5th edition. 550pp.)

   University of Alberta, Department of Biology, Biology 366: Boreal Ecology, The Boreal Ecosystem Nitrogen Cycle. http://www.biology.ualberta.ca/courses.hp/bio366/n-cycle.gif (Graphic taken from Miller, G. and R. E. Ricklefs. 1999. Ecology. W. H. Freeman, 4th edition. 896 pp.)
5. In the dairy context, other forms of nitrogen contained both within the cows' feces and urine are converted to ammonia through the action of the urease enzyme also excreted in the feces, and bacteria under the anaerobic conditions that can exist whenever the manure waste is allowed to sit.
6. Ogram, Andrew. 1998. Teaching Soil Bacterial Diversity from a Phylogenetic Perspective: A Term Project Utilizing the Ribosomal Database Project. *J. Nat. Resour. Life Sci. Educ*. 27:93-96. http://www.faculty.virginia.edu/evolutionlabs/OgramJNRLSE1998.pdf

   PIER Industrial/Agricultural/Water Program Area, January 2002 Biological Denitrification Demonstration at Modesto, California: A Status Report, EPRI, Palo Alto, CA: 2001. CEC Report No. 090661. http://www.energy.ca.gov/pier/final_project_reports/500-02-019.html#ExecutiveSummary

   Robbins, Janelle. 2005. *Understanding Alternative Technologies for Animal Waste Treatment: A Citizen's Guide to Manure Treatment Technologies*. Waterkeeper Alliance., 154 pp.
7. The traditional practice on many dairy farms is to assume that the anaerobic conditions within unaerated lagoons will allow bacteria to convert most of the nitrogen in the waste to ammonia. The assumption is then that if the farm applies this ammonia-containing waste to land at agronomically appropriate rates, that the ammonia will either be taken up by the roots of plants (plants use the nitrogen from the ammonia to make proteins and other complex compounds) or be denitrified by soil bacteria. However, sulfide (a reduced sulfur compound produced by bacteria under the same anaerobic conditions used to generate ammonia) can also be present in the very same land-applied waste. Sulfide inhibits the ability of soil bacteria to denitrify the nitrogen compounds in the applied waste and this can lead to these compounds contributing to air emissions from the soil. Likewise, partial denitrification can allow compounds such as nitrate (NO_3^{-1}) to accumulate in the soil and pollute the water table. Incomplete pre-treatment of dairy waste can also lead to the emissions of other nitrogen compounds to the air. By at least pre-treating the dairy waste to allow for nitrification to occur, the oxidation of sulfur containing compounds encourages the formation of sulfate, the presence of which encourages denitrification by soil bacteria. In contrast, when the waste is nitrified and then applied at agronomically appropriate rates, NO_3^{-1} in the water can either be converted by bacteria to NH_3 in the soil for rapid uptake by plants, and with a reduced danger of the NH_3 escaping into the air, or denitrified. However, application in excess of agronomic rates will either allow for the resulting NH_3 and other nitrogen compounds to escape to the air before plant uptake can occur, or for nitrogen compounds to accumulate in the soil potentially leading to pollution of the ground water. See:
   - the section below, "Lessons/perspectives on How Nitrification/Denitrification Applies to California Dairies"

- Percheron, G., N. Bernet, and R. Moletta. 1999. Interactions between methanogenic and nitrate reducing bacteria during the anaerobic digestion of an industrial sulfate rich wastewater. *FEMS Microbiology Ecology* 29:341-350.
- Hasegawa, K. et al. 2004. Nitrate removal with low N2O emission by application of sulfur denitrification in actual agricultural field. *Water Sci Technol* 50(8):145–51.
- Akiyama, H. and H. Tsuruta. 2003. Nitrous Oxide, Nitric Oxide, and Nitrogen Dioxide Fluxes from Soils after Manure and Urea Application. *J. of Env. Quality* 32:423-431.

The dairy owner should also understand that nitrification of the lagoon waste-water will not reduce the concentration of any other accumulated nutrients and salts that may also be in the wastewater, and this should also be considered when determining whether it is appropriate to use the treated waste-water for irrigation.

8. Robbins, Janelle. 2005. *Understanding Alternative Technologies for Animal Waste Treatment: A Citizen's Guide to Manure Treatment Technologies*. Waterkeeper Alliance, Tarrytown, NY. 154 pp.
9. This is especially true if the treatment conditions are not optimized.
    - Gerardi, M. H., and M. C. Zimmerman. 2004. Wastewater Pathogens: A practical guide to wastewater pathogens. John Wiley & Sons, Inc. 179pp.
10. Montgomery Watson Harza (MWH) Global, Inc. 2005. Water Treatment: Principles and Design, 2nd Edition. John Wiley & Sons, Inc. 1968 pp.

    Droste, R. L. 1996. Theory and Practice of Water and Wastewater Treatment. John Wiley & Sons, Inc. 816 pp.

    Burton, C.H., and C. Turner. 2003. Manure Management: Treatment Strategies for Sustainable Agriculture, 2nd edition. Silsoe Research Institute, Silsoe, UK. 451 pp.
11. Please refer to the separate summary section dealing with aeration systems.
12. Robbins, Janelle. 2005. *Understanding Alternative Technologies for Animal Waste Treatment: A Citizen's Guide to Manure Treatment Technologies.* Waterkeeper Alliance, Tarrytown, NY. 154 pp.

    Rodriguez, Mora F, G. Ferrara de Giner, A. Rodríguez Andara, and J. Lomas Esteban 2003. Effect of organic carbon shock loading on endogenous denitrification in sequential batch reactors. *Bioresource Technology* 88(3): 215-219, July 2003.

    CEC PIER, January 2002. Electrotechnology Applications for Potable Water Production And Protection of the Environment. 146pp plus 19 appendices. Consultant Report, prepared by: Southern California Edison and Utility Technologies Associates
    http://www.energy.ca.gov/reports/2004-04-02_500-02-019/500-02-019.pdf

2.9 Covers for Lagoons, Manure Storage, and Compost

2.9.1 Description

Covers are made of permeable or relatively-impermeable material and provide a barrier between a surface and the atmosphere. Permeable covers are used to reduce odor emissions from manure storage areas. Permeable covers can be designed to support facultative microbes whose end products penetrate the cover and enter the atmosphere; the end products are less odorous when permeable covers function properly. Typically, permeable covers are designed to allow some penetration of rainfall.

Relatively-impermeable covers are designed to prevent atmospheric exchange with the storage surface. These covers are used in silage storage and are designed to maintain anaerobic conditions. The covers are also used on wastewater ponds to exclude rainfall and/or to collect methane gas for combustion or powering a generator. Compost piles can also be covered to reduce air emissions.

2.9.2 Benefits and Challenges of Covers for Lagoons, Manure Storage, and Compost Facilities

Covers can provide benefits in several areas at a dairy. Covers are used in feed storage areas to exclude rainfall and maintain feed quality. Covers are used in manure storage areas to prevent odor nuisances and reduce emissions to the atmosphere in order to comply with requirements set by regulatory agencies. Covers used on waste storage facilities also prevent rainfall from contacting the wastes and then needing to be contained and properly managed.

The primary challenges with covers involve maintenance and periodic replacement. Some covers on wastewater ponds are floating and require maintenance to keep them properly positioned. Other covers on wastewater ponds are fixed and require that the volume of wastes be maintained within a specific range. Covers must be periodically maintained to address rainwater, dirt, foreign material, etc., on the cover. Even with proper maintenance, the lifespan of many covers is unknown. When covers need to be replaced, the old cover becomes a waste that must be properly disposed.

It is important to consider additional human safety cautions that may be necessary at a facility where a cover is installed. Also, any water that ponds on the surface of the cover needs to be managed to minimize mosquito breeding sites

2.9.3 Implementation Status

Relatively-impermeable covers are presently used at many dairies to collect methane for heat or power generation. However, these covers have been in use for a limited time, and their longevity is unknown. Floating covers for odor control are not being used in California at this time.

2.9.4 Lessons/perspectives on Applicability of Covers for Lagoons, Manure Storage, and Compost to California Dairies

Well-managed impermeable covers are already being used in California. However, covers do have the potential to hold standing water and create mosquito habitat, which is undesirable.

2.9.5 Technologies Received and Reviewed by the Panel that Include of Covers for Lagoons, Manure Storage, and Compost

Vendor	**Technology**
Agrimass Enviro-Energy, Inc	Induced Blanket Reactor
Baumgartner Environics, Inc.	Bio-Cap ML
Baumgartner Environics, Inc.	MDN Management System

2.10 Microbial Cultures, Enzymes, and Other Additives

Microbes, enzymes, and other additives are sold to improve waste management at a dairy in several ways. One approach is to supplement feed with additives that are claimed to increase the efficiency with which nutrients in the feed are assimilated by cows and converted to production of milk, thereby reducing the amount of nutrients in the feces and urine and reducing the potential for environmental impacts when the manure is stored or applied to cropland. Refer to Section 2.11 "Feed Management" for a discussion of this approach

A second approach is to use microbes to convert nutrients into inert forms. For example, nitrogen exists in dairy waste in many reactive forms (NH_3, NH_4^+ NO_2^{-1}, NO_3^{-1}, NO, and N_2O). Many of these forms can be converted into non-reactive N_2 via nitrification/denitrification reactions. This approach is discussed in Section 2.8 "Nitrification/denitrification Systems."

A third approach to reducing the amount of nutrients entering the environment is to retain more of the nutrients within the solid fraction and reduce the nutrients in the aqueous/labile portion of the waste stream. Coagulants, flocculants, agglutinates, chelating agents, polymers and similar additives are claimed to increase the amount of solids that can be separated from manure slurry or wastewater. Some of these additives are claimed to alter the ionic conditions within the waste, thereby causing the finer particles to clump together. Other additives are claimed to cause certain minerals and salts within the dairy waste to precipitate out of solution, to then be captured during solids separation. This approach is discussed below, and also in Section 2.4 "Solid-Liquid Separation."

A fourth approach is to bind up nutrients within the microorganisms that live in the waste, allowing the nutrients to be more easily removed as part of the solid waste stream. This approach is further discussed below.

2.10.1 Description

Additives are marketed to treat manure slurry, manure solids, or dairy wastewater to increase the efficiency of desired chemical and biological processes that occur within the wastes during storage. The additives used include organic and inorganic chemicals, enzymes, and microbial cultures called inoculants. These additives are claimed to work by affecting the chemical or enzymatic reactions that occur within the dairy waste or by altering the populations of microscopic organisms (archaea, bacteria, protozoa, fungi, helminths, etc.) that live in the dairy waste. These additives are primarily used on manure slurry or wastewater.

2.10.2 Benefits and Challenges of Using Additives

Additives are claimed to achieve certain goals more effectively and economically than other approaches.

- Compounds containing problematic constituents are claimed to be broken down in a manner that reduces odors (Reference 1), while at the same time avoiding other impacts on air (Reference 2) and water quality (Reference 3). Additives used to reduce odor can include the following:
    - Masking agents - compounds that have their own strong but non-offensive smell, which are used to mask/cover-up any offensive odors generated by the dairy.

  - Adsorbents – substances having a large molecular surface-area upon which odor causing compounds can adsorb (attach) and be trapped before they escape into the surrounding air.
  - Counteractants - compounds that neutralize odors. These can include chemicals that react directly with the odor causing compounds.
  - Microbial modifiers – compounds that reduce the activity of microorganisms that produce the odor-causing compounds.
- Manure solids are claimed to be degraded with greater efficiency during anaerobic digestion and composting, thereby reducing problems with solids and the amount of manure solids that need to be handled
- During aerobic/facultative digestion, a higher percentage of nutrient and mineral elements are claimed to be sequestered within the microorganisms so that they may be removed as part of the solids. Nutrients trapped within solids can be collected at several stages in the waste stream: 1) when solids are separated from manure-slurry; 2) when solids are collected at the end of anaerobic/anaerobic/facultative digestion; and 3) after the treatment of wastewater and before it is either recycled for use as flush-water, or used for irrigation.
- Composting produces a higher-quality product for use or sale as bedding material, a soil-amendment, or organic fertilizer.

The challenges of using additives include:

- Past research and experience indicates that in many situations additives are not at all, or only slightly more, effective than when systems are properly operated without the use of additives
- For effectiveness, it may be necessary to use large quantities of additives at a corresponding high cost
- Some additives may require addition of supplements to ensure effectiveness of the additives
- Some additives may have unexpected and undesirable effects that create management problems or new potential for adverse environmental impacts.

It should be recognized that the microorganisms that live within the waste constitute a biological community (Reference 4). The actions and interactions of these micro-organisms in turn reinforce, inhibit, and alter the environmental conditions within the waste (i.e., oxygen content, pH, labile nutrients, etc.) (Reference 5). Over time, these interactions and the resulting environmental conditions lead to changes in the types of microorganisms within each of the dairy waste streams.

Organisms that dominate the biological community may determine the nature of the chemical and enzymatic reactions that occur within the waste stream (Reference 6), creating an equilibrium that can be both self-sustaining and very stable (Reference 7). Such conditions can pose a considerable challenge to any dairy seeking to alter the conditions within the manure via artificial means. This is because either:

- The additives being used to alter conditions would have to be constantly administered in order to counter the dominant community dynamics already present within the waste, and/or
- Secondary/supplementary additives have to be applied to overcome the dominant naturally-occurring community dynamics within the waste to create and maintain optimal conditions for the desired chemical and enzymatic reactions or for the introduced organisms to become dominant (Reference 8), and/or
- The temperature, aeration, pH, moisture regime, etc., may have to be closely controlled and monitored for the desired conditions to prevail.

Recent research suggests that there is little or no advantage to be gained through the use of additives to control and enhance the removal of micro- and macro-nutrients from dairy waste, at least in the case of waste stored in lagoons (Reference 9). In some situations, additives may help protect indigenous microbial population from exposure to toxins and other chemical stressors (Reference 10).

2.10.3 Cost of Implementation

Technology submittals that were reviewed by the Panel used differing metrics to express the cost of their systems: by the cow, by the gallon, and by the ton of manure solids being composted. It appears that the costs for additives would break down to a few cents per cow per day for each of the submitted approaches. However, these cost data may be based on dairy operations outside of California, and may thus be underestimates. Most dairies in California use large amounts of flush water on a daily basis, typically hundreds of thousands of gallons for a large dairy. (Often this is water recycled from other uses on the dairy or from the wastewater holding pond.) (Reference 11). Dairies in other states typically are smaller and do not use such high volumes of flush water, or water from the same sources; thus, cost estimates may not be appropriate for the typical California dairy. Vendors focusing on treatment of wastewater and who provided data for capital costs, rated support equipment costs at a few thousand dollars. It is not clear how costs relate to the rate of waste production and how this would scale with dairy size.

It is easier and cheaper to mix and/or aerate wastewater than manure-slurry. Therefore, it is less expensive to add microbes and chemicals to the liquid portion of the manure, after solid separation, than to the unseparated whole manure.

2.10.4 Submissions Received by the Panel

Vendor	**Technology**
Agrimass Enviro-Energy	Biological Remediation
Bencyn West, Inc.	OrTec Biocatalyst
Everstech Consulting (UK) - Everstech LLC (USA)	Everstech ET ™
Midwestern Bio-Ag Products and Services Inc.	HumaCal™
Nutrient Control Systems, Inc.	Integrity Nutrient Control System
Pro-Act Microbial, Inc.	Pro-Act Microbial Manure Munching Microbes

The submissions received by the panel represented several approaches. They ranged from:

- Digestion of liquid waste with aeration or mixing (Agrimass Enviro-Energy, and Everstech Consulting (UK) - Everstech LLC (USA))
- Anaerobic Digestion of manure solids (Bencyn West, Inc.)
- Digestion of manure-slurry in a stratified lagoon (Pro-Act Microbial, Inc)
- Treatment of dairy wastewater after removal of solids (Nutrient Control Systems, Inc.)
- Composting (Midwestern Bio-Ag Products and Services Inc.).

2.10.5 Implementation Status

Most submissions had problems in that they either provided no data for the Panel to be able to evaluate their claims, or it was not clear how the data that were provided were collected (i.e., what experimental protocols were followed in generating the data). Although additives are being used at some dairies in California and at many dairies in other states, until it can be demonstrated that a particular additive is effective in addressing specific problems at California dairies, the technologies should be considered unproven. Furthermore, different technologies are at different stages of progress. These stages include test and evaluation (Agrimass Enviro-Energy), development (Everstech Consulting (UK) - Everstech LLC (USA)), and demonstration (Bencyn West, Inc., and Nutrient Control Systems, Inc). One of the technologies (from Midwestern Bio-Ag Products and Services Inc.), appears to be somewhat widely used outside of California but insufficient documentation is available to verify its effectiveness.

It should be noted that there has been relatively little scientific analysis done on the use of additives at dairies, especially within the California context. Detailed research employing a systems/mass-balance approach to examine nutrient flows, and not just focused on odor control, should be pursued for the use of additives on flush-dairies.

2.10.6 References and Notes

1. Jacobson, L., J. Lorimor, J. Bicudo, and D. Schmidt. 2001. Emission Control Strategies for Manure Storage Facilities. Lesson 43 from: The Livestock and Poultry Environmental Stewardship Program, Curriculum Lessons. http://www.lpes.org/Lessons/Lesson43/43_4_Biological_Processes.pdf
2. There are well over 100 compounds that can be emitted into the air from livestock operations. See for example:
    - Hobbs, P.J., J. Webb, T.T. Mottram, B. Grant, and T.M. Misselbrook. 2004. Emissions of volatile organic compounds originating from UK livestock agriculture. *Journal of the Science of Food and Agriculture* 84:1414-1420.
    - National Research Council. 2003. Air Emissions from Animal Feeding Operations: Current Knowledge, Future Needs. The Ad Hoc Committee on Air Emissions From Feeding Operations, Committee on Animal Nutrition, Board on Agriculture and Natural Resources, Board on Environmental Studies and Toxicology. National Academies Press. 286pp. http://books.nap.edu/books/0309087058/html/51.html.
3. See for example:
    - USGS National Water-Quality Assessment Program (NAWQA). Water quality and nonpoint sources in agricultural watersheds. http://water.usgs.gov/nawqa/informing/agriculture.html
    - USGS, NAWQA Program, Nutrients National Synthesis, Publications about Nutrients. http://water.usgs.gov/nawqa/nutrients/nspubs.html
    - Nitrate in Farmland Streams and Groundwater. In: The State of the Nation's Ecosystems. The John Heinz III Center for Science. http://www.heinzctr.org/ecosystems/farm/indicators.shtml
    - Nolan, Bernard T., Barbara C. Ruddy, Kerie J. Hitt, and Dennis R. Helsel. 1998. A National Look at Nitrate Contamination of Ground Water. Water Conditioning and Purification, 39(12):76-79. http://water.usgs.gov/nawqa/wcp/
4. See for example:
    - McGarvey, Jeffery A., William G. Miller, Susan Sanchez, and Larry Stanker. 2004. Identification of Bacterial Populations in Dairy Wastewaters by Use of 16S rRNA Gene

Sequences and Other Genetic Markers. *Applied and Environmental Microbiology* 70(7):4267–4275.

- Juteau P., D. Tremblay, R. Villemur, J.G. Bisaillon, and R. Beaudet, 2004. Analysis of the bacterial community inhabiting an aerobic thermophilic sequencing batch reactor (AT-SBR) treating swine waste. *Applied and Environmental Microbiology*, 66(1):115-122. E-pub July 2004. Erratum in: *Applied and Environmental Microbiology* April 2005, 67(2):287
- Peters S., S. Koschinsky, F. Schwieger, and C.C. Tebbe, 2000. Succession of microbial communities during hot composting as detected by PCR-single-strand-conformation polymorphism-based genetic profiles of small-subunit rRNA genes. *Applied and Environmental Microbiology*, 66(3):930-936.

5. Zuller, C.D., 2003. Manipulation of Microbial Metabolic Pathways for the reduction of Sulfide Production. MS Thesis, Mississippi State University, May 2003. 79pp.
6. Fernández, Ana, Suiying Huang, Sherry Seston, Jian Xing, Robert Hickey, Craig Criddle, and James Tiedje. 1999. How Stable Is Stable? Function versus Community Composition. *Applied and Environmental Microbiology*,, 65(8): 3697–3704
7. Jacobson, L., J. Lorimor, J. Bicudo, and D. Schmidt, 2001. Emission Control Strategies for Manure Storage Facilities. Lesson 43 from: The Livestock and Poultry Environmental Stewardship Program, Curriculum Lessons. http://www.lpes.org/Lessons/Lesson43/43_4_Biological_Processes.pdf
8. For example, in order for any additive - whether chemical, enzyme, or microbial culture - to be effective it may be necessary to alter the conditions in either the manure slurry, manure solids, or wastewater collected after solids separation, by using other supplemental additives (such as lime) to alter the pH, etc.
9. See for example:
    - Robbins, Janelle. 2005. Understanding Alternative Technologies for Animal Waste Treatment: A Citizen's Guide to Manure Treatment Technologies. Waterkeeper Alliance., 154pp.
    - Dabert, Patrick, Jean-Philippe Delgenès, and Jean-Jacques Godon. 2005. Monitoring the impact of bioaugmentation on the start up of biological phosphorus removal in a laboratory scale activated sludge ecosystem. *Applied Microbiology and Biotechnology*, 669(5):575–588.
    - The National Pork Producers Council's (NPPC) Odor Solutions Initiative: Manure Pit Additive Evaluation; http://www.porkboard.org/environment/Programs/osi.asp http://www.porkboard.org/environment/Programs/PDFs/executiveSummary.pdf http://www.porkboard.org/environment/Programs/CompleteManual.pdf
    - Zhu, J., A. Luo, and Z. Zhang. 2003. Effect of a microbial additive on the removal of nutrients in swine manure by aeration. ASAE Paper No. 034152. St. Joseph, Mich.: ASAE Annual International Meeting, Las Vegas, NV July 27-30, 2003.
    - Jacobson, L., J. Lorimor, J. Bicudo, and D. Schmidt. 2001. Emission Control Strategies for Manure Storage Facilities. Lesson 43 from: The Livestock and Poultry Environmental Stewardship Program, Curriculum Lessons.
10. Boon N., E.M. Top, W. Verstraete, and S.D. Siciliano. 2003. Bioaugmentation as a tool to protect the structure and function of an activated-sludge microbial community against a 3-chloroaniline shock load. *Applied Microbiology and Biotechnology*, 69(3):1511-20.
11. It is estimated that about 70 - 80% of the dairy manure in California is processed in flush lane dairies. See for example California Air Resources Board, May 6, 2005. Staff Report: Initial Statement of Reasons for Rulemaking. Public Hearing to Consider the Large Confined Animal Facility Definition. 54pp. plus Appendices.

2.11 Feed Management

2.11.1 Description

,Dietary manipulation (i.e., source reduction), is the first control point to reduce excretion of nutrients from dairy cattle. Nutrients fed in excess of animal requirements add to the nutrient content of the excreted manure. The National Research Council Subcommittee on Dairy Cattle Nutrition published its Seventh Revised Edition of Nutrient Requirements of Dairy Cattle (Reference 2). The NRC recommendations are considered by nutritionists and veterinarians who formulate diets for dairy cows.

If current diets are above the nutrient needs of the cows, changing the diet can result in significant reduction in nutrient excretion. Phosphorus excretion was reduced by 36% when dietary phosphorus for lactating cows fed above National Research Council recommendations was reduced an equal amount (Reference 1). This does not mean a 36% reduction can be expected in all cases, as the start point may be different. It does demonstrate that reductions may be possible in some cases. Tomlinson et al. (Reference 3) demonstrated that nitrogen excretion by dairy cows could be predicted from dietary intakes of dry matter and its nitrogen content. Dietary manipulation can reduce total N excreted as well as alter the form of nitrogen excreted.

Feed Management includes the use of dietary additives to enhance milk production by cows. The additives may be yeasts, enzymes, microbials, ionophores, or proprietary materials. Some additives are well researched, and their mode of action is well defined. Some of these are effective as long as the animal is consuming them; others are effective only during the first weeks or months and become less effective over time. For some of the additives there has been research to evaluate effects on manure that is applied to land. Other additives have undergone less rigorous research and little is known of their efficacy in the animal or their subsequent impact on the environment.

2.11.2 Benefits and Challenges of Feed Management

Benefits include:

- Dietary manipulation can reduce excretion of nutrients (macro and micro elements) <u>if they are currently overfed.</u>
- Dietary manipulation may be a cost-effective method to reduce nutrient excretion.
- Altering digestibility of dry matter in the rumen can improve feed efficiency, thereby potentially reducing gaseous emissions per gallon of milk produced per anima.
- Additives may work to reduce emissions of methane (a green house gas) from the animal. The net effect on the entire system is unknown.

Challenges include:

- Certain by-products fed to animals are high in particular nutrients and consequently may not be suitable for inclusion in a feed management program
- Reduced N excretion does not necessarily result in a system-wide reduction in ammonia emissions. Research is needed to define the system-wide air quality implications of a reduced N diet.
- The effects of biologically-active additives that have been excreted are predominantly unresearched.

2.11.3 Implementation Status

Some consulting nutritionists and veterinarians have implemented dietary manipulation to reduce excretion of nutrients.

2.11.4 Lessons/perspectives on How Feed Management Applies to California Dairies

There are commercial products that have documented efficacy and are being used on dairies. There are other products without documentation that have been used occasionally, inconsistently, etc.

2.11.5 Technologies Received and Reviewed by the Panel that Include Feed Management

Vendor	**Technology**
Agricultural Modeling & Training Systems	AMTS Cattle computer software

The Panel received no applications to review technologies for feed management.

2.11.6 References

1. Morse, D., H.H. Head, C.J. Wilcox, H.H. VanHorn, C.D. Hissem, and B. Harris, Jr. 1992. Effects of concentration of dietary phosphorus on amount and route of excretion. *J. Dairy Sci.* 75:3039-3049.
2. National Research Council. 2001. Nutrient Requirements of Dairy Cattle, seventh revised edition. Subcommittee on Dairy Cattle Nutrition; Committee on Animal Nutrition. National Academy Press, Washington, D.C.
3. Tomlinson, A.P., W.J. Powers, H.H. VanHorn, R.A. Nordstedt, and C.J. Wilcox. 1996. Dietary protein effects on nitrogen excretion and manure characteristics of lactating cows. *Trans. ASAE* 39:1441-1448.

3 Conclusions and Recommendations

3.1 Conclusions

There are a great many companies selling products and processes to treat manure. Although the Panel accepted submissions for only 6 weeks, we received 44 submissions, and another 25 after the deadline. We also identified several dozen more companies (Appendix 2) that are marketing technologies that are intended to treat manure, but that did not submit information for review by the Panel. It is apparent that many companies are seeing entrepreneurial opportunities for industrial-scale manure management and treatment, and that these technologies hold promise for potential use as best management practices at dairies.

The Panel was unable to determine the environmental and economic performance of most of the technologies submitted. There are two major reasons:

- **Insufficient Scientific Data.** In this first round of evaluations, only a few companies provided scientific data that allowed the Panel to determine the environmental and economic performance and appropriateness of a technology. Much of the material submitted to the Panel was company marketing claims that were neither adequate nor appropriate for the Panel to use in determining the environmental and economic performance of a technology. Instead, the Panel needs independent, scientific data. Lack of scientific data to support company claims does not mean the technologies are without merit, but does severely limit the Panel's ability to assess the technologies.

  In addition, few of the submissions provided an accounting of the form and fate of all constituents in the manure as it enters, moves through, and exits the processing technology. Of particular concern are nitrogen, phosphorus, carbon, and salts. For example, the Panel could not determine the impact of many of the submitted technologies on converting nitrogen from one form to another (organic nitrogen, nitrate, nitrite, ammonium, ammonia, nitrous oxide, and nitrogen gas). Without knowing the biological and chemical transformations that affect the form and amount of these compounds, it is not possible to determine if there are environmental benefits from the technology.

- **Untested on California Dairies.** Many of the technologies examined by the Panel have never been tested under conditions that occur on dairies in California's San Joaquin Valley. Some have not yet been tried on dairies at all. Although a majority of dairies in the San Joaquin Valley collect at least at some of their manure by flushing with recycled wastewater, many of the technologies submitted to the Panel are appropriate for, or have been tested only on, dairies or feedlots where manure is scraped or vacuumed and handled "dry." Some technologies have been tested only on other types of animals such as swine, or on human wastewater, and some are still in the conceptual stage.

Most technologies address only a limited portion of the environmental issues associated with manure. The Panel found few technologies that had been packaged into a whole-systems approach to address all the components of the manure stream. Many treat only a portion of the manure. For example, gasification technologies burn manure solids to generate energy, and are not intended to treat the salts and nitrogen that are in the manure wastewater. Anaerobic digestion converts organic carbon to carbon dioxide and methane, which can be burned to generate energy, but does not treat salts and also leaves ammonium-nitrogen in the liquid fraction. Composting can stabilize organic matter, but impacts on air quality from emissions of ammonia, volatile organic compounds, and nitrous oxide, or on water quality from run-off or leaching of ammonium and nitrate, were not reported or addressed by many of the technologies submitted to the Panel. Some technologies intentionally or unintentionally transfer pollutants from one medium to another. For example, technologies that volatilize ammonia reduce the potential for impacts to groundwater but have a negative effect on air emissions and potential subsequent deposition to soils and surface waters. The challenge in evaluating a single component of a system is understanding the net effect on the entire manure stream. Although some submissions were comprehensive packages of technologies, most were not, and the lack of technology packages that comprehensively treat all components of manure remains a challenge for the dairy industry, regulatory agencies, and technology providers.

Treating Manure is Expensive. Some manure processing operations are relatively inexpensive. For example, settling ponds to separate liquids and solids are relatively inexpensive to construct and maintain and have a long operating life. Other operations are considerably more expensive. For example, a system to collect and use biogas (i.e., an anaerobic digester with a methane-powered generator) may have construction costs of $200 per cow (for a simple covered lagoon digester) to more than $800 per cow (for a plug flow digester), and nitrification/dentrification systems can have construction costs of $600 per cow plus operating and maintenance costs of $120 per cow per year. These costs are a significant barrier to wider adoption of manure treatment technology, even when offset by the value of products - such as bedding, compost, fertilizer, and electricity - that result from treatment.

3.2 Recommendations

1. **Develop standard test methods so that the environmental and economic performance of technologies can be fairly evaluated and compared.** Panelists believe additional technology assessments will not be worthwhile until the quality of the submitted data can be improved.

   Data submitted by vendors on environmental performance should include results from properly controlled, replicated studies, preferably at commercial-scale dairies, and also should include an accounting of the fate and form of all components of the manure as it is treated. Companies should make their sampling and analysis protocols available to the dairy industry and regulatory agencies.

   Ongoing air quality monitoring research that will take place over the next few years at animal feeding operations in California, and throughout the nation under agreements between the dairy industry and US EPA, will support the development of standardized test methods, particularly for volatile organic compounds (VOCs). Until standardized test methods exist, technology vendors will not be able to accurately claim or compare the impact of their products on reducing emissions of VOCs.

   Data submitted on economic performance should account for the full cost of implementing the technology, including not only the obvious construction and operating costs, but also the costs for land, training operators, infrastructure changes and additional equipment needed to integrate the new technology into the existing dairy, etc., as well as realistic assumptions about the value of any products (fertilizer, soil amendments, energy, etc.).

2. **Conduct applied research on key data gaps.** These gaps include:

   - **Technology Verification.** An independent program to test and compare technologies under controlled conditions in the field would provide the dairy industry, technology providers, and regulatory agencies with a better understanding of the required environmental performance standards, and provide information about the ability of particular products to meet those standards. A program that could assist in this effort is the US EPA's Environmental Technology Verification Program (www.epa.gov/etv), but so far this program has tested only a few manure treatment products, and most were not for cows and were not tested under California conditions. At the state level, the California Environmental Technology Certification Program is no longer funded. A program should be created to test technologies most appropriate for treating dairy manure in California.

   - **Salts.** Dairies use large amounts of water and import large amounts of feed from California and from other states. The salts in the water and feed are concentrated in the dairy manure, and contribute to the Central Valley's problems with salt accumulation, which is a challenge in all irrigated agriculture systems. Data are needed on the contribution of dairy manure relative to other sources of salts, such as fertilizers, compost, and irrigation water; on the efficacy and costs of technologies that remove salts from manure; and on disposal options, especially the merits of diluting versus concentrating salts for relocation and/or disposal.

   - **Volatile Organic Compounds (VOCs).** There are significant questions about the quantities of VOCs emitted from various portions of dairies (animals and housing, liquid and solid manure, lagoons, feed, compost, and land application), and about the chemical species and processes involved in the formation of ground-level ozone. Without this information, it is difficult to assess how various technologies will reduce VOC emissions. Since the research and regulatory communities have not yet reached consensus on how to measure or reduce VOC emissions from processes on dairies, it is not surprising that companies often do not know – and do not know how to determine – the impact of their technologies on VOC emissions. Definitive measurement techniques to adequately characterize VOC emissions are needed.

3. **Establish pilot projects to assess comprehensive technology combinations for treating dairy manure in the San Joaquin Valley.** The Projects should monitor and assess environmental and economic performance, and demonstrate the technologies to the wider community so that the best technologies can be more widely adopted. The dairy industry, private technology vendors, and public agencies and universities may all be expected to participate in funding, siting, monitoring, and publicizing the results of these projects. Key elements of these projects should include:
   - Construction and operation at full-scale commercial dairies
   - Environmental monitoring to determine if the technology reduces or captures emissions of nutrients, salts, volatile organic compounds, ammonia, methane, pathogenic bacteria, and odors
   - Economic analysis to determine the viability for a typical California dairy

- Education and outreach to the dairy industry so that successful technologies are more likely to be implemented
- Collaboration with key stakeholders, including dairy industry, technology providers, federal and state agencies, UC Cooperative Extension, environmental NGOs, communities, utilities, irrigation districts, etc.

The pilot projects should combine technologies into packages that comprehensively address all of the environmental concerns associated with manure (excess nutrients and salts, air pollutants, pathogens, odors, etc.), and also utilize the value of manure (compost, soil amendments, fertilizer, energy and fuel). Such a comprehensive system could include some or all of the technology approaches discussed in this report (thermal conversion, solid-liquid separation, composting, anaerobic digestion, aerators/mixers, nitrification/denitrification, covers for lagoons and compost piles, microbial and other additives, and feed management), as well as comprehensive wastewater treatment, and technologies that the Panel has not yet considered.

Appendices

Appendix 1 Technology Assessments

Appendix 2 Alphabetical Company Contact Information

Appendix 3 General References on Managing and Treating Dairy Manure

Appendix 1: Technology Assessments

1 Advanced Concept Technologies LLC

Product/Process: PSRG Gasification and Catalytic Reduction to produce Ethanol from Manure

1.1.1 Description

Advanced Concept Technologies (ACT) supplies a biomass waste-to-ethanol conversion plant that can be used to convert manure to synthesis gas, or "syngas", composed primarily of carbon monoxide, hydrogen, and methane, which is then cleaned and cooled and converted to ethanol. The primary systems that comprise the plant consist of a manure receiving area, feedstock storage area, pyrolytic steam reforming gasification unit, ethanol production plant, and facility control center where a programmable logic controller operates all systems (See figure below).

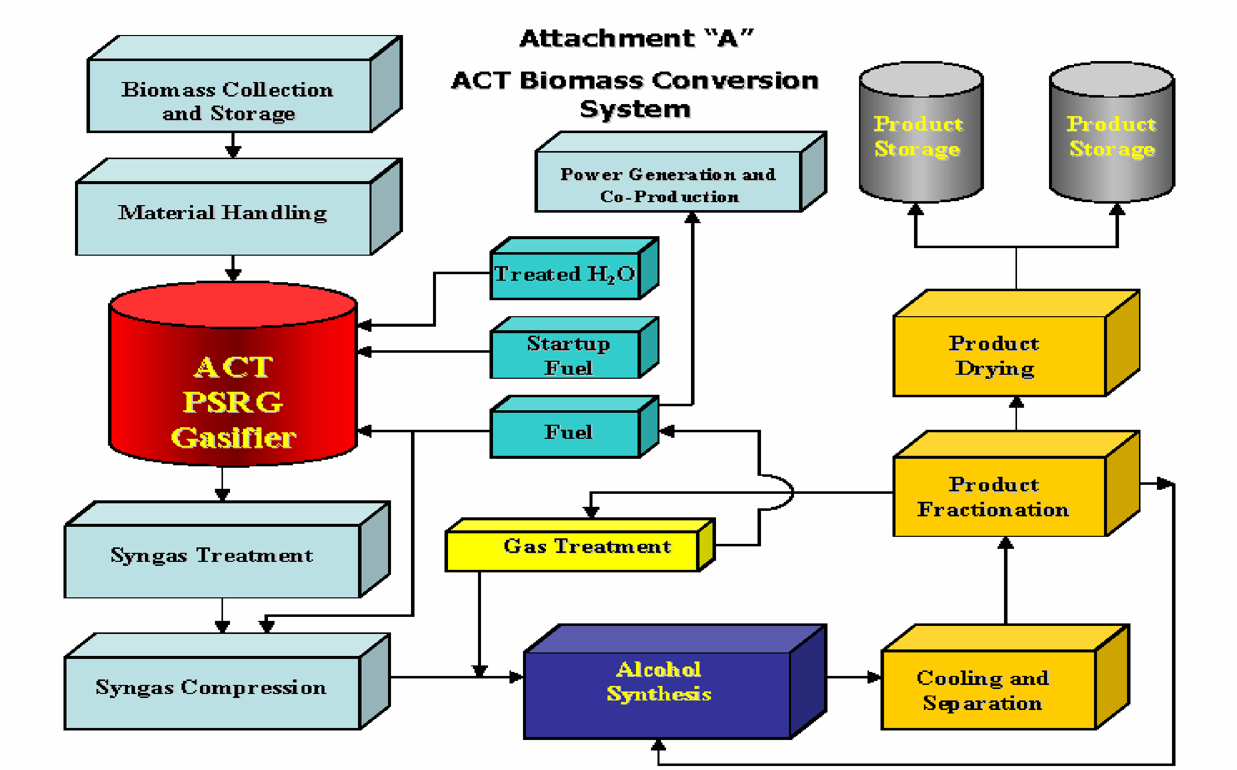
In the manure receiving area, material is unloaded onto the tipping floor. If drying is needed, it is accomplished at this stage. Equipment needed to sufficiently remove liquids prior to gasification is not included with this system. The applicant indicates there should be some air emissions control by limiting the feedstock residence time and drawing air for the gasifier burner from above the feedstock storage area. An inclined tipping floor conveyor moves the feedstock from the receiving floor to a storage bunker designed to hold at least 72 hours worth of feedstock. Feedstock is conveyed via a screw conveyor to the gasifier input hopper.

In the gasifier, feedstock reacts with steam at high temperature in an oxygen-starved environment and is thermochemically converted to syngas and ash. The gasifier is equipped with a pre-burner. When the temperature reaches 850 °F, a small amount of feedstock is added. At 1000 °F, the feed rate is increased. It is estimated to take a couple of hours for the process to become self-sustaining. Ash in the syngas is removed by a dual cyclone system. Applicant states ash is benign and can be used as fertilizer or animal feed supplement. The syngas is sent to a quench circuit and then to a venturi scrubber. Tars and phenols still in the gas condense and are removed by demisters. The cleaned syngas is then sent to the ethanol plant.

The syngas is compressed and sent to a catalyst where carbon monoxide and hydrogen in the syngas are converted to ethanol. Finished alcohol is dried in a mol bed dryer.

Excess cooling water and wastewater not recycled to the gasifier are treated with ACT's Non Chemical Water Treatment Technology called e-OXIS. In the e-OXIS technology, ionized air is stated to create electro-coagulation mechanisms that cause contaminants to form magnetic clusters; then a charge either oxidizes or kills the contaminants and a magnetic filter removes them.

The system being marketed is tailored to a processing rate of 400 tons/day of 40 percent moisture content manure (17,000 gal/day ethanol produced) with a minimum heating value of 4,812 BTU/lb. The plant water requirement is 20-40 gallons per minute (gpm) and parasitic electric load is 1.725 megawatts (MW). The system footprint is approximately 200 by 250feet exclusive of feedstock and output storage. Up front equipment is required to dewater the manure to 25 percent prior to entering the gasifier. Dewatering equipment is not included in this system; however, the company works with vendors to acquire dewatering equipment for use with their system.



1.1.2 Environmental Impacts

This technology is intended to control:

Air Emissions	Non-volatile waste components
☒ Reactive organic gases	☐ Organic nitrogen
☒ Ammonia	☒ Ammonium nitrogen
☒ Particulates	☒ Nitrates
☒ Odors	☒ Phosphorus
☒ Methane	☒ Salts
☒ Hydrogen sulfide	☒ Pathogens

The technology produces the following air emissions:

- ☒ Oxides of nitrogen (NOx)
- ☒ Carbon monoxide
- ☒ Carbon dioxide
- ☒ Reactive organic gases
- ☒ Particulates
- ☒ Sulfur dioxide

By products suitable for commercial sale or use:

- ☒ Heat energy
- ☒ Electrical energy
- ☒ Fuel - Syngas
- ☐ Fertilizer
- ☐ Soil amendments
- ☐ Bedding

☐ Other

To reduce air emissions from the manure receiving and feedstock storage areas, manure is treated within 72 hours of excretion. In addition, air for gasifier burner is drawn from above the storage area. It appears that salts are controlled by off-site disposal of residuals from the process. The fate of the nitrogen compounds is not clear.

The company indicated that the technology reduces net emissions of NOx, CO, and CO_2. Overall reductions or increases in air pollutants would depend on the baseline established for comparison; however due to fuel combustion, the Panel expects net increases in NOx, CO, CO_2, and SO_2. Although emissions data were provided for wood waste combustion rather than manure, NOx, CO, reactive organic gases, particulate matter, and SO2 were present in the exhaust from the gasifier burner.

1.1.3 Economic Performance

ACT stated that costs are project and product dependent, and size and scale affect the cost and performance. Other items that affect project economics include the type and amount of feedstock, energy value of the feedstock, moisture content, price of feedstock supply, and the price received for products sold. ACT states that they will provide detailed cost information when a project and the feedstock and products to be produced are put forward.

The facility owner will be responsible for all necessary site improvements and construction to include site preparation, buildings, roads, and utilities, and for the sale or disposal of byproducts and wastes (ethanol, water, non-gasifiable materials).

In a phone conversation with a Panel member, the company was able to provide a verbal estimate of the capital cost for a full project at $17to 18 million. This cost figure includes the gasifier and associated subsystems; ethanol plant; engineering of building and battery limits infrastructure; project development; spare parts for the first year of operation; and supervision of installation, startup, and operator training. The ethanol catalyst is not sold as part of this system. It is only rented on an annual fee basis and a per-gallon royalty basis to the facility owner. ACT estimates equipment life at 25 years.

1.1.4 Quality of Supporting Data

☐ Sufficient data were provided to demonstrate effectiveness of technology
☒ Data were provided, but effectiveness of the technology is inconclusive - need more data
☐ Data are said to exist, but data are not yet available or were not provided
☐ No data are available

No specific performance guarantees regarding air emission reductions were provided. The company did provide emission test results from the pilot facility gasifier burner located in Denver, Colorado; however the results are from a run on wood waste. The results were: 82.8 ppm NOx, 257.3 ppm CO, 8.1 ppm VOC, and 0.2 ppm SO_2 (all at 6% O_2) and 0.002 lb/hr total particulates. No burner stack tests have been conducted on manure yet. A syngas composition analysis was provided for two runs (hog manure and cow manure with 30% petroleum coke) and resulted in heating values of 446 BTU/SCF and 302 BTU/SCF. Based on these data, the plant produces a medium BTU gas.

No ash analysis was provided to evaluate the value of the byproduct. No water analysis was provided to fully evaluate the impacts of the wastewater and the effectiveness of the e-OXIS water treatment used to treat the scrubber/cooling water.

No specific claims regarding the percentage reduction of odors reduced were provided. The company provided qualitative statements that the odors will be reduced by limiting the residence time for the feedstock to 72 hours in the storage area, drawing process air from the gasifier burner from above the feedstock storage area, and optional spraying of CBPA (anti-pollutant bio-stimulant produced by EcoChem) on the feedstock pile.

1.1.5 Development Status of the Technology

- ☐ Research (basic research and applied research)
- ☐ Development (concept development and prototype development)
- ☐ Test and evaluation (product/process development)
- ☒ Demonstration (full or field relevant scale)
- ☐ Commercial application

In materials submitted to the Panel, the company described their technology as both demonstration and commercial ready; however only the eight-ton per day pilot test facility is in operation. Commercial readiness may be applicable, but would depend on whether there are any scale-up issues. ACT stated that there are two full-scale dairy manure projects proposed in New Mexico, where there are concentrated dairy operations, but they are still in the contract negotiation phase.

1.1.6 Applicability of the Technology to California Dairies

The system is designed for a manure throughput of 400 tons per day with 40 percent moisture content. Based on a manure output of 120 lb/day per cow, this equates to approximately 6,667 cows (since the 120 lb/day is a wet manure value, the number of cows would actually be much higher). This restricts application to very large dairy operations or regions where multiple dairies are aggregated in a geographic area and the cost of hauling the manure is not cost prohibitive. There must be a market for ethanol fuel sales and a market or cost-effective method of ash disposal to justify the investment.

At least one Panelist liked the technology concept of converting manure to fuel with resulting climate benefits and believed it may be well-suited for California. However, critical information needed to confirm its suitability for dairies includes a comprehensive cost analysis; details on how odors, air emissions, and water discharges are controlled; and whether this technology would encourage larger dairies or whether waste from small dairies could be transported to a centrol co-operative facility.

1.1.7 What Data Gaps Exist?

The following information is needed to better assess the applicability and effectiveness of the technology in reducing the environmental impacts from dairies:

- Quantification of the air emissions concentrations from the gasifier burner when fired on both the startup fuel and the waste gas.

- Evaluation of the constituents of the gasifier ash as a pollutant or suitability to market it as a soil amendment, etc.
- Evaluation of the quality of the wastewater discharges from the up front dewatering equipment not included as part of this system and the scrubbers and cooling system.
- Assessment of air emissions from the feedstock storage area and the associated effectiveness of the CBPA anti-pollutant bio-stimulant by EcoChem to reduce odors.
- Complete economic analysis of the entire system from processing to generating products to sale of products to disposal and treatment of waste streams.

1.1.8 What Additional Research and/or Verification Work should be done?

Up front feasibility work involving investigation into the state's ethanol resources and future demand, policy drivers, and barriers to implementation is needed before proceeding. If the system seems economically viable for California, a test program that could be applied to the demonstration scale system to quantify the environmental benefits and impacts and address any scale-up issues should be developed.

1.2 Agricultural Modeling & Training Systems

Product/Process: AMTS.Cattle

1.2.1 Description

"AMTS Cattle" is a software application based upon the Cornell Net Carbohydrate and Protein System (CNCPS). Agricultural Modeling and Training Systems (ATMS) is a new company that is taking the CNCPS development/marketing/sales/training/support outside of Cornell and making it a commercial venture. ATMS Cattle is the first commercial application of CNCPS and has many improvements for managing biological data and in the user interface. ATMS Cattle is intended for use by dairy nutritionists, but can be used by advanced producers. In the application, a model predicts nutrient requirements and nutrient supply values that are unique for each group of cattle and available feeds. Animal performance is predicted, and excretion of nutrients (nitrogen and phosphorous) and total manure is calculated. From an environmental perspective, the objective of this process is to decrease the mass of nutrients being excreted.

1.2.2 Environmental Impacts

This technology is intended to control:

Air Emissions	Non-volatile waste components
☐ Reactive organic gases	☒ Organic nitrogen
☒ Ammonia	☒ Ammonium nitrogen
☐ Particulates	☐ Nitrates
☐ Odors	☒ Phosphorus
☐ Methane	☐ Salts
☐ Hydrogen sulfide	☐ Pathogens

The technology produces the following air emissions:

- ☐ Oxides of nitrogen (NOx)
- ☐ Carbon monoxide
- ☐ Carbon dioxide
- ☐ Reactive organic gases
- ☐ Particulates
- ☐ Sulfur dioxide

By products suitable for commercial sale or use:

- ☐ Heat energy
- ☐ Electrical energy
- ☐ Fuel
- ☐ Fertilizer
- ☐ Soil amendments
- ☐ Bedding
- ☐ Other:

1.2.3 Economic Performance

An economic evaluation could not be performed because the operating costs and pricing system are still being determined by AMTS.

1.2.4 Quality of Supporting Data

- ☐ Sufficient data were provided to demonstrate effectiveness of technology
- ☒ Data were provided, but effectiveness of the technology is inconclusive - need more data
- ☐ Data are said to exist, but data are not yet available or were not provided
- ☐ No data are available

1.2.5 Development Status of the Technology

- ☐ Research (basic research and applied research)
- ☐ Development (concept development and prototype development)
- ☒ Test and evaluation (product/process development)
- ☐ Demonstration (full or field relevant scale)
- ☐ Commercial application

The company has installations in the state of New York. Demonstration trials have been underway since 2000.

1.2.6 Applicability of the Technology to California Dairies

Having a diet formulated to minimize nutrients excreted is a good step. It does not guarantee that the formulation is actually mixed, fed to, and consumed by the cows. There are always three diets for a given group of cows: the one on paper, the one in the feed truck, and the one the animals consume. Without working with the software it is impossible to determine if this will allow nutrient tracking for the facility. Use of a whole farm nutrient balancer may prove more beneficial to an operator.

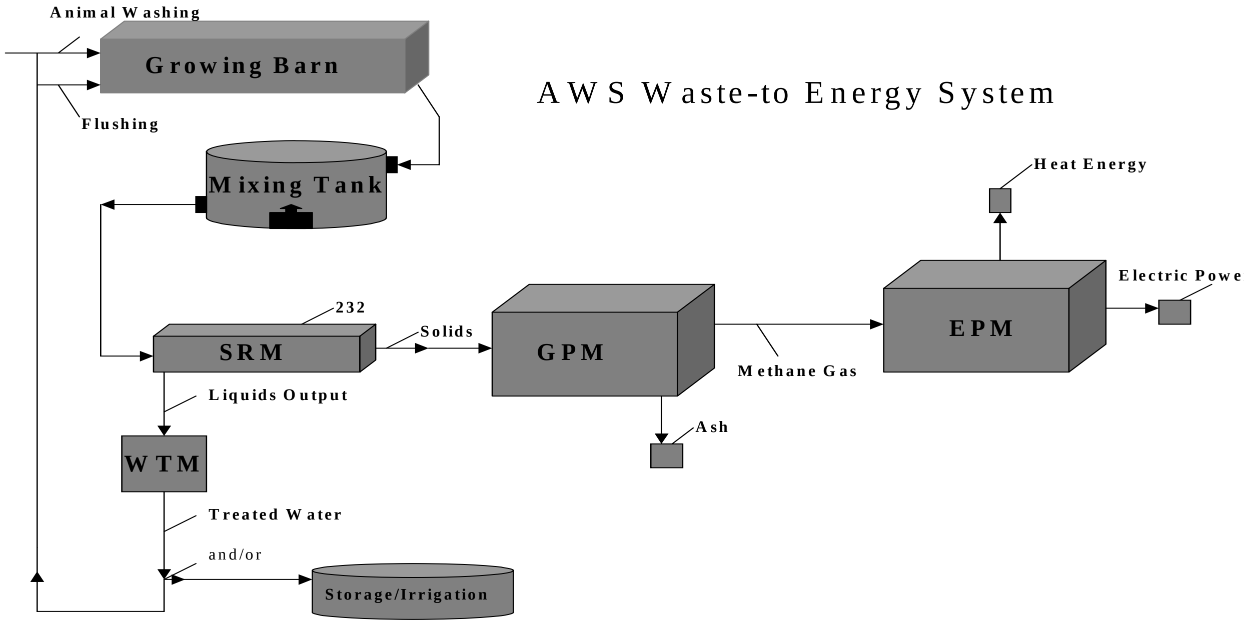
1.3 Agricultural Waste Solutions, Inc.

Product/Process: System for Converting Animal Wastes to Energy and Useful By-Products

1.3.1 Description

The Agricultural Waste Solutions (AWS) technology integrates four separate patented processes as a total system to convert manure into energy and useful byproducts. Module 1 - “Solids Recovery Module” (SRM) - is a self-contained unit that works on centrifugal action with an internal collection scroll for solids discharge and a polymer flocculent additive to dewater the manure (98% solids removal of particles above 5 microns in size). The solids are sent to Module 2, and the liquid is sent to Module 3. Module 2 - “Gas Production Module” (GPM) - is a gasifier that uses pyrolysis to thermally decompose organic material at elevated temperatures in the absence of oxygen to produce a high-value syngas (reported at 1100 BTU/SCF) and ash (reported as less than five percent of the feedstock). Module 3 - "Water Treatment Module” (WTM) - will be used to treat the SRM liquid effluent; however, the technology to be used has not yet been determined. The company will test options in a demonstration project. Module 4 - "Energy Production Module” (EPM) – will use the syngas from the GPM to run a motor that powers an electrical generator. The technology for the EPM has also not yet been determined.

Trials conducted by the company showed the best SRM separation results occur with an influent waste stream containing 8 percent solids or less; therefore, higher concentrations would need to be diluted before treatment. The optimal solids concentration will be determined during a demonstration program. A mixing tank, which is not included with this system, is required before the SRM to keep the solids suspended in solution in the fresh-waste stream so they do not settle out before treatment. The SRM is skid mounted with a 15 by 6 foot base. The GPM is skid mounted with an 18 by 7 foot base. Both are “plug and play” in terms of connecting to gas and electric supplies. A diagram provided by AWS for the system is shown below.



1.3.2 Environmental Impacts

This technology is intended to control:

<u>Air Emissions</u>
- ☒ Reactive organic gases
- ☒ Ammonia
- ☐ Particulates
- ☒ Odors
- ☒ Methane
- ☒ Hydrogen sulfide

<u>Non-volatile waste components</u>
- ☒ Organic nitrogen
- ☒ Ammonium nitrogen
- ☒ Nitrates
- ☒ Phosphorus
- ☒ Salts
- ☒ Pathogens

The technology produces the following air emissions:
- ☒ Oxides of nitrogen (NOx)
- ☒ Carbon monoxide
- ☒ Carbon dioxide
- ☒ Reactive organic gases
- ☒ Particulates
- ☒ Sulfur dioxide

By products suitable for commercial sale or use:
- ☒ Heat energy
- ☒ Electrical energy
- ☒ Fuel
- ☐ Fertilizer
- ☐ Soil amendments
- ☐ Bedding
- ☒ Other: Treated Water

The company indicated that the technology results in a net reduction of NOx, CO, and CO_2. Overall reductions or increases in air pollutants would depend on the baseline established for comparison; however due to fuel combustion, the Panel expects net increases in NOx, CO, CO_2, and SO_2 to be emitted from the GPM burner.

It is not clear how the technology achieves the claimed reductions in salts, phosphorous, and nitrogen compounds. Much of the nitrogen is expected to be in the liquid phase and the technology for treating this material is not identified.

1.3.3 Economic Performance

AWS provided cost information based on a generic 500 milking cow facility (30,000 gal/day waste volume, 10 tons/day solids removed, and 48,000 cubic feet syngas used to generate 200 kW). Actual costs will be project specific. All system modules are not reflected in the cost estimates at this time, because the company is still evaluating various options for the WTM and EPM components.

Pricing is dependent upon the existing infrastructure at the site (e.g., electricity, propane, lagoon for treated water, etc.). The SRM plus GPM will be retail priced at $500,000 for the fully skid-mounted units. Infrastructure and installation costs will vary from farm to farm; however, the company expects skid mounting to keep these costs below $50,000 if an existing lagoon can be utilized as a treated water collection pond. AWS stated that the WTM would not be required for most California dairies that will utilize the SRM-treated water as irrigation water because the phosphorous removal from the SRM is high and the ratio of organic to total nitrogen is good for most California-grown crops. The EPM is required for energy production, and the company assumes a retail price of $170,000 for a 200 kW unit. Information collected by California Air Resources Board staff in 2001 estimated the installed cost of a microturbine at $1,000-1,500 per kW; therefore, the Panel believes the AWS figure is reasonable.

Annual operating and maintenance costs are attributed to polymer supply and general maintenance and are estimated to be $30,000 per year. Breakdown of polymer quantity and unit price was not given, nor was specific information on maintenance parts and labor. Annual electricity costs to operate system equipment are expected to be offset by energy production in the EPM.

The company estimates 8-10 years before a major overhaul of the system equipment. The key to the durability of SRM is the internal scroll-separator device. In the trial unit, AWS reported that it has lasted 2.5 years with no maintenance or replacement.

1.3.4 Quality of Supporting Data

- ☐ Sufficient data were provided to demonstrate effectiveness of technology
- ☒ Data were provided, but effectiveness of the technology is inconclusive - need more data
- ☐ Data are said to exist, but data are not yet available or were not provided
- ☐ No data are available

A gas analysis was provided for testing on a GPM prototype using dairy manure at North Carolina State University. The analysis showed a gas with a heating value of about 1,100 BTU/SCF (comparable to natural gas) composed of mostly ethane, carbon dioxide, methane, and nitrogen. No quantitative air emission reduction guarantees for the system were provided at this time. Air emissions are expected from the gasifier and electrical generator. Data will be available upon completion of a test program at the Inland Empire Utilities Agency (IEUA) in Chino, California.

The company provided one set of measurements of the influent (flushed liquids containing a combination of feces, urine, and wash-down liquids) and effluent (liquids and solids) from the SRM at a test site at North Carolina State University for two swine and one dairy waste streams. Results from the dairy manure liquids portion reported the following: 70% removal of total Kjeldahl nitrogen, 91% removal of total phosphorus, 36% removal of potassium, and 150% increase in nitrate. A Panelist with water quality expertise indicated that data provided at this time are inadequate to draw definite conclusions as to the effectiveness of the technology in reducing threats to water quality because there was no comparison to a control.

Data were not provided to demonstrate pathogen reduction. The Panel does not expect pathogens to survive the high temperatures in the GPM, but the liquid waste stream from the SRM could contain pathogens.

1.3.5 Development Status of the Technology

- ☐ Research (basic research and applied research)
- ☐ Development (concept development and prototype development)
- ☐ Test and evaluation (product/process development)
- ☒ Demonstration (full or field relevant scale)
- ☐ Commercial application

Demonstration of the system in the field was scheduled to commence in late April 2005 at IEUA and should conclude within 6 to 12 months. The SRM to be demonstrated is rated from 5 to 50 gallons per minute (gpm). The company plans to supply models up to 250 gpm in the future, and the GPM is rated at 700 pounds per hour of solids feedstock (the company plans the standard model to be rated at 1,000 pounds per hour with models eventually available up to 8,000 pounds per hour). These larger units have not yet been built and tested.

1.3.6 Applicability of the Technology to California Dairies

The system may be beneficial for dairies if excess nutrients are an issue and the generated electricity could be used at the site or sold back to the electric supply grid. The overall environmental benefits of the system as a total package need to be determined based on the testing at IEUA.

1.3.7 What Data Gaps Exist?

The following information is needed to better assess the applicability and effectiveness of the technology in reducing the environmental impacts from dairies:

- Analysis of the dairy manure syngas composition and quantification of the air emissions from the GPM burners when fired on both the startup fuel and the syngas
- Data on the effectiveness of the WTM for further treatment of the SRM liquid effluent
- Data on the air emissions from the EPM across varying loads, along with the thermoelectric efficiency
- More complete cost information to determine the actual costs for the total four-module system package.

1.3.8 What Additional Research and/or Verification Work should be done?

Testing and evaluation of the environmental performance of the AWS system was scheduled to start in April 2005 at IEUA. The testing period is expected to complete within 6 to 12 months. The testing plan and protocols were not provided to the Panel for review; however the Panel expects that the information collected will help fill in the data gaps outlined above.

1.4 Agrimass Enviro-Energy, Inc.

Product/Process: Biological Remediation of manure wastewater and manure solids

1.4.1 Description

The Agrimass Enviro-Energy (Agrimass) biological treatment system treats dairy wastewater through aeration and bio-augmentation. The aeration system ("aerator") utilizes a 1-horsepower compressor to deliver pressurized air to the wastewater via a submerged air diffuser. Agrimass states that a level of 1 to 2 mg/L dissolved oxygen (DO) is maintained in the wastewater lagoon by the aerator. The pond volume that can be treated with a single aerator was not stated. The company literature states that a proprietary brewing process by Anderson Bio Systems (ABS) is used to create a blend of microorganisms specific to the site to assist in the biological treatment of the wastewater.

The company stated benefits of the Agrimass biological treatment process are reductions in odors, nutrient loading and solids. Specifically, the company reports reductions in nitrogen, reductions in the aqueous fraction of phosphorus, chemical oxygen demand (COD), biological oxygen demand (BOD), and total volatile solids (TVS).

This technology is similar to other oxygen and microbe augmentations processes. As in the other processes, data are needed to verify the air quality claims and other performace claims. Details regarding the treatment process, design criteria , equipment performance parameters, and detailed cost information also needs to be provided to fully evaluate the technology.

1.4.2 Environmental Impacts

This technology is intended to control:

Air Emissions	Non-volatile waste components
☐ Reactive organic gases	☒ Organic nitrogen
☒ Ammmonia	☒ Ammonium nitrogen
☐ Particulates	☐ Nitrates
☒ Odors	☒ Phosphorus
☒ Methane	☐ Salts
☒ Hydrogen sulfide	☒ Pathogens

The technology produces the following air emissions:

- ☐ Oxides of nitrogen (NOx)
- ☐ Carbon monoxide
- ☐ Carbon dioxide
- ☐ Reactive organic gases
- ☐ Particulates
- ☐ Sulfur dioxide

By products suitable for commercial sale or use:

- ☐ Heat energy
- ☐ Electrical energy
- ☐ Fuel
- ☒ Fertilizer (on-farm use)

☐ Soil amendments
☐ Bedding
☐ Other

The information provided claims reductions in the parameters checked above. It is not clear how the technology controls emissions of ammonia or reduces organic nitrogen and ammonium nitrogen. BOD, COD, and TVS are also reported to decrease.

1.4.3 Economic Performance

The cost data provided as part of the technology package were not responsive to the Panels request. For example, a detail, itemized cost breakdown was not provided. Additional clarification of the cost information was sought for standardized hypothetical conditions such as power cost of $0.10 per kilowatt-hour (kW-hr) and a 1,000-cow dairy, but that also was not provided. The following summary information was provided:

- Capital investment costs plus first year cost of treatment: 5 to 7 cents/ milking cow/day
- Second year annual operation and maintenance costs: 3 to 5 cents/cow/day
- Estimated life of aeration equipment: compressors – 3 years, aeration heads – 5 years
- Normal monthly operating cost is $40 to $45 per unit (depending on power costs)
- Annualized cost of $25,000 to $33,000 was provided for a hypothetical 1,000-cow dairy ($0.07 to $0.09 per cow per day); these costs include installation, initial dosage, the monthly dosage, and maintenance, cost of aeration equipment, and laboratory and monthly report
- Second year cost for the 1000-cow hypothetical dairy is between $18,000 and $25,000 ($0.05 to $0.07 per cow per day)
- The cost of operating the largest aeration unit was approximately $50 per month based on a 1-horsepower (hp) compressor and 18 aeration discs.

The range in reported costs is due to variability in nutrient loading and power costs. The costs information lacked details for adequate evaluation. For example, it is unclear what the $45 monthly operating cost per unit covers – a single aerator? How many aerators are needed to treat a hypothetical 1,000-cow dairy? The stated power needs (1-hp) and costs in maintaining oxygen levels at 1 to 2 mg/L do not seem reasonable (see discussion in section 2.7 in the main body of this report). Since details of the process and information such as oxygen requirements and aerator performance were not provided, the costs estimates could not be evaluated. It seems likely that considerably more power than a single 1-hp compressor for a 1,000-cow dairy will be required for nitrification and to reduce organic concentrations. This conclusion is based on typical diffused-air, fine-bubbler aerator performance.[1] Other aeration systems for dairy wastewater treatment report much higher power requirements in the order of 50 hp or more (see reports for Haskell Edwards and Air Diffusion Systems).

---

[1] Metcalf and Eddy, Inc., 1979. Wastewater Engineering. Pg 497, Table 10-6.

1.4.4 Quality of Supporting Data

- ☐ Sufficient data were provided to demonstrate effectiveness of technology
- ☒ Data were provided, but effectiveness of the technology is inconclusive - need more data
- ☐ Data are said to exist, but data are not yet available or were not provided
- ☐ No data are available

Data to support claims for reduction of gas emissions or reduction in pathogens were not provided. Summary data for the reduction of nutrients and other inorganic and organic components in the wastewater were provided and is shown below. However, there are some inconsistencies with the data. For example, the data show a 69% reduction in BOD in Lagoon 1, but no reduction in COD or TVS. This is not logical as TVS and BOD are fractions of COD, and a reduction in BOD would result in a reduction in COD. TVS is the most labile fraction of the organics, and a reduction in BOD would certainly result in a reduction in TVS. Similar confounding results were noted for Lagoons 6, 7, 8, 9, and 10. The performance of the system is inconsistent as indicated by reported reductions in soluble phosphorus ranged from 4 to 70 percent and 0 to 95 percent for ammonia nitrogen. The performance of the technology cannot be ascertained from these data, as there was no control treatment to compare with. Additionally, dairy wastewater lagoons are generally heterogeneous, and a sampling program must take this variability into account through a statistically-based design. It is not known if this was done in this case as only summary data were provided. The data provided seem to show a trend for reduction of those parameters; however, this conclusion is contingent on the quality of the data.

1.4.5 Development Status of the Technology

The company indicated that they have 29 installations in six states: Indiana, Kansas, Idaho, Nebraska, Georgia and Iowa. One installation has operated for four years.

1.4.6 Applicability of this Technology for Dairies in California

To the extent that the claims regarding odor control and gaseous emissions reductions are accurate, the technology would be of benefit in California. However, data supporting these claims need to be provided. The reduction of phosphorus in the soluble phase is of little value if the lagoon solids are harvested and applied to cropland on the dairy. Reductions of nitrogen through mineralization and denitrification may be of value in nitrogen balance if the dairy is in a situation of excessive nitrogen production beyond that which it can assimilate at the dairy and there are no other economical means of disposal. In situations where the objective is to reduce the nitrogen load to achieve nutrient balance, it may be more economical to treat a portion of the wastewater stream rather than the entire waste load.

1.4.7 What Data Gaps Exist?

The information provided was insfficient with respect to the process description, design parameters, and cost information to adequately evaluate the technology. It is stated that nitrogen is reduced through denitification. However, a denitrification step which would require establishing anoxic conditions following nitrification was not noted. All that is known is that the wastewater lagoon is maintained at a DO level of 1-2 mg/L.

Appreciable denitrification would not take place under these conditions as denitrificaton is the reduction of nitrate to the final products of N_2O and N_2 (see section 2.8 in the main body of this report).

Design parameters and process needs to be provided. It was noted that a proprietary software package is used to design the treatment system. While it is not necessary to provide the software, a description of the process and considerations can be provided. For example, what are the waste loading rates with respect to volume, organic strenght and nutrient content? What are the treatment objectives and the design considerations in achieving those objectives based on the amount of oxygen required and the performance of the aerators (e.g., standard oxygen transfer rate, and aerator efficiency). What are the hydraulic retention time (HRT) and solids retention time (SRT) based on the aerator performance. It is noted that 1-hp blower provides the air for the aeration process. This would appear to be woefully inadequate for the oxygen demand in a dairy wastewater lagoon and to achieve nitrification. Thus, the aforementioned information is needed to evaluate the claims and additional information such as the DO concnetrations needs to be provided. With respec to the organic reductions, the confounding results (decrease in BOD without a commensurate decreases in COD) need to be resolved. Additionally, the inconsistent performance with respect to nutrients suggests sampling errors or design flaws.

Quantitative or scientifically derived data were not provided for gas emmisisions or odors. Mass balance data would be useful for nitrogen and sulfurto help assess their fate and to estimate emmisions for these two important parameters.

The need for the inoculum needs to be established (see Section 2.8 in the main body of this report). That is, once the ponds are inoculated and the microbes established, is it necessary to continually innoculate?

1.4.8 What Additional Research and/or Verification Work should be done?

Aeration/biological treatment is a well-established technology. The engineering design principles have been developed. Further work is needed to confirm the claims of reduced emissions and to quantify odor reduction. Design considerations need to be provided, but given the high variability in performance (nutrient and organic reductions) it appears that further work is needed to optimize the design.

1.5 Agrimass Enviro-Energy, Inc.

Product/Process: Induced Blanket Reactor

1.5.1 Description

On 18 December 2002, Conly L. Hansen and Carl S. Hansen, of Utah filed for a patent on the Induced Blanket Reactor (IBR) technology. The patent is currently pending. Andigen, an S-Corporation, has rights to this technology. Agrimass Enviro-Energy Inc. provides operating and managing services as part of the sales contract for the technology.

The IBR works by treating manure in a tank with a certain height to diameter ratio. The tank is loaded with methanogenic bacteria that eat the waste and produce gas bubbles which make the bacteria float. Near the top of the tank is a cone-shaped septum with an aperture in the center. The aperture contains an auger-like mechanism with a uniform diameter and shape. The septum and the auger are submerged in liquid all of the time (anaerobic environment). The bacteria and attached solids float to the top and contact the septum. The concave shape of the under side of the septum helps to dislodge the gas because the bacteria roll along the septum after hitting it. The turning auger is operated to push material down to help separate the gas from the bacteria. The turning action prevents the hole in the septum from plugging while allowing gas and effluent liquid to flow up around it. The gas and digested effluent flow around the auger and exit through the aperture. The bacteria and undigested solids sink. Solids that do escape through the septum sink down the top of the septum (which is convex) and are directed back into the bottom part of the tank. The cycle then repeats. Although the auger acts as a control device to retain solids below the septum, it can be reversed to move solids above the septum if the aperture is plugged.

1.5.2 Environmental Impacts

This technology is intended to control:

Air Emissions	Non-volatile waste components
☐ Reactive organic gases	☐ Organic nitrogen
☐ Ammonia	☐ Ammonium nitrogen
☐ Particulates	☐ Nitrates
☒ Odors	☐ Phosphorus
☒ Methane	☐ Salts
☐ Hydrogen sulfide	☐ Pathogens

The technology produces the following air emissions:

- ☐ Oxides of nitrogen (NOx)
- ☐ Carbon monoxide
- ☒ Carbon dioxide
- ☐ Reactive organic gases
- ☐ Particulates
- ☐ Sulfur dioxide

By products suitable for commercial sale or use:

- ☒ Heat energy
- ☒ Electrical energy
- ☐ Fuel

☒ Fertilizer
☒ Soil amendments
☒ Bedding
☐ Other

1.5.3 Economic Performance

The vendor provided the following economic cost information: The total cost of IBR will be between $700 and $1,000 per animal unit but will vary from one dairy to another based on many factors including, but not limited to, size, location of the IBR on the dairy, type of manure collection (flush, scrape or vacuum), use of gas (used in a generator to produce electricity or compressed and used as natural gas), location of generator for interconnection to the energy distribution grid, use of boiler to produce steam, and many other considerations.

1.5.4 Quality of Supporting Data

☐ Sufficient data were provided to demonstrate effectiveness of technology
☐ Data were provided, but effectiveness of the technology is inconclusive - need more data
☒ Data are said to exist, but data are not yet available or were not provided
☐ No data are available

1.5.5 Development Status of the Technology

The vendor provided the following development status: Three full-scale IBR digesters are currently operating in the US. The sizes of these full scale facilities are 1) A 100,000 gallon IBR at a dairy with 1,200 cows; 2) A 60,000 gallon IBR at a dairy that currently has about 1,000 cows and will eventually have 6000 cows; and 3) a 35,000 gallon IBR at a pig farm with 4,400 pigs.

1.5.6 Applicability of the Technology to California Dairies

The IBR technology is currently being full-scale tested for animal wastes with total solids contents between 4-8%. If the technology can achieve the intended results, it will demonstrate that a small IBR reactor can achieve the same level of volatile solids reduction as existing anaerobic digestion technologies that use large facultative ponds. Thus, IBR will be an addition to the existing anaerobic treatment technologies. The IBR technology may be more suitable for dairy manure collected through scrape or vacuum systems.

1.5.7 What Data Gaps Exist?

Technical, economical, and environmental performance data are lacking and need to be released if the data are available.

1.5.8 What Additional Research and/or Verification Work should be done?

Additional research needs dependson what data are currently available.

1.6 Agriventures

Product/Process: Vermi-composting

1.6.1 Description

Vermi-composting is a bio-oxidation and stabilization process for organic material that, in contrast to composting, involves the joint action of earthworms and microorganisms and does not involve a thermophilic stage. The method of vermi-composting offered by Agriventures is windrows with a water misting system. Windrows are linear piles on the ground containing feedstock generally up to 2to 3 feet high and 4to 10 feet wide. Length varies depending on space availability, ease of material handling, and other factors. The distance between windrows should be sufficient to allow room for manually or mechanically operated equipment to be used between the windrows for feeding and harvesting. Worms most commonly used are *Eisenia fetida* / *Eisenia andreii* (common name, red worm). These worms are epigeic species that are found in nature in the upper topsoil layer where they feed in decaying organic matter. They build no permanent burrows and prefer loose topsoil to the deeper soil environment.

Windrows are typically started with 12 to 18 inches of manure solids with worms applied at a rate of 1 pound per square foot of windrow surface area as suggested by California Integrated Waste Management Board (CIWMB) staff contacted by the Panel, although Agriventures recommends an application rate of 1 pound per cubic foot of feedstock. CIWMB staff noted that worms will regulate their population according to the surrounding conditions; if there is more living space and if food, temperature, pH, and moisture are tolerable, then the population will increase. If there is less food and other conditions are the same, the population will decrease.

When people start a bed (windrow or “rick”), they talk of “seeding” the bed. This is because the worms are expected to multiply. However, some people prefer to seed more heavily so they do not have to wait for the worms to multiply. Each week, a 2 to 3 inch layer of manure is added to each windrow to gradually increase the windrow depth. Vermi-composting operates on the principle that worms are surface feeders, so after about 1 to 2 months, the top layer is removed with a front-end loader and the worms are separated from their castings using screens.

Optimal living conditions for the worms must be maintained in order for the system to be most effective. These include bed temperatures of 55-85 °F, with an ideal range of 60-80 °F; adequate moisture of 60-85% to help them breathe through their skin; oxygen; darkness (worms are photosensitive); grit (sand, oyster flour, sterile soil) to aid digestion; and a slightly acidic environment (6.5 pH, but can tolerate 5 to9 pH). According to Agriventures, windrow piles should not be greater than 4 to5 feet in height, presumably to limit the creation of anaerobic conditions.

Information provided by the company indicates that worms live about seven years, double their population every 120 days, and are most reproductive from 1 February to 1 June and from 30 September to the first frost. Worms are hermaphroditic; mature eggs and sperm are deposited in a cocoon. For Eisenia fetida, approximately four baby worms emerge from a cocoon in 30-75 days and reach sexual maturity in another 53 to 76 days must pass for the newly hatched worms to. Both Agriventures and CIWMB-staff stated that a solids separator is not needed to prepare the manure for vermi-composting.

1.6.2 Environmental Impacts

This technology is intended to control:

Air Emissions	Non-volatile waste components
☒ Reactive organic gases	☐ Organic nitrogen
☒ Ammonia	☐ Ammonium nitrogen
☒ Particulates	☐ Nitrates
☒ Odors	☐ Phosphorus
☐ Methane	☐ Salts
☒ Hydrogen sulfide	☒ Pathogens

The technology produces the following air emissions:

- ☐ Oxides of nitrogen (NOx)
- ☐ Carbon monoxide
- ☐ Carbon dioxide
- ☐ Reactive organic gases
- ☐ Particulates
- ☐ Sulfur dioxide

By products suitable for commercial sale or use:

- ☐ Heat energy
- ☐ Electrical energy
- ☐ Fuel
- ☐ Fertilizer
- ☒ Soil amendments
- ☐ Bedding
- ☐ Other

1.6.3 Economic Performance

Technology cost information was not available from Agriventures during the Panel's review period. The company is currently working with New Era Farm Services out of Tulare, California, to start a joint venture to market vermi-composting systems. New Era will determine the scope and cost of these systems. Agriventures does not expect to market the vermi-composting systems to individual dairy farms. Rather, the company plans to focus on operations where farmers would pay to have the manure removed from the dairy to be vermi-composted at a separate facility.

CIWMB staff estimated the cost of worms at $10 to 20 per pound on the open market. The price paid for worm castings is variable and depends on local demand. Agriventures stated that they sell castings for $4.50 per gallon.

1.6.4 Quality of Supporting Data

- ☐ Sufficient data were provided to demonstrate effectiveness of technology
- ☐ Data were provided, but effectiveness of the technology is inconclusive - need more data
- ☒ Data are said to exist, but data are not yet available or were not provided
- ☐ No data are available

Agriventures did not provide data to substantiate the environmental benefits of vermi-composting. The company was not aware of any current or past research studies that measured air pollutant emissions or nutrient pathways from vermi-composting. The company stated that there is no odor once the worms are active in the windrows for three days; however, no measurement data were provided to verify this claim. Traditional methods of aerobic composting to reduce pathogen levels elevate the temperature of the feedstock to between 135°F and 160 °F for a sufficient time to ensure pathogen destruction. With vermi-composting, the system is managed to ensure temperatures remain below 90 °F to support high levels of worm activity. However, CIWMB staff stated that some research was conducted recently in Orange County, Florida, to test the pathogen (fecal coliform, Salmonella sp., and enteric virus) reduction potential of vermi-composting of domestic wastewater residuals (biosolids). The research found that vermi-composting reduced pathogen levels to meet the definition of a U.S. EPA Class A biosolid.

1.6.5 Development Status of the Technology

- ☐ Research (basic research and applied research)
- ☐ Development (concept development and prototype development)
- ☐ Test and evaluation (product/process development)
- ☐ Demonstration (full or field relevant scale)
- ☒ Commercial application

1.6.6 Applicability of the Technology to California Dairies

Of primary consideration is whether there is a market for the worm castings. Unless a dairy operates as an integrated system that can utilize the vermi-compost onsite, then the technology is probably better suited to operations whose primary business is to produce vermi-compost and acts as a centralized manure collection point. In addition, successful vermi-composting requires that the optimal living conditions for the worms be consistently maintained. Therefore, each dairy must evaluate its own resources to assess whether vermi-composting will work for their site. Limiting site factors include insufficient water supply to keep the piles moist, cold weather conditions, and limited land surface area for the beds. Beds must be properly maintained, so time and labor investment is an important consideration.

1.6.7 What Data Gaps Exist?

The following information is needed to better assess the applicability and effectiveness of the technology in reducing the environmental impacts from dairies:

- Quantitative data on the associated air pollutant emissions from the manure piles at various stages of the vermi-composting process.
- Data on how vermi-composting changes the nutrient availability of dairy manure.
- Whether leaching of nutrients from open vemicomposting piles is an issue, particularly during periods of higher rainfall. It should be noted that there are companies selling compost covers that provide moisture control during the composting process. The covers create a lightweight yet durable blanket which sheds precipitation off a compost pile while remaining permeable to oxygen, carbon dioxide, and water vapor.
- Data on the odor abatement capabilities of vermi-composting.

- Whether medication given to livestock enters the waste stream and affects or kills the worms.
- Itemized cost breakdown of capital and associated annual operating and maintenance costs for a vermi-composting system.

1.6.8 What Additional Research and/or Verification Work should be done?

To provide a comprehensive picture of vermi-composting options, the Panel suggests that other types of vermi-composting methods in addition to the windrow system offered by the company be investigated for feasibility, cost, and reduction of environmental impacts. Other options incorporate stacked bins and in-vessel equipment, including the use of a biofilter to further mitigate emissions from enclosed systems.

Vermi-composting is not a new technology. Therefore, conducting a wide literature search for existing peer-reviewed papers and published studies on air emissions benefits, nutrient pathways, pathogen reduction, and odor abatement capabilities of vermi-composting will help to identify where additional research should be focused, if needed.

A listing of vermi-composting equipment vendors is available on the CIWMB web site (http://www.ciwmb.ca.gov/Organics/Worms/BinSuply.htm). The Panel suggests that a phone survey of these worm bin suppliers to inquire about any known studies on the environmental benefits/impacts of vermi-composting and to obtain cost information would help fill in some of the data gaps.

1.7 AgSmart, Inc.

Product/Process: The O_2 Solution ™

1.7.1 Description

The O_2 Solution by AgSmart Inc., utilizes partial aeration of the dairy wastewater lagoon combined with periodic seeding with microorganisms to assist in the breakdown of organic components. As noted by the company literature, the primary benefits of this trreament process are reductions in odors, sludge volumns, and gaseous emissions. The O_2 Solution uses a low powered compressor (4-hp) to deliver air to the bottom of the lagoon through a micro-diffuser system. According to the company, the micro-diffuser not only adds air but also mixes the lagoon contents. The aeration provided by the micro-diffuser reportedly accounts for 5% of the biological oxygen demand (BOD). Company literature reports a blend of mciroorgnaisms that include aerobes, facultative microbes and algae are cultured on-site and periodically addedd to the wastewater lagoon. The microbes assist in the digestion, and the algae contribute oxygen to the lagoon.

Data supporting the claimed benefits are lacking. If the claims can be subtantiated through scientifcally valid data then the technology has promise for California dairies. A mass balance approach shoul be used in evaluating the fate of nitrogen under this system.

1.7.2 Environmental Impacts

This technology is intended to control:

Air Emissions	Non-volatile waste components
☒ Reactive organic gases	☒ Organic nitrogen
☒ Ammonia	☐ Ammonium nitrogen
☒ Particulates	☐ Nitrates
☒ Odors	☒ Phosphorus
☒ Methane	☐ Salts
☒ Hydrogen sulfide	☐ Pathogens

The technology produces the following air emissions:

- ☐ Oxides of nitrogen (NOx)
- ☐ Carbon monoxide
- ☐ Carbon dioxide
- ☐ Reactive organic gases
- ☐ Particulates
- ☐ Sulfur dioxide

By products suitable for commercial sale or use:

- ☐ Heat energy
- ☐ Electrical energy
- ☐ Fuel- Charcoal
- ☐ Fertilizer
- ☐ Soil amendments
- ☐ Bedding
- ☐ Other

1.7.3 Economic Performance

The submission package was not responsive for the cost information requested. Cost information was clarified, and additional information requested for a hypothetical 1,000-cow dairy but the information was not forthcoming. Itemized costs were not provided, but total costs were aggregated and reported on a per cow basis. The following are the cost information provided:

For the first year the costs are $40 to $60 per cow. This appears to cover capital and operating costs and includes:

- Greenhouse to house culturing tanks
- Tanks
- Algae feeding and distribution system
- Micro-diffuser system

There is no mention of costs associated with design, installation, construction, permits, and useful life of the major components. It appears that capital and operating costs (for the first year) are amortized over the first year. It would be more useful to amortize capital costs over the life of the equipment.

The operating costs after the first year of operation are reported as $0.50 to $0.75 per cow. Again, the costs are not itemized. Detailed and complete economic information along with verified and quantified benefits of the technology are needed so that a dairy producer may weigh the cost and benefits of this technology versus the cost and benefits of other management options.

1.7.4 Quality of Supporting Data

- ☐ Sufficient data were provided to demonstrate effectiveness of technology
- ☒ Data were provided, but effectiveness of the technology is inconclusive - need more data
- ☐ Data are said to exist, but data are not yet available or were not provided
- ☐ No data are available

This report lacks sound quantitiative measures to support the claims. For example, anectodal accounts and qualitative measures were offered for odor reductions, and no scientifically derived data were provided to support the claim. With respect to other air quality benefits such as reduced gaseous emissions, no data were provided to support these claims. Likewise, with respect to claims of reduction of sludge, no supporting data were propvided. Data collection methodology was also flawed as it lacked a statistical basis. BOD was measured at the surface at four locations prior to the treatment, and the mean of the measurements was used as representative of the conditions prior to the start of the treatment. The mean was then compared with what appears to be a composite sample taken at 6 feet during the treatment. No consideration appears to have been given to the hetergeonity of the lagoon. The sampling at 6 foot depth appears to have been assumed to be representative of the entire lagoon, but no information was provided to show that the diffused air provided for complete mixing.

Data provided for dissolved oxygen showed an increase in oxygen concentration from 0.05 mg/L (one measurement) to approximately 0.35 mg/L as a result of the treatment. However, data also indicate that oxidation reduction potential (ORP) become more negative (less than - 400mV) as a result of the aeration and microbial augmentation. This is contrary to what one would expect. The low ORP suggests reducing conditions, not an aerobic environment as is claimed to be produced and not consistent with the DO concentrations. ORP in the zero to slightly positive range would be expected for the DO concentrations reported. Dairy lagoons managed for storage and having high organic loading rates that result in anaerobic conditions generally have ORPs in the - 200 to - 300 mV range. Although it was claimed that the air diffusion provides for mixing, no data were gathered to support that mixing had been achieved.

1.7.5 Development Status of the Technology

This technology is reportedly being applied at four dairies in Colorado. It appears that the main issue being addressed is odors. Only anecdotal and qualitative information (number of complaints) have been offered to support the claim of reduced odors. Additional testing of the technology is needed to verify the claims. Inconsistencies in the data, in particular with respect to oxidation-reduction potentials and dissolved oxygen, need to be resolved.

1.7.6 Applicability of the Technology to California Dairies

To the extent that this technology reduces odors, it is positive for California dairies. It is also likely to reduce some gaseous emissions, but this needs to be verified. One potential advantage of this aeration system over other partial aeration systems is that the algae contribute oxygen without agitation. Agitation as it occurs with mechanical surface aerators may potentially cause ammonia volatilization.

1.7.7 What Data Gaps Exist?

Detailed cost information is needed so that dairy producers may compare the costs of this technology againstother technologies to assess which is most cost-effective for their facility. The claimed benefits of reductions in odors , gaseosus emisssions (ammonia, VOCs, etc.) and reduced sludge production need to be supported with data. The fate of nitrogen should be evaluated through a mass balance approach. Additionally, the confounding data results with respect to DO and oxidation reduction potential need to be resolved.

1.7.8 What Additional Research and/or Verification Work should be done?

The scientific and engineering principles behind aeration have been well developed. This particular system introduces a twist in that the algae partially contribute to the oxygen augmentation of the lagoon. The relative contributions by the aerator and by algae need to be assessed to demonstrate the effectiveness of the algae system at improving the oxygen status of the lagoon. Additionally, the basis for the continual augmentation of the lagoon with algae needs to be established. It would seem that once the lagoon is inoculated the algae would flourish and grow as long as the appropriate environmental conditions are maintained.

In addition to developing data to support the claimed benefits, studies need to be conducted to assess the affect on ammonia volatilization. These studies may require a mass balance approach. All studies should consider the variability of the lagoons contents in the context of data collection and the need to develop a statistically based sampling program.

1.8 Air Diffusion Systems

Product/Process: AMTS - Advance Microbial Treatment System

1.8.1 Description

Air Diffusion Systems (ADS) provides wastewater treatment services to municipalities and animal agriculture sector through application of its Advance Microbial Treatment System (AMTS) process. The basics of the AMTS is diffused air aeration with bioaugmentation and the use of biofilters to support the bacterial growth to enhance the biological treatment. According to information provided by ADS, the process has been applied at at 100 sites in the midwest. A case study was provided for swine operation. A full-scale operatin has not been implemented for a dairy operation.

Based on the swine case study provided, the process involves successive treatment of the wastewater through a series of lagoons. First, the wastewater is held in an untreated anaerobic lagoon for an unspecified amount of time. This step is followed by feed of wastewater at 50,000 gpd to a 4.8 million gallon lagoon that is 11 feet deep. This lagoon is aerated with diffused air supplied by an appropriately-sized blower designed to meet the oxygen demand in the wastewater and reduce nutrients by 75 percent. This lagoon is partioned by a baffled curtain into secondary and teritary treatment cells. The secondary cell is augmented continously with a "benefical sludge digested liquid bacterial product" (Bacta-Pur XLG) for biological treatment. The tertiary cell is augmented with a liquid containing nitrifying bacteria (Bacta-Pur N-3000).

According to the company, AMTS reduces odors and emissions of ammonia and volatile organic compounds, hydrogen sulfide, and other gases and particulates. The company claims that ATMS also reduces concentrations of nitrogen, phosphorus, and metals in wastewater used for land application. As with other aeration technologies evaluated, supporting information is needed to verify the claims; in particular, those of reduced odors and gasesous emissions. The technology appears to mineralize nitrogen and convert it to nitrate. This has generally been considered an undesirable process in California owing to the potential groundwater contamination with nitrate from leakage of lagoons and from non-uniform land application. Additionally, the sequestering of phosphorus and metals into biomass and/or sludge does not eliminate the need to manage these materials, as the sludge will eventually need to be disposed or utilized.

1.8.2 Environmental Impacts

This technology is intended to control:

Air Emissions	Non-volatile waste components
☒ Reactive organic gases	☒ Organic nitrogen
☒ Ammonia	☒ Ammonium nitrogen
☒ Particulates	☐ Nitrates
☒ Odors	☒ Phosphorus
☐ Methane	☐ Salts
☒ Hydrogen sulfide	☒ Pathogens

The technology produces the following air emissions:

☐ Oxides of nitrogen (NOx)

- ☐ Carbon monoxide
- ☐ Carbon dioxide
- ☐ Reactive organic gases
- ☐ Particulates
- ☐ Sulfur dioxide

By products suitable for commercial sale or use:

- ☐ Heat energy
- ☐ Electrical energy
- ☐ Fuel- Charcoal
- ☐ Fertilizer
- ☐ Soil amendments
- ☐ Bedding
- ☐ Other

1.8.3 Economic Performance

As noted, a case study for a swine operation was provided. Cost information provided for this project is presented as follows:

- Total capital costs for a 10,800 annual hog operation is $250,000
- Capital costs amortized over 10-year useful life and expressed as per pound of animal production is $0.01
- Operating and maintenance costs are $96 per day and include:
  - electricity costs of $65 per day for a 60 hp blower
  - 1.04 man-hours per day
  - bioaugmentation at 2 liters per day, (approximately $7.50 per liter)
  - hydrogen chloride cleaning solution ($500 per year)
- Annual production costs expressed on a per pound basis is $0.015.

A full scale aeration and bioaugmentation technology has not been applied for a dairy; however, based on a hypothetical 1,000-cow dairy, cost information was provided based on the following assumptions:

- The wastewater is treated to reduce the nutrient load by 75%
- An 80 hp blower is used to supply air
- The BOD load is 1,380 mg/L
- Electricity costs are $0.1 per kW-hr.

Based on those assumptions, the following costs were developed: Electricity - $160 per day, Bioaugmentation - less than $60,000 per year.

BOD loading is generally highon dairies in California and may be as high as 5,000 to 10,000 mg/L. Treatment can be achieved for this additonal load with longer retention times and/or a larger blower. Thus, energy requiremets may be substatially higher in California than elsewhere.

1.8.4 Quality of Supporting Data

- ☐ Sufficient data were provided to demonstrate effectiveness of technology
- ☒ Data were provided, but effectiveness of the technology is inconclusive - need more data
- ☐ Data are said to exist, but data are not yet available or were not provided
- ☐ No data are available

Several case studies were presented to explain the technology and demonstrate its benefits; however, no scientifically derived data were presented to support the claims. Reductions in odors were not quantified. Claims for the reductions in the emissions of gases were also not supported with data. Reported reductions for wastewater at the swine operation were: total ammonia nitrogen (TAN) - 79%, phosphorus - 43%, BOD_5 - 63%, COD - 65%, TSS - 86%, copper - 80%, and zinc - 78%. The quality of these data cannot be verified since only summary data were provided.

1.8.5 Development Status of the Technology

Although aeration technology and biological treatment is a well-understood process, and the technology has been applied at 100 sites (mostly swine and municipal wastewater facilities), additional information is needed in order to classify the technology as effective for commercial application at California dairies. The treatment system should be evaluated in a California dairy setting. Climate, waste loading rates, salt concentrations, and wastewater management practices need to be evaluated. Additionally, scientifically derived data supporting the claimed benefits of reduced odors, gaseous emissions, sludge reduction, and reduced concentrations of wastewater constituents need to be developed. Detailed and itemized cost information needs to be provided so that dairy producers may weigh the cost and benefits of this system versus alternatives.

1.8.6 Applicability of the Technology to California Dairies

If claims regarding odor and gaseous emissions reductions can be substantiated, the technology might provide environmental benefits to California dairies. However, detailed cost estimates also need to be developed so that dairy producers may weigh the benefits of this system in relation to other options that may achieve similar results. The high level of treatment to nearly eliminate the organic load may not be necessary for most dairies, which may have adequate land to use manure for cropland fertilization. Dairies which may not have adequate land to assimilate all of the organic matter without degrading soil or groundwater might consider using this system on a portion of their waste stream.

It was reported that nutrients and metals concentrations were reduced in the wastewater. With the exception of nitrogen and sulfur, both of which may be volatilized, nutrients and metals are conserved, so they must be in the suspended particulates or in the sludge. If the suspended particulates are not settled, then they will be distributed on cropland and become available. If they settle out in sludge, then the dairy producer must remove the sludge from the facility to reduce loadings on the farm.

Of additional concern is the mineralization of nitrogen and conversion to nitrate. Nitrate from lagoon leakage and from cropland leaching has a high potential for groundwater contamination. It would be better to denitrify this nitrogen unless there is ample land for nutrient assimilation.

1.8.7 What Data Gaps Exist?

Full-scale implementation of the AMTS process has not been tested at a dairy. As noted in the swine case study, wastewater was first held for an undertermied amount of time in a holding lagoon, probably under anaerobic conditions, before being transferred to the aerated and biouaugmented treatment lagoon. Apparently, the purpose in this is to reduce the BOD to a level (200 mg/L) that is optimum for the AquaMat operations. It would appear the holding time in this pond would be substatial as animal maure lagoons generally have elevated BOD(a dairy lagoon can have BOD levels between 5,000 to 10,000 mg/L). During retention in the holding lagoon, it is likely that significant off-gasing and odor production occur. In personal communications with Mr. Brian Lewis, representative for ADS, he noted that bacterial supplements added to the lagoon are able to digests the wastewater without creating odors or enhanced gaseous emisisons. Data supporting the claim that bioaugmentation alone can control odors and digest wastewater constituents need to be demonstrated in California. If the bacteria in an anaerobic lagoon can treat BOD to such low levels (200 mg/L) without generating odors or additonal gaseous emissions, then additonal aeration steps may not be necessary.

The efficacy and necessity for continual augmentation with microorganisms needs to be established. Although there may be some benefit by initial seeding with acclimated microorganisms, it would seem that these populations could be self sustaining and propagating as long as the environemtal conditons are conducive (see Section 2.10 in the main body of this report for a discussion of this topic).

1.8.8 What Additional Research and/or Verification Work should be done?

See the previous discussion.

1.9 Bakersfield - Solid Waste Division

Product/Process: **Wood Chips**

1.9.1 Description

The City of Bakersfield generates a significant volume of wood chips as part of its green waste program. It is offering these wood chips as either a stand-alone product for covering loafing areas, or as a bulking agent for use in composting dairy manure. When used as bedding, the wood chips could absorb dairy waste and produce organic compost at the same time. When used for composting, the wood chips could also be used as a bulking agent and would increase the C:N ratio. The wood chips could also serve as a reservoir for microbes if they are separated at the end of the compost process and returned to the front of the process.

1.9.2 Environmental Impacts

This technology is intended to control:

Air Emissions
- ☐ Reactive organic gases
- ☐ Ammonia
- ☐ Particulates
- ☐ Odors
- ☐ Methane
- ☐ Hydrogen sulfide

Non-volatile waste components
- ☐ Organic nitrogen
- ☐ Ammonium nitrogen
- ☐ Nitrates
- ☐ Phosphorus
- ☐ Salts
- ☐ Pathogens

The technology produces the following air emissions:
- ☐ Oxides of nitrogen (NOx)
- ☐ Carbon monoxide
- ☒ Carbon dioxide
- ☐ Reactive organic gases
- ☐ Particulates
- ☐ Sulfur dioxide

By products suitable for commercial sale or use:
- ☐ Heat energy
- ☐ Electrical energy
- ☐ Fuel- Charcoal
- ☐ Fertilizer
- ☒ Soil amendments
- ☒ Bedding
- ☐ Other

1.9.3 Economic Performance

No economic performance data were provided. The cost to transport wood chips from point of generation to point of use needs to be considered when evaluating potential costs.

1.9.4 Quality of Supporting Data

- ☐ Sufficient data were provided to demonstrate effectiveness of technology
- ☐ Data were provided, but effectiveness of the technology is inconclusive - need more data

☐ Data are said to exist, but data are not yet available or were not provided
☒ No data are available

1.9.5 Development Status of the Technology

The idea needs to be tested and developed.

1.9.6 Applicability of the Technology to California Dairies

The potential use of wood chips as bedding material for cows reportedly came from the observation of cows preferentially loafing on piles of wood chips that were available after piles of wood chop piles were placed in fields for disposal. Cows in free ranging situations will generally choose appealing locations to congregate. If they lie on wood chips, composting of the chips may occur, and food costs may be reduced because cows are more comfortable. However, these are not issues relevant to most dairies in California. Using wood chips as bedding could present problems for manure transfer pumps or irrigation pumps. However, wood chips may have applicability for composting operations.

1.9.7 What Data Gaps Exist?

The idea needs to be tested and developed.

1.9.8 What Additional Research and/or Verification Work should be done?

The idea needs to be tested and developed.

1.10 Baleen Filters

Product/Process: **Baleen Filter**

1.10.1 Description

The Baleen Filter technology is described as offering two distinct treatment approaches: 1) "Primary Filtration" to remove visible and/or suspended substances greater than 100-microns or as precursor to higher-order tertiary filtration technologies, and 2) "Secondary Filtration" with biochemical assistance to remove particles greater than 25-microns. The Baleen Filter system uses a static screen that can be purchace with different settings. The trade off is that removal of finer materiat reduces the feed rate.

1.10.2 Environmental Impacts

This technology is intended to control:

Air Emissions	Non-volatile waste components
☐ Reactive organic gases	☐ Organic nitrogen
☐ Ammonia	☐ Ammonium nitrogen
☐ Particulates	☒ Nitrates
☐ Odors	☒ Phosphorus
☐ Methane	☐ Salts
☐ Hydrogen sulfide	☐ Pathogens

The technology produces the following air emissions:

- ☐ Oxides of nitrogen (NOx)
- ☐ Carbon monoxide
- ☐ Carbon dioxide
- ☐ Reactive organic gases
- ☐ Particulates
- ☐ Sulfur dioxide

By products suitable for commercial sale or use:

- ☐ Heat energy
- ☐ Electrical energy
- ☐ Fuel- Charcoal
- ☒ Fertilizer
- ☒ Soil amendments
- ☒ Bedding
- ☐ Other

This product is for separation of solids from the liquid stream. If the screen can remove organic solids down to 65 microns there is a potential to reduce nutrient loading to the liquid system. The nutrients will be in the solids portion that is more easily exported.

1.10.3 Economic Performance

The cost of a system to remove solids from a 2,000-cow dairy could vary from $50,000 to $130,000 depending on the degree of solids removal required. The screen life is estimated to be three to five years, and the screens cost is estimated at approximately 5% of the system cost. This cost could be reasonable if there is a need to export nutrients and other options are more costly.

1.10.4 Quality of Supporting Data

- ☐ Sufficient data were provided to demonstrate effectiveness of technology
- ☒ Data were provided, but effectiveness of the technology is inconclusive - need more data
- ☐ Data are said to exist, but data are not yet available or were not provided
- ☐ No data are available

1.10.5 Development Status of the Technology:

The product is commercially available.

1.10.6 Applicability of the Technology to California Dairies

The technology makes sense if it can remove a significant amount of nutrients and salts from dairy waste competitively with other technologies. The product is being used in on dairies in Australia and New Zealand. It has not been tried on a dairy in California.

1.10.7 What Data Gaps Exist?

Based on the information supplied, the effectiveness of nutrient removal from dairy waste is unclear, and there are no comprehensive cost estimates.

1.10.8 What Additional Research and/or Verification Work should be done?

Trials need to be conducted with dairy wastes to evaluate effectiveness of nutrient and salt removal. Cost estimates need to be developed for installation and operating costs at typical dairies of various animal populations.

1.11 Baumgartner Environics, Inc.

Product/Process: **Bio-Cap ML**

1.11.1 Description

Bio-Cap ML is a patented, floating, and permeable cover for manure storage and treatment ponds. It covers the entire surface of the pond and is intended to provide both physical retention and biological treatment of gases. The vendor states that the cover causes the pond to stratify, with an anaerobic zone at the bottom and an aerobic zone near the surface beneath the cover. Odorous gases such as ammonia and hydrogen sulfide that are produced in the anaerobic zones are said to be metabolized into less odorous compounds by nitrifying and other bacteria growing on the cover.

The Bio-Cap ML cover is made of permeable 13 oz per square yard, non-woven geotextile. The covers are fabricated on site and trenched around the perimeter of the manure pond. UV coating, access ports, and floats are available.

1.11.2 Environmental Impacts

This technology is intended to control:

Air Emissions	Non-volatile waste components
☐ Reactive organic gases	☐ Organic nitrogen
☒ Ammonia	☐ Ammonium nitrogen
☐ Particulates	☐ Nitrates
☒ Odors	☐ Phosphorus
☐ Methane	☐ Salts
☒ Hydrogen sulfide	☐ Pathogens

The technology produces the following air emissions:

- ☐ Oxides of nitrogen (NOx)
- ☐ Carbon monoxide
- ☐ Carbon dioxide
- ☐ Reactive organic gases
- ☐ Particulates
- ☐ Sulfur dioxide

By products suitable for commercial sale or use: None in this submission, although the cover is said to be patented for collecting methane from anaerobic lagoons.

- ☐ Heat energy
- ☐ Electrical energy
- ☐ Fuel
- ☐ Fertilizer
- ☐ Soil amendments
- ☐ Bedding
- ☐ Other

Company literature states that use of Bio-Cap ML reduces emissions of odor by 84%, of ammonia by 66%, and of hydrogen sulfide by 95%. The company's submission to the Panel also states qualitatively that emissions of VOCs, NOx, CO, CO_2, and PM, are reduced, but these claims are not made or supported elsewhere in the submission, nor are they discussed in the company research report.

There are no claims made for control of water pollution. However, if emissions to the air of ammonia is reduced, then a mass balance analysis suggests that nitrogen will be retained in the lagoon water and may need additional treatment.

1.11.3 Economic Performance

The vendor provided cost data for design capacity, capital investment costs, annual operation and maintenance costs, and estimated useful life of product (stated to be between six and ten years). Assumptions and accounting breakdown for installation, materials, maintenance,removal, and disposal costs were not provided. Total cost is said to be $0.45 to $0.65 per square foot of cover. A figure for cost per cow was not provided and is not easily determined since all of the applications to date are at hog facilities. A solid separator is suggested as a pre-treatment for manure entering the pond, but not does appear to be an absolute requirement and is not included in these calculations.

1.11.4 Quality of Supporting Data

- ☐ Sufficient data were provided to demonstrate effectiveness of technology
- ☐ Data were provided, but effectiveness of the technology is inconclusive - need more data
- ☒ Data are said to exist, but data are not yet available or were not provided
- ☐ No data are available

There is little explanation or data on the physical, biological and chemical impacts and mechanism of action of this specialized type of cover. It is not evident how a lagoon cover could be permeable, allowing rain to enter the pond, water to evaporate out of the pond, and oxygen to diffuse into the pond, but still prevent emissions of air pollutants and trap methane gas. The proposed mechanism is that microbes growing on the cover oxidize and deodorize noxious gases emitted by the lagoon, but there are no data to characterize the numbers, species, ecological diversity or function of this microbial community.

Specific reductions in emissions of odors, ammonia and hydrogen sulfide are claimed, but supporting data come from a company research report. Sampling and statistical methods are not described in this report and no independent data exist yet, although the company expects data later in 2005 from Iowa State University/USDA and the Meat Animal Research Center in Nebraska.

1.11.5 Development Status of the Technology

- ☐ Research (basic research and applied research)
- ☐ Development (concept development and prototype development)
- ☐ Test and evaluation (product/process development)
- ☐ Demonstration (full or field relevant scale)
- ☒ Commercial application

The cover is patented (#6,659,688). The company states that some 135 covers have been installed in 15 states and Canada, and that the oldest have been in operation for 6 years. A letter from the State of Colorado indicates the Bio-Cap ML is an “approved alternative cover” for odor control. All data and installations appear to be at hog facilities.

1.11.6 Applicability of the Technology to California Dairies

It is unclear whether this system would be advantageous for California dairies. Environmental and economic performance data for the covers are not available for dairies, or for California conditions. Reductions in ammonia emissions would be desirable, especially if documented, but the product's impacts on aqueous nitrogen are unknown. The vendor states that the product also helps stabilize berms, but this may not be of great importance in the San Joaquin Valley where winters are mild.

1.11.7 What Data Gaps Exist?

- System has been tried only on hog operations.
- Marketing literature claims that the cover does not affect evaporation of water from the lagoon, but the attached company research report indicates a reduction in evaporation rate of 32 to 65% in small-scale trials.
- Claims for reductions in emissions of VOCs, NOx, CO, CO_2, and particulate matter are not supported by any data.
- The mechanism of action by which microbes living on a permeable lagoon cover reduce emissions of gases is unclear.

1.11.8 What Additional Research and/or Verification Work should be done?

Bio-Cap ML needs to be tested on dairy manure ponds under California conditions. There is a need for independent, third party verification of the claims for reductions of odor and air pollution emissions. Studies on the mechanisms of action are needed.

1.12 Baumgartner Environics, Inc.

Product/Process: Bio Curtain™

1.12.1 Description

Baumgartner Environics, Inc. (BEI), states that the BEI Bio-Curtain® is a freestanding, custom-designed dispersion wall that enables the capture of particulate-laden, odorous exhaust air from indoor livestock production facilities. The Electrostatic Space Charge System (ESCS) is an electrostatic air-scrubbing device that imparts a high-voltage electrical charge to a space. Once a space is charged, particulates within that space also become charged and subsequently are attracted to a grounded surface. In the space inside a Bio-Curtain, the ground is the surface where particulates collect. The panel agrees that the Bio-Curtain allows for possible treatment and redirection of particulate laden exhaust air from indoor livestock production facilities. However, dairy cows in California are not housed indoors (e.g., in tunnel-ventilated barns for which Bio Curtain is designed) but in open corrals and open wall freestall barns. The panel views this application as suitable for indoor facilities (e.g., poultry) but sees no application for commercial dairies in California.

1.12.2 Environmental Impacts

This technology is intended to control:

Air Emissions	Non-volatile waste components
☐ Reactive organic gases	☐ Organic nitrogen
☒ Ammonia	☐ Ammonium nitrogen
☒ Particulates	☐ Nitrates
☐ Odors	☐ Phosphorus
☐ Methane	☐ Salts
☐ Hydrogen sulfide	☐ Pathogens

The technology produces the following air emissions:

- ☐ Oxides of nitrogen (NOx)
- ☐ Carbon monoxide
- ☐ Carbon dioxide
- ☐ Reactive organic gases
- ☐ Particulates
- ☐ Sulfur dioxide

By products suitable for commercial sale or use:

- ☐ Heat energy
- ☐ Electrical energy
- ☐ Fuel
- ☐ Fertilizer
- ☐ Soil amendments
- ☐ Bedding
- ☐ Other

1.12.3 Economic Performance

The cost of ESCS with an air capture device such as the BEI Bio-Curtain ranges between $100 to $140 per linear foot of installation depending upon different configurations or specialized designs. An 80-foot indoors barn with tunnel ventilation fans approximately 10 feet above ground level would be approximately cost $10,000, installed.

1.12.4 Quality of Supporting Data

- ☐ Sufficient data were provided to demonstrate effectiveness of technology
- ☐ Data were provided, but effectiveness of the technology is inconclusive - need more data
- ☒ Data are said to exist, but data are not yet available or were not provided
- ☐ No data are available

The BEI Bio-Curtain has been developed to address particulate emissions from tunnel-ventilated barns. Several peer reviewed journal articles report the effectiveness to reduce particulate matter emission in enclosed buildings and ventilation air streams. No data exist related to applications for the dairy industry.

1.12.5 Development Status of the Technology

Electrostatic Precipitator (ESP) technology has been used in industrial processes for years. A research test facility has tested the technology.

1.12.6 Applicability of the Technology to California Dairies

As stated above, the technology only applies to indoor facilities and dairy production in California is characterized either by open dry-lot corrals or open walled freestall barns. Claims that this technology could be used under commercial dairy conditions are not substantiated by the documentation provided.

1.12.7 What Data Gaps Exist?

No data exist on applicability of the technology for California dairies.

1.12.8 What Additional Research and/or Verification Work should be done?

N/A

1.13 Baumgartner Environics, Inc.

Product/Process: **Nitrification/Denitrification (NDN) Nutrient Management System**

1.13.1 Description

BEI states that this process reduces odors, manages nutrients, and reduces the need for land application through a (patent pending) four step process. Step 1: cover an existing lagoon with BEI's Bio-Cap ML cover to reduce odors and promote anaerobic digestion in the first step. Step 2: build a new (or retrofit an existing) storage impoundment with a Hoffland High-Efficiency Aeration System and draw semi-clarified effluent from the storage lagoon (Step 1) into the aerated storage unit (Step 2) for treatment. In the treatment process, superoxygenation/nitrification occurs in which NH_3 is converted to NO_3^{-1}. Step 3: build a new (or retrofit an existing) storage impoundment to function as anoxic or denitrification cell in which anoxic bacteria strip oxygen from NO_3^{-1} creating N_2 gas which is released to the atmosphere. Step 4 (if needed): application of treated anoxic liquid on top of the Bio-Cap ML covered digestor (Step 1).

Nitrification/denitrification is a series of processes that are well understood and can reduce the environmental impact of reactive nitrogen compounds (NH_3, NO_2, NO_3^{-1}), methane, and volatile organic compounds. It is likely that these processes also reduce odors. However, it is unclear if aeration systems such as that used by BMI provide the oxygenation needed for nitrification of dairywaste and what the costs are for sufficient oxygenation. Furthermore, it is unclear how much training and/or daily maintenance is required to operate such a complex system. Conceptionally, this technology shows great promise for California dairies, but dairy specific data are needed for further assessment.

1.13.2 Environmental Impacts

This technology is intended to control:

<u>Air Emissions</u>

- ☒ Reactive organic gases
- ☒ Ammonia
- ☐ Particulates
- ☒ Odors
- ☒ Methane
- ☐ Hydrogen sulfide

<u>Non-volatile waste components</u>

- ☒ Organic nitrogen
- ☒ Ammonium nitrogen
- ☐ Nitrates
- ☒ Phosphorus
- ☐ Salts
- ☐ Pathogens

The technology produces the following air emissions:

- ☐ Oxides of nitrogen (NOx)
- ☐ Carbon monoxide
- ☐ Carbon dioxide
- ☐ Reactive organic gases
- ☐ Particulates
- ☐ Sulfur dioxide

By products suitable for commercial sale or use:

- ☐ Heat energy
- ☐ Electrical energy
- ☐ Fuel

- ☐ Fertilizer
- ☐ Soil amendments
- ☐ Bedding
- ☐ Other

The BEI process is intended to transform ammonium into nitrate (nitrification) during aeration, and the nitrate is then converted into nitrogen gas. The aeration will prevent methane from being produced. The denitrification step system includes a bio-cover, which will likely reduce emissions of volatile organic compounds.

1.13.3 Economic Performance

BEI's cost for a nitrification/denitrification system is approximately $150,000 to $200,000 for 500 dairy cows, assuming that an existing anaerobic storage lagoon is available for retrofit. The cost of the system would include the cost of a BEI-Cap ML permeable cover, Hoffland High-Efficiency Aeration System, two new or retrofitted treatment cells, and components to make the system operational. Specific costs depend on the size of the farm, the infrastructure in place, and specific needs of the farm. Annual cost of operation would include the energy cost to run an approximately 15 horsepower (hp) pump, and up to three transfer pumps. The estimated useful life is approximately 8 to 15 years for the components. The main cost benefits for the system would be the reduction in emissions and in the cost for land application of manure. The system has two main components 1) Bio-Cap ML covered anaerobic lagoon and 2) Hoffland Superoxygenation system. The rest of the system can be modified to fit the needs of the operation. BEI is exploring the possibility of making the technology energy-independent with the addition of an impermeable cover and power generation equipment.

1.13.4 Quality of Supporting Data

- ☐ Sufficient data were provided to demonstrate effectiveness of technology
- ☒ Data were provided, but effectiveness of the technology is inconclusive - need more data
- ☐ Data are said to exist, but data are not yet available or were not provided
- ☐ No data are available

Data showing the applicability and cost effectiveness for California dairies are currently not available. The system has been studied by North Carolina State University for hog operations, and reduction of several air pollutants has been shown. BEI states a 90% odor reduction, which should be substantiated with appropriate data for dairies.

1.13.5 Development Status of the Technology

The nitrification/denitrification system has not been tested under dairy conditions. However, BEI has worked with a large hog facility in North Carolina where the system was field tested.

1.13.6 Applicability of the Technology to California Dairies

Nitrification/denitrification is designed to reduce the amount of reactive nitrogen in the lagoon water, thus reducing the land acreage needed per dairy. From the information provided to the panel, it cannot be assessed for which dairy size the technology is most appropriate.

This technology has potential and should be evaluated under California conditions. The conversion of reactive N into N_2 gas has appeal, especially where a dairy does not have adequate land to manage nutrients at an agronomic rate; removing excess N as inert N_2 gas relieves the pressure on the dairy to dispose of nutrients.

1.13.7 What Data Gaps Exist?

The technology has not been tested on daires.

1.13.8 What Additional Research and/or Verification Work should be done?

This technology was tested in swine facilities and needs to be tested for dairies. All biochemical processes, nitrification and denitrification are well understood and applied in this technology to reduce nutrient load and emissions. If the potential user intends to reduce nitrogen nutrients by converting reactive nitrogen to nitrogen gas this sytem might work well. It is unclear if the cost estimates provided by the company can be realized and how much training/service efforts are required. Research and documentation in these areas is needed.

1.14 Bencyn West, Inc.

(dba BWI Solutions, Inc)

Product/Process: OrTec Biocatalyst

1.14.1 Description

The technology consists of a "biocatalyst" additive that is used to enhance the digestion of organic matter in manure-handling systems including anaerobic digesters. The stated mechanism of action is by improving growth conditions for the different kinds of bacteria, and the stated benefits are enhanced digestion of sludge, reduction of BOD, and increased methane production. In addition, ammonia and hydrogen sulfide numbers are claimed to be greatly reduced and odors eliminated. It is stated that the additive may also be used for "dust abatement" in a feedlot and is efficient at dissolving and preventing calcium deposits that can be a problem in drip irrigation systems.

1.14.2 Environmental Impacts

This technology is intended to control:

Air Emissions	Non-volatile waste components
☐ Reactive organic gases	☐ Organic nitrogen
☒ Ammonia	☐ Ammonium nitrogen
☐ Particulates	☐ Nitrates
☒ Odors	☐ Phosphorus
☐ Methane	☐ Salts
☒ Hydrogen sulfide	☒ Pathogens

The technology produces the following air emissions:

- ☐ Oxides of nitrogen (NOx)
- ☐ Carbon monoxide
- ☐ Carbon dioxide
- ☐ Reactive organic gases
- ☐ Particulates
- ☐ Sulfur dioxide

By products suitable for commercial sale or use:

- ☐ Heat energy
- ☐ Electrical energy
- ☐ Fuel
- ☐ Fertilizer
- ☐ Soil amendments
- ☐ Bedding
- ☐ Other

1.14.3 Economic Performance

Application equipment is identified as "normal water treatment equipment" and is said to cost less than $1,000 per installation. Operating costs vary because they are determined by gallons of wastewater used. The cost is stated to vary between $0.23 and $1.14 per 1000 gallons treated (equivalent to $230 to $1,140 per million gallons), but the treatment frequency is not specified. Treating a 2 million gallon digester and associated holding lagoon during a 4-month study at a 4,000 head dairy in Indiana was stated to have cost about $108.00 a day (equivalent to $39,420 per year)

1.14.4 Quality of Supporting Data

- ☐ Sufficient data were provided to demonstrate effectiveness of technology
- ☐ Data were provided, but effectiveness of the technology is inconclusive - need more data
- ☒ Data are said to exist, but data are not yet available or were not provided
- ☐ No data are available.

During the study at the 4,000 head dairy in Indiana, samples were reportedly taken from seven different locations in the processing system each week. Analyses are stated to include moisture, solids, ammonium nitrogen, organic nitrogen, phosphorous, potassium, pH, fecal coliform and BOD_5. The digester was reported to have also had an online gas analyzer measuring CH_4, CO_2, O_2 and H_2S. However, no test data were submitted to the Panel for review for the stated reason that "it exceeds the file size limit for the review."

A laboratory-scale study was also performed, and data from the study were submitted to the Panel. However, the data submitted cannot be extrapolated to assess the technology performance at a dairy.

1.14.5 Development Status of the Technology

- ☐ Research (basic research and applied research)
- ☐ Development (concept development and prototype development)
- ☒ Test and evaluation (product/process development)
- ☒ Demonstration (full or field relevant scale)
- ☐ Commercial application

1.14.6 Applicability of the Technology to California Dairies

Insufficient data are available to evaluate the performance of the technology at typical dairies in California. Additional testimonials from unbiased evaluators are needed to assess claims on odor control. Data are needed to evaluate claims on reduced production of ammonia and hydrogen sulfide and on increased production of methane. If the technology is effective as claimed, it appears to make sense for use at dairies in California because the initial cost and operating costs are low.

1.14.7 What Data Gaps Exist?

It is unclear for a wastewater recycling system if both the fresh material and the recycled material would need to be treated daily. It is desirable to have data on methane production and air emissions from a methane digester before and after using the product. Preferably, one or more studies would be conducted using existing methane digesters in California. Odors are subjective; no supporting testimonials were submitted to support the claimed odor reductions.

1.14.8 What Additional Research and/or Verification Work should be done?

Obtain the report for the study at the 4,000 head dairy in Indiana. If data support the vendor's claims, support trial use of the product at one or more dairies in California with an existing digester and sufficient historical data so that increased methane generation and digester performance can be verified. During the trial, note the effect of the product on sludge quantity and the amounts of nutrients in the sludge and digester effluent, and determine if use of the product reduces odors.

1.15 Bigadan

Product/Process: Anaerobic Digestion/Biogas Technology

1.15.1 Description

Bigadan offers an integrated package that uses anaerobic digestion in tanks to produce biogas from dairy manure, and combusts the gas to produce heat and/or to power a generator. Manure slurry is first heated to 70ºC for one hour to kill pathogens and seeds — as per European Union specifications and standards — before being placed in a digester that allows for continuous mixing of the waste. Bigadan did not indicate how its process re-initiates microbial activity in the manure slurry after heating, but it appears from their website schematic (http://www.bigadan.dk/uk/Teknologi.htm) that other organic waste could be added to the manure slurry before digestion.

Biogas produced from the anaerobic digestion is combusted after being processed to remove H_2S and other impurities. The digester tanks are run either at mesophilic or thermophilic temperatures. It is not clear how the effluent from the digester is managed, save for the indication that there is solids separation. According to their website schematic, some component of the digested manure is "refined," but the process used is not evident.

The integrated package appears to use heat exchangers to capture heat for use during the initial sterilization of the waste, for domestic heating, for the heating of the digester tanks, for combined heat and power (CHP), or for some other use. Bigadan does not indicate if the dairy owner could contract separately for the installation of some of the equipment for the integrated package or if the owner would have to purchase all of the equipment from or through Bigadan.

1.15.2 Environmental Impacts

This technology is intended to control:

Air Emissions	Non-volatile waste components
☒ Reactive organic gases	☐ Organic nitrogen
☒ Ammonia	☐ Ammonium nitrogen
☐ Particulates	☐ Nitrates
☒ Odors	☐ Phosphorus
☒ Methane	☐ Salts
☒ Hydrogen sulfide	☒ Pathogens

The technology produces the following air emissions:

- ☒ Oxides of nitrogen (NOx)
- ☐ Carbon monoxide
- ☒ Carbon dioxide
- ☐ Reactive organic gases
- ☐ Particulates
- ☐ Sulfur dioxide

While the vendor indicated reduction of oxides of nitrogen in their submission, other information in their submittal indicated that they were referring to reductions in the green house gas N_20. Any combustion of biogas will have some NOx emissions associated with it.

By products suitable for commercial sale or use:

- ☒ Heat energy
- ☒ Electrical energy
- ☐ Fuel
- ☒ Fertilizer
- ☐ Soil amendments
- ☐ Bedding
- ☒ Other (Carbon Credits)

1.15.3 Economic Performance

Specific economic performance data may exist but were not included in the submittal. Several papers from the University of Southern Denmark on the socio-economic analysis for centralized biogas plants provided generalized data for plants operating at the 300, 550 and 800 m^3/day (~80,000, ~145,000, and ~210,000 gallons/day) capacities. The analysis appears to be within the context of the European market, and examined various scenarios: with and without tax incentives, and with and without the inclusion of externalities (environmental co-benefits). Dairies within Europe tend to be smaller than in California, and thus the biogas plants must collect the dairy-waste from several dairies in order to take advantage of the economies of scale gained from having a larger centralized plant.

1.15.4 Quality of Supporting Data

- ☐ Sufficient data were provided to demonstrate effectiveness of technology
- ☐ Data were provided, but effectiveness of the technology is inconclusive - need more data
- ☒ Data are said to exist, but data are not yet available or were not provided
- ☐ No data are available

Bigadan's submittal indicated that information on treatment system performance had been provided to "the EPA" although it is not clear whether the vendor was referring to the Danish-EPA or the US EPA. No performance data were provided to the Panel.

1.15.5 Development Status of the Technology

According to Bigadan's website (http://www.bigadan.dk/uk/index.htm), they have 30 facilities operating in Europe and Asia, some of which have been in operation for over 20 years. It appears that this is a commercialized technology that can be adapted to handle food waste, industrial organic waste, municipal sewage waste, etc. Within the California dairy context, however, it should probably be viewed as a "demonstration technology."

1.15.6 Applicability of the Technology to California Dairies

The technology appears to be able to operate at a capacity appropriate for a typical Central Valley dairy. If the technology can be justified from an economic perspective, it would seem to be appropriate for use on dairies in California.

1.15.7 What Data Gaps Exist?

Bigadan did not provide economic and performance data specific to this technology package, especially within a United States or California context. Data are required in order to determine how this integrated package affects the nutrient mass-balance at a dairy. Nutrients become problematic for a dairy operator when they exceed the amount required for fertilization of cropland associated with the dairy. Bigadan should provide data to show how the nutrients are partitioned in the solid, liquid, and gas phases as manure is processed using their system.

Bigadan did not clarify what they mean when applying the term “refine” to the digested waste, although they do refer to a “phosphorous-rich compost” generated at one of the facilities (Fangel) featured on their website. It is also not clear what is done with the liquid-waste after separation of the solids from the digested waste. Bigadan’s Japanese sales agent indicated that if the liquid waste could not be applied to land it would be discharged to a municipal waste-water treatment system. More information on the use of the technology in Japan is available on the web (http://www.jfe-steel.co.jp/en/research/report/003/pdf/003-07.pdf).

Bigadan does not indicate what types of air emissions might be generated with its power-generation system. Even with the most efficient combustion, some small amounts of NOx would be produced. While sulfur compounds and other impurities are scrubbed from the biogas, the efficiency of this scrubbing is not indicated.

1.15.8 What Additional Research and/or Verification Work Should be Done?

Based on information that Bigadan provided to the Panel, technology it is unclear how use of the technology affects the complete nutrient-budget of a dairy. The potential environmental impacts of the technology should be assessed by using a mass-balance approach. Bigadan should evaluate how nutrients are partitioned between the solid and liquid fractions of the dairy waste-stream, and include any gaseous emissions of nitrogen within the mass balance.

While the vendor has several installations operating elsewhere in the world, the technology performance should be evaluated relative to environmental regulations in California. It is recommended that research be done to collect data from a facility that is typical of the type of dairy operations in California. An alternative would be to use the technology at a demonstration project in California.

1.16 Bion Dairy Corporation

Product/Process: Bion Biological Nutrient Removal Waste Treatment System

1.16.1 Description

Manure and wastewater, with or without milking-parlor wastewater, is captured in a contact chamber where it is mixed to maintain solids in suspension. The waste is then processed to remove coarse solids using a static screen or other mechanical solids separator. The liquid fraction is then discharged into a two-stage bioreactor, which includes an anaerobic treatment zone and a micro-aerobic treatment zone. In the bioreactor, soluble P is converted to particulate, organic form via its uptake into microbial biomass. Ammonia is converted to nitrate and then to N_2 gas via nitrification/denitrification processes, or is incorporated in microbial biomass. The wastewater from the bioreactor is recycled for flushing the barns, is added back to the contact chamber, or discharged to a storage lagoon for application to cropland. The wastewater from the bioreactor can also be treated via fine screening or centrifuging to remove additional solids. The solid fraction(s) can be used as bedding or composted for use as a soil amendment.

The complete system is designed to reduce the nutrient load (nitrogen and phosphorus) and air emissions (ammonia, reactive organic gases, methane, hydrogen sulphide, and odors). BION also states that the process substantially reduces pathogen levels in the waste-stream.

1.16.2 Environmental Impacts

This technology is intended to control:

Air Emissions	Non-volatile waste components
☒ Reactive organic gases	☒ Organic nitrogen
☒ Ammonia	☒ Ammonium nitrogen
☒ Particulates	☒ Nitrates
☒ Odors	☒ Phosphorus
☒ Methane	☒ Salts
☒ Hydrogen sulfide	☒ Pathogens

The technology produces the following air emissions:

- ☐ Oxides of nitrogen (NOx)
- ☐ Carbon monoxide
- ☐ Carbon dioxide
- ☐ Reactive organic gases
- ☐ Particulates
- ☐ Sulfur dioxide

By products suitable for commercial sale or use:

- ☐ Heat energy
- ☐ Electrical energy
- ☐ Fuel
- ☒ Fertilizer
- ☒ Soil amendments
- ☒ Bedding
- ☐ Other

Reports submitted by Bion to the Panel indicate that 79% of phosphorus and 35% of nitrogen is captured in the solid fraction, primarily as microbial biomass, and 39% of nitrogen is denitrified to N_2 gas. Data indicate up to 99% reductions in emissions of ammonia and VOCs, up to 98% reduction in hydrogen sulfide emissions, and up to 87% reduction in methane emissions. Quantitative data were not provided for the stated reductions in pathogen numbers.

1.16.3 Economic Performance

Costs vary with herd size, and there are significant economies of scale, i.e., the economics improve with increasing dairy size. For a 3000-cow dairy, capital costs for retrofitting the dairy are approximately $500 per milk cow; debt plus operation and maintenance costs are estimated to be approximately $130 per milk cow. Saleable products, greenhouse gas and nutrient credits, fertilizer, soil amendments, compost, and bedding, may reduce these costs, but economic details were not provided for these values, and the greenhouse gas and nutrient credits do not exist for California dairies at this time. Bion estimates a 25-year life for the facility.

Bion states that use of its technology may allow a dairy to expand herd size. The reasoning is that in some parts of the San Joaquin Valley, there is insufficient cropland available to accept nutrients, and reducing the nutrient load in the manure via denitrification and phosphorous removal could allow an increase in herd size for the same amount of available cropland.

The technology includes a series of process steps. It is not clear how vulnerable the system is to upset or what level of operator attention is needed. This system may require considerable training and/or additional staffing to operate.

1.16.4 Quality of Supporting Data

- ☒ Sufficient data were provided to demonstrate effectiveness of technology
- ☐ Data were provided, but effectiveness of the technology is inconclusive - need more data
- ☐ Data are said to exist, but data are not yet available or were not provided
- ☐ No data are available

Bion assembled and hired a group of experts to study the nutrient and atmospheric emissions from its installation at the DeVries Dairy in Texas. The methods and results are detailed in a substantial report that is available to the public (http://www.biontech.com/). Wholly independent, peer-reviewed scientific studies have not been published.

1.16.5 Development Status of the Technology

- ☐ Research (basic research and applied research)
- ☐ Development (concept development and prototype development)
- ☐ Test and evaluation (product/process development)
- ☐ Demonstration (full or field relevant scale)
- ☒ Commercial application

A Bion facility has been in operation at the 1,250-cow DeVries Dairy near Dublin, Texas since July 2003. The company states that the technology is available for commercial application at other sites.

1.16.6 Applicability of the Technology to California Dairies

This technology addresses two challenges facing the California dairy industry: nutrient management and emissions of air pollutants. The conversion of organic and mineral nitrogen in manure into N_2 gas reduces the value of the manure as a nitrogen fertilizer. However, in some parts of the San Joaquin Valley dairies do not have sufficient cropland to apply nutrients at agronomic rates. For those dairies, removing excess nitrogen as N_2 gas may be a desirable alternative to acquiring sufficient cropland for proper application of nutrients.

The Bion system's reductions in VOC emissions are also of great interest. However, their significance and appeal is clouded by current uncertainties in baseline data on emissions of these compounds from various parts of a dairy.

1.16.7 What Data Gaps Exist?

In light of new research data coming out of the San Joaquin Valley, it will be important to revisit Bion's stated reductions in VOC emissions, for each part of the dairy and for the system as a whole. For example, if the Bion system reduces 99% of VOC emissions from the lagoon, but the lagoon emissions are only a small percentage of the total, then BION's net reduction of VOCs may account for only a small portion of the total VOC emissions from the dairy.

Data should be provided to support the claimed reductions in NOx, CO and CO_2. Denitrification is often associated with increases in N_2O, a potent greenhouse gas. Information supplied by Bion mentions N_2O reductions as an attribute, but no data were provided to support claims for reductions in N_2O emissions.

More detail is needed for the cost analysis. The assumptions for valuing greehouse gas credits and emissions reducton s credits should be made explicit. More information is also needed on the required training and skill level of personnel to operate the system.

Manure treatment systems based on controlled microbial activity can be vulnerable to upsets in the populations and metabolic functions of the microbes. More detail is needed on the stability of the Bion system.

1.16.8 What Additional Research and/or Verification Work should be done?

A pilot project in the San Joaquin Valley would provide a test of the technology under California conditions, as well as an opportunity to collect aditional data that would increase confidence in the system.

1.17 CH2M Hill, Inc.

Product/Process: Portable and Re-locatable Composting System

1.17.1 Description

CH$_2$M Hill offers an aerated static pile composting technology that is re-locatable and re-configurable that uses forced aeration to accelerate the composting process without enclosures. The system used to induce a pressurized and vacuum airflow on the compost piles can be located above-grade. Positive-airflow piles minimize anaerobic activity, and negative airflow allows for the capture and treatment of air emissions using a biofilter integrated into the forced air exhaust. The company's literature indicates that the technology was developed and patented with the idea of providing a high level of process control at a low capital cost. The technology carries a U.S. Patent, Trademark, and Servicemark.

1.17.2 Environmental Impacts

This technology is intended to control:

Air Emissions	Non-volatile waste components
☒ Reactive organic gases	☐ Organic nitrogen
☒ Ammonia	☒ Ammonium nitrogen
☒ Particulates	☐ Nitrates
☒ Odors	☐ Phosphorus
☐ Methane	☐ Salts
☒ Hydrogen sulfide	☒ Pathogens

The technology produces the following air emissions:

- ☐ Oxides of nitrogen (NOx)
- ☐ Carbon monoxide
- ☐ Carbon dioxide
- ☐ Reactive organic gases
- ☐ Particulates
- ☐ Sulfur dioxide

By products suitable for commercial sale or use:

- ☐ Heat energy
- ☐ Electrical energy
- ☐ Fuel
- ☐ Fertilizer
- ☒ Soil amendments
- ☒ Bedding
- ☐ Other

CH2M Hill states that the technology transforms nitrogen into "stable and slow-release forms to protect water resources." No data were provided to clarify how this occurs, but the Panel assumes it is by removing ammonia and leaving organic nitrogen. However, organic nitrogen is difficult to manage for crop production and cannot be claimed to protect water quality.

1.17.3 Economic Performance

CH2M Hill provided capital and operating costs FOB for three sizes of operating systems. The following are approximate capital/operating costs for a dairy acting as the general contractor:

- Number of cows served – 3200
- Quantity of manure 13,249 cubic yards
- Total fixed improvements $1,218,179
- Cost per cow (entire facility) $381
- Cost per cow (system only) $146.

As stated, the operating costs include labor, fuel, power, water, and the cost of amendments (green waste and/or wood chips) if none are available at the facility. The facility is expected to produce 81,000 cubic yards of compost per year. As noted by CH2M Hill, the value of the compost may vary.

1.17.4 Quality of Supporting Data

- ☒ Sufficient data were provided to demonstrate effectiveness of technology
- ☐ Data were provided, but effectiveness of the technology is inconclusive - need more data
- ☐ Data are said to exist, but data are not yet available or were not provided
- ☐ No data are available

Analysis cited several commercial examples of facilities meeting performance data stated for NH_3 and VOC. Valid test data were supplied to support the stated reductions in odor and organic carbon. Using negative aerated static pile, the capture efficiency of the compost pile was 95% for ammonia and 93% for non-methane non-ethane organic carbons. The panel was surprised at the high capture efficiency of the composting system. The average destruction efficiency of the biofiltration system was 98% for ammonia and 97% for non-methane non-ethane organic carbons.

1.17.5 Development Status of the Technology

This system is commercially available and CH2M Hill cited 12 locations where the technology is currently being commercially operated, including two locations in California. From the location descriptions, the technology is not currently operating at dairies, but may use dairy manure at one or more facilities.

1.17.6 Applicability of the Technology to California dairies

In situations where there are odor problems with manure solids storage or open composting, the technology should provide remedy, but at a relatively high cost. The technology may be most appropriate for larger dairies or for a regional composting facility. Cost may be reduced if market for produced compost is available.

1.17.7 What Data Gaps Exist?

While CH2M Hill cited several examples, and sets of test data of commercial facilities reducing air emissions and odor, no description or reference was given as to who or how the quantitative data were determined. CH2M Hill also stated that the technology transforms nitrogen into "stable and slow-release forms to protect water resources," but no data were provided to clarify how this occurs.

1.17.8 What Additional Research and/or Verification Work should be done?

It appeared to the panel that substantial research was conducted with respect to air and odor mitigation. This information needs to be referenced. With respect to nitrogen, additional data need to be provided to indicate how nitrogen is transformed into "stable and slow-release forms to protect water resources," as stated by CH2M Hill. Data on pathogen destruction also need to be included.

1.18 Coaltec Energy USA.

Product/Process: Gasification

1.18.1 Description

The technology utilizes a fixed-bed gasifier as the main component of a two-module system. The first module is a gasifier that thermally decomposes organic material at elevated temperatures in a reducing atmosphere to generate synthesis gas (or "syngas") and ash. The second module is an oxidizer where the syngas is burned to generate heat - the syngas from the gasifier is drawn through a transition pipe where air is introduced to complete combustion and produce a flue gas stream of approximately 2000 F. The heat produced can be used directly or to generate steam and/or electricity via addition of an off-the-shelf heat recovery boiler and turbine.

Coaltec stated that the configuration of the gasifier and oxidizer allows separation of the syngas prior to the introduction of air - providing an opportunity to separate and produce hydrogen gas or various liquid fuels. The modular design enables the system to be flexible for use in conjunction with other technologies to produce several products.

The raw manure consumed by the gasifier must be mechanically separated to less than 70% moisture content (fresh dairy manure is 90% water). The method of moisture removal was not discussed as part of this technology package. Therefore, the impacts of the liquid manure fraction are not addressed with this technology.

1.18.2 Environmental Impacts

This technology is intended to control:

Air Emissions

- ☐ Reactive organic gases
- ☒ Ammonia
- ☐ Particulates
- ☒ Odors
- ☒ Methane
- ☐ Hydrogen sulfide

Non-volatile waste components

- ☒ Organic nitrogen
- ☒ Ammonium nitrogen
- ☒ Nitrates
- ☒ Phosphorus
- ☒ Salts
- ☒ Pathogens

The technology produces the following air emissions:

- ☒ Oxides of nitrogen (NOx)
- ☒ Carbon monoxide
- ☐ Carbon dioxide
- ☒ Reactive organic gases
- ☒ Particulates
- ☐ Sulfur dioxide

By products suitable for commercial sale or use:

- ☒ Heat energy
- ☒ Electrical energy
- ☐ Fuel- Charcoal
- ☐ Fertilizer
- ☐ Soil amendments
- ☒ Bedding
- ☐ Other

Coaltec indicated that the company is unsure of the overall environmental effects of the technology on the following air pollutant emissions but that the information would be available after a test burn is conducted on dairy manure: reactive organic gases (ROG), hydrogen sulfide (H_2S), particulate matter (PM), nitrogen oxides (NOx), carbon monoxide (CO), and carbon dioxide (CO_2). The company tied odor reduction benefits to processing the manure soon after it leaves the cow.

There will still be air emissions during the storage and dewater processes. Air emissions are reduced only when manure is processed instead of remaining in storage or being applied to land.

The Panel expects reductions in ammonia emissions from the manure solids portion only. Ammonia emissions from separated solids are not expected to be as high as the liquid portion, and most of the ammonia from a drylot would have already been emitted before gasification. According to U.S. EPA, methane emissions from solids are expected to be low; therefore there would be a small reduction in total methane with this technology. Emissions of PM, NOx, ROG, and CO are not characterized but are expected to be emitted from the gasifier and an engine/boiler that would likely be utilized in conjunction with the technology. Emissions of $PM_{2.5}$ in the form of polyaromatic hydrocarbons may be a concern.

Nitrogen, fecal coliform, and salmonella are expected to be consumed in the gasification process, but the liquid waste stream could still be a source. Phosphorus and salts are expected to remain in the ash so the impact depends on the method of disposal.

1.18.3 Economic Performance

Coaltec estimates the cost of the gasification system at about $150 per cow, although they noted that the actual cost would be dependent on the conditions and needs of the facility. This figure does not include fuel preparation equipment or energy consumption equipment. Savings on fuel that otherwise would have been spent to produce heat, steam, or electricity prior to use of a gasification system will help offset the capital cost. The company estimates less than 5% of the capital cost for annual maintenance.

The company also identified cost savings through sale of the ash byproduct; however, no market was identified for the material, and it is likely that the ash will need to be disposed as a waste. Other cost-saving factors identified, but information was not provided to quantify these benefits. The potential cost savings were from elimination or reduction of transportation and labor costs for land application of manure solids and less labor and expense for lagoon maintenance because solids are removed before manure is conveyed to lagoons. However, most dairies already utilize a solids removal process.

Coaltec indicated that similar gasification units have been operating continuously for over 10 years on wood waste. They expect that their system will run for at least 15 years.

1.18.4 Quality of Supporting Data

- ☐ Sufficient data were provided to demonstrate effectiveness of technology

☐ Data were provided, but effectiveness of the technology is inconclusive - need more data
☐ Data are said to exist, but data are not yet available or were not provided
☒ No data are available

Several test burns on the demonstration unit have been completed over the past two years on various biomass fuels including wood waste, corn stover, ethanol mash, and brewery spent grain; however, the technology has not been demonstrated on dairy manure. These tests were privately funded and the data are proprietary and owned by the clients.

1.18.5 Development Status of the Technology

Coaltec has a demonstration unit at a coal research facility in Carterville, Illinois. It is designed to process two tons of biomass per hour and has a footprint of 100 by 100 feet. The company stated that units could be made larger or smaller. There is no lower limit on size from an operational standpoint, but the economics are more difficult. The upper limit is reported to be approximately three times the size of the demonstration unit. However, at larger scale the advantages of the modular design and ease of installation are reduced.

Coaltec stated that the unit is commercially proven with wood waste, but will require extensive testing and demonstration with a new fuel such as dairy manure. The company estimates that the technology can be ready for commercial fabrication within one year, and installed and ready to operate within 18 months.

1.18.6 Applicability of the Technology to California Dairies

There appear to be potential technology and other barriers to applying the technology to dairy manure in California. First, fresh dairy manure has too much moisture to make it an ideal fuel for this technology. Equipment capable of reducing the manure moisture content is not included with this system; therefore, only separator solids or drylot manure can be used. Second, if the dairy does not have a need for the heat or quantity of electricity produced, the ability to merchant the energy product of the system may be an issue. Third, the dairy would loose the nitrogen nutrient value of the solid manure—though this may be a benefit for daries without sufficient land for proper application. Fourth, scale is an issue for on-farm systems. The demonstration unit is rated at 17,000 dry tons of manure per year (100,000 lbs/day). Since mature dairy cows produce about 18 lbs/day of solids, the system would require at least 5,500 cows to feed it, assuming that all solids could be separated and used in the process. Therefore, the technology may be more suitable for a centralized system. And fifth, the air emissions from the gasifier were not characterized and could be an issue.

1.18.7 What Data Gaps Exist?

The technology has not been demonstrated on a dairy facility. More data are needed on air emissions from the gasifier to fully assess the overall environmental benefits of the technology. NOx, ROG, CO, and $PM_{2.5}$ are likely to increase somewhat and this trade-off should be evaluated. Total ash volume and composition are needed to fully evaluate impacts and value of this by-product. Capital, as well as annual operating and maintenance, costs of a fully integrated dairy system are needed.

1.18.8 What Additional Research and/or Verification Work should be done?

Air emissions from the gasification system using dairy manure as feedstock should be quantified so that the overall environmental benefits can be determined. As the system requires a manure moisture content of less than 70%, more information is needed on the amount of actual manure solids that could be used in this system from a flush dairy. Additional instruction is needed on the education, training, and experience that may be required for a dairy operator to maintain and manage the system.

1.19 Engineered Compost Systems

Product/Process: **In-vessel and Aerated Static Pile (ASP) Composting Systems**

1.19.1 Description

Engineered Compost Systems (ECS) provides high tech in-vessel and aerated static pile composting systems. The aeration system is designed to provide both reversing and re-circulating aeration, which minimizes the volume of exhaust air to be scrubbed in the biofilter. The aeration system includes process blowers, motorized and manual dampers, and pipes. ECS offers a computer interface that allows real-time monitoring of process variables, selection of process set-points, and data storage. The in-vessel system features their proprietary control and monitoring system, floor aeration and site-built vessels. Aerated static pile components include pile-building conveyors, in-floor aerators and pile-covering fabrics.

1.19.2 Environmental Impacts

This technology is intended to control:

<u>Air Emissions</u>

- ☒ Reactive organic gases
- ☒ Ammonia
- ☒ Particulates
- ☒ Odors
- ☒ Methane
- ☒ Hydrogen sulfide

<u>Non-volatile waste components</u>

- ☐ Organic nitrogen
- ☒ Ammonium nitrogen
- ☒ Nitrates
- ☐ Phosphorus
- ☒ Salts
- ☒ Pathogens

The technology produces the following air emissions:

- ☐ Oxides of nitrogen (NOx)
- ☐ Carbon monoxide
- ☒ Carbon dioxide
- ☐ Reactive organic gases
- ☐ Particulates
- ☐ Sulfur dioxide

By products suitable for commercial sale or use:

- ☐ Heat energy
- ☐ Electrical energy
- ☐ Fuel
- ☐ Fertilizer
- ☒ Soil amendments
- ☐ Bedding
- ☐ Other

Because Engineered Compost Systems offers an in-vessel and reversing and re-circulating aerated static pile system, the Panel believes that the technology could impact, to some degree, those waste constituents identified above. However, the ECS provided no environmental discharge or emission data. ECS has the ability, but did not supply, time and temperature graphs that show biomass can meet USEPA 503 protocols for biosolids, and O_2 data showing biomass remains aerobic.

The system treats composting manure to reduce ammonia levels; the impact of this treatment on reducing nitrate loads on cropland is unclear. Similarly, the mechanism by which salt emissions are controlled is unclear.

1.19.3 Economic Performance

ECS stated it could not provide reliable cost estimates without some key parameters, such as daily throughput and type of facility. ECS did state that its in-vessel system can range anywhere from $500-$750 per cubic yard of installed capacity. In addition, the aerated static pile systems are considerably less expensive and their cost depends on the type of aeration floor and the level of process control desired. As stated by ECS, the price of the compost can vary from $10 to $22 per cubic yard.

1.19.4 Quality of Supporting Data

- ☐ Sufficient data were provided to demonstrate effectiveness of technology
- ☐ Data were provided, but effectiveness of the technology is inconclusive - need more data
- ☐ Data are said to exist, but data are not yet available or were not provided
- ☒ No data are available

ECS did not supply environmental discharge or emission data.

1.19.5 Development Status of the Technology

ECS has 20 commercial facilities operating in North America. One facility is operating in California.

1.19.6 Applicability of the Technology to California dairies

Before applicability can be assessed, environmental data need to be provided. The potential air or water quality benefits are unclear. If the benefits can be substantiated, the technology may be most appropriate for larger dairies or for a regional composting facility. Costs for deploying the technology may be reduced if markets for produced compost are available.

1.19.7 What Data Gaps Exist?

ECS did not supply environmental discharge or emission data. As such, air emission and water impact data are not available.

1.19.8 What Additional Research and/or Verification Work should be done?

Environmental discharge data need to be provided to evaluate potential effectiveness of technology. Complete cost estimates are needed.

1.20 Everstech Consulting (UK) - Everstech LLC (USA)

Product/Process: Everstech ET Process

1.20.1 Description

Everstech Consulting - Everstech LLC (collectively, "Everstech") employs a proprietary system for the processing of waste containing high-fiber solids. Through the use of a combination of "facultative, aerobic and/or anaerobic digestions, utilizing bioaugmentation," Everstech seeks to produce a higher yield of biosolids to be used as "as a high nitrogen organic soil conditioner" and other by-products consisting of "a directly-usable, clean, high-calorific-value biogas" and "recyclable water." If all processes are included (facultative, aerobic and/or anaerobic), the facultative stage is employed first as a pre-digestion stage, where microbial organisms "hydrolyze the complex carbohydrates (polysaccharides), the proteins and fats, into organic acids and volatile fatty acids, which are the standardized substrates for the subsequent stages." The material from this process can subsequently be fed into either an aerobic digester or an anaerobic digester. Everstech states that their aerobic digestions process "requires much less oxygenation and aeration capacity" than in a typical digester, and, where anaerobic digestion is included in the treatment package, "the quality of biogas is improved to over 80% methane, with no contamination by hydrogen sulphide." At each stage, Everstech's process employs customized blends of microbial cultures as bioaugmentation to both control and accelerate the digestion process. Based on the schematics submitted, it would also appear that the process might employ nutrient or other supplementation to control the process.

Everstech indicates that its system will reduce odors and emissions of ammonia, nitrogen oxides, VOCs, carbon dioxide, carbon monoxide, hydrogen sulfide, PM_{10} and $PM_{2.5}$ from a dairy. Everstech also indicates that its system will reduce the movement of nitrogen, phosphorous, salts, and pathogens from the dairy's wastewater into the environment.

1.20.2 Environmental Impacts

This technology is intended to control:

Air Emissions	Non-volatile waste components
☒ Reactive organic gases	☒ Organic nitrogen
☒ Ammonia	☒ Ammonium nitrogen
☒ Particulates	☒ Nitrates
☒ Odors	☒ Phosphorus
☒ Methane	☒ Salts
☒ Hydrogen sulfide	☒ Pathogens

The technology produces the following air emissions:

- ☐ Oxides of nitrogen (NOx)
- ☐ Carbon monoxide
- ☐ Carbon dioxide
- ☐ Reactive organic gases
- ☐ Particulates
- ☐ Sulfur dioxide

By products suitable for commercial sale or use:

- ☐ Heat energy
- ☐ Electrical energy
- ☒ Fuel – Biogas (methane)
- ☐ Fertilizer
- ☐ Soil amendments
- ☐ Bedding
- ☐ Other

Although Everstech indicates that, the digested solids can be used "as a high nitrogen organic soil conditioner," no claims are made for use of the digester solids as an organic fertilizer.

1.20.3 Economic Performance

Everstech stated in their submission that, "it is impossible to be specific on costs, since there are so many influencing factors, such as extent of treatment required, by-products and resources to be recovered, volume and strength of the waste, and of course economies of scale." However, a range of cost data were provided (capital costs $250 to $1,000 per cow, annual operating costs $50 to $200, annual benefits $325 to $850) but the basis for these numbers was not revealed. Everstech also stated that there ". . . are no special requirements for the operator, other than normally required for a waste water treatment plant." Everstech provides an on-site training program and also supervises the operation and management under a multi-year licensing agreement with the dairy owner.

Based on the schematics provided for the Everstech system, it appears that a dairy would have to install/retrofit its facility with the prescribed equipment (tanks for reagents, coagulant, and flocculent; pumps; plumbing; solids handling and storage equipment; monitoring equipment; etc.). It is not clear if the dairy would have to purchase this equipment from a vendor working with Everstech, or if the dairy could purchase the equipment from any suitable equipment supplier. It is also not clear if the dairy owner would have to contract separately for the installation of the power-generation equipment that would use the biogas (methane) as fuel.

Everstech states that their system "…takes up a considerably reduced land space," but it is not clear how this would relate to a combination system using a more traditional approach when applied to a California flush dairy. The relative amount of land required for the use of this system may be something that a dairy owner would have to examine when considering potential costs and/or savings.

1.20.4 Quality of Supporting Data

- ☐ Sufficient data were provided to demonstrate effectiveness of technology
- ☐ Data were provided, but effectiveness of the technology is inconclusive - need more data
- ☒ Data are said to exist, but data are not yet available or were not provided
- ☐ No data are available

Although Everstech referred to 30-35 years of experience with "…very significant design/construct and operation/management contracts, on waste management and treatment facilities, and resource recovery projects throughout the world," and that its microbial formulations "…have been subjected to a major series of case studies on municipal sewage treatment for various Water Authorities, and on abattoirs, meat processing, fish processing, piggeries, poultry farms, cattle feedlots, breweries, sugar alcohol distilleries and many other waste products worldwide, but particularly in the UK and Australia," no data from these studies were submitted to the panel, even after an e-mail enquiry was made to Everstech. The information that was submitted was for a milk-processing facility in New York State.

It is also not clear how the economics would work for a dairy that would like to 1) use anaerobic digestion in order to generate biogas for methane, and 2) digest the resulting solids for use as a soil amendment. Anaerobic digestion typically reduces the amount of solids since much of the carbon containing compounds are converted to methane and other carbon containing gases, and since some non-carbonaceous components within the waste will be converted into volatile compounds.

1.20.5 Development Status of the Technology

Until data can be provided to demonstrate that this provider's process has been employed in a flush-dairy context, it should be viewed as a technology requiring further testing and evaluation. The technology needs to be demonstrated at a flush dairy under conditions similar to those in California.

1.20.6 Applicability of the Technology to California Dairies

This technology may indeed be able to work in California dairies. However, considering the microbial environment in manure, it needs to be demonstrated that the custom-designed and blended microbial cultures can dominate the community structure in situ and either generate higher-quality methane under anaerobic conditions or, under aerobic conditions, generate microbial biomass that can be used as a soil amendment. It would also be helpful to demonstrate that this system can do this significantly better than the traditional approaches broadly in use today.

1.20.7 What Data Gaps Exist?

While data are provided for the wastewater treatment at the milk-processing facility in Vernon, New York, no data have been provided from a dairy facility handling manure to demonstrate the feasibility of this process for use at dairy operations. Thus, no data were provided to support any of the Everstech's claims. Data are required in order to determine how this system addresses the mass-balance of the nutrient inputs and exports at the dairy. Everstech should provide data to show how nutrients change as the manure is processed using their system.

Relative to a typical California dairy, it is not clear if the combination of "facultative, aerobic and/or anaerobic digestions" is intended to work with raw manure, the separated manure solids, or the wastewater that results after the solids have been removed from the raw manure. It is logical to assume that this combination system would be applied to either the raw manure or manure-solids if anaerobic digestion were to be employed to generate biogas for methane. However, if Everstech is expecting to apply its system to dairy wastewater, it is not clear that this would be sustainable given the huge volumes of liquid generated on a daily basis at a typical California flush-dairy.

It is also not clear if Everstech is anticipating handling both the liquid and solid waste streams as separate components of the process. In the handling of the wastewater, it is not clear if this process takes advantage of nitrification-denitrification to deal with reactive-nitrogen as a potential pollutant, even though this system would appear to be capable of doing that. It is not clear if the Everstech system requires the solids remaining after anaerobic digestion to be further processed in their aerobic digesters.

Whether the solids collected at the end of the aerobic or anaerobic digestion phase of the process regardless of the anaerobic/aerobic sequence still need to be composted is also not clear. If the solids are collected at the end of aerobic digestion, are they suitable for use as a soil amendment/organic fertilizer, or is further processing or composting required?

1.20.8 What Additional Research and/or Verification Work should be done?

Based on the Everstech's submission for this system, it is difficult to determine whether the complete nutrient-budget of a dairy is addressed using this process. Everstech needs to account for how nutrients are partitioned in the dairy waste streams, and include any gaseous emissions of nitrogen in the nutrient budget. It is recommended that this type of data be collected either from a facility that is typical of the type of dairy operations in California, or from a demonstration farm within California.

1.21 Flex Energy

Product/Process: **Flex-Microturbine**

1.21.1 Description

The Flex Energy technology is a microturbine (Flex-Microturbine), where fuel and air enter the combustor and produce hot combustion gases that spin a turbine that is connected to the shaft of an electrical generator. Unlike other turbines, the gas is accepted at atmospheric pressure. This particular microturbine was adapted from a Capstone C30 biogas-fired unit with an output capacity of 30 kW - the primary difference being that a catalyst is employed to aid in the combustion process and to allow low-BTU gases to be consumed. Primary components consist of the catalytic combustor (platinum and palladium coated on a stainless steel substrate), gas-to-gas heat exchanger (recuperator), digester gas/air compressor, and integrated generator. The unit requires a minimum fuel input heating value of 15 BTU per SCF.

1.21.2 Environmental Impacts

This technology is intended to control:

Air Emissions	Non-volatile waste components
☒ Reactive organic gases	☐ Organic nitrogen
☒ Ammonia	☐ Ammonium nitrogen
☒ Particulates	☐ Nitrates
☒ Methane	☐ Phosphorus
☒ Hydrogen sulfide	☐ Salts
	☐ Pathogens

The technology produces the following air emissions:

- ☒ Oxides of nitrogen (NOx)
- ☒ Carbon monoxide
- ☒ Carbon dioxide
- ☒ Reactive organic gases
- ☒ Particulates
- ☒ Sulfur dioxide

By products suitable for commercial sale or use:

- ☒ Heat energy
- ☒ Electrical energy
- ☐ Fuel
- ☐ Fertilizer
- ☐ Soil amendments
- ☐ Bedding
- ☐ Other

The company stated that the environmental benefits of the technology are related solely to reduced emissions of air pollutants. The company indicated that the technology actually results in a net reduction of NOx and carbon monoxide (CO), with no effect on carbon dioxide (CO2). Overall reductions or increases in air pollutants would depend on the baseline established for comparison; however due to biogas combustion, the Panel expects net increases in NOx, CO, CO2, and sulfur dioxide (SO2).

1.21.3 Economic Performance

An itemized cost breakdown was not provided. However, the company estimates the cost of generating electricity at 4 to 6 cents/kW-h). Flex Energy expects the equipment to last five years before a major overhaul and estimates a catalyst life of 2,000 to 4,000 hours. Their development target is an 8,000-hour catalyst life before replacement.

1.21.4 Quality of Supporting Data

- ☐ Sufficient data were provided to demonstrate effectiveness of technology
- ☒ Data were provided, but effectiveness of the technology is inconclusive - need more data
- ☐ Data are said to exist, but data are not yet available or were not provided
- ☐ No data are available

Flex Energy provided a chart summarizing the NOx and CO emissions from the microturbine over varying loads. However, these emission results are based on combustion of natural gas, which may not produce the same results when using dairy manure biogas—though low NOx levels would be expected due to the catalytic combustor staving off thermal NOx formation. The chart shows NOx emissions from 20-30 ppb at 19% O_2 and CO emissions ranging from 5-30ppm at 19% O_2. A review of actual emissions monitoring data and/or source test reports (rather than a summary chart) for parameters and methodology used to quantify the emissions would strengthen and verify the claims. The Panel requested any available inlet gas analysis and exhaust air emissions data from the prototype units running on digester and landfill gas, but did not receive additional information from the company in time for the publishing of this report.

1.21.5 Development Status of the Technology

- ☐ Research (basic research and applied research)
- ☐ Development (concept development and prototype development)
- ☐ Test and evaluation (product/process development)
- ☒ Demonstration (full or field relevant scale)
- ☐ Commercial application

There are three Flex-Microturbine demonstration prototypes operating in the field on various types of fuel: (1) uses wastewater treatment plant digester gas that includes dairy manure in the digester; (2) uses natural gas (with plans to test on wood-waste gas); and (3) uses landfill gas. Prototype #1 is located at the Inland Empire Utilities Agency (IEUA) Recycling Plant No. 1 in Ontario, California.

Moisture and sulfur in dairy manure biogas may be an issue, so pre-conditioning of the gas is needed. The unit operating at IEUA includes a digester gas pretreatment system consisting of a chiller, desiccant dryer, and carbon filter. This technology has not been tested on high-sulfur gas yet.

1.21.6 Applicability of the Technology to California Dairies

Where manure management methods generate biogas, it makes sense to utilize the fuel to generate electricity and provide heating/cooling (by utilizing the waste heat from the generator) rather then just flaring it. Depending on the size of the facility, it may be possible to satisfy the site's parasitic load requirements and also provide a net flow of excess electricity to the primary grid. In order for the technology to be used in

California, it must be determined whether emission levels will meet the California Air Resources Board's (ARB) distributed generation (DG) standards for waste gas-fired units if exempt from local air district permit.

1.21.7 What Data Gaps Exist?

The following information is needed to better assess the applicability and effectiveness of the technology in reducing the environmental impacts from dairies:

- Fuel biogas composition requirements—what, if any, pretreatment is needed in order for the microturbine to operate effectively.
- Quantitative data to verify the air emissions and performance (e.g., thermoelectric efficiency) of the microturbine when fired on dairy manure biogas over the operating load of the unit.
- Ability of the microturbine to meet ARB 2007 DG emission standards, which are equivalent to ARB's 1999 best available control technology (BACT) emission levels for state-of-the-art large central station natural gas-fired power plants (NOx = 0.07 lb/MWh, CO = 0.10 lb/MWh, VOC = 0.02 lb/MWh, PM = limit corresponding to natural gas with a fuel sulfur content of no more than 1 gr/100 SCF).

1.21.8 What Additional Research and/or Verification Work should be done?

Emissions testing should be conducted to verify the performance of the Flex-Microturbine on dairy manure biogas. This would include an analysis of biogas composition and exhaust emissions measured across the operating range of the unit. The company indicated that Prototype #1 will be moved to the digester located at California Polytechnic State University at San Luis Obispo in approximately six months. Therefore, this work may be able to help close some of the data gaps mentioned above.

As mentioned previously, data exist for the digester and landfill gas-fired prototypes, but was not provided during the Panel’s review period. Analysis of gas composition and emissions from the prototype waste gas-fired units may reveal some correlation with dairy manure biogas, and therefore, expected emissions performance.

Economic feasibility of the technology may depend on the sale of excess electricity. Therefore, power grid interconnectivity issues for DG should be investigated. The California Energy Commission should be consulted, as they may have already completed such studies.

1.22 Greenfinch Ltd

Product/Process: Anaerobic Digestion/Biogas Technology

1.22.1 Description

Greenfinch, Ltd. (Greenfinch) offers an integrated package that uses anaerobic digestion to produce biogas from dairy manure, and combusts the gas to produce heat and/or to power a generator. After collection in a "reception tank," dairy manure slurry is transferred to a continuously-stirred tank reactor (CSTR) and anaerobically digested to produce biogas. The heat generated from combustion of the biogas can be used to either heat farm facilities and/or to create temperature conditions within the CSTR that allow for a greater production of biogas. An alternative is to use some or all the biogas to generate electricity. The waste remaining after digestion (i.e., the "digestate") can be used as a fertilizer on cropland.

1.22.2 Environmental Impacts

This technology is intended to control:

Air Emissions	Non-volatile waste components
☒ Reactive organic gases	☐ Organic nitrogen
☒ Ammonia	☐ Ammonium nitrogen
☐ Particulates	☐ Nitrates
☒ Odors	☐ Phosphorus
☒ Methane	☐ Salts
☒ Hydrogen sulfide	☒ Pathogens

The technology produces the following air emissions:

☐ Oxides of nitrogen (NOx)
☐ Carbon monoxide
☒ Carbon dioxide
☐ Reactive organic gases
☐ Particulates
☐ Sulfur dioxide

Though this vendor indicated that its process would lead to a reduction in the oxides of nitrogen, the combustion of biogas will lead to the production of some NOx, even with the most stringent emissions control technology.

By products suitable for commercial sale or use:

☒ Heat energy
☒ Electrical energy
☐ Fuel
☒ Fertilizer
☐ Soil amendments
☐ Bedding
☒ Other - Carbon Credits. Though not mentioned in the vendor's submittal to the Panel, this is referred to on the vendor's website.

1.22.3 Economic Performance

No data were provided.

1.22.4 Quality of Supporting Data

- ☐ Sufficient data were provided to demonstrate effectiveness of technology
- ☐ Data were provided, but effectiveness of the technology is inconclusive - need more data
- ☐ Data are said to exist, but data are not yet available or were not provided
- ☒ No data are available

1.22.5 Development Status of the Technology

Greenfinch indicates that it has seven full-scale on-farm biogas plants as part of a research program being carried out under the auspices of the Scottish Executive (Government). The primary stated goal of the research program is to investigate the ability of this system to help reduce diffuse water pollution from agriculture in Scotland. The Scottish Environment Protection Agency (SEPA) is funding the project. Although these facilities have been operating for less than a year, Greenfinch indicates that it considers this technology to be at a commercial status. Although Greenfinch has experience in applying this technology to the processing of organic wastes, the technology should be considered to be at the test-and-evaluation stage or the demonstration stage for use on California dairies.

1.22.6 Applicability of the Technology to California Dairies

In principal this approach could be applicable to California. However, given the lack of data provided to the Panel in Greenfinch's submittal, it is difficult to assess how feasible this technology is for California dairies at this time.

1.22.7 What Data Gaps Exist?

No economic or environmental performance data were provided to the Panel by Greenfinch. Although Greenfinch acknowledges the importance of using a mass-balance approach in tracking nutrients, the acknowledgement on their website only refers to the application of their technology to the processing of food waste (http://www.greenfinch.co.uk/mass.html). Data review using a mass balance approach is necessary to determine how this technology affects nutrients at a dairy. Greenfinch should evaluate how nutrients are partitioned between the solid and liquid fractions of the dairy waste-stream, and include any gaseous emissions of nitrogen within the mass balance.

Greenfinch does not indicate what air emissions might be generated with its power-generation system. Even with the most efficient combustion, some small amounts of NOx would be produced. Also, there is no mention of what emissions control technology would be used for the combustion of the biogas nor how this might influence SOx and other emissions.

Greenfinch does not indicate if the dairy owner could contract separately for the installation of some of the equipment for the integrated package or if the owner would have to purchase all of the equipment from or through Greenfinch.

1.22.8 What Additional Research and/or Verification Work Should be Done?

Greenfinch did not submit economic and environmental performance data to the Panel. It would be useful if Greenfinch could provide such data from its Scottish operations.

Greenfinch also needs to use a mass balance approach in monitoring the effects of its technology on nutrients in the manure. Because of the unique environmental conditions and dairy practices in California's Central Valley, data should be collected from a dairy in California or from a facility typical of the type of dairies in California.

1.23 Haskell Edwards

Product/Process: WaterReclamation System

1.23.1 Description

The Water Reclamation System is a biological wastewater treatment process consisting of four interconnected vessels that provide aerobic treatment and reduction of biosolids followed by oxidation, denitrification, and clarification of effluent. The system is claimed to reduce odors and levels of COD, TSS, TKN, NO_3-N, NO_2-N, and phosphorus and to produce an effluent that can be used for crop irrigation. Stated maximum organic loading rate is 4 kg COD per cubic meter of reactor volume. The biosolids (sludge) from the system reportedly can be used as a fertilizer. However, the sludge is unlikely to be saleable due to the form it is in.

1.23.2 Environmental Impacts

This technology is intended to control:

Air Emissions
- ☒ Reactive organic gases
- ☒ Ammonia
- ☐ Particulates
- ☒ Odors
- ☒ Methane
- ☒ Hydrogen sulfide

Non-volatile waste components
- ☒ Organic nitrogen
- ☒ Ammonium nitrogen
- ☒ Nitrates
- ☒ Phosphorus
- ☐ Salts
- ☒ Pathogens

The technology produces the following air emissions:
- ☐ Oxides of nitrogen (NOx)
- ☐ Carbon monoxide
- ☐ Carbon dioxide
- ☐ Reactive organic gases
- ☐ Particulates
- ☐ Sulfur dioxide

By products suitable for commercial sale or use:
- ☐ Heat energy
- ☐ Electrical energy
- ☐ Fuel
- ☒ Fertilizer
- ☐ Soil amendments
- ☐ Bedding
- ☐ Other

1.23.3 Economic Performance

The vendor provided the following economic performance assessment:
- The capital cost per head is estimated at $392.00. For a 5,000 head dairy, an initial investment of $1,960,000 is required.
- The annual operating cost will be $45,000 (800 cubic meters manure treated per day; equivalent to 320,000 tons of manure treated annually).
- The useful life is estimated at 30 years
- Compost is a product.

The economic assessment provided by the technology vendor is based on the following assumptions: 5,000 head dairy, liquid waste per head is 0.16 cubic meters @ 2,000 mg/l, organic loading is 4 kg COD per cubic meter of reactor volume, aeration of 1,080 Standard Cubic Feet per Minute (SCFM) is provided by a 60 HP blower using 1,080 kW-h at $0.10 per kW-h.

The 320,000 tons dairy influent design criteria equates to 350 lbs cow per day. This is a potential underestimate of input. If parlor washwater is 35 gallons per cow per day (that is at the low end of the typical range in values) and manure collection (feces and urine) is 120 pounds per cow per day, the total daily input per cow is over 400 lbs. If rain runoff is also subjected to the system, and recycle flush water enters the system, the identified costs are significantly underestimating actual costs.

1.23.4 Quality of Supporting Data

- ☐ Sufficient data were provided to demonstrate effectiveness of technology
- ☒ Data were provided, but effectiveness of the technology is inconclusive - need more data
- ☐ Data are said to exist, but data are not yet available or were not provided
- ☐ No data are available

The technology vendor states that the system will provide 98% removal of COD, 94% removal of total-N, and 58% removal of phosphorus. Data provided were from tests on food processing waste and showed reductions in total nitrogen and phosphorus. However, no data were provided for use at a typical dairy in California.

1.23.5 Development Status of the Technology

- ☐ Research (basic research and applied research)
- ☐ Development (concept development and prototype development)
- ☒ Test and evaluation (product/process development)
- ☐ Demonstration (full or field relevant scale)
- ☐ Commercial application

No operating installations. Evaluation of the system was conducted at McCain Foods in Grand Falls, New Brunswick, Canada.

1.23.6 Applicability of the Technology to California Dairies

The estimated capital cost for a 5,000 head dairy farm is $1,960,000, and estimated annual operating costs are $45,000. The estimated useful life is 30 years, and the product is “compost.” That is a high capital cost and operating cost relative to the value of compost. Therefore, the technology may be economically viable only if it substantially reduces air emissions and/or reduces nitrogen and phosphorus loading as necessary for the dairy to continue operating. The process is expected to have little effect on total dissolved solids, and the effluent from the treatment process is unlikely to be suitable for discharge into waters of the state (i.e., it must be used for irrigation or process water at the dairy).

1.23.7 What Data Gaps Exist?

It is unknown if the system will work directly with dairy manure. The test system utilized food production waste with characteristics different from dairy manure. No material balance measurements were provided. Odors are subjective; no supporting testimonials were submitted to support the claimed odor reductions.

1.23.8 What Additional Research and/or Verification Work should be done?

In order to evaluate reductions in air emissions and in nutrient levels in treatment system effluent, testing, data evaluation and economic evaluation should occur at a facility typical of dairies in California. During the testing, the effect of the treatment on odors should be documented.

1.24 Hydrolve

Product/Process: Tempest Drying System

1.24.1 Description

Hydrolve offers an integrated package that utilizes a suite of technologies for biosolids management and treatment. The package includes the proprietary "Tempest Drying System" that is used to dry biosolids for more cost-effective handling and transport. In Hydrolve's process, biosolids are run through a screw-press to produce solids at 75% moisture content; the solids are then dried to a moisture content of 20% using the Tempest Drying System. The Tempest Drying System can be powered by an electric motor or a diesel engine. The heat from either power source is used to pre-treat the biosolids prior to processing in the Tempest Drying System. The pre-treatment heats the biosolids to more than 80ºC to kill pathogens in the material. In addition to separating and drying solids and killing pathogens, Hydrolve indicates that its technology will scrub particulate and gaseous pollutants and reduce odors released during the processing of the manure.

The materials submitted to the Panel do not identify the stage of manure handling where Hydrolve proposes to use their Tempest Drying System at dairies. Hydrolve indicated in one place that the solid portion of the treated effluent would be incinerated. However, in Hydrolve's brochure it was stated that the manure would be used for "a methane digestion system [that] will capture methane to generate power for a fuel cell. This will power the Hydrolve Plant and create excess energy." Apparently, the Tempest Drying System could be used to dry the digested manure waste after anaerobic digestion or used to dry the manure at the dairy for later transport to a centrally located plant for biogas and energy production.

Hydrolve indicated that their technology could be used for a "mobile division" employing "a fleet of trailer mounted Tempest Drying System(s)." This is further supported by their statement that, "Some CAFOs will receive rent if outside processing occurs. Mobile units will also be made available for smaller projects and clients." The dried manure solids would be blended with "other waste materials" (presumably biological) then condensed into a product with an increased energy content "making an excellent alternative fuel."

Hydrolve also indicates that their technology can be used to "manage the salts, phosphorous, and nitrates in the effluent." Hydrolve states that they have a technology for the removal of trace metals that could presumably be applied to wastewater generated in the handling of manure.

Hydrolve also states that, "Our technologies will be made available to clients on a fee-for-processing basis only. There will be no capital costs or investment required by the CAFO." They further claim that, "The most efficient use of Hydrolve technologies will involve permanent processing plants", and that, "Hydrolve technologies will benefit tremendously from economies of scale…Costs will be offset by revenue sharing in by-products and clients will benefit from the excess power generated. Some CAFOs will receive rent if outside processing occurs."

Much of the technology is proprietary. To protect patents and "a competitive position in the marketplace," Hydrolve did not provide the Panel with details of some its technologies.

1.24.2 Environmental Impacts

This technology is intended to control:

Air Emissions	Non-volatile waste components
☐ Reactive organic gases	☒ Organic nitrogen
☒ Ammonia	☒ Ammonium nitrogen
☐ Particulates	☒ Nitrates
☒ Odors	☒ Phosphorus
☒ Methane	☒ Salts
☒ Hydrogen sulfide	☒ Pathogens

The technology produces the following air emissions:

- ☒ Oxides of nitrogen (NOx)
- ☒ Carbon monoxide
- ☒ Carbon dioxide
- ☒ Reactive organic gases
- ☒ Particulates
- ☒ Sulfur dioxide

By products suitable for commercial sale or use:

- ☒ Heat energy
- ☒ Electrical energy
- ☒ Fuel
- ☐ Fertilizer
- ☐ Soil amendments
- ☐ Bedding
- ☐ Other: Hydrolve indicated in the submitted review form that the intended disposition of the solids would be for incineration. Pending clarification of the details of processing by Hydrolve, the solid end product might also be suitable for use either as fertilizer, soil amendment, or bedding.

The basis for the claimed reductions in emissions of pollutants is unclear, since little data were provided. Air emissions are expected from the diesel engines and other machinery, and it is not clear whether the proprietary technology will scrub or capture some of these emissions. Hydrolve claims in its brochure that it could reduce particulate emissions during certain stages of its process, but as indicated above, it did not stress this claim on the submitted review form.

1.24.3 Economic Performance

Hydrolve did not provide economic data. Therefore, an economic assessment could not be performed.

The business model that this vendor has adopted assumes that the drying of manure/biosolids provides it with cost advantages because "transporting only the solids without the moisture will decrease the costs of hauling by approximately 66%."

1.24.4 Quality of Supporting Data

- ☐ Sufficient data were provided to demonstrate effectiveness of technology
- ☐ Data were provided, but effectiveness of the technology is inconclusive - need more data
- ☒ Data are said to exist, but data are not yet available or were not provided
- ☐ No data are available

The technology descriptions provided by Hydrolve are not clear. This may be because, as stated in a letter submitted by the company, Hydrolve wishes to protect their proprietary information. However, technologies that are still in the concept and development stage cannot be fully documented. The Tempest Drying System is described in the most detail by the company literature. However, it is not clear how the system achieves reductions in emissions of air pollutants and against which standard these reductions are referenced.

1.24.5 Development Status of the Technology

Tempest Drying System is commercially available for the concentration of biosolids from various sources (paper processing facilities, food-processing facilities, municipal sewage treatment facilities, etc.). However, the two installations referenced in Hydrolve's submission and reportedly operating for one year in Iowa and Wisconsin are not being used to treat dairy manure. Other components of the technology package appear to be in much earlier stages of development, including many that are "discussions" with other interested companies. Thus, given the lack of both economic and performance data, it would appear that the suitability of this solutions package for dealing with dairy manure would require testing and evaluation at a demonstration facility.

1.24.6 Applicability of the Technology to California Dairies

The applicability of this solutions package to a California dairy is unclear. A great many technologies are mentioned, and many could be useful for dairies in California. However, few details are provided about the technologies' operation, performance, cost, etc.

Two claims were made for the ability of the Tempest Drying System to handle organic waste. On a video submitted to the Panel it was claimed that the portable system could process 2 to 4 wet tons per hour, but elsewhere the claimed rate was 3 to 9 wet tons per hour. It was also claimed that over 90 wet tons per hour could be processed at a centralized co-processing plant. Based on those claims, the Tempest Drying System component of technology package appears capable of handling the amount of manure generated by a Central Valley dairy on a daily basis. However, it is not clear what moisture content Hydrolve is referring to and whether similar processing rates would apply to the manure slurry generated by a flush dairy.

1.24.7 What Data Gaps Exist?

Hydrolve provided the Panel only with a business plan that does not include specifics on environmental or economic performance. No detailed descriptions of the other technology components and how they deal with nutrients, salts, and trace metals, from dairies was provided. Likewise, data are needed on the air emissions from the technology package and along with data on any emissions controls associated with the technology package. Air emissions data are essential for this technology package since much of the process involves heating moist biosolids, which would rapidly volatilize problematic compounds. If a diesel engine were used to power the drying system and pre-treatment process, then an assessment of air emissions from the engine should be made. Hydrolve also assumes that by drying the solids prior to transport to a processing facility, emissions reductions are gained because fewer truck-trips would be required relative to the transporting wet waste. However, because data are lacking, the total process emissions — including those involved in the processing and transport of the dried waste — cannot be compared to the total emissions of other approaches for managing dairy manure.

With respect to the metal ion recovery system described in the submission, no data were provided, either as a stand-alone analysis or relative to other approaches, on the volumes of waste that can be treated, the recovery rate, or the economic performance.

1.24.8 What Additional Research and/or Verification Work Should be Done?

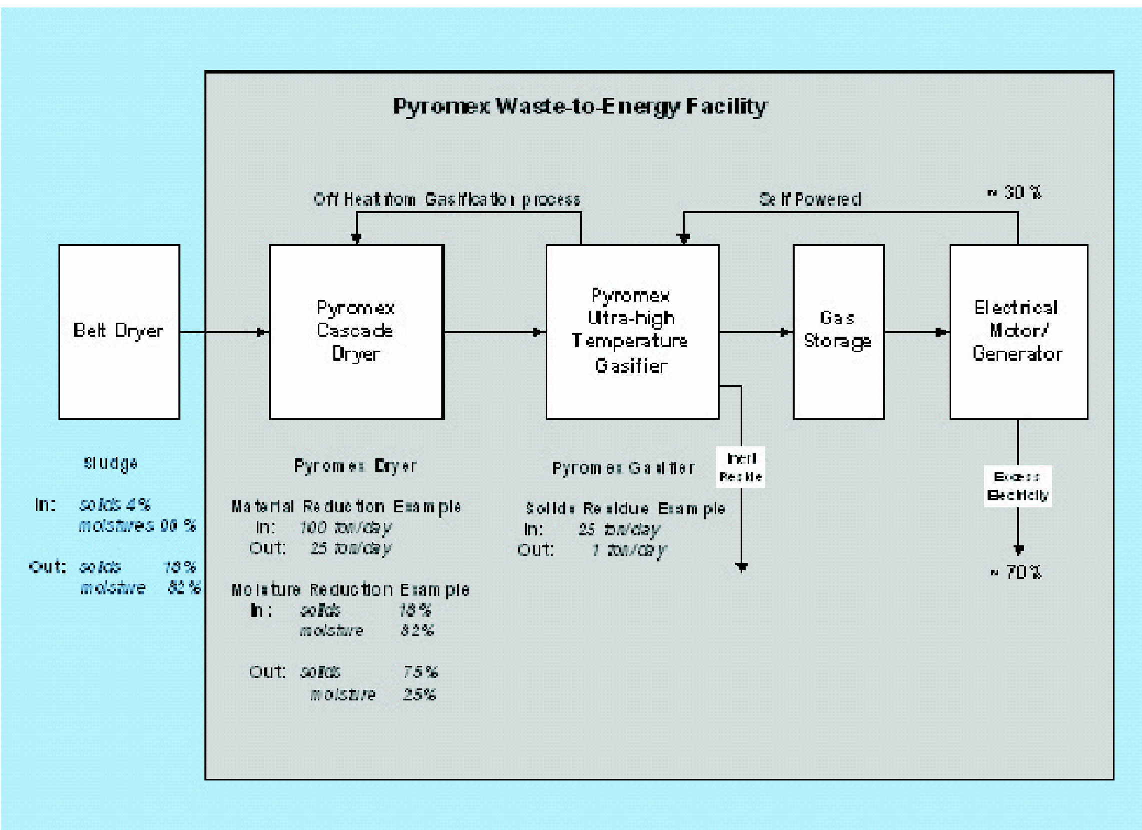
A typical Central Valley dairy should be found where this solutions provider could apply its solutions package for demonstration, testing, and evaluation. In conducting the evaluation, Hydrolve should employ a mass-balance approach to assess the flow of nutrients, salts, and trace minerals/metals through the treatment process.

1.25 ILS-Partners, Inc.

Product/Process: Pyromex-Pyrolysis-Hydrolysis Ultrahigh Temperature

1.25.1 Description

The Pyromex Waste-To-Energy technology is an induction-heated, ultra-high-temperature gasification process developed in Switzerland and licensed to ILS-Partners, Inc., for applications in the United States. After the manure is dried to 10-12% moisture, the Pyromex process converts the organic content of a waste stream into a synthetic gas for further use either for power generation or fuel for sale. The inorganic content is converted to a slag or ash. Using induction heating, the process generates heat in an oxygen-free environment causing a series of chemical reactions to occur through pyrolysis and hydrolysis. A diagram of the process was submitted by Pyromex and is reproduced below.



1.25.2 Environmental Impacts

This technology is intended to control:

Air Emissions	Non-volatile waste components
☒ Reactive organic gases	☐ Organic nitrogen
☒ Ammonia	☒ Ammonium nitrogen
☒ Particulates	☐ Nitrates

- ☒ Odors
- ☒ Methane
- ☒ Hydrogen sulfide
- ☒ Phosphorus
- ☒ Salts
- ☒ Pathogens

The technology produces the following air emissions:

- ☐ Oxides of nitrogen (NOx)
- ☒ Carbon monoxide
- ☒ Carbon dioxide
- ☐ Reactive organic gases
- ☐ Particulates
- ☐ Sulfur dioxide

By products suitable for commercial sale or use:

- ☒ Heat energy
- ☒ Electrical energy
- ☒ Fuel- methane, hydrogen, synthesis gas
- ☐ Fertilizer
- ☐ Soil amendments
- ☐ Bedding
- ☐ Other

1.25.3 Economic Performance

The company estimates a $50 million investment is required for a facility that will generate approximately 21 megawatt (MW). The economic evaluation relies on tipping and other fees of $18.50/ton and $12.50/ton. Dairy producers may not be willing to pay this for solids disposal if they have land to apply it or other disposal options. Cost of transporting manure also has to be considered.

1.25.4 Quality of Supporting Data

- ☐ Sufficient data were provided to demonstrate effectiveness of technology
- ☐ Data were provided, but effectiveness of the technology is inconclusive - need more data
- ☒ Data are said to exist, but data are not yet available or were not provided
- ☐ No data are available

The technology has been developed and tested in Switzerland for use in Europe. The tests were discussed but sufficient data were not provided for further analysis.

1.25.5 Development Status of the Technology

The technology has been developed and tested in Switzerland at small scale or pilot scale. The economic evaluation was based on farms producing 25, 50, 100, and 500 tons of manure per day.

1.25.6 Applicability of the Technology to California Dairies

There appear to be significant technology and other barriers to applying this technology as an on-site dairy manure treatment system. First, a substantial amount of moisture must be removed from manure before feeding the manure to the pyrolizer. The water removed will contain nutrients, pathogens and dissolved solids. Second, the dairy itself may not have a need for all of the heat or electricity that could be produced with the system. The ability to sell the energy by connecting to the energy grid may be an issue. Third, the dairy would loose the nitrogen nutrient value of the solid manure; this may be a benefit for diaries without sufficient land for proper application. Fourth, air emissions and wastewater from the process could result in the facility being classified as an industrial source. As a technology for centralized processing of manure solids:

- The economics are predicated on the willingness of dairy producers to pay transport, tipping and "treatment" fees.
- There may be significant permitting issues. Pollutant emissions and wastewater from process could be issues, and should be evaluated to determine how they affect the system life cycle.

This technology appears to be the most developed of the thermal conversion technologies submitted to the panel in terms of handling a waste stream like manure. The technology seems best suited to a large centralized facility or treatment plant. Transporting manure from flush dairies may be an issue and would require infrastructure costs.

On-farm systems have not been tried. Most dairies would not need all of the heat and steam generated on-site. Therefore, off-site energy markets and electricity transmission policies would need development. The absence of such development has been a barrier to using electricity from on-farm sources in the California utility market.

1.25.7 What Data Gaps Exist?

There are data gaps in three main areas: 1) wastewater, airborne, and toxics emissions from the process, 2) costs of a fully-integrated dairy system, and 3) operating requirements for a on-site system. These issues are discussed below.

Coliform and salmonella bacteria from the manure are expected to be consumed in the process, and ammonia and organic nitrogen are expected to be converted to nitrogen gas (N_2). However, the separated wastewater on a dairy will retain pathogens, ammonia, and some organic nitrogen; so this technology does not capture the full waste stream. Phosphorous and salts are expected to remain in the ash or separated wastewater, and will require proper management or disposal. Other potential pollutants from the process are not discussed but could be an issue. Wastewater treatment is a large part of the operating cost of the "waste-to-energy" hypothetical facility. Ammonia is reduced from the solids only and would still be present in the wastewater.

Carbon dioxide emissions may be considered renewable and should balance with the amount of manure consumed. Other air emissions from pyrolysis, in particular PM, NOx, CO and VOC, need to be fully characterized. Data on emissions should be evaluated to fully assess this technology and should be compared with other power generation methods. This comparison was not made in this review.

1.25.8 What Additional Research and/or Verification Work should be done?

Additional research in the following areas is needed: 1) amount of actual manure solids that could be used in this system from a flush dairy, 2) the demands on the dairy operator to maintain and manage the system, and 3) information on potential air emissions and wastewater composition.

1.26 Integrated Separations Solutions

Product/Process: Separators

1.26.1 Description

Integrated Separations Solutions (ISS) specializes in water purification and has extensive experience with the treatment of wastewater from food-processing and other industries. Their proposed technology for dairy waste in intended to first separate solids from manure slurry and then to recover the dissolved nutrients, salts, and trace metals from the liquid portion thereby producing water “purified” to the desired level. The technology involves pre-processing manure slurry using rotary filtration followed by additional solids separation using a screw press. The resulting liquid would be either microfiltered or ultrafiltered to remove fine and ultrafine solids. ISS indicates that the resulting water could either be used for irrigation, or further processed using reverse osmosis to remove all dissolved salts and nutrients. The microfiltrate and/or ultrafiltrate could be run through another iteration of the rotary centrifuge and screw press to recover any further liquid for processing. The vendor indicated that the solids could be used either for bedding, composting, or fertilizer, but did not address this aspect of the waste-stream as part of their technology. ISS indicates that they would prescribe the appropriate combination of technologies to use and which may involve products/processes from other companies.

It appears that, depending on how much a dairy owner was willing to spend, that this system could be used to collect and purify water from manure slurry. The solids would have to be handled separately from this solutions provider’s processes.

1.26.2 Environmental Impacts

This technology is intended to control:

Air Emissions	Non-volatile waste components
☒ Reactive organic gases	☒ Organic nitrogen
☒ Ammonia	☒ Ammonium nitrogen
☒ Particulates	☒ Nitrates
☒ Odors	☒ Phosphorus
☒ Methane	☒ Salts
☐ Hydrogen sulfide	☒ Pathogens

The technology produces the following air emissions:

- ☐ Oxides of nitrogen (NOx)
- ☐ Carbon monoxide
- ☒ Carbon dioxide
- ☐ Reactive organic gases
- ☐ Particulates
- ☐ Sulfur dioxide

While this vendor seeks to help control the emissions of air pollutants typically emitted from dairy waste (ROG, ammonia, hydrogen sulfide, odors, etc.), the ability of its technology to reduce these emissions will be very much a function of how quickly the manure waste is collected and processed with their system.

By products suitable for commercial sale or use:

- ☐ Heat energy
- ☐ Electrical energy
- ☐ Fuel
- ☒ Fertilizer
- ☐ Soil amendments
- ☒ Bedding
- ☐ Other:

1.26.3 Economic Performance

The vendor indicated that cost data were available but no data were provided to the Panel.

1.26.4 Quality of Supporting Data

- ☐ Sufficient data were provided to demonstrate effectiveness of technology
- ☐ Data were provided, but effectiveness of the technology is inconclusive - need more data
- ☒ Data are said to exist, but data are not yet available or were not provided
- ☐ No data are available

1.26.5 Development Status of the Technology

ISS stated, "There [are] many types of equipment necessary, some of them are in production and some are in development" and indicated that portions of its technology package ranged from being at the development stage to being ready for commercial application. The development stage of the individual technologies applied at different steps in the treatment process was not clarified. Thus the overall development status for the technology package is unclear, but the overall technology should probably be viewed as at the test and evaluation stage.

1.26.6 Applicability of the Technology to California Dairies

While sequential separation has great promise for concentrating solids, it may not be cost effective, even for a large Central Valley dairy. Adding reverse osmosis as a step to further treat the water fraction adds additional costs. It is also unclear if the technology package has ever been applied to dairy manure. This technology package may only be suitable for a centralized treatment center such as that at the Inland Empire Utilities Agency. In the absence of any economic and environmental performance data, it is difficult to determine how appropriate this technology package is for a dairy.

1.26.7 What Data Gaps Exist?

No performance or cost data were provided to the panel. While ISS appears to have experience in the purification of wastewater — and their sequential separation approach might effectively remove solids and nutrients from manure slurry — it is likely that the cost exceeds other treatment and utilization options.

Technical information on system flow rates, separation efficiency, and emissions would be helpful. Also, information on the need to alter existing manure collection practices should be provided; in particular, information on the space needed for the physical footprint of the equipment should be provided.

Disposal options for the brine generated by using reverse osmosis should be identified. A review of the ISS website (http://www.isepsol.com) provided no additional information.

1.26.8 What Additional Research and/or Verification Work Should be Done?

A demonstration project at a dairy representative of a large facility in the Central Valley would be useful in determining how the economics relate to the environmental performance of the technology. The economic data could help assess the practicality of a large centralized processing facility serving several large dairies in close proximity to one another. A mass-balance assessment of nutrients, salts, trace metals, etc., through the treatment process is also necessary.

1.27 Jeesung Livestock Engineering Co. Ltd.

Product/Process: Organic Waste Composting Unit

1.27.1 Description

This composting technology is from Korea. The structure of the composter is similar to a silage pit, covered with a transparent roof. Augers are installed vertically on a frame that moves along the pit. The augers turn and inject air into the material lowering the moisture content of the feedstock. The system is fitted to spray liquid manure and leachate over the top of the pile. The floor of the pit has a drainage/collection system and also operates as a forced air aeration system. Fans to evaporate the liquid exhaust air from the structure. The company is testing the integration of a biofilter. Currently, the system is used to compost poultry and pig manure (with bulking material), but they have begun looking at dairy manure.

1.27.2 Environmental Impacts

This technology is intended to control:

Air Emissions	Non-volatile waste components
☒ Reactive organic gases	☐ Organic nitrogen
☒ Ammonia	☐ Ammonium nitrogen
☒ Particulates	☐ Nitrates
☒ Odors	☐ Phosphorus
☒ Methane	☐ Salts
☒ Hydrogen sulfide	☐ Pathogens

The technology produces the following air emissions:

- ☐ Oxides of nitrogen (NOx)
- ☐ Carbon monoxide
- ☐ Carbon dioxide
- ☐ Reactive organic gases
- ☐ Particulates
- ☐ Sulfur dioxide

By products suitable for commercial sale or use:

- ☐ Heat energy
- ☐ Electrical energy
- ☐ Fuel
- ☐ Fertilizer
- ☒ Soil amendments
- ☒ Bedding
- ☐ Other

No environmental discharge or emission data were provided to support the above statements. The Technical Contact, located in Israel, stated that, “little is known about any research done on the performance of the JS2000.” Apparently there is one unit at the University of Korea that is being tested for composting urban organic wastes.

1.27.3 Economic Performance

No cost data were provided. The vendor stated that “The JS2000 is very compact and its unique features make it very cost effective.”

1.27.4 Quality of Supporting Data

- ☐ Sufficient data were provided to demonstrate effectiveness of technology
- ☐ Data were provided, but effectiveness of the technology is inconclusive - need more data
- ☐ Data are said to exist, but data are not yet available or were not provided
- ☒ No data are available

No environmental discharge or emission data were provided at this time.

1.27.5 Development Status of the Technology

The company has commercial installations. There are over 50 units (pig/poultry/organic wastes/R&D) at locations in Korea and Malaysia.

1.27.6 Applicability of the Technology to California Dairies

Before applicability can be assessed, environmental data need to be provided. A biofilter most likely would need to be incorporated into the treatment system. In situations where there are problems with manure solids, lagoon storage, or open composting, the technology could possibly provide environmental benefits, but data are not available to validate claims. . The technology may be most appropriate for larger dairies or for a regional composting facility. Markets may need to be developed for compost produced by the technology.

1.27.7 What Data Gaps Exist?

No environmental discharge, emission or cost data were provided.

1.27.8 What Additional Research and/or Verification Work should be done?

Environmental discharge, emission, and cost data need to be provided.

1.28 Kyte Centrifuge Sales and Consulting

Product/Process: **Triton Separator**

1.28.1 Description

The Triton Separator is a solid-bowl basket-centrifuge designed to continuously separate fresh manure into solid and liquid fractions. It is powered by an electric motor. Although Kyte Centrifuge Sales and Consulting (Kyte) indicated that there are two models of this separator, the TS-3000 and the TS-5000, the submission to the Panel focused on the TS-5000.

The information provided to the Panel was reportedly based on work "performed, and supervised by, the North Carolina State University Animal and Waste Research Facility in Raleigh, North Carolina." The US-EPA Environmental Technology Verification (ETV) Program also tested the Triton TS-5000 Separator. Results are on the Web (http://www.epa.gov/etv/verifications/vcenter9-4.html).

The Triton Separator is designed to separate solids, not to remove or recover nutrients. Nevertheless, significant amounts of nitrogen and phosphorus appear in the separated solids. The percentage of these nutrients claimed by the manufacturer is slightly higher than that found in the EPA's ETV report, probably because the ETV results were based on batch tests while the company report is based on the recommended continuous processing. Kyte states that 24 to 30% of nitrogen and 55 to 65% of phosphorous is captured in the separated solid fraction. In contrast, the ETV report indicates only 20% of nitrogen and 42% of phosphorus was captured in the separated solids. Kyte also states that the device removes 65 to 85% of suspended solids from the manure; the ETV report indicates 55% removal. Finally, Kyte states that the centrifuge reduced coliform bacteria populations, but no quantification was provided, and these claims were not supported by the EPA's ETV report.

1.28.2 Environmental Impacts

This technology is intended to control:

Air Emissions
- ☐ Reactive organic gases
- ☐ Ammonia
- ☐ Particulates
- ☐ Odors
- ☐ Methane
- ☐ Hydrogen sulfide

Non-volatile waste components
- ☒ Organic nitrogen
- ☐ Ammonium nitrogen
- ☒ Nitrates
- ☒ Phosphorus
- ☐ Salts
- ☒ Pathogens (coliform bacteria were claimed to be controlled)

The technology produces the following air emissions:
- ☐ Oxides of nitrogen (NOx)
- ☐ Carbon monoxide
- ☐ Carbon dioxide
- ☐ Reactive organic gases
- ☐ Particulates
- ☐ Sulfur dioxide

By products suitable for commercial sale or use:
- ☐ Heat energy

- ☐ Electrical energy
- ☐ Fuel
- ☒ Fertilizer
- ☒ Soil amendments
- ☒ Bedding
- ☐ Other: Kyte indicated that the separated solids could be composted, used for anaerobic digestion, or used for feeding soldier fly larvae or worms. Though not claimed by the vendor, the liquid fraction can be used for fertilizer and irrigation, or for additional flushing of stalls.

1.28.3 Economic Performance

The TS-5000 costs $150,000 per unit, plus $10,000 for installation. No estimated values were provided for the recovered solids, which could be used for bedding, soil amendments, or fertilizer. Kyte suggests that compost facilities might charge lower tipping fees for the separated solids than for non-separated manure. Kyte estimates that with basic maintenance the unit should last 30 to 50 years, based on a track record of similar devices at wastewater treatment facilities.

Kyte calculates that, for hog manure, the TS-5000 has a capacity sufficient for 8 barns or 10,000 animals, and that the capital costs is $0.19 per hundredweight over the first 10 years. Total costs per hundredweight over 10 years (including capital cost plus power at $0.07 per kW-hr, maintenance, and labor) were estimated at $0.48. No data were provided for dairies and dairy manure. In addition, typical electricity rates in California are more than the estimated $0.07 per kW-hr.

A typical new San Joaquin Valley dairy has 2,000 cows that each produces 15 gallons of manure per day and use 100 gallons of washwater per day per cow. Such a facility thus produces approximately 230,000 gallons of wastewater per day. The Triton Separator has a maximum processing rate of 50 gallons per minute, which computes to 72,000 gallons per day if the separator were run 24 hours per day. Separating the wastewater produced at a 2,000 cow dairy volume using the Triton Separator would require at least three of the machines.

1.28.4 Quality of Supporting Data

- ☒ Sufficient data were provided to demonstrate effectiveness of technology
- ☐ Data were provided, but effectiveness of the technology is inconclusive - need more data
- ☐ Data are said to exist, but data are not yet available or were not provided
- ☐ No data are available

1.28.5 Development Status of the Technology

- ☐ Research (basic research and applied research)
- ☐ Development (concept development and prototype development)
- ☐ Test and evaluation (product/process development)
- ☒ Demonstration (full or field relevant scale)
- ☐ Commercial application

All tests were performed on hog, not dairy, waste. No dairy using a Triton Separator was reported to be operating. However, a full-size test unit is reportedly available for purchase.

Based on the Triton Separator' history of use at wastewater treatment facilities, Kyte states that the technology is particularly sturdy and reliable. However, the ETV report notes that the test unit suffered from several operational problems, including erratic operating speeds, out-of-balance conditions that caused unplanned shut-downs, failure of the device to follow the intended cycle sequence, and the introduction of significant amounts of air in the liquid effluent, causing foaming that persisted for 24 to 48 hours. Some of these problems may have been a result of testing the unit in batch mode, rather than running it continuously as is specified by the manufacturer.

1.28.6 Applicability of the Technology to California Dairies

Solid separation is a common and important step in manure processing. This device could be useful for that purpose, but its economics and efficacy compared to other separation devices are not known at this time because it has not been tested on dairy manure.

1.28.7 What Data Gaps Exist?

The device has not yet been tested on dairy manure.

1.28.8 What Additional Research and/or Verification Work Should be Done?

The device should be tested on dairy manure at a typical California flush dairy in order to evaluate its cost performance and to check the device's reliability, efficiency of solids separation, and nutrient recovery. These tests should be conducted under continuous operation, as specified by the manufacturer. Costs and performance data could then be compared with other types of solid separators tested under identical conditions.

1.29 Lanstar

Product/Process: Carbonisation

1.29.1 Description

Lanstar proposes to convert manure solids into charcoal using continuous kilns. The advantage of continuous kilns and continuous multiple-hearth kilns is that they are more amenable to the control of emissions than are batch kilns. This is largely achieved by cycling the gases that would otherwise escape through the kiln exhaust into an afterburner to ensure that they are completely combusted. The result is that compounds to be exhausted to the air are more benign. Substantial reductions in overall emissions can be achieved in this manner. Lanstar's Carbonisation process uses an afterburner to further reduce air emissions.

Lanstar indicates that its Carbonisation system will reduce odors and the release of ammonia, VOCs, carbon dioxide and carbon monoxide, and methane to the air. Lanstar also indicates that its Carbonisation system will reduce the movement of nitrogen, phosphorous, and pathogens from the dairy's wastewater into the environment.

1.29.2 Environmental Impacts

This technology is intended to control:

Air Emissions	Non-volatile waste components
☒ Reactive organic gases	☒ Organic nitrogen
☒ Ammonia	☐ Ammonium nitrogen
☐ Particulates	☒ Nitrates
☒ Odors	☒ Phosphorus
☒ Methane	☐ Salts
☐ Hydrogen sulfide	☒ Pathogens

The technology produces the following air emissions:

- ☐ Oxides of nitrogen (NOx)
- ☐ Carbon monoxide
- ☐ Carbon dioxide
- ☐ Reactive organic gases
- ☐ Particulates
- ☐ Sulfur dioxide

By products suitable for commercial sale or use:

- ☐ Heat energy
- ☐ Electrical energy
- ☒ Fuel- Charcoal
- ☐ Fertilizer
- ☒ Soil amendments
- ☐ Bedding
- ☒ Other - reductant for metallurgy or semiconductor manufacture

1.29.3 Economic Performance

Lanstar recommends that the facility have the ability to process 9,000 tons (dry weight) of manure annually, although Lanstar admits that the technical and economic feasibility of such a system has yet to be evaluated at a test facility. Lanstar estimates that to set up a test facility in the Republic of South Africa would require $2.3 million (U.S.) in up-front capital costs. Estimated operating costs would be $284,000 during the first year, $665,000 during the second year, and $947,000 during each subsequent year. Based on the information submitted, the unadjusted costs for the first 7 years of operation of the test facility would equal roughly $8,000,000. The costs would likely be higher for a California based facility. Even recognizing that this is a test facility, the competitiveness of such a facility might be an issue.

Lanstar has noted that some modifications would be required to their kilns in order to allow their process to handle dried manure. No cost estimates were provided for the expected modifications.

In response to an e-mail enquiry from the panel, Lanstar indicated that the Carbonisation system would require feed manure to be at less than 30% moisture. This might add to the expense of processing, unless waste-heat from the kilns can be captured for the desiccation of the manure prior to treatment.

With regards to the competitiveness of the charcoal product, in response to an e-mail inquiry from the panel, Lanstar stated that for its operations producing charcoal from wood in the Republic of South Africa were "…expecting to achieve the British Pound equivalent of nearly US$600/ton CIP main port. This is before inland distribution. The primary market is for use in restaurants because their smoke emissions are efficiently policed. Lump-wood charcoal currently supplies this market." It is not clear whether this price-point would be competitive for a US-based facility producing charcoal from dairy-manure. Depending upon the quality of the charcoal produced, it might be suitable as a metallurgical reductant.

1.29.4 Quality of Supporting Data

- ☐ Sufficient data were provided to demonstrate effectiveness of technology
- ☐ Data were provided, but effectiveness of the technology is inconclusive - need more data
- ☐ Data are said to exist, but data are not yet available or were not provided
- ☒ No data are available

This vendor has only used their kilns to generate charcoal from wood/wood-waste. Beyond some testing on manure at the kilogram scale, this system has not been applied at a commercial scale to produce charcoal from dairy manure. Lanstar did not supply any measurement data for nutrient flows or air emissions.

1.29.5 Development Status of the Technology

This technology is at the test and evaluation stage.

1.29.6 Applicability of the Technology to California Dairies

Given California's air quality issues, it is not evident that the kilns would meet California emissions standards. It is also not clear whether the quality of product that could be produced by the conversion of dairy manure into charcoal would be a competitive product within the U.S. market place. This would require further determination. It should be noted that there are commercial operations manufacturing wood charcoal in California.

1.29.7 What Data Gaps Exist?

Lanstar made subjective claims for how its process would help with pollution control/prevention at a California dairy. No measurement data were provided for how the nutrients are captured and cycled through its process. No information was provided on the effectiveness of the emissions-control technology (i.e., the afterburners, etc.) at minimizing emissions from the kilns. No assessment has been conducted on how the high protein and sulfur content of manure will affect air emissions from the kilns.

1.29.8 What Additional Research and/or Verification Work should be done?

A test and evaluation facility would have to be established and a comprehensive mass-balance analysis conducted for the system. Monitoring would need to be conducted to evaluate the effectiveness of pollution controls for emissions from the kiln(s).

Monitoring data would then need to be evaluated to assess if the Carbonisation system reduces emissions of problematic compounds that normally are produced from untreated manure. Assessment results should be compared to the emissions profiles of other treatment systems such as aerobic digesters and anaerobic digesters with methane capture and utilization.

The issue of preprocessing of the manure (separation of solids drying to achieve suitable moisture content, etc.) and the associated environmental issues were not discussed in Lanstar's submission. Emissions of ammonia, hydrogen sulfide, methane, etc., from manure prior to desiccation and during storage prior to being placed in the kiln need to be assessed. Lanstar will need to demonstrate how wastewater and air emissions produced by the process are to be controlled.

Given that manure contains more protein and sulfur than does wood, an assessment should be made to determine the suitability of using manure in the Carbonisation process. Presumably, if sulfur volatilized in the kiln it could be emitted as sulfur oxides, mercaptans, thioethers, or sulfur hydrides. Such emissions would have to be scrubbed from the kiln exhaust. Alternatively, a problem would arise if the sulfur was not volatilized during processing but remained within the finished charcoal. This would mean that combustion of the charcoal elsewhere would lead to the emission of sulfur oxides and/or other sulfur compounds. One way to assess concerns about sulfur is by determining how the sulfur compounds are partitioned between the charcoal solids and the gasses produced when test batches of manure are carbonized in the kilns Lanstar is currently operating in the Republic of South Africa.

1.30 Midwestern Bio-Ag Products and Services, Inc

Product/Process: HumaCal™

1.30.1 Description

This product consists of humic substances and two calcium minerals. It is either fed directly to livestock or spread on manure. It is claimed that when direct fed it reduces free nitrates in the blood stream and is also used to detoxify the effects of moldy forage. The vendor cites a study (Steinberg, C. 2003. Ecology of Humic Substances in Freshwaters. Springer, New York) to document that feeding humic substances to animals can provide bactericidal, antimicrobial, and anti-viral effects.

The application of calcium containing minerals to reduce manure emissions is a long time practice. By simple ionic exchange, phosphates and nitrates are combined into calcium compounds. Nitrates are stabilized and removed from the microbial reactions creating ammonia emissions. Phosphates are partitioned into various calcium phosphate complexes, including the mineral apatite, which are chemically stable compounds that are converted into bioavailable nutrients via soil microbial colonization. Phosphates and nitrates are said to combine into calcium compounds reducing emissions and improving stability. However, the stabilized material still needs to be land applied at appropriate rates.

1.30.2 Environmental Impacts

This technology is intended to control:

<u>Air Emissions</u>

- ☒ Reactive organic gases
- ☒ Ammonia
- ☐ Particulates
- ☒ Odors
- ☒ Methane
- ☒ Hydrogen sulfide

<u>Non-volatile waste components</u>

- ☐ Organic nitrogen
- ☒ Ammonium nitrogen
- ☐ Nitrates
- ☒ Phosphorus
- ☐ Salts
- ☒ Pathogens

The technology produces the following air emissions:

- ☐ Oxides of nitrogen (NOx)
- ☐ Carbon monoxide
- ☐ Carbon dioxide
- ☐ Reactive organic gases
- ☐ Particulates
- ☐ Sulfur dioxide

By products suitable for commercial sale or use:

- ☐ Heat energy
- ☐ Electrical energy
- ☐ Fuel
- ☒ Fertilizer
- ☒ Soil amendments
- ☐ Bedding
- ☐ Other:

1.30.3 Economic Performance

Cost of product stated to be $170 per ton, FOB Harvey, Iowa; stated application rate is "25 to 50 pounds per ton of manure;" stated application cost is "approximately $2.50 to $5.00 per ton. One study (Shi et al. 2001. *Trans. Amer. Soc. Agric. Engineers* 44(4):677-682.) was cited as "demonstrating the effectiveness of raw Leonardite in reducing feedlot emissions," but it was also noted that the study "concluded that the applications were not economically feasible."

1.30.4 Quality of Supporting Data

- ☐ Sufficient data were provided to demonstrate effectiveness of technology
- ☒ Data were provided, but effectiveness of the technology is inconclusive - need more data
- ☐ Data are said to exist, but data are not yet available or were not provided
- ☐ No data are available

Insufficient information is provided to evaluate claims for improved animal health or reduced emissions from treated manure. Additional information on animal health may be in a cited reference (Steinberg, 2003) that was not provided or reviewed.

1.30.5 Development Status of the Technology

- ☐ Research (basic research and applied research)
- ☐ Development (concept development and prototype development)
- ☐ Test and evaluation (product/process development)
- ☐ Demonstration (full or field relevant scale)
- ☒ Commercial application

1.30.6 Applicability of the Technology to California Dairies

Technology is claimed to reduce air emissions when treated manure is applied to cropland. However, no quantitative data or estimates of the reductions were provided. No documented benefits to water quality were identified from use of the treated manure as a "buffered fertilizer."

1.30.7 What Data Gaps Exist?

Other than proprietary information, publicly accessible research on the practical application of humic substances in agricultural programs is scarce. There are numerous references to a large body of research in Russia that has not been translated into English. The vendor cited Steinberg’s (2003) opinion that most of the information is buried as internal reports within universities. Research demonstrating the use of humic substances as part of sustainable, biological or organic agricultural programs does not exist.

Actual reduction in air emissions should be documented.. The potential long-term effects on water quality should also be assessed.

1.30.8 What Additional Research and/or Verification Work should be done?

Controlled studies to validate potential reduction in air emissions and to assess potential effects of treatment on water quality should be completed.

1.31 Natural Aeration, Inc.

Product/Process: CIRCUL8 Systems

1.31.1 Description

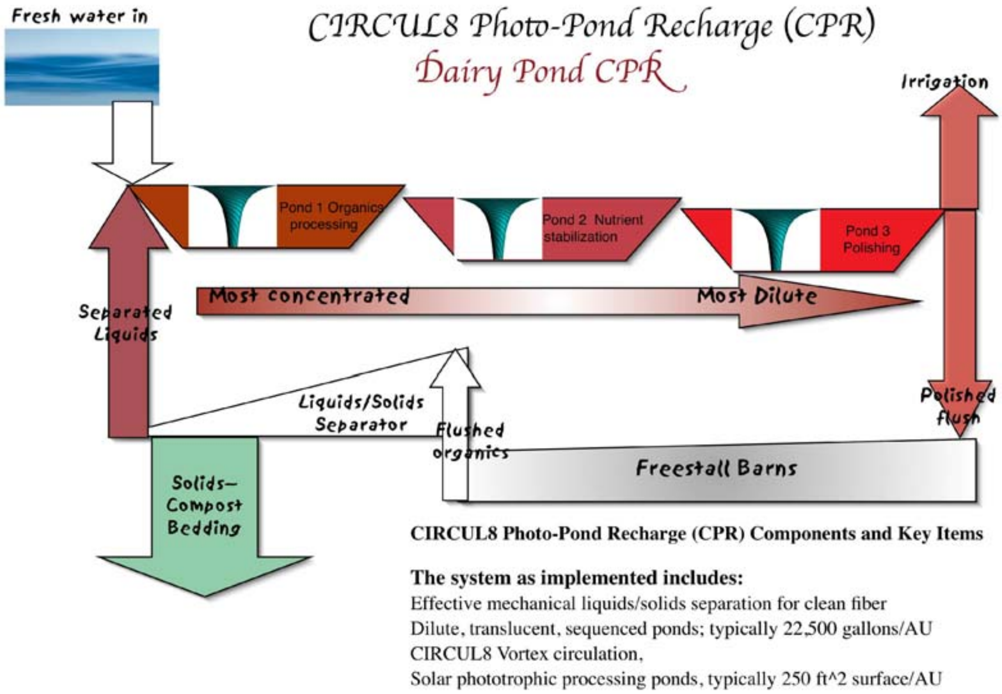
Natural Aeration Inc., markets the "CIRCUL8 Photo-Pond Recharge™" system (CIRCUL8) that circulates the upper portion of a wastewater pond so that sunlight, air, and bacteria will deactivate pathogens and break down organic materials. The company reports that the treatment reduces odors and gaseous emissions and stabilizes nutrients for use in crop production. The circulation is accomplished by a mechanical agitator/aerator located on the pond surface and powered by a 1.5-hp motor.

The odor reduction is reported to involve phototrophic metabolism by purple sulfur bacteria in the absence of oxygen. The nutrient stabilization is purported to occur by stabilizing nitrogen in an organic form that contains 85% of the total nitrogen and prevents volatilization of ammonia and VOCs that contribute to odors. In addition, it is reported that the purple sulfur bacteria oxidize reduced sulfur compounds and assimilate most of the sulfur thereby preventing the emission of reduced sulfur compounds that contribute to offensive odors.

The company reports the following benefits of the technology:

- Reduction of odors through stabilization and assimilation of nutrients and metabolic destruction of VOCs;
- De-activation of pathogens in wastewater through solar radiation, aeration, and turbulence;
- Improved properties of the wastewater that result in increased efficiency of mechanical solids separators and reduction of injuries to cows caused by slippery surfaces in flushed lanes.

Wastewater circulation/aeration systems have been actively marketed to dairies in the San Joaquin Valley by a number of companies and they have been installed at a number of dairies. Data regarding the benefits are based mostly on testimonials, and scientifically-derived quantitative data have not been produced to support the claims. Without data, the hypothesis for the mode of action of the technology cannot be validated. In fact, the hypothesis for the way that the technology functions has undergone an evolution in response to findings that did not support the original hypothesis regarding lagoon aeration. The following figure was provided by Natural Aeration to illustrate the CIRCUL8 technology.



1.31.2 Environmental Impacts

This technology is intended to control:

<u>Air Emissions</u>

- ☒ Reactive organic gases
- ☒ Ammonia
- ☒ Particulates
- ☒ Odors
- ☐ Methane
- ☒ Hydrogen sulfide

<u>Non-volatile waste components</u>

- ☒ Organic nitrogen
- ☒ Ammonium nitrogen
- ☐ Nitrates
- ☒ Phosphorus
- ☐ Salts
- ☒ Pathogens

The technology produces the following air emissions:

- ☐ Oxides of nitrogen (NOx)
- ☐ Carbon monoxide
- ☐ Carbon dioxide
- ☐ Reactive organic gases
- ☐ Particulates
- ☐ Sulfur dioxide

By products suitable for commercial sale or use:

- ☐ Heat energy
- ☐ Electrical energy
- ☐ Fuel- Charcoal
- ☒ Fertilizer
- ☐ Soil amendments
- ☐ Bedding
- ☐ Other

1.31.3 Economic Performance

The submission package did not provide adequate cost information. The following information was obtained during a February 2004 tour, hosted by Natural Aeration, of a dairy equipped with CIRCUL8 circulators. The 800 milking-cow dairy was equipped with 12 circulators. One circulator is needed for 50 to 100 cows. The design also requires 22,500 gallons and 250 square feet of pond surface area per animal unit (1,000 pounds of animal weight). The capital cost for each circulator is approximately $8,000. Additional capital costs may be incurred in providing power, pond enlargement to meet design parameters, and unspecified infrastructure needs.

Power cost for the technology is approximately $9,800 per year for the 800-cow dairy, or approximately $68 per circulator per month. Additional operating costs may also be involved but were not provided by Natural Aeration. One such cost may be for water to dilute the wastewater to the "desired phototroph processing concentrations." These costs would need to be evaluated against other dairy emissions treatment options.

1.31.4 Quality of Supporting Data

- ☐ Sufficient data were provided to demonstrate effectiveness of technology
- ☒ Data were provided, but effectiveness of the technology is inconclusive - need more data
- ☐ Data are said to exist, but data are not yet available or were not provided
- ☐ No data are available

Most of the claims have not been substantiated by experimental data but rather are provided from testimonials. Little quantitative or scientifically derived data are provided. For example, only anecdotal information is provided regarding odor reductions. No data are provided for reduced gaseous emissions. Information regarding cleaner flush alleys and reduced cattle slippage are also anecdotal. No information is provided on the pathogen quality of the bedding and incidence of mastitis and other disease in cattle to substantiate that this process produces a pathogen free product that results in healthier cattle.

A published scientific paper (McGarvey, et al., 2004) was provided to the Panel as support for some of the claims about nutrient processing and pathogen quality of the treated wastewater. The McGarvey study was not designed to evaluate a Natural Aeration CIRCUL8 system, or any circulator for that matter, but rather to characterize the microbial population shift in a dairy lagoon. The study lacked a statistical basis from which to evaluate the performance of a circulator and did not include an evaluation against a control. The study evaluated the microbial composition of the waste stream at different points during handling. Thus, the results from this study have limited value in drawing conclusions regarding the performance of a Natural Aeration circulator.

While the McGarvey study identified purple sulfur bacteria in the lagoon, it was not demonstrated that these microorganisms would not have been found in the absence of circulation, that circulators are necessary for the formation of purple sulfur bacteria, or that the presence of purple sulfur bacteria in a lagoon has environmental benefits. Blooms of purple sulfur bacteria have been identified in animal wastewater lagoons that do not have aeration/circulation. In most cases, dairy lagoons are designed for storage and not for treatment and are therefore generally overloaded with organics and salts. Such overloaded lagoons are an unfavorable environment for the propagation of purple sulfur bacteria. The design for the CIRCUL8 system is more conducive to propagation of purple sulfur bacteria in that it calls for ample lagoon volume (22,500 gallons and 250 square feet of pond surface area per animal unit), sequential lagoons of decreasing concentration, and addition of fresh water to dilute nutrients to the desired concentration for phototrophs.

It is claimed that circulators stabilize the nutrients in the lagoon and reduce volatile emissions. McGarvey et al. (2004) provide some data for nitrogen that suggest stabilization. However, these data are not compared with an untreated lagoon to show that this is a treatment effect. McGarvey et al. (2004) note that total nitrogen concentration decreased two-fold from the separator to the lagoon. Since mass is conserved, this suggests that the lost N volatilized. However, the TKN data were not provided nor was a mass balance approach provided to decipher the fate of N. The percentage of N as ammonia (NH_3) was reported lower in the lagoon (70%) versus the separator (83%) suggesting that some stabilization of N occurs; however, a large amount on N still remains in the ammonia form and subject to volatilization. Zhang et al. (1997) found that low-level continuous aeration resulted in enhanced NH_3 volatilization. In evaluating the performance of a Natural Aeration circulator, Rumberg et al. (2003), found no difference in atmospheric NH_3 before and after treatment. The study is inconclusive as to the fate of NH_3 when using the Natural Aeration circulator. Claims are also made regarding the fate of sulfur but no data are provided to substantiate these claims. Rumberg et al. (2003) also found no measurable dissolved oxygen, NO_3^{-1}, or NO_2^{-1}. This indicates that the aerators were not effective at introducing oxygen, oxidizing NH_3, or in metabolizing the organic matter. They also found stratification of TKN, total solids, and volatile solids, indicating limited effectiveness of mixing.

1.31.5 Development Status of the Technology

- ☐ Research (basic research and applied research)
- ☐ Development (concept development and prototype development)
- ☒ Test and evaluation (product/process development)
- ☐ Demonstration (full or field relevant scale)
- ☐ Commercial application

Although an unknown number of aerators/circulators have been installed at a number of dairies in the Central Valley, information is lacking to substantiate the claimed benefits the scientific principles underlying the technology, or the appropriate engineering design parameters. Zhang et al., (2003) conducted an evaluation of circulator/aeration treatment system of a mechanical surface agitator similar in design to Natural Aeration's product. A 20 to 40 percent reduction in odors and reduced rate of accumulation of solids was found as compared to a control. However, 28 aerators/circulators were required to produce these results for the treatment of half of the waste stream from a 3,000-cow operation. Thus, approximately one circulator/aerator per 50 cows was required to produce these results. Zhang et al., (2003) found that one circulator/aerator per 100 milking cows was inadequate.

Rumberg et al., (2004) evaluated two Natural Aerator circulators/aerators in a wastewater lagoon at a dairy with 170 milking cows and 350 total cows. Assuming that manure only from the milking cows was flushed into the lagoon, then the ratio of cows to circulators was 85 to 1, which is within the suggested design recommendations. The evaluation focused on the performance of the circulators with respect to ammonia emissions and mixing efficiency. The pond was only 1.89 m deep; typical lagoons in the Central Valley range in depth from 5 to 7 meters. There was no difference in ammonia concentration in the atmosphere or in the lagoon before and after the application of the circulators. It was also found that dissolved constituents were distributed equally, indicating that those constituents had been adequately mixed. However, sampling was conducted only at depths of 0.15 and 0.9 meters. Analysis of TKN showed stratification with depth suggesting that solids were not adequately mixed.

For the Rumberg tests, the circulator was only operated for 30-days, but in that time it was noted that there was a build up of solids around the circulators that diminished their mixing performance. The buildup occurred even though the wastewater stream had been subjected to a solids separator and a settling lagoon before the circulators were introduced in the second lagoon. It is not known if the accumulation of solids was due to design or performance deficiencies. This highlights the lack of available design standards and performance information for the circulator technology.

The manufacturer of the CIRCUL8 has offered numerous hypotheses for the mode of action by which the technology functions. The hypothesis has evolved from an aeration system that maintained dissolved oxygen (DO) at concentration of 1 to 2 mg/L, to an aerobic system that promoted purple sulfur bacteria propagation, to the current hypothesis. The current hypothesis is that the technology is a vortex mixing system that promotes pathogen inactivation by sunlight and supports the propagation of purple sulfur bacteria for the oxidation of reduced sulfur compounds. These hypotheses have evolved as third parties have demonstrated that a hypothesis was not supported by information obtained from operating circulator systems. For example, it was found that DO was not affected by the CIRCUL8 as compared to conventional anaerobic dairy lagoons (Zhang et al., 2003, Rumberg, et al., 2004, and Mitloehner et al., 2004). No scientifically derived data were presented to support the current hypothesis.

In summary, additional information is needed with respect to the performance of the aerators/circulators; in specific, the standard oxygen transfer rate (SOTR), the aeration efficiency (AE), and the mixing performance. Additionally, the claimed benefits must be evaluated by the scientific process; in particular, ammonia and organic gas emissions. There is a potential that ammonia emissions may be enhanced by mechanical aeration (Zhang et al., 1997). The scientific principles behind the mode of action need to be developed along with the engineering design parameters to optimize the performance of the treatment system. The proponents have not established that a circulator system will always lead to the development of a lagoon with purple sulfur bacteria, or that the bacterial produce environmental benefits. It needs to be determined if circulators are needed to produce red bacteria or if changes in the design parameters (such as larger storage capacities) and operating conditions (such as dilution of wastewater) can increase red bacteria populations in facultative lagoons.

1.31.6 Applicability of the Technology to California Dairies

This technology has been used on a few Central Valley dairies for several years. Although, scientifically-derived information has not been provided, testimonials by some of the dairy producers that have implemented this technology support reduced odors, reduced animal slippage in flush lanes, and enhanced mechanical separator performance. Once the benefits are documented, dairy producers need to weigh the value of these benefits in relation to the capital investment and on-going operational costs against other options that achieve similar results.

1.31.7 What Data Gaps Exist?

Given the testimonials by those that use the technology, the technology appears to reduce odors, stabilize pond contents, and improve flushing and separator efficiencies. However, these potential benefits need to be supported with scientific data. The claimed benefits of reduced animal disease and off-gassing of VOCs needs to be evaluated and quantified. Zhang et al. (2003) has shown some benefits of surface mechanical aerator such as reduced odors and solids accumulation rates. However, this was not for the CIRCUL8 system. The lack of performance data makes it difficult to assess if the CIRCUL8 system will perform as well or better than the circulators with reported benefits.

The use of three lagoons for the CIRCUL8 system is adopted from treatment and facultative lagoon systems utilized in municipal wastewater treatment. More research is needed to understand the actual processes taking place in the dairy system, to optimize the system, and to quantify potential benefits. For example, what is the appropriate spacing to achieve complete mixing of the lagoon? Is mixing efficiency more a function of the dimensions of the ponds than the number of animals? What vertical and horizontal extent of mixing [defined by Moore (2001) as the zone where the circulator maintains a liquid velocity of 1 fps] is necessary to achieve desired results? What are the hydraulic retention times? How much oxygen needs to be delivered? What is the optimum mixing and aerator performance? If purple sulfur bacteria play a major role, what are the opportunities for inoculums? Since purple sulfur bacteria flourish in the springtime when temperatures are optimum, is it necessary to operate the circulators year-round?

1.31.8 What Additional Research and/or Verification Work should be done?

Research is needed to answer the questions identified in the previous section in order to decipher the mechanism by which the technology operates and to verify the environmental benefits. The engineering parameters need to be developed for design criteria and to optimize operation of the technology. Additionally, the performance of the technology needs to be verified with scientifically-derived data obtained from actual dairies where the technology is in use. Of primary importance is the fate of ammonia and data on emissions of reactive organic gases. Finally, the performance of the technology needs to be evaluated in comparison to similar lagoon designs without circulators.

1.31.9 References

McGarvey, J. A., W. G. Miller, S. Sanchez, and L. Stanker. 2004. Identification of Bacterial Populations in Dairy Wastewaters by Use of 16s rRNA Gene Sequences and Other Genetic Markers. *Applied and Environmental Microbiology* 70:7:4267-4275.

Mitloehner, F. M., N. M. Marcillac, K. M. Eslinger, A. L. Schnitz, and R. H. Zhang. 2004. Effects of Dairy Liquid Manure Aeration on Air Quality and Nutrient Cycling. Presented at 2004 University of California Dairy Day, Modesto, California.

Moore, L. W. 2001. Performance of Floating Horizontal Aerators in Aerated Lagoons and Oxidation Ditches. Texas Water 2001 Annual Conference, April 4, 2001.

Rumberg, B., N. Manjit, G. H. Mount, D. Yonge, J. Filipy, J. Swain, R. Kincaid, K. Johnson. 2004. Liquid and Atmospheric Ammonia Concentration from a Dairy Lagoon During Aeration Experiment. *Atmospheric Environment* 38(2004) 1523-1533.

Zhang, R. H., P. N. Dugba, and D. S. Bundy. 1997. *Transactions of the ASAE* 40(1):185-190.

Zhang, R. H., P. Yang, C. A. Collar, and L. Ham. 2003. Treatment of Flushed Dairy manure by Solid-Liquid Separation and Lagoon Aeration. Ninth International Symposium of Animal, Agricultural and Food Processing Wastes. October 2003, Raleigh, North Carolina.

1.32 Nutrient Control Systems, Inc.

Product/Process: Manure Separation and Treatment

1.32.1 Description

Nutrient Control Systems, Inc., (Nutrient Control) markets technologies to separate and treat manure. These technologies include: screen and roller press separators to remove solids from scrape or flush systems; an aeration system to mechanically oxygenate the top portion of the lagoon; pumps, augers, and microbial products intended to "improve lagoon performance;" "PulseJet" pump, and static or traveling "PulseJet" sprayers, to spread manure for land application; and an aeration system for static compost piles. Nutrient Control submitted a combination of their technologies for evaluation.

1.32.2 Environmental Impacts

This technology is intended to control:

Air Emissions	Non-volatile waste components
☐ Reactive organic gases	☐ Organic nitrogen
☐ Ammonia	☐ Ammonium nitrogen
☐ Particulates	☒ Nitrates
☒ Odors	☒ Phosphorus
☒ Methane	☐ Salts
☒ Hydrogen sulfide	☒ Pathogens

The technology produces the following air emissions:

- ☐ Oxides of nitrogen (NOx)
- ☐ Carbon monoxide
- ☐ Carbon dioxide
- ☐ Reactive organic gases
- ☐ Particulates
- ☐ Sulfur dioxide

By products suitable for commercial sale or use:

- ☐ Heat energy
- ☐ Electrical energy
- ☐ Fuel
- ☐ Fertilizer
- ☒ Soil amendments
- ☒ Bedding
- ☐ Other

This is a systems approach to manure management. However, the technology performance could not be evaluated because performance data for each segment of the system were not provided. In particular, no data were provided on the effects of the aeration system that mechanically oxygenates the top portion of the lagoon, on the microbial products intended to "improve lagoon performance," or on the performance of the aerated static compost pile. In addition, Nutrient Control claims significant control of pollution e.g., "sequesters or removes more than 80% N and more than 80% P" and a land application system that "eliminates runoff, soil compaction and maximizes infiltration and nutrient uptake". However, no environmental data were provided to support these statements.

1.32.3 Economic Performance

Nutrient Control provided complete cost information representative of a 1,000-cow dairy. Total annual cost (e.g., fixed capital improvements, equipment cost, interest and depreciation, treatment operating cost, manure spreading cost, and NCS maintenance contract) is $126,439 ($126.44 per cow) or $0.010 per gallon based on an annual wastewater production of about 12,650 gallons per cow per year.

1.32.4 Quality of Supporting Data

- ☐ Sufficient data were provided to demonstrate effectiveness of technology
- ☐ Data were provided, but effectiveness of the technology is inconclusive - need more data
- ☐ Data are said to exist, but data are not yet available or were not provided
- ☒ No data are available

No environmental discharge or emission data were provided at this time. There is however, a statement that data on nutrients and mass balance are available on request (although this request for dairy manure technology was in fact a request for that data). Environmental test results from a study being conducted at Virginia Tech are said to be available beginning July 2005.

1.32.5 Development Status of the Technology

The Company states that 50 installations are operating in the United States, and one of them has been operating for nine years.

1.32.6 Applicability of the Technology to California Dairies.

Before applicability can be assessed, environmental data need to be provided. In situations where there are problems with manure solids, lagoon storage, or open composting, the technology could provide remedy. The technology may be most appropriate for larger dairies or for a regional composting facility. Cost may be reduced if a market for produced compost is available.

1.32.7 What Data Gaps Exist?

No data on environmental discharge or emission were submitted.

1.32.8 What Additional Research and/or Verification Work should be done?

Environmental discharge data need to be provided.

1.33 Octaform

Process/Product : **Octaform PVC Lined Concrete Tanks with CIRCUL8 System**

1.33.1 Description

The Octaform technology is a tank forming system that produces a PVC-lined concrete tank. The lining is chemically resistant and is intended to extend the life of a tank in comparison to an unlined concrete tank. Octaform markets its tanks in a package with circulation pumps to contain and control manure and to reduce odors, ammonia, hydrogen sulfide, and volatile organic compounds. The circulation process was submitted for separate review (see the review of the CIRCUL8 System) under the company "Natural Aeration, Inc." The following review applies only to the lined tanks.

1.33.2 Environmental Impacts

This technology is intended to control:

Air Emissions	Non-volatile waste components
☐ Reactive organic gases	☐ Organic nitrogen
☐ Ammonia	☐ Ammonium nitrogen
☐ Particulates	☐ Nitrates
☐ Odors	☐ Phosphorus
☐ Methane	☐ Salts
☐ Hydrogen sulfide	☐ Pathogens

The technology produces the following air emissions:

- ☐ Oxides of nitrogen (NOx)
- ☐ Carbon monoxide
- ☐ Carbon dioxide
- ☐ Reactive organic gases
- ☐ Particulates
- ☐ Sulfur dioxide

By products suitable for commercial sale or use:

- ☐ Heat energy
- ☐ Electrical energy
- ☐ Fuel- Charcoal
- ☐ Fertilizer
- ☐ Soil amendments
- ☐ Bedding
- ☐ Other

1.33.3 Economic Performance

There are several options for above ground tanks: lined and unlined steel, lined and unlined concrete, and plastic. Given the volume of liquids generated on a dairy, the plastic tanks are not an option for California. Both concrete and steel tanks are expensive storage options but have been used for anaerobic digestion in lieu of, or in combination with, covered lagoons. The aboveground tanks can generate more bio-gas than the covered lagoons options. Manure storage in concrete tanks could also facilitate additional waste treatment if necessary, but in most cases this specific type of tank would not be a requirement.

1.33.4 Quality of Supporting Data

- ☐ Sufficient data were provided to demonstrate effectiveness of technology
- ☐ Data were provided, but effectiveness of the technology is inconclusive - need more data
- ☐ Data are said to exist, but data are not yet available or were not provided
- ☒ No data are available

1.33.5 Development Status of the Technology

The design of concrete tanks is well understood. The requirement for this product is dependant on the comparison between the PVC liner / preformed tank costs, and the standard concrete forming costs and treatments to increase resistance to chemical attack.

1.33.6 Applicability of the technology to California Dairies

Aboveground tanks would be applicable where ground conditions preclude in-ground storage or as part of an anaerobic digester system.

1.33.7 What Data Gaps Exist?

Unit cost information was not provided.

1.33.8 What Additional Research and/or Verification Work should be done?

The tank structure itself is supported by an ASAE 2004 paper.

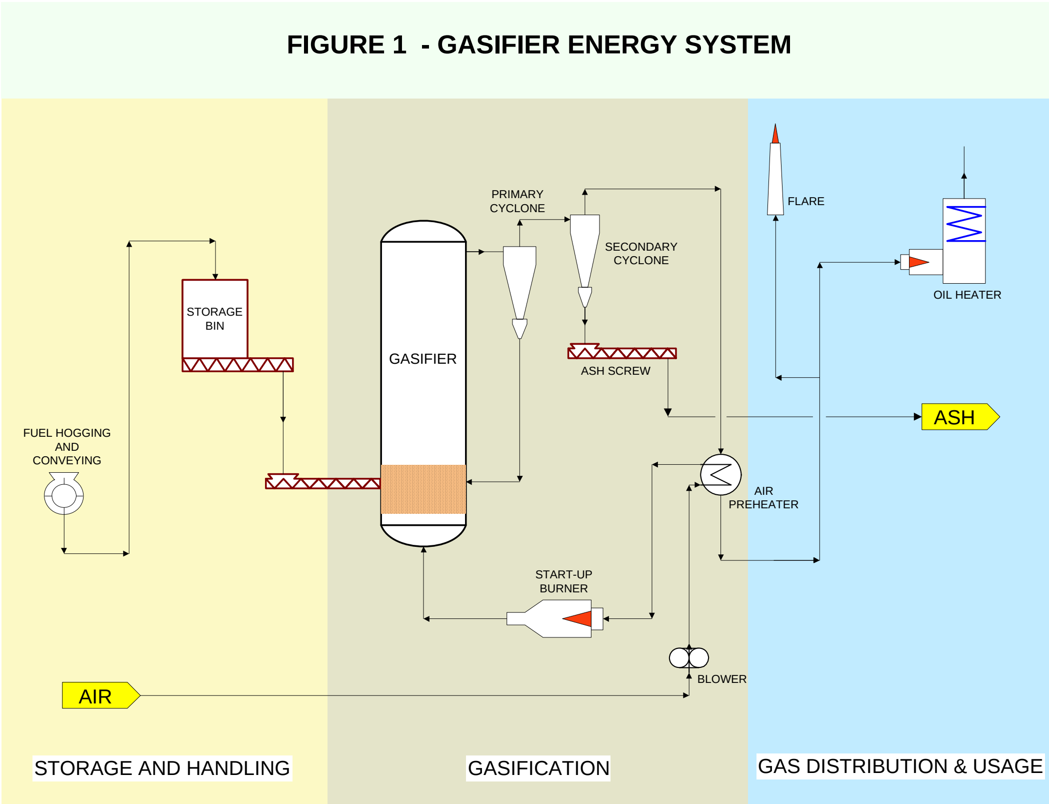
1.34 Omnifuel Technologies, Inc.

Product/Process: Rapid Pyrolysis

1.34.1 Description

The oxygen-blown fluid-bed gasifier technology used in the Rapid Pyrolysis system was developed by Canadian Industries Limited in the late 1970s to make a fuel from municipal and industrial refuse. In the 1980s, the Biosyn project used the technology on wood wastes to produce methanol. In 1981, a 23-megawatt (MW) facility was constructed and operated on wood waste in Ontario, Canada. Omnifuel Technologies believes that the technology can be applied to manure by adding a solid liquid separation system prior to the gasifier. A schematic of a typical system is shown in Figure1.

The Omnifuel's Rapid Pyrolysis technology is designed to dewater manure, convert the manure to clean gas, and combust the gas for the production of power in a bank of micro-turbines or, for large quantities of manure, in conventional gas or steam turbines. Omnifuel Technologies states that the residue could be converted to fertilizer components, or, alternatively, be used to produce activated carbon for commercial use.



1.34.2 Environmental Impacts

This technology is intended to control:

<u>Air Emissions</u>

- ☒ Reactive organic gases
- ☒ Ammonia
- ☒ Particulates
- ☒ Odors
- ☒ Methane
- ☒ Hydrogen sulfide

<u>Non-volatile waste components</u>

- ☐ Organic nitrogen
- ☒ Ammonium nitrogen
- ☐ Nitrates
- ☒ Phosphorus
- ☒ Salts
- ☒ Pathogens

The technology produces the following air emissions:

- ☐ Oxides of nitrogen (NOx)
- ☐ Carbon monoxide
- ☒ Carbon dioxide
- ☐ Reactive organic gases
- ☐ Particulates
- ☐ Sulfur dioxide

By products suitable for commercial sale or use:

- ☐ Heat energy
- ☒ Electrical energy
- ☒ Fuel
- ☐ Fertilizer
- ☒ Soil amendments
- ☐ Bedding
- ☐ Other

This technology would reduce but not entirely eliminate the dairy's liquid waste stream, which would have to be managed appropriately to contain ammonia, organic nitrogen, phosphorous, salts, and pathogens. In addition, salts in the ash from combustion are controlled only if they are transported off the dairy for disposal in a landfill, or use in industrial processes, or as soil amendments.

1.34.3 Economic Performance

Omnifuel has begun marketing this gasifier technology for the management of manure and other solid wastes in the United States. The economic analysis provided by the company was applicable for wood waste as the feedstock. Several pre-combustion components necessary for using manure including a solid separator and drying equipment were not discussed in the information provided. The cost estimate provided was for a large central processing facility, and the company did not account for the difference in heating value of the manure as compared to the wood waste. The manure has less heating value than the wood and is higher in moisture content even when most of the liquid is removed.

1.34.4 Quality of Supporting Data

- ☐ Sufficient data were provided to demonstrate effectiveness of technology
- ☒ Data were provided, but effectiveness of the technology is inconclusive - need more data
- ☐ Data are said to exist, but data are not yet available or were not provided
- ☐ No data are available

The data provided are for a wood waste facility, not for manure of any type.

1.34.5 Development Status of the Technology

The technology has been demonstrated at large scale using wood waste. The company indicates that a facility could be ready within six months to one year using manure as a feed to the gasifier.

1.34.6 Applicability of the Technology to California Dairies

There appear to be significant technology and other barriers to applying this technology to dairy manure. First, a significant amount of moisture must be removed from manure before using the manure in the system. The process to remove moisture is not developed. Second, the dairy itself may not have a need for all the electricity that could be produced with the system, and ability to sell interconnect to the power grid and sell surplus power may be an issue. Third, the dairy would loose the nitrogen nutrient value of the solid manure. This may be a benefit for diaries without sufficient land for proper application. Fourth, pollutant emissions and wastewater from process are not characterized and could be an issue.

1.34.7 What Data Gaps Exist?

Emissions from the process are not identified. Costs to construct a fully-integrated dairy system are not available. Operating costs have not been estimated. Emissions of particulate matter, NOx, CO, and VOCs are not characterized but are expected to be emitted from gasifier and engine/boiler. Data should be provided on emissions to fully assess this technology. Emissions of $PM_{2.5}$ and organic gases may be concerns.

Nitrogen and bacteria are expected to be consumed in the process. However, the remaining liquid waste stream will still contain such constituents (i.e., the technology does not treat the full waste stream). Residuals need to be quantified for the treatment process.

1.34.8 What Additional Research and/or Verification Work should be done?

Panel members are unaware of any commercially-proven technologies for filtering particulates from hot gas. It may be necessary for the company to demonstrate a hot gas clean-up system and a tar reforming process to as part of a viable biomass gasification system. Omnifuel Technologies identified treatment of gas and tar as a problem in 1988. It is not clear whether they have resolved the problem. Work is also needed to identify or develop manure-dewatering systems that can be effectively integrated into the system, and then tests must be performed showing the effectiveness of manure as a feedstock.

1.35 Organic Waste Management

Process/Product: Wet Composting

1.35.1 Description

Organic Waste Management's Wet Composting system has been tested using wastewater and manure from a flush dairy. The materials were mixed in a tank along with air, proprietary enzymes, and microbes that were specially bred for the particular dairy. The material was then added to chopped municipal yard waste in a static pile aerated from below with air forced through perforated 3-inch diameter PVC pipes. The air blower was on a timer and operated about three minutes out of every 30-minute period. Excess liquid was recycled back into the pile or drawn off for use as a "compost tea" to irrigate and fertilize a nearby pasture. Plastic beneath the pile prevented leaching, and plastic on top of the pile retained heat and shed rainwater. Details of pile size, material composition, pipe size, air flows, collection of leachate, etc., were provided to the Panel and are available from the vendor. The system functions as a sort of trickling filter that uses the municipal yard waste as the filter media. Microbial activity heats the pile to an average daily temperature of approximately 140º F. After 30 to 45 days the pile has decomposed and must be replaced.

1.35.2 Environmental Impacts

This technology is intended to control:

Air Emissions	Non-volatile waste components
☒ Reactive organic gases	☐ Organic nitrogen
☒ Ammonia	☒ Ammonium nitrogen
☒ Particulates	☒ Nitrates
☒ Odors	☒ Phosphorus
☒ Methane	☐ Salts
☒ Hydrogen sulfide	☒ Pathogens

The technology produces the following air emissions:

- ☐ Oxides of nitrogen (NOx)
- ☐ Carbon monoxide
- ☒ Carbon dioxide
- ☒ Reactive organic gases
- ☐ Particulates
- ☐ Sulfur dioxide

By products suitable for commercial sale or use:

- ☐ Heat energy
- ☐ Electrical energy
- ☐ Fuel
- ☒ Fertilizer
- ☒ Soil amendments
- ☐ Bedding
- ☒ Other: compost and compost tea

1.35.3 Economic Performance

No data were provided on cost of materials, installation, site preparation, operating costs of air pump, hauling dairy manure and yard waste to processing site, preparation of yard waste by grinding, treating manure (enzymes, microbes, and aeration), etc. Therefore, the Panel could not determine the economic performance of this technology.

1.35.4 Quality of Supporting Data

- ☐ Sufficient data were provided to demonstrate effectiveness of technology
- ☒ Data were provided, but effectiveness of the technology is inconclusive - need more data
- ☐ Data are said to exist, but data are not yet available or were not provided
- ☐ No data are available

Large amounts of data were provided on system design and construction, size and moisture content of the compost, air flow rates, temperature of the compost pile, etc. However, some important environmental data were not available. The vendor claims the technology reduces emissions to air of NH_3, VOCs, and H_2S, but no measurements of these compounds were taken in the air above the compost piles. In addition, because the piles are aerated from below, causing some 80% of the water to be lost as evaporation, it seems likely that some other gases were also blown into the air. Nor is there an analysis of the mass flow of nutrients into and out of the system. This is particularly important for nitrogen. The vendor measured decreases in the NH_3-nitrogen concentration of the leachate from the composting piles, but did not determine where the nitrogen went; likely possibilities include volatilization as NH_3 and incorporation into microbial biomass. Since phosphorous does not volatilize and the liquid and solid residues are land applied, it seems unlikely that the technology decreases the amount of phosphorus, despite the vendor's claims.

1.35.5 Development Status of the Technology

- ☐ Research (basic research and applied research)
- ☐ Development (concept development and prototype development)
- ☒ Test and evaluation (product/process development)
- ☐ Demonstration (full or field relevant scale)
- ☐ Commercial application

This technology existed as small-scale research and demonstration studies that were conducted in Sonoma County during the past year.

1.35.6 Applicability of the Technology to California Dairies

Co-composting manure with urban yard waste could be beneficial, since the yard waste needs the added water that the manure has in excess. In addition, the final product has a higher nitrogen value than yard waste composted without manure. However, large-scale composting of dairy manure may produce volatile gas emissions. If these gases are not captured, the potential environmental benefits of the technology are reduced.

A more serious challenge concerns the volumes of yard waste required for this process. In the tests, wastewater was applied at a rate of 0.5 to 5 gallons per cubic yard of yard waste per day. Assuming 100 gallons of fresh washwater are used per cow per day, which is typical for many dairies in the San Joaquin Valley, the process would require 20 to 200 cubic yards of yard waste per cow per day. Thus, a typical dairy with 2,000 milk cows would need 14.6 to 146 million cubic yards of yard waste per year to process all the wastewater that is produced. Volumes this large are several orders of magnitude beyond what is available. However, the process may be appropriate for individual dairies that establish relations co-composting operations with nearby municipalities.

An additional challenge is determining nitrogen mineralization rates for the organic matter that results from the composting process and is used as a fertilizer. Mineralization rates of organic nitrogen are often unpredictable and hard to control. Thus, despite the vendor's belief in the use of compost and compost teas as "safe" fertilizers, the use of compost is not by itself an assurance that nitrogen is being applied at agronomic rates and that ground water is protected.

Permits were issued for the test sites. Full-scale on-going operation would require additional permits from the California Integrated Waste Management Board.

1.35.7 What Data Gaps Exist?

- Quantification of air emissions (VOCs, NH_3, H_2S, etc.). Compost and manure are already known and regulated sources of VOCs, and H_2S (e.g., SouthCoast Air District Rule 1127, which requires compost facilities to capture emissions to air).
- Fate of the phophorous. The relationship of P in the influent to the leachate was highly variable (from an 81% increase to a 65% decrease).
- Quanitification of pathogens. The tests for presence of pathogens in the finished compost do not appear to include the appropriate controls: there are no values for pathogen concentrations in the raw material or in material to which no microbes were added.

1.35.8 What Additional Research and/or Verification Work should be done?

- Demonstrating that co-composting manure with yard waste has practical and economic benefits. Making this determination will require quantifying:
  - Air emissions
  - Economics, including a system that captures volatile emissions;
  - Value, if any, of pre-treating the manure with aeration and proprietary enzymes and microbes.

1.36 Primenergy, L.L.C.

Product/Process: Solids Gasification and Energy Production

1.36.1 Description

Primenergy's process uses a variety of biomass feedstocks, including manure, in a gasification process that recovers energy in the form of heat, steam, and electricity. The technology uses a fixed bed, updraft unit that operates at sub-stoichiometric conditions. At elevated temperatures, oxygen reacts with the hydrocarbon feed to produce heat and a synthesis gas comprised of CO_2, CO, H_2, H_2O, N_2, and light hydrocarbons. According to the company, for all biomass materials tested to date, the process is autogenetic, requiring no auxiliary fossil fuel to maintain continuous operation. Primenergy has also developed and patented a method of cooling and cleansing the synthesis gas to a specification suitable for use in an internal combustion engine. The cleansing process is called PARS™ (Particulate and Aerosol Removal System). According to Primenergy, for applications under five megawatts using synthesis gas to generate electricity requires less capital investment and is more efficient than electrical production using steam. Another process developed by the company and identified as "synthesis gas scrubbing system" or "S3" allows the gasification technology to be employed for biomass wastes that have contaminants and would otherwise not be acceptable fuels. These wastes include sewage sludge, poultry litter, paper mill sludge, and dairy manure, but to date the process has not been tried on dairy manure. Drying of the biomass is required at moisture content at or above 25%.

1.36.2 Environmental Impacts

This technology is intended to control:

Air Emissions	Non-volatile waste components
☒ Reactive organic gases	☐ Organic nitrogen
☒ Ammonia	☒ Ammonium nitrogen
☒ Particulates	☒ Nitrates
☒ Odors	☐ Phosphorus
☒ Methane	☐ Salts
☒ Hydrogen sulfide	☒ Pathogens

The technology produces the following air emissions:

- ☐ Oxides of nitrogen (NOx)
- ☐ Carbon monoxide
- ☐ Carbon dioxide
- ☐ Reactive organic gases
- ☐ Particulates
- ☐ Sulfur dioxide

By products suitable for commercial sale or use:

- ☒ Heat energy
- ☒ Electrical energy
- ☒ Fuel- Charcoal
- ☒ Fertilizer
- ☐ Soil amendments
- ☐ Bedding
- ☐ Other

Although the Panel cannot verify the above claims, the company states that the results were documented by independent third-party evaluations. However, detailed information was not provided to the Panel.

1.36.3 Economic Performance

According to Primenergy, equipment is priced on a project basis as each project will have different feed materials with unique characteristics, differing feed rates, energy output forms, energy output rate and environmental limitations. They estimate the installed cost at approximately $2,800 per gross kW or a total of approximately $20 million for a small to medium sized plant that they include in their process description.

1.36.4 Quality of Supporting Data

- ☐ Sufficient data were provided to demonstrate effectiveness of technology
- ☒ Data were provided, but effectiveness of the technology is inconclusive - need more data
- ☐ Data are said to exist, but data are not yet available or were not provided
- ☐ No data are available

The data provided were not comprehensive and were often by way of reference to third party assessments.

1.36.5 Development Status of the Technology

Primenergy has operated a pilot plant in Oklahoma, and a couple of dozen similar operations have been demonstrated in the U.S. It is not clear if any full-scale commercial plants are currently operating in the U.S. using this technology or an analogous technology.

1.36.6 Applicability of the Technology to California Dairies

It is the Panel's opinion that, without an operating commercial plant using dairy manure or similar agriculture materials, it is difficult to draw definitive conclusions. Primenergy does not currently have operating commercial plants using dairy manure as a feedstock. Therefore, it is not possible for the Panel to determine the specific economics or environmental performance of this technology. It seems that the preferred application of the technology would be to waste streams that require comparatively more expensive disposal (i.e., have tipping fees). Dairy manure can be utilized on cropland at relatively low cost and therefore does not have a "tipping fee" to help finance use of the technology (in addition to energy derived revenue). Also, the technology would appear best suited to regional plants that would utilize feedstocks from a larger geographic area than just properties contiguous or nearby to a plant. However, no specific data were provided on this point. Also, because dairy manure is typically more than 25% moisture, a drying step would have to be introduced with an associated means for pre-treating and/or discharging to a wastewater treatment facility; no data were provided on drying costs.

1.36.7 What Data Gaps Exist?

There appears to be a lot of operating information about the pilot plant in Oklahoma. However, that facility is not a full-scale plant and dairy manure has not been used as a feedstock. Having performance data related to the use of dairy manure as a feed in a full-scale commercial operation would be useful. Also capital and operating cost information for such a plant is desirable. Such information was not provided to the Panel and may not exist. Finally, it is unclear to the Panel how the ash would be utilized as a fertilizer.

1.36.8 What Additional Research and/or Verification Work should be done?

Operating a pilot gasification plant using dairy manure as produced in California would be helpful. Air and water quality data from such a plant would be important to assessing environmental and public health impacts.

1.37 Pro-Act Microbial, Inc.

Product/Process: Pro-Act Microbial Manure Munching Microbes

1.37.1 Description

Pro-Act Microbial describes their process as follows: the Manure Munching Microbes and amendments convert an anaerobic lagoon into a three-stage digester, anaerobic on the bottom, facultative in the middle, and aerobic on the top. The digester is faster and more efficient than single-stage anaerobic processing.

The Panel concludes that the Pro-Act Microbial process uses a combination of bio-augmentation and surface aeration. The bio-augmentation ingredients are proprietary in nature, and therefore the panel cannot assess possible chemical and biological processes and pathways. A study conducted by the Miner Institute is said to have confirmed the odor reducing potential; however, the study report was not provided). The data (N, P, K and pH) provided to the Panel were inconclusive and insufficient with regards to the technology's air emission mitigation effects. However, it has been reported in the literature that surface aeration might indeed be an effective way to reduce air emissions. Additional data are needed to prove the effectiveness of the Pro-Act Microbial process on emission reduction.

1.37.2 Environmental Impacts

This technology is intended to control:

Air Emissions	Non-volatile waste components
☐ Reactive organic gases	☐ Organic nitrogen
☒ Ammonia	☒ Ammonium nitrogen
☒ Particulates	☐ Nitrates
☒ Odors	☐ Phosphorus
☐ Methane	☐ Salts
☒ Hydrogen sulfide	☐ Pathogens

The technology produces the following air emissions:

- ☐ Oxides of nitrogen (NOx)
- ☐ Carbon monoxide
- ☐ Carbon dioxide
- ☐ Reactive organic gases
- ☐ Particulates
- ☐ Sulfur dioxide

By products suitable for commercial sale or use:

- ☐ Heat energy
- ☐ Electrical energy
- ☐ Fuel
- ☐ Fertilizer
- ☐ Soil amendments
- ☐ Bedding
- ☐ Other

Pro-Act claims that its technology reduces odor emissions, reduces solids, and decreases organic nitrogen. No data were provided to support these claims.

1.37.3 Economic Performance

ProAct Microbial states that the capital investment will vary due to the size and nature of each farm. One aerator is needed per surface acre of lagoon storage. Cost of one aerator is $4,400 plus installation cost of $1,000 (not including electrical wiring). Start-up inoculation of manure currently in storage is $2,000 per million gallons. The company states that the annual operation costs are as follow: cost to operate one aerator with a 1 hp blower is $365 per year on average, maintenance and inspection of the equipment is estimated at less then $200 per year, monthly cost of microbes and amendments will vary due to the difference between dairy operations, but are estimated at $12 per cow per year. The estimated useful equipment life of the aerator is over 5 years.

1.37.4 Quality of Supporting Data

- ☐ Sufficient data were provided to demonstrate effectiveness of technology
- ☐ Data were provided, but effectiveness of the technology is inconclusive - need more data
- ☒ Data are said to exist, but data are not yet available or were not provided
- ☐ No data are available

Supporting data were insufficient to assess the effects of the technology on air emissions. Data provided were for pH and concentrations of N, P, and K in wastewater and not for air emissions.

1.37.5 Development Status of the Technology

The technology is reported to be in use on more than 40 dairies in Wisconsin, Pennsylvania and New York.

1.37.6 Applicability of the Technology to California Dairies

The technology is straight forward and is relatively inexpensive. However, without data on the effectiveness of the process in reducing air emissions, it is not possible to evaluate the applicability of the process to dairies in California.

1.37.7 What Data Gaps Exist?

Data need to be provided for the effects of the technology on air pollutants (odors, NH_3, VOCs, and H_2S) as well as on pH, redox potential, and oxygen levels. The company states that the Miner Institute tested the technology, but the actual report was not provided. The company's summary was inconclusive and did not provide relevant data that the Panel could use.

1.37.8 What Additional Research and/or Verification Work should be done?

This technology needs to be field tested in California to assess if it reduces air emissions as claimed. The field tests should be adequtely monitored to develop data that can be used to evaluate the effectiveness of the technology.

1.38 Renewable EnergyWorks (REW)

(Formerly Agricultural Sustainable Energy Technologies (ASET))

Product/Process: **Anaerobic digestion and biogas power generation and fiber conditioning**

1.38.1 Description

Renewable EnergyWorks (REW) is an integrator of solutions from partner corporations. Their technology utilizes an anaerobic (mixed-plug) digester unique to REW, an Internal Combustion Engine (ICE) component for power generation, a Combined Heat and Power (CHP) component, and a process to integrate the dairy's electrical system into the regional electrical distribution grid.

In the REW system, supplemental organic matter taken from "local food processors, area creameries, and others" is blended with manure solids in a mixing tank before going into the digester. The anaerobically digested solids are composted for use either as bedding in the dairy or for sale as a soil amendment. The biogas is collected from the anaerobic digester and used in the ICE to run a generator. Heat is collected from the ICE to maintain the mesophilic (105ºF) temperature of the anaerobic digester, and to dry the composted digester solids to 10-30% moisture content. Solids separation occurs at two stages in the process; 1) when the manure flushed from the animal housing is collected for anaerobic digestion, and 2) when the digested solids are collected for composting. Composting is carried out using open rows in roofed buildings. The liquids collected during the two stages of solids-separation appear to be either recycled for flush-water or applied to cropland after lagoon storage.

REW claims that its solutions-package will reduce odors and the release of ammonia, VOCs, hydrogen sulfide, PM_{10}, $PM_{2.5}$, and methane to the air. REW also indicates that its solutions-package will reduce the movement of nitrogen, phosphorous, salts, and pathogens from the dairy's wastewater into the environment.

Environmental Impacts

This technology is intended to control:

Air Emissions	Non-volatile waste components
☒ Reactive organic gases	☒ Organic nitrogen
☒ Ammonia	☐ Ammonium nitrogen
☒ Particulates	☒ Nitrates
☒ Odors	☒ Phosphorus
☒ Methane	☒ Salts
☒ Hydrogen sulfide	☒ Pathogens

The technology produces the following air emissions:

- ☐ Oxides of nitrogen (NOx)
- ☐ Carbon monoxide
- ☐ Carbon dioxide
- ☐ Reactive organic gases
- ☐ Particulates

- ☐ Sulfur dioxide

By products suitable for commercial sale or use:

- ☒ Heat energy
- ☒ Electrical energy
- ☒ Fuel Biogas (methane)
- ☐ Fertilizer
- ☒ Soil amendments
- ☒ Bedding
- ☒ Other: Renewable Energy Credits

Although REW states "The digested solids have higher nutrient values per unit mass than the undigested feed solids and are effectively slow-nitrogen-release fertilizers because the readily biodegradable material has already been gasified," no claims are made for use of the composted digester-solids as an organic fertilizer.

It is unclear how this technology reduces salts and phosphorus unless they are exported off of the dairy.

1.38.2 Economic Performance

REW did not provide any economic data. However, since REW maintains ownership of the operation (REW refers to their business model as BOOM – Build/Own/Operate/Maintain), it appears that the dairy need not concern itself with the cost of this system. However, the dairy will need to consider the cost of land needed to accommodate this operation. REM did not explain whether there would be some form of revenue-sharing arrangement with the dairy.

1.38.3 Quality of Supporting Data

- ☐ Sufficient data were provided to demonstrate effectiveness of technology
- ☐ Data were provided, but effectiveness of the technology is inconclusive - need more data
- ☒ Data are said to exist, but data are not yet available or were not provided
- ☐ No data are available

REW was not inclined to share specific data, but maintained in an e-mail exchange that it is, "…in the process of helping some dairies double their herd size under the same nutrient loading limitations." In the same e-mail exchange REW also indicated that the ICE, "... meets all BACT requirements in North America, including guideline 3.3.12 of the San Joaquin Valley Air Pollution Control District."

1.38.4 Development Status of the Technology

REW states that this solutions package is in use throughout the United States and is commercially available. They claim that there are "one dozen domestic" and "several dozen" other operations which have been operating as long as a few decades.

1.38.5 Applicability of the Technology to California Dairies

Assuming that REW can provide data to substantiate its claims, this technology package would appear to be appropriate for use on California dairies. Given that REW takes care of running the facility and handling the manure, it would seem most attractive to a dairy operator who does not want to be distracted or encumbered with having to manage and operate such a facility. While the system is scalable, REW indicates that the dairy should have a minimum of 2,000 cows in order for the REW technology to be economically viable. According to REW, the typical size of operations installed throughout the country is roughly 2,500 cows.

1.38.6 What Data Gaps Exist?

No data were provided to support any of REW's claims. Data are required in order to determine how this integrated solutions-package addresses the mass-balance of nutrients at the dairy. Nutrients must be examined using a mass-balance approach in order to account for all potential environmental impacts. REW should provide data to show how the nutrients move through the solid, liquid, and gas phases as the manure waste is processed using their system.

REW states, "By extracting nutrients out of the manure waste, the digester system will also reduce on-farm nutrient (N, P, K) concentrations to help meet federal CAFO requirements and minimize potentially offensive local odors." However, REW did not provide data to demonstrate to what extent its processing of the manure-slurry would work to capture the nutrients. For example, extracting solids from the manure-slurry will still leave nutrients and salts within the liquid waste-stream. Data should be provided on the typical nutrient and salt loads expected in the wastewater produced with their process and information provided on how these materials are managed other than by conventional land application practices. Nutrients in the liquids that drain from compost piles and emissions generated within storage lagoons and the composting area are not addressed.

It appears that the vendor is assuming that collection of the manure solids from the flushing of the milking parlors will capture the bulk of the nutrients. In fact, studies indicate that most of the nutrients and salts remain in the liquid fraction after solids separation. Furthermore, the practice of recycling this wastewater as flush-water leads to cumulatively greater accumulations of dissolved nutrients and salts. Unless a treatment process is used to reduce salt and nutrient levels, the high concentration of nutrients and salts in the recycled flush-water must be considered when establishing land-application rates.

1.38.7 What Additional Research and/or Verification Work should be done?

Based on the information submitted to the Panel, the integrated solutions package proposed by REW does not appear to address the complete nutrient management process needed at a dairy. While REW indicates that it has installed this solutions-package at dairies elsewhere in the United States and internationally, they have not adequately addressed the potential environmental impacts of nutrients in all portions of the waste stream by using a mass-balance approach. The vendor needs to account for how nutrients are partitioned between the solid and liquid fractions of the dairy waste stream, and include any gaseous emissions of nutrient compounds (especially nitrogen) within the nutrient budget. It is recommended that research be done to collect this type of data from one of their facilities if that facility is typical of the type of dairy operations in California. Failing that, this approach should be applied to a demonstration farm in California.

1.39 Sharp Energy

Product/Process **Anaerobic Digester Lagoons**

1.39.1 Description

This technology consists of a floating cover over part or all of a lagoon to capture methane and produce power by using the methane for fuel in an engine and generator set.

1.39.2 Environmental Impacts

This technology is intended to control:

Air Emissions	Non-volatile waste components
☒ Reactive organic gases	☐ Organic nitrogen
☐ Ammonia	☐ Ammonium nitrogen
☐ Particulates	☐ Nitrates
☒ Odors	☐ Phosphorus
☐ Methane	☐ Salts
☐ Hydrogen sulfide	☒ Pathogens

The technology produces the following air emissions:

- ☒ Oxides of nitrogen (NOx)
- ☒ Carbon monoxide
- ☒ Carbon dioxide
- ☐ Reactive organic gases
- ☐ Particulates
- ☐ Sulfur dioxide

By products suitable for commercial sale or use:

- ☐ Heat energy
- ☒ Electrical energy
- ☐ Fuel- Charcoal
- ☐ Fertilizer
- ☒ Soil amendments
- ☒ Bedding
- ☐ Other

Anaerobic digestion is well understood and is an effective methodology for odor control. Using anaerobic digestion with methane capture and use reduces the use of fossil fuels. However, the generator-system emissions will need some type of emissions control for the internal combustion portion of the system. For the partial-cover systems, the uncovered portion of the storage lagoon could be a source of ammonia emmissions; hovever, the mass of emissions is dependent on several factors including the pH of the lagoon.

Using anaerobic digestion is not expected to reduce the amount of nutrients present in the waste material, but it does change the form of some nutrients and affect the partitioning of the nutrients between the solid and wastewater fractions. The concentrations of nutrients in the liquid and solid fractions must be measured before land application in oder to avoid applicationof excess nutrients. Anaerobic digestion is just a step in the overall nutrient management process. However, it does provide for volume reduction of solids, some pathogen control, odor control if loading rates are not excessive, potential reductions in emissions of H_2S if a scrubber is included, and financial benefits from either a reduction of electricity purchases or from sale of excess electricity.

1.39.3 Economic Performance

The example cost provided for the system was approximately $150 per cow for a 2,000-cow herd. The expected life of the cover was not stated in the information packet. The economic data are a bit general but is similar to other reports on the returns from energy generation using boigas from anaerobic lagoons. The use of the existing lagoon reduces the initial cost for a energy system but the trade off is in the lower gas generation and winter production reductions due to outdoor temperatures.

1.39.4 Quality of Supporting Data

- ☐ Sufficient data were provided to demonstrate effectiveness of technology
- ☒ Data were provided, but effectiveness of the technology is inconclusive - need more data
- ☐ Data are said to exist, but data are not yet available or were not provided
- ☐ No data are available

1.39.5 Development Status of the Technology

Anaerobic digestion systems with this type of lagoon cover have been installed in California.

1.39.6 Applicability of the Technology to California Dairies

Insufficient data are available to evaluate the performance of the technology at typical dairies in California. However, some dairies are installing this type of technology based on assumed benefits.

1.39.7 What Data Gaps Exist?

Data are needed on the reduction of air emissions, changes in the quality of the effluent over the influent, and on the initial costs and maintenance costs associated with the technology. In addition, reduction in odors is a subjective assessment; no supporting testimonials were submitted to support the claimed odor reductions.

1.39.8 What Additional Research and/or Verification Work should be done?

Trial use of the product at one or more dairies in California is desirable. Sufficient data must be obtained to assess system performance relative to air emissions prior to installation of the cover and associated gas collection and use components and on the amounts of nutrients in the sludge and digester effluent. Also documentation of the reduction of odors relative to various loading rates would be desirable.

1.40 Sprecher Architects

Product/Process: Solar drying of manure

1.40.1 Description

Sprecher Architects' (Sprecher's) technology is a passive-drying process for manure solids that uses the sun's heat concentrated by placing the manure into a greenhouse. Sprecher's submission mentioned a number of associated technologies that the Panel did not evaluate. These included: drying the manure outdoors, as is already in common practice in California; use of a Honey-Vac to collect and spread manure; and equipment for turning manure, as in composting. The Panel examined only Sprecher's submission for the use of a greenhouse to enhance the drying of manure. Sprecher's submission indicates the intent is to use this approach for manure solids in excess of that which can be applied to cropland at the facility at agronomic rates.

1.40.2 Environmental Impacts

This technology is intended to control:

Air Emissions	Non-volatile waste components
☐ Reactive organic gases	☐ Organic nitrogen
☒ Ammonia	☐ Ammonium nitrogen
☐ Particulates	☐ Nitrates
☒ Odors	☐ Phosphorus
☐ Methane	☐ Salts
☐ Hydrogen sulfide	☐ Pathogens

The technology produces the following air emissions:

- ☐ Oxides of nitrogen (NOx)
- ☐ Carbon monoxide
- ☐ Carbon dioxide
- ☐ Reactive organic gases
- ☐ Particulates
- ☐ Sulfur dioxide

Sprecher did not indicate what the emissions would be. The Panel expects that the technology would have emissions in several of these categories.

By products suitable for commercial sale or use:

- ☐ Heat energy
- ☐ Electrical energy
- ☐ Fuel
- ☐ Fertilizer
- ☐ Soil amendments
- ☒ Bedding
- ☒ Other: Land applied solids.

1.40.3 Economic Performance

No economic data were submitted, and thus it was not possible to perform an economic assessment of this technology.

1.40.4 Quality of Supporting Data

- ☐ Sufficient data were provided to demonstrate effectiveness of technology
- ☐ Data were provided, but effectiveness of the technology is inconclusive - need more data

- ☐ Data are said to exist, but data are not yet available or were not provided
- ☒ No data are available

1.40.5 Development Status of the Technology

- ☐ Research (basic research and applied research)
- ☐ Development (concept development and prototype development)
- ☐ Test and evaluation (product/process development)
- ☒ Demonstration (full or field relevant scale)
- ☐ Commercial application

Based on Sprecher's submittal, "Demonstration" appears to be referring to the Honey Vac, while "winter greenhouse drying is still to be implemented."

1.40.6 Applicability of the Technology to California Dairies

It is not clear what advantages (practical, economic, or environmental) Sprecher's technology has compared to practices already in use in many California dairies. Sprecher suggests that it's approach controls ammonia and can also control odors. However, there will be direct ammonia and odor emissions during any drying process. Under the hot drying conditions during summer in Israel and in California's interior regions, the manure solids might dry very quickly and thus might have reduced emissions relative to either composting the manure or letting manure sit in moist piles or in lagoons. However, the reduced emissions would only be for the dry season and would not occur during the wet winter months.

Greenhouses would have to be used during the winter months (as is proposed by the vendor), and it is expected that the passive drying process would be a slow process, even to 75% moisture content. This slow drying would allow for potentially significant emissions of ammonia and other gasses. Employing bio-filters or scrubbers of some sort at the discharge point of the building's ventilation system would be necessary to control these emissions. This emissions control approach was not proposed as part of Sprecher's technology. In addition, the buildings would have to be large to handle the manure loads typical of a dairy in California's Central Valley. The economics of such an approach are not expected to be favorable to using the technology.

No information was provided regarding the ventilation system, if any, that would be installed on the greenhouses to protect health of workers exposed to these gases when in the greenhouses.

While it is recognized that Sprecher is trying to provide the dairy owner with an approach that allows for the economical processing and handling of manure waste, it is not clear to the Panel how their approach has advantages over other methods for handling manure.

1.40.7 What Data Gaps Exist?

No data were provided for the environmental performance or the economic performance of this technology.

1.40.8 What Additional Research and/or Verification Work should be done?

To indicate the advantages of this technology over conventional approaches to the separation and handling of manure solids, Sprecher should indicate how the technology is expected to scale in terms of size and cost on a seasonal basis (i.e., how much manure could be dried in the summer and in the winter and how much land or how large a greenhouse would be required to process a specific volume of manure solids during each season). Information should also be developed on how quickly manure would dry during each season, how any collected wastewater would be handled, what emissions would occur, and how they would be handled. This information could then be compared to other manure handling practices. It would be best to develop such information during a demonstration test under conditions seen in California's Central Valley. During the demonstration, a mass-balance approach should be applied to the fate of nutrients and salts.

1.41 Tennessee Valley Authority

Product/Process: ReCiprocating Wetlands™

1.41.1 Description

The ReCiprocating Wetlands™ technology is a wastewater treatment system that uses man-made wetlands to remove nitrogen. The system can be used on wastewater produced at confined animal facilities. The wetlands are constructed in one or more "cell pairs" that can receive anaerobic wastewater by subsurface flow. Multiple cell pairs can be operated in parallel or serial arrangements. The depth of cells can range to three meters, and possibly deeper. Each cell is lined with an 'impermeable' synthetic liner and filled with various grades of gravel. The gravel serves as a substrate where microbial biofilms attach and grow. Water is pumped back and forth between the cells at a controlled rate, thereby creating alternating aerobic and anoxic/anaerobic conditions. Such conditions support a diverse microbial population that can achieve biological removal of nitrogen. It is stated that selected vegetation can be planted to enhance removal of nutrients, but no information on harvesting and handling the plants was provided.

1.41.2 Environmental Impacts

This technology is intended to control:

Air Emissions	Non-volatile waste components
☐ Reactive organic gases	☒ Organic nitrogen
☒ Ammonia	☒ Ammonium nitrogen
☐ Particulates	☒ Nitrates
☒ Odors	☐ Phosphorus
☐ Methane	☐ Salts
☒ Hydrogen sulfide	☒ Pathogens

The technology produces the following air emissions:

- ☐ Oxides of nitrogen (NOx)
- ☐ Carbon monoxide
- ☐ Carbon dioxide
- ☐ Reactive organic gases
- ☐ Particulates
- ☐ Sulfur dioxide

By products suitable for commercial sale or use:

- ☐ Heat energy
- ☐ Electrical energy
- ☐ Fuel
- ☐ Fertilizer
- ☐ Soil amendments
- ☐ Bedding
- ☐ Other

1.41.3 Economic Performance

A list of 16 locations where the technology has been used was provided. The largest system listed is 528,000 gallons per day (gpd) system located in Egypt and is designed to treat mixed municipal, industrial, agricultural wastewater. Three of the facilities are at agricultural sites including two hog farms. The system at one of the hog farms had a 50,000 gpd design flow and operating electrical cost of approximately $6,000 per year, based on $0.075 per kW-h and an average use of 220 kW-h/day.

A materials list and cost estimate was provided for a 40,000 gallons per day (gpd) ReCiprocating Wetlands™ system. The cost estimate of $54,726 did not include labor, cost of rock transport, engineering design, or licensing fees. It was noted that transportation costs for sand and gravel could be significant if sources are distant from the treatment site.

One Panel member estimated the cost to install a ReCiprocating Wetlands™ system at a typical dairy in the San Joaquin Valley to be approximately $100,000 where the system receives influent from an existing lagoon and discharges back to the lagoon.

1.41.4 Quality of Supporting Data

- ☒ Sufficient data were provided to demonstrate effectiveness of technology
- ☐ Data were provided, but effectiveness of the technology is inconclusive - need more data
- ☐ Data are said to exist, but data are not yet available or were not provided
- ☐ No data are available.

Data from the studies at two hog farms indicate that the ReCiprocating Wetlands™ is effective in reducing nitrogen levels present in animal waste. In Alabama, the ReCiprocating Wetlands™ system removed 91% of ammonia-N and 82% of total Kjeldahl nitrogen (TKN) from swine lagoon water. At the same facility, the system reduced E-Coli by 99% and odor reductions were reported. In North Carolina, a ReCiprocating Wetlands™ system reduced ammonia-N by 57.3%, TKN by 87.5%, and total solids by 47.7%. Other studies have shown reductions in pathogens. Phosphorus levels were reduced initially, but the reduction was not sustained. Data indicate that nitrate is formed in the treatment cells, but does not remain in the lagoon that receives the effluent. Ammonia volatilization was not monitored, but was reported to be negligible in the wetland system based on apparent high nitrification rates and pH regimes which would tend to minimize volatilization.

No tests have been run using dairy manure, but the system should have similar effects on such waste. Data should also be collected on air emissions to verify that the emissions from the treatment cells will not adversely impact air quality.

1.41.5 Development Status of the Technology

- ☐ Research (basic research and applied research)
- ☐ Development (concept development and prototype development)
- ☐ Test and evaluation (product/process development)
- ☒ Demonstration (full or field relevant scale)
- ☐ Commercial application

1.41.6 Applicability of the Technology to California Dairies

Based on the available data, the technology appears to be suitable for use at dairies in California where there is excess nitrogen relative to crop needs. The initial cost and operating costs appear to be reasonable considering the alternatives for managing excess nitrogen.

1.41.7 What Data Gaps Exist?

Additional testing is needed to verify that the technology is effective on dairy wastes and to better characterize overall air emissions from a system that includes ReCip® Biofilter treatment cells. Preferably, one or more studies would be conducted on a dairy in the San Joaquin Valley.

1.41.8 What Additional Research and/or Verification Work should be done?

The technology vendor should be contacted to obtain any additional air emission studies conducted at other test sites. Sustainable Conservation is developing a grant request for a study to evaluate the ReCiprocating Wetlands™ treatment process at a dairy in the San Joaquin Valley. If vegetation is to be planted to enhance removal of nutrients, information on harvesting and handling the plants should be developed.

1.42 Waste Technology Transfer, Inc.

Product/Process: Waste Technology Transfer

1.42.1 Description

The Waste Technology Transfer (WTT) technology converts biomass, including manure and organic wastes, into a "bio crude" using an anaerobic environment and heat and pressure to make a high BTU liquid fuel. It also generates co-products that can include asphalt additives and "fuel blending stock." The company states that the process is similar to how crude oil forms naturally when organic matter is subjected to heat and pressure over geologic time. The WTT technology claims to greatly accelerate that process to produce fuel and related products.

1.42.2 Environmental Impacts

This technology is intended to control:

Air Emissions	Non-volatile waste components
☒ Reactive organic gases	☐ Organic nitrogen
☒ Ammonia	☐ Ammonium nitrogen
☒ Particulates	☐ Nitrates
☒ Odors	☐ Phosphorus
☒ Methane	☐ Salts
☒ Hydrogen sulfide	☒ Pathogens

The technology produces the following air emissions:

- ☐ Oxides of nitrogen (NOx)
- ☐ Carbon monoxide
- ☐ Carbon dioxide
- ☐ Reactive organic gases
- ☐ Particulates
- ☐ Sulfur dioxide

By products suitable for commercial sale or use:

- ☐ Heat energy
- ☐ Electrical energy
- ☒ Fuel - oil
- ☐ Fertilizer
- ☐ Soil amendments
- ☐ Bedding
- ☐ Other

Because there is no combustion involved, there are no combustion by-products, according to the company.

1.42.3 Economic Performance

The technology has not yet been commercialized, and no specific cost data were provided.

1.42.4 Quality of Supporting Data

- ☐ Sufficient data were provided to demonstrate effectiveness of technology
- ☐ Data were provided, but effectiveness of the technology is inconclusive - need more data

☒ Data are said to exist, but data are not yet available or were not provided
☐ No data are available

Lack of data makes it difficult to evaluate the viability of the technology for dairy manure.

1.42.5 Development Status of the Technology

The company claims the technology is ready for commercial use. However, there is insufficient information to verify this, particularly as it relates to dairy manure.

1.42.6 Applicability of the Technology to California Dairies

Economy of scale issues relative to dairies and manure were not addressed in the information provided, nor was any specific financial information provided. Therefore, it is difficult to assess manure feedstock requirements for a given plant and how to optimize financial and technical performance.

1.42.7 What Data Gaps Exist?

There is a lack of financial information and environmental or technical data related to a dairy manure. Because the technology has not yet been commercialized, it is difficult to draw any conclusions or make analogy to existing plants.

1.42.8 What Additional Research and/or Verification Work should be done?

More research related to manure as a feedstock would be useful as well as third-party verification of potential environmental impacts and benefits to air and water.

1.43 Western Milling Transfer

Product/Process: Aeration and Wet Combustion

1.43.1 Description

Western Milling Transfer's Vacuum Bubble Technology (VBT) produces small air bubbles that are used to aerate manure lagoons. The vendor also adds proprietary bacteria to the lagoon. The combination of aeration and bacteria are claimed to reduce odors, hydrogen sulfide, ammonia, biological oxygen demand, and organic matter.

The vendor characterizes the oxidation reactions in the lagoon as "wet combustion." However, conventional (high temperature) combustion is not a part of this technology.

1.43.2 Environmental Impacts

This technology is intended to control:

Air Emissions
- ☒ Reactive organic gases
- ☒ Ammonia
- ☐ Particulates
- ☒ Odors
- ☐ Methane
- ☒ Hydrogen sulfide

Non-volatile waste components
- ☐ Organic nitrogen
- ☒ Ammonium nitrogen
- ☐ Nitrates
- ☒ Phosphorus
- ☒ Salts
- ☐ Pathogens

The technology produces the following air emissions:
- ☐ Oxides of nitrogen (NOx)
- ☐ Carbon monoxide
- ☐ Carbon dioxide
- ☐ Reactive organic gases
- ☐ Particulates
- ☐ Sulfur dioxide

By products suitable for commercial sale or use:
- ☐ Heat energy
- ☐ Electrical energy
- ☐ Fuel- Charcoal
- ☐ Fertilizer
- ☐ Soil amendments
- ☐ Bedding
- ☐ Other

1.43.3 Economic Performance

The vendor estimates that for a 1000 cow freestall flushed dairy with no support animals, three bubble units (2 HP each, running continuously) would be required at a cost of $7500 each. Electrical installation is estimated to be an additional $2,250, for a total capital cost of $24,750. The electrical motors are estimated to last five to seven years. Operating costs are estimated to be $14,600 per year, which includes $10 per day for electricity and $30 per day for bacterial cultures.

1.43.4 Quality of Supporting Data

- ☐ Sufficient data were provided to demonstrate effectiveness of technology
- ☒ Data were provided, but effectiveness of the technology is inconclusive - need more data
- ☐ Data are said to exist, but data are not yet available or were not provided
- ☐ No data are available

The vendor provided several sets of data. In studies conducted at a flush dairy in Iowa, within 60 days of initiating treatment biological oxygen demand (BOD) was reduced by 75% and total suspended solids (TSS) were reduced by 65%. Data from a separate trial conducted by Iowa State University indicate that within the first two weeks of treatment odor decreased 80%, hydrogen sulfide decreased by 90%, and ammonia concentrations were reduced by 80%. Additional reductions in odor, hydrogen sulfide and ammonia occurred over the subsequent four weeks of sampling.

Tests conducted by NSF International on the performance of the VBT Aerator at treating municipal wastewater indicated that BOD was reduced by 35-80% and TSS were reduced by 48-86%. Data were not provided on the dissolved oxygen concentration of the wastewater during treatment.

At a flush dairy in California treatment of a manure lagoon over six weeks were said to show 83% reduction in BOD, 48% reduction in total solids, 48% reduction in nitrites, 37% reduction in total Kjeldahl nitrogen, and 65% reduction in phosphorus.

1.43.5 Development Status of the Technology

The company indicates they have study sites on dairies in Iowa and California. Photographs of the treatment process and provided for the California dairy. There do not appear to be any full-scale commercial operations running at this time.

1.43.6 Applicability of the Technology to California Dairies

High efficiency aerators that raise dissolved oxygen levels and have low energy requirements could be quite desirable. The technology appears to be available off-the-shelf and is scaleable for various sizes of lagoons.

1.43.7 What Data Gaps Exist?

There are significant gaps in the description and data presented for this technology:

- There is no indication of the dissolved oxygen levels in treated lagoons. Without this information it is not possible to determine if the aerators oxygenate the lagoons. This is of importance because dissolved oxygen concentrations have a great impact on the chemistry and biology of the lagoon. It is not clear how such a small unit could aerate manure lagoons, which have extremely high biological and chemical oxygen demands.
- The fates of the carbon, nitrogen, phosphorus and salts are not known. The vendor claims significant reductions in volatile organic matter, TSS, salts, nitrogen compounds and phosphorus, but there is no indication of where this mass goes. Without knowing the fate of these elements and compounds it is not possible to determine the environmental benefits of the technology.

- It is not clear why bacteria are added to the system, what their population levels are without continual augmentation, and what benefit they provide.

1.43.8 What Additional Research and/or Verification Work should be don e?

Dissolved oxygen levels should be quantified to determine if the bubble units can aerate a manure lagoon. A mass balance should be performed to determine the fate and form of all the carbon, nitrogen, phosphorus, and salts entering, leaving, and retained in the system. To determine the significance and activity of the added proprietary bacterial cultures, bacterial numbers and population diversity should be quantified over time with and without augmentation, and with and without the VBT aerators.

1.44 Wildcat Manufacturing

Product/Process: Windrow Composting

1.44.1 Description

Windrow composting is a method for managing manure. Wildcat Manufacturing produces equipment for turning compost piles. Turning aerates and mixes the piles and physically reduces particle size, all of which make the composting process progress more rapidly and uniformly. Several companies produce equipment to turn compost. The equipment manufactured by Wildcat is reviewed here.

1.44.2 Environmental Impacts

This technology is intended to control:

<u>Air Emissions</u>	<u>Non-volatile waste components</u>
☒ Reactive organic gases	☐ Organic nitrogen
☒ Ammonia	☒ Ammonium nitrogen
☐ Particulates	☐ Nitrates
☒ Odors	☒ Phosphorus
☒ Methane	☐ Salts
☐ Hydrogen sulfide	☒ Pathogens

The technology produces the following air emissions:

- ☒ Oxides of nitrogen (NOx)
- ☒ Carbon monoxide
- ☒ Carbon dioxide
- ☒ Reactive organic gases
- ☐ Particulates
- ☐ Sulfur dioxide

By products suitable for commercial sale or use:

- ☐ Heat energy
- ☐ Electrical energy
- ☐ Fuel
- ☒ Fertilizer
- ☒ Soil amendments
- ☒ Bedding
- ☐ Other

The manufacturer claims reductions in emissions, but peer-reviewed analysis is needed to verify and quantify these claims. It is not clear how composting would reduce quantities of phosphorous in manure. An internal combustion engine powers the equipment; therefore, combustion gases are produced and should be addressed in the technology evaluation. It is expected, however, that the engines will comply with California regulations.

1.44.3 Economic Performance

A review of economic performance could not be performed with the data provided.

1.44.4 Quality of Supporting Data

☐ Sufficient data were provided to demonstrate effectiveness of technology

- ☐ Data were provided, but effectiveness of the technology is inconclusive - need more data
- ☒ Data are said to exist, but data are not yet available or were not provided to adequately assess the implications for control of air emissions.
- ☐ No data are available

1.44.5 Development Status of the Technology

- ☐ Research (basic research and applied research)
- ☐ Development (concept development and prototype development)
- ☐ Test and evaluation (product/process development)
- ☐ Demonstration (full or field relevant scale)
- ☒ Commercial application

1.44.6 Applicability of the Technology to California Dairies

This technology may be applicable to dairies in California, depending on composting regulations currently under development. Composting is already being done on many farms, and the Wildcat equipment is well known. However, there are serious concerns and increasing regulatory oversight focused on air emissions from the composting process itself. For example, California's South Coast Air Quality Management District has already proposed Rule 1133 to require containment of ammonia and volatile organic compounds from composting activities. Wildcat claims advantages for their composting process, but actual field measurements of air emissions are yet to be presented to the satisfaction of air quality authorities. In the San Joaquin Valley, Rule 4702 is under development to govern composting. The subject of the rule making is not the compost turning equipment, but rather the process of composting. If composting of dairy manure in the open-air continues to be an acceptable practice in the San Joaquin Valley, the Wildcat equipment could aid in the composting activities.

1.44.7 What Data Gaps Exist?

Air emissions information needs to be documented and presented to appropriate air regulatory authorities for their review. Water quality benefits also require substantiation.

1.44.8 What Additional Research and/or Verification Work should be done?

Monitoring of air emissions at each stage of the process should be done, including an evaluation of the net emissions produced from composting, versus not composting the manure. A similar analysis should also be performed to evaluate the fate of nutrients in the solids.

Appendix 2: Alphabetical Company Contact Information

This Appendix lists companies that market technologies to manage or treat manure. This list is not comprehensive; it lists only those companies known to the Panel. Inclusion in this list does not indicate any endorsement by the Panel of companies, their products, or their marketing claims.

➢ indicates that the company's technology is assessed in Appendix 1 of this report.

Accent Manufacturing, Inc.
Kerry Doyle, Vice President
#602-30731 Simpson Road
Abbotsford BC V2T 6Y7
Canada
Phone: 604-850-7799
Fax: 604-850-7909
Email: kerryd@nsibrew.com
Web: www.accentmanufacturing.com
Solid-liquid separators

ADI Systems Inc.
182 Main Street, Unit 6
Salem NH 03079
Phone: 603-893-2134 / 800-561-2831
Fax: 603-898-3991
Email: systems@adi.ca
Web: www.adisystems.ca
Proprietary anaerobic and aerobic industrial waste/wastewater treatment technologies

➢**Advanced Concept Technologies, LLC**
Alfred R. Dozier
1712 Pedregoso Place SE
Albuquerque NM 87123
Phone: 505-294-5068
Fax: 505-294-5069
Email: globalc@earthlink.net
PSRG Gasification and Catalytic Reduction to produce Ethanol from Manure

Ag-Bag Environmental
Debbie Linder, Director of Operations
2320 SE Ag-Bag Lane
Warrenton OR 97146
Phone: 503-861-4226
Fax: 503-861-1648
Email: dlinder@ag-bag.com
compost@ag-bag.com
Web: www.ag-bag.com
Aerated in-vessel composting system

AgriClean, LLC
David Palmer, Managing Partner
1328 Kinnard Drive
Franklin TN 37064
Phone: 615-794-7124
Fax: 615-794-3456
Email: davidcpalmer@agriclean.com
Web: www.agriclean.com
Fixed film anaerobic digester

Agricultural Engineering Associates
John A. George, P.E.
1000 Promontory Dr.
Uniontown KS 66779
Phone: 316-756-1000
Fax: 316-756-4600
Email: webmaster@agengineering.com
Web: www.agengineering.com
Consulting and design for waste management systems

Agricultural Modeling & Training Systems
Thomas P Tylutki, PhD
418 Davis Rd
Cortland NY 13045
Phone: 607-423-3327
Fax: 607-838-3523
Email: tomamts@gmail.com
Web: www.agmodelsystems.com
AMTS.Cattle computer program for feed management

Agricultural Sustainable Energy Tech.
Will Charlton
9300 NW Cornell Road
Portland OR 97229-6449
Phone: 503-209-6950
Fax: 503-384-9579
Email: will@aset.us
Web: www.aset.us
Architect/engineering/financing firm providing digester biogas systems and by-products

Agricultural Waste Solutions, Inc.
Stephen McCorkle
4607 Lakeview Canyon Rd., Ste. 185
Westlake Village CA 91361
Phone: 805-551-0116
Fax: 805-375-0134
Email: mccorkle@agwastesolutions.com
System for Converting Animal Waste to Energy & Useful By-Products

Agrimass Enviro-Energy, Inc
Leonard Chapman
1144 S. Demaree, Ste B
Visalia CA 93277
Phone: 559-687-3306
Fax: 559-687-3307
Email: Lenchapman@agrimassenviroenergy.com
Web: www.agrimassenviroenergy.com
- *Biological remediation of manure wastewater and manure solids*
- *Induced Blanket Reactor (anaerobic digestion)*

Agriventures
Robert Warkentin
2834 South Kent Street
Visalia CA 92377
Phone: 559-732-4486
Fax: 559-732-4486
Web: agrivent@aol.com
Vermi-composting

AgriWaste Technology, Inc.
Lawson M. Safley Jr., Ph.D., P.E.
5400 Etta Burke Ct.
Raleigh NC 27606
Phone: 919-859-0669
Fax: 919-233-1970
Email: awt@agriwaste.com
Web: www.agriwaste.com
Design/engineering total waste handling systems and strategies

AgSmart, Inc.
Loren L. Losh
PO Box 329
Strasburg CO 80136
Phone: 303-622-4567
Fax: 303-622-4527
Email: lllosh@aol.com
Web: www.agsmart.com
The O_2 Solution ™ aerators and microbial additives for lagoons

Agviro, Inc.
Ronald D. MacDonald, P.E.
367 Gordon St.
Guelph, Ontario N1G 1X8
Canada
Phone: 519-836-9727
Fax: 519-836-5708
Email: agviro@mlg.ca
Web: www.agviro.com
Designs of: heating, ventilation, control and lighting systems for optimum indoor environment; manure management

➢ **Air Diffusion Systems**
Brian Lewis
28846-C Nagel Court, P.O. Box 38
Lake Bluff IL 60044
Phone: 817-361-0710
Fax: 270-812-6506
Email: eastwind@charter.net
Web: www.airdiffusion.com
AMTS - Advance Microbial Treatment System

Alternative Energy Systems Consulting, Inc.
Dara Salour
449 15th Street, Ste. 401
Oakland CA 94612
Phone: 510-899-7625
Fax: 510-899-7629
Email: dsalour@aesc-inc.com
Web: www.aesc-inc.com
Technical consulting services on energy issues, including using manure as a fuel

Altex Technologies Corporation
Dr. John T. Kelly, President
244 Sobrante Way
Sunnyvale CA 94086
Phone: 408-328-8302
Fax: 408-328-8313
Email: john@altextech.com
Web: www.altextech.com
Power generation technology from dewatered manure

AnAerobics
Eastgate Square, Suite 200
50 Square Drive
Victor NY 14564
Phone: 585-421-3500
Fax: 585-421-3535
Email: info@ecovation.com
Web: www.anaerobics.com
Organic waste treatment technologies that create opportunities for renewable energy utilization

Anergen Corp.
2332 Marcy Ave.
Evanston IL 60201
Phone: 847-424-0290
Fax: 847-424-8221
Email: enoojibail@comcast.net
Web: www.anergen.com
Biological process that converts agricultural wastes into energy, nutrient-rich solids and liquid effluents

Applied Technologies, Inc.
16815 W. Wisconsin Ave.
Brookfield WI 53005
Phone: 262-784-7690
Fax: 262-784-6847
Email: jfkouba@ati-ae.com
Web: www.ati-ae.com
Engineering design and consulting for anaerobic contact processes

Arge Biogas des Naturschutzbund
Österreich
Museumsplatz 2
A-5020 Salzburg
Austria
Phone: 0043-(0)-662-64 29 09
Fax: 0043-(0)-662-64 37 344
Email: arge.biogas@naturschutzbund.at
Web: www.naturschutzbund.at/arge_biogas/ziele.html
Consulting services on construction of biological gas facilities

➢ **Bakersfield, City of, Solid Waste Div.**
Kevin Barnes, Solid Waste Director
4101 Truxtun Ave Bldg A
Bakersfield CA 93309-0602
Phone: 661-326-3109
Fax: 661-322-7503
Email: Kbarnes@ci.bakersfield.ca.us
Proposal to co-compost manure with wood chips

➢ **Baleen Filters**
Marcus Jones
P.O. Box 1189
North Adelaide, South Australia, 5006
Australia
Phone: 61-7-4697-3344
Fax: 61-7-4697-3532
Email: marcusj@cefn.com.au
Web: www.baleen.com
Filtration to remove solids

Banning Engineering, P.C.
Jeffery W. Healey, P.E.
698 Tower Rd. Suite 100
Plainfield IN 46168
Phone: 317-839-2581
Fax: 317-838-9171
Email: jhealy@banning-eng.com
Web: www.banning-eng.com
Consulting, planning and design for agricultural waste systems

Bauer North America, Inc.
PO Box 8943
Michigan City IN 46360-8943
Phone: 800-922-8375
Email: bauer@bauer-at.com
Web: www.bauer-at.com
Solid-liquid separators

➢ **Baumgartner Environics, Inc.**
Wade Jager
2510 W. Lincoln Ave.
Olivia MN 56277
Phone: 641-969-5207 / 641-670-0135
Fax: 320-523-1998
Email: wadejag@earthlink.net
Web: www.beiagsolutions.com
- *Bio Cap ML lagoon cover*
- *Bio-Curtain plus Electrostatic Particulate Precipitation*
- *Nitrification/Denitrification (NDN) Nutrient Management System*

➢ **Bencyn West, Inc. (dba BWI Solutions, Inc.)**
Leo Dobitz
5549 Luce Avenue
McClellan CA 95652
Phone: 916-922-7028
Fax: 916-922-7143
Email: leo@bwisolutions.com
Web: www.bwisolutions.com
OrTec Biocatalyst

➢ **Bigadan**
MCON BIO, Inc.
Vroldvej 168, DK- 8660
Skanderborg
Denmark
Contact in United States: Hans Meyer
Phone: 951-600-1385
Fax: 951-600-1285
Email: mconbio@mconbio.com
Web: www.bigadan.com
Anaerobic digestion systems

Biogas Energy Systems
Brian Gannon, Director
5784 E Green Lake Way N
Seattle WA 98103
Phone: 206-369-8580
Fax: 815-301-3432
Email: bgannon@biogas-energy.com
bgannon@yahoo.com
Web: www.biogas-energy.com
Designs, builds and operates anaerobic digestion systems

➢ **Bion Dairy Corp**.
Dominic Bassani
P.O. Box 323
Old Bethpage NY 11804
Phone: 631-499-4930
Fax: 631-499-4718
Email: brightcap@aol.com
Web: www.biontech.com
Bion Biological Nutrient Removal Waste System

Biosa Canada
Niels Wandler, Managing Director
4290 Marisa Cr.
Niagara Falls, Ontario L2H3C2
Canada
Phone: 905-357-0800
Fax. 905-357-4367
Email: info@bitabiosa.ca
Web: www.biosa.dk
Microbes to reduce odors and ammonia emissions from composting manure

Bioscan A/S
Tagtækkervej 5
5230 Odense M
Denmark
Phone: 45-66-15-70-71
Fax: 45-66-15-77-71
Email: bioscan@bioscan.dk
Web: www.bioscan.dk
Consultant on anaerobic digesters, biomass energy systems, methane biogas production

Biowaste Energy, Inc.
Zia Khan
P.O. Box 8520
Stockton CA 95208
Phone: 209-465-0296
Fax: 209-465-1605
Email: ziakhan@pacbell.net
Web: http://home.pacbell.net/ziakhan
Developer zero discharge projects with anaerobic technology

Boldt Fabrication and Design
Bob Stevenson
4412 West 3rd Avenue
Amarillo TX 79106
Phone: 806-467-2096
Email: boldt4412@cox.net
Screw presses and solid-liquid separators

Bridgestone Associates, Ltd.
124 N. Village Lane, Suite 100
Chadds Ford PA 19317
Phone: 610-388-6191
Fax: 610-388-0394
Email: mcta@brdgstn.com
Web: www.brdgstn.com
Consultant for renewable energy projects, including animal manure anaerobic digestion

Carl Bro Environmental
Carl Bro Group
Granskoven 8
DK-2600 Glostrup Denmark
Phone: 45 4348 6060
Fax: 45 4348 6660
Email: Cbg@carlbro.com
Web: www.carlbro.dk
Consultant on composting, biogas, incineration, landfill and heating plants

➢**CH$_2$M Hill, Inc.**
Jan Allen
PO Box 91500
Bellevue WA 98009
Phone: 425-233-3110
Fax: 425-468-3110
Email: Jan.allen@ch2m.com
Web: www.ch2m.com/composting
C:N Composting Systems - Portable and Re-locatable Composting System

➢**Coaltec Energy USA**
Barbara T. Gaume
5749 Coal Drive
Carterville IL 62918
Phone: 214-542-3321
Fax: 214-353-2950
Email: bgaume@sbcglobal.net
Web: www.cdp.siu.edu
Gasification technology systems

Continental Cogeneration Services
Ronald M. Svendsgaard
964 Ebbetts Ave.
Manteca CA 95337
Phone/Fax: 209-825-8071
Email: contcogn@comcast.net

Curry-Wille & Associates, Consulting Engineers, P.C.
Jerry L. Wille, P.E., President
P.O. Box 1732
Ames IA 50010
Phone: 515-232-9078
Fax: 515-232-9083
Email: willecwa@aol.com
Consultation on agricultural storage

CiTEC International Ltd Oy
Mr Jan Teir
Silmukkatie 2
FI-65100 VAASA
Finland
Phone: 358 (0)6 3240 700
Fax: 358 (0)6 3240 800
Email: jan.teir@ citec.fi
Web: www.citec.fi
WAASA process for anaerobic digester

Dranco Organic Waste Systems
Winfried Six
Dok Noord 4
B-9000 Gent
Belgium
Phone: 32 9 2330 204
Fax: 32 9 2332 825
Email: mail@ows.be
Web: www.ows.be
Developer of DRy ANaerobic COmposting (DRANCO)

E3 Regenesis Solutions
James T. Caldwell. Ph.D., President/CEO
840 Sea Spray Lane #102
Foster City CA 94404-2459
Phone: 1-650-571-5392
Fax: 1-650-571-5392
Email: jcaldwell@e3regenesis.com
Web: www.e3regenesis.com
E3 Regenesis process that generates energy.

EA Engineering, Science, and Technology, Inc.
11019 McCormick Road
Hunt Valley MD 21031
Phone: 410-584-7000
Fax: 410-771-1625
Email: info@eaest.com.
Web: www.eaest.com
Biogas projects

EarthRenew, Inc.
Gene Dillahunty, General Manager
107 San Pedro Rd.
Half Moon Bay CA 94019-4912
Phone: 650-743-2659 / 403-228-5070
Fax: 650-726-3278
Email: gened@earthrenew.com
Email af@earthrenew.com
Process "cooks" manure, converting it to high organic matter, high organic N, granular products

Eco-Cure, Inc.
Jim Kritchever, Chairman/CEO
1525 Casa Buena Drive, Suite D
Corte Madera CA 94925
Phone/Fax: 1-415-924-8450
Email: jimkritchever@yahoo.com
Eco-Cure, Inc. manufactures a proprietary enzymes and microbes designed to degrade animal waste

➢ **Engineered Compost Systems**
Steve Diddy
4211 24th Ave West
Seattle, WA 98199
Phone: 360-280-8985
Fax: 360-634-1309
Email: steve@compostsystems.com
Web: www.compostsystems.com
In-vessel and aerated static pile (ASP) composting systems

Engineering Resources Corp.
George Aull, Ph.D., P.E.
P.O. Box 910
Orangeburg SC 29116
Phone: 803-536-6808
Fax: 803-531-3262
Email: erc@ercorp.net
Web: www.ercorp.net
Consultant for agricultural water, waste and wastewater systems

Environmental Energy Company
6007 Hill St., NE
Olympia WA 98516
Phone: 360-923-2000
Fax: 360-923-1642
Email: dab@cyclus.com
Web: www.makingenergy.com
Anaerobic technology, anoxic gas flotation technology

Environomics
Richard Mattocks
2517 Rte. 44, 11-221,
Salt Point NY 12578
Phone: 845-635.4206
Fax: 845-635.4169
Email: rpm@waste2profits.com
Web: www.waste2profits.com
Consultant on manure and organic waste digestion system projects

Envirowaste Technology, Inc.
Edward Puck, President
506 W 21st St
Carroll IA 51401
Phone: 712-790-2552
Fax: 712-792-5181
Email: epuck@envirowastetech.com
Web: www.envirowastetech.com
Solid separation and nutrient partitioning using flocculants and the Geotube NRS

➢**Everstech Consulting (UK)**
Everstech LLC (USA)
Dennis Evers
8417 Oswego Road, #227
Baldwinsville NY 13027
Phone: 315-622-3630
Fax: 315-622-3630
Email: devers@everstech.com
Web: www.everstech.com
Everstech ET™ Process, anaerobic and aerobic digestion with bio-augmentation

Fan Separator (USA), Inc.
456 Randy Road
Carol Stream IL 60188
Phone: 630-871-8882 / 800-451-8001
Fax: 630-871-8886
Email: fanusa@fan-separator.com
Web: www.fan-separator.de
Solid-liquid separators

F.D. Deskins, Inc
F. David Deskins
23 Fairway Drive
Alexandria IN 46001
Phone: 765-724-7878
Fax: 765-724-7267
Web: www.deskinsinternational.com
Web: www.deskinsprocesstech.com
Solid-liquid separation through the Deskins Quick-Dry Dewatering Process

Five-G Consulting, Inc.
P.O. Box 30940
Reno TX 75462
Phone: 903-783-9995
Fax: 903-784-2317
Web: www.fiveg.com
Consultant on agricultural waste management

➢**Flex Energy**
Edan Prabhu
22922 Tiagua
Mission Viejo CA 92692
Phone: 949-380-4899
Fax: 949-380-8407
Email: edanprabhu@cox.net
Web: www.flexenergy.com
Flex-Microturbine

Fournier Industries Inc.
3787 Frontenac Blvd. West
Thetford Mines, Quebec G6H 2B5
Canada
Phone: 450-375-7060
Fax: 450-777-6066
Email: p.gagne@rotary-press.com
Web: www.rotary-press.com
Solid-liquid separators

Fox Engineering Associates, Inc.
1601 Golden Aspen Drive, Suite 103
Ames IA 50010
Phone: 515-233-0000 / 800-433-3469
Fax: 515-233-0103
Email: info@foxeng.com
Web: http://foxeng.com
Engineering consultant

GHD, Inc.
Stephen Dvorak, President
P.O. Box 69
Chilton WI 53014
Phone: 920-849-9797
Fax: 920-849-9160
Email: ddghd@tds.net
Web: www.ghdinc.net
Design and engineering of two-stage modified mixed plug flow anaerobic digesters

➢**Greenfinch Ltd.**
Michael Chesshire
The Business Park, Coder Road
Ludlow, Shropshire, SY8 1XE,
United Kingdom
Phone: 01584 877687
Fax: 01584 878131
Email: biogas@greenfinch.co.uk
Web: www.greenfinch.co.uk
Biogas technology systems

Haase Energietechnik GmbH
Oliver Martens
Gadelanderstraße 172
D-22531 Neumünster
Germany
Phone: 49 4321 8780
Fax: 49 4321 87829
Email: oliver.martens@haase.de
Web: www.haase-energietechnik.de
Anaerobic digesters, cogeneration units, biogas flares, booster units, and membrane systems.

➢**Haskell Edwards**
38500 109-R Hwy 190
Springville CA 93265
Email: haskeledwards@aol.com
Water Reclamation Systems

HotRot Composting Systems
Craig Whan, U.S. Programs Manager
P.O. Box 661
Santa Barbara CA 93102
Phone: 805-455-2871
Email: cwhan@silcom.com
Web: www.hotrotsystems.com
Composting systems

➢**Hydrolve**
Kevin R. Doran
438 E. Shaw Avenue, #241
Fresno CA 93710
Phone: 559-589-1000
Fax: 559-746-7200
Email: krdoran@hydrolve.com
Web: www.hydrolve.com
Tempest Drying System solid separator

➢**ILS-Partners, Inc.**
Rick Diederich
1 Como Circle
Palm Desert CA 92211
Phone: 760-568-9369
Fax: 775-213-0554
Email: rick@ils-partners.com
Web: www.ils-partners.com
Pyromex-Pyrolysis-Hydrolysis Ultrahigh Temperature Gasification

IMK BEG Bioenergie GmbH (AGR Group)
Heidestraße 80
45701 Herten
Germany
Phone: 49 209 - 3580-05 / 201 2429-156
Fax: 49 209 - 3580-06 / 201 2429-417
Email: bioenergie@gmx.de
Web: www.agr.de
Consultant on generation of electricity and heat from organic agricultural waste

Industrial & Environmental Concepts, Inc.
6009 Chapel Drive, Suite 101
Minneapolis MN 55439
Phone: 952-829-0731
Fax: 952-829-9770
Email: iecoffice@aol.com
Web: www.ieccovers.com
Patented geomembranes

➢ **Integrated Separations Solutions**
Steve Hynds
210 New Factory Rd.
Sharon WI 53585
Phone: 262-736-4211
Fax: 262-736-4214
Email: shynds@isepsol.com
Web: www.isepsol.com
Wastewater recovery systems

Intellergy Corporation
Fred Schwartz, Vice President
6801 Sherwick Drive
Berkeley CA 94705-1744
Phone: 415-499-1589
Email: schwartz@intellergy.com
Web: www.intellergy.com
Steam reformatting technology

Intertape Polymer Group
Dohn Berger, US Sales Manager
P.O. Box 868
50 Abbey Avenue
Truro, Nova Scotia B2N 5G6
Canada
Phone: 800-565-2000, 972-596-9470
Fax: 902-893-0220
Web: info@itape.com
Manufacturer of geo-membranes and pond liners

➢ **Jeesung Livestock Engineering Co. Ltd.**
1176-5 Su Suk Dong
Seo-San City, Chung Nam
Korea
Contact in United States:
Mr. Eung Il Kim
2360 E Devon Ave., suite 2010
Des Plaines, IL 0018
Phone: 82-16-93990120 (Korea)
Fax: 847-699-1022
Email: jeesungle@hotmail.com
Web www.jeesungle.com
JS-2000 Organic Waste Composting Unit

Joseph G. Martin III, P.E.
6024 SW 89th Terrace
Gainesville FL 32608
Phone: 352-371-4655
Fax: 352-371-1677
Email: Jake@DairyDesign.com
Web: www.dairydesign.com
Consultant on manure and wastewater systems

Jones-Hamilton Co.
Glen Wilkinson, Manager
Agricultural Division
8400 Enterprise Drive
Newark CA 94560
&
30354 Tracy Road,
Walbridge OH 43465
Phone: 770-716-1873
Fax: 770-716-0572
Email: gwilkinson@jones-hamilton.com
Web: www.jones-hamilton.com
Parlor Pal (sodium bisulfate & proprietary ingredients) to lower pH and reduce ammonia emissions and bacterial populations in manure

Krieg & Fischer Ingenieure GmbH
Torsten Fischer
Hannah-Vogt-Straße 1
D-37085 Göttingen
Germany
Phone: 49 551 30574-32
Fax: 49 551 77077-12
Email: Fischer@KriegFischer.de
Web: www.kriegfischer.de
Design of cofermentation biogas plants

Krüger A/S
Gladsaxevej 363
DK-2860 Søborg
Denmark
Phone: 45 - 3969 0222
Email: kruger@kruger.dk
Web: www.kruger.dk
Kruger decanter centrifuge for separation of liquid manure

➢ **Kyte Centrifuge Sales & Consulting**
Kenneth B. Kyte
4901 Morton Road
New Bern NC 28562-5041
Phone: 252-633-5783
Fax: 252-633-4826
Email: kyte.ken@juno.com
Web: www.kcentrifuge.com
Triton TS-5000 solid bowl basket centrifuge for solid separation

➢ **Lanstar**
John Hofmeyr
PO Box 95617
Grant Park 2051, Johannesburg
South Africa
Phone: 27-11-788-7040
Email: lanstar@global.co.za
High temperature kiln process to produce charcoal

Larsen Engineers
700 West Metro Park
Rochester NY 14623-2678
Phone: 585-272-7310 / 800-836-3540
Fax: 585-272-0159
Email: info@larsen-engineers.com
Web: www.larsen-engineers.com
Consultant for anaerobic treatment lagoons, sludge drying beds and a wetland ecosystem

Linde-KCA-Dresden GmbH
Bodenbacher Straße 80
01277 Dresden
Germany
Phone: 49 (0)3 51 250-30
Fax: 49 (0)3 51 250-48 00
Email: lkca.dresden@linde-kca.com
Web: www.linde-kca.com
Consultant for digestion and biogas plants and composting for biowastes

McLanahan Corporation
200 Wall Street
Hollidaysburg PA 16648
Phone: 814-695-9807
Fax: 814-695-6684
Email: agdivision@mclcnahan.com
Web: www.mclanahan.com
Solid-liquid separators

Microgy, Inc.
(a subsidiary of Environmental Power Corporation)
One Cate Street, 4th Floor
Portsmouth NH 03801
Phone: 603-431-1780
Fax: 603-431-2650
Web: http://www.environmentalpower.com/
Builds, owns and operates anaerobic digestion & energy production facilities which utilize agricultural and food by-product waste

➢**Midwestern Bio-Ag Products & Services, Inc.**
Lawrence Mayhew
PO Box 160
Blue Mounds WI 53588
Phone: 608-583-3095
Fax: 608-583-3086
Email: lmayhew@mhtc.net
Web: midwesternbioag.com
HumaCal™ pelleted humic substances for animal feed and manure treatment

Midwest Bio-Systems
Edwin Blosser, President
28933 35 E Street
Tampico IL 61283
Phone: 815-438-7200
Fax: 815-438-7028
Email: mbs@emypeople.net
Web: www.midwestbiosystems.com
Microbial inoculants and aeration to compost manure and bind salts

MPC Containment
4834 S. Oakley
Chicago IL 60609-4036
Phone: 773-927-4120 / 800-621-0146
Fax: 773-650-6028
Email: info@mpccontainment.com
Web: www.mpccontainment.com
Consultant for design, fabrication and installation of floating membrane liner systems

MWH Energy Solutions
370 Interlocken Boulevard
Suite 300
Broomfield CO 80021
Phone: 303-410-4000
Fax: 303-410-4100
Email: webinfo@mwhglobal.com
Web: www.mwhglobal.com/power.asp
Consultant for the recovery, cleaning and combustion of biogas

➢**Natural Aeration Inc.**
Gary Wegner
28598 N Riffe Road
Reardon WA 99029
Phone: 509-796-4825 / 509-998-2932
Fax: 509-796-4826
Email: Gary@CIRCUL8.com
Web: www.CIRCUL8.com
CIRCUL8 Systems for lagoon mixing

➢**Nutrient Control Systems, Inc.**
Bob Blythe
145 Siloam Road
Chambersburg PA 17201
Phone: 717-261-5711
Fax: 717-263-7399
Email: bobblythe@earthlink.net
Web: integrityagsysems.com
Integrity Nutrient Control System with solid separation, composting and aeration

➢**Octaform**
James Johnson
520-885 Dunsmuir Street
Vancouver BC V6C 1N5
Canada
Phone: 604-408-0558
Fax: 604-408-0595
Email: jjohnson@octaform.com
Web: www.octaform.com
Octaform PVC-lined concrete tanks

➢**Omnifuel Technologies, Inc.**
Robert McChesney
8421 Auburn Blvd., Suite 258
Citrus Heights CA 95610
Phone: 916-294-0696
Fax: 916-357-5157
Email: rmc@inreach.com
Web: www.downstreamsystems.com
Rapid Pyrolysis systems

➢**Organic Waste Management**
Bruce Bryson
P.O. Box 2288
Sebastopol CA 95473
Phone: 707-829-7345
Email: bbryson0846@sbcglobal.net
Wet composting system

Praxair Inc.
39 Old Ridgebury Road
Danbury, CT 06810
Mikko Ollila
Tel: 203-837 2076
Email: mikko_ollila@praxair.com
Provides pure oxygen fo rwaste treatment systems

Press Technology & Mfg., Inc.
1315 Lagonda Avenue
Springfield OH 45503
Phone: 937-327-0755
Fax: 937-327-0756
Web: www.presstechnology.com
Solid-liquid separators

➢ **Primenergy, L.L.C.**
W.N. (Bill) Scott
P.O. Box 581742
Tulsa OK 74158
Phone: 918-835-1011
Fax: 918-835-1058
Email: wnscott@primenergy.com
Web: www.primenergy.com
Solids gasification and energy production

➢ **Pro-Act Microbial, Inc**.
Bill Campion
P.O. Box 345
Warren RI 02885
Phone: 800-772-3775
Fax: 401-633-6270
Email: bill@ProActMicrobial.com
Web: www.ProActMicrobial.com
Pro-Act Microbial Manure Munching Microbes

➢ **Renewable Energy Works**
Loren Fechter, Director of Operations
9300 NW Cornell Road
Portland OR 97229-6449
Phone: 503-209-6950
Fax: 503-384-9579
Email: loren@reneworks.us
Web: www.reworks.us
Anaerobic digestion and biogas power generation and fiber conditioning systems

RCM Digesters, Inc.
Mark Moser , President
P.O. Box 4716
Berkeley CA 94704
Phone: 510-834-4568
Fax: 510-834-4529
Email: mmoser@rcmdigesters.com
Web: http://www.rcmdigesters.com
Engineering design for anaerobic digesters

Schwarting Umwelt GmbH
Environmental Engineering and Biotechnology
Lise-Meitner-Str. 2
D-24941 Flensburg
Germany
Phone: 49 0-461 / 9992-121
Fax: 49 0-461 / 9992-101
Email: info@schwarting-umwelt.de
Web: www.schwarting-umwelt.de
Schwarting/Uhde co-digestion process for biogas

➢ **Sharp Energy**
Roy Sharp
24684 Road 148
Tulare CA 93274
Phone: 559-688-2051
Fax: 559-688-1111
Email: rsharp6363@aol.com
Anaerobic digester lagoon systems

➢ **Sprecher Architects**
Wayne Raiche
10 Halamed Hai Street
Tel Aviv 69277
Israel
Phone: 604-826-7844 (Canada)
Fax: 604-826-6051 (Canada)
Email: wayne.raiche@loewenwelding.com
Web: www.loewenwelding.com
Solar drying of manure and liquid wastes outside and inside greenhouse structures

Synagro Technologies, Inc.
1800 Bering Dr., Suite 1000
Houston TX 77057
Phone: 713-369-1700 / 800-370-0035
Fax: 713-369-1750
Email: bodette@synagro.com
Web: www.synagro.com
Anaerobic digestion technologies.

Technical & Engineering Associates, Inc.
Gary Norton, President
PO Box 708
Livermore CA 94551
Phone: 925-606-9800
Fax: 925-606-1187
Email: nortongd@tdl.com
Fixed-film anaerobic digester with floating cover

➢**Tennessee Valley Authority**
Keith Rylant
CEB 1-C
Muscle Shoals AL 35662
Phone: 256-386-2835
Fax: 256-386-2520
Email: wkrylant@tva.gov
Web: www.tva.gov/environment/envservices
ReCiprocating Wetlands™ for denitrification

Thöni Industries Gmbh
Dept. Environmental and Energy Technology
Maria Koch, Marketing Manager
Obermarkt 48
6410 Telfs
Austria
Phone: 0043-5262-6903-503
Fax: 0043-5262-6903-8503
Email: maria.koch@thoeni.com
Web: www.thoeni.com
Mixed mesophilic anaerobic digester that co-digests animal manure and crop residue

US Filter
181 Thorn Hill Rd.
Warrendale PA 15086
Phone: 724-772-0044 / 800-525-0658
Email: information@usfilter.com
Web: www.usfilter.com/water
Equipment for solid separation, anaerobic digestion, and wastewater treatment.

Valley Air Solutions LLC
Robert Patrick, Manager
PO Box 4517
Stockton CA 95204
Phone: 209-430-7600
Fax: 877-430-7600
Email: info@valleyairsolutions.com
robert.patrick@valleyairsolutions.com
Web: www.valleyairsolutions.com

- *Dairy/AG Digester Biogas Hydrogen Sulfide Removal System*
- *Dairy/AG Digester Biogas Gas Monitoring and Alarm System*
- *Dairy/AG Digester Biogas Hydrogen Sulfide Monitoring and Alarm System*
- *Dairy/AG Digester Biogas Carbon Dioxide Monitoring and Alarm System*
- *Dairy/AG Digester Biogas Methane Monitoring and Alarm System*
- *Dairy/AG Wastewater Monitoring System*
- *Dairy/AG Digester Biogas Mass Flow and Temperature Monitoring System*
- *All Natural Dairy Covered Lagoon Anaerobic Digester*
- *NRCS 359 Anaerobic Treatment Lagoon*
- *All Natural Co-Digestion Dairy/AG Covered Lagoon Digester*
- *All Natural Co-Digestion Complete Mix Digester*
- *Dairy Digester Feasibility Study*

Vaughan Co., Inc.
364 Monte-Elma Rd.
Montesano WA 98563
Phone: 360-249-4042 / 888-249-2467
Fax: 360-249-6155
Email: info"@chopperpumps.com
Web: www.chopperpumps.com
Consultant for hydraulics mixing systems for methane digesters and sludge storage tanks

Wallace Group
Scott Stoller, Associate Engineer
1330 Arnold Drive, Suite 249
Martinez CA 93553
Phone: 925-228-5801
Fax: 925-228-5804
Email: info@wallacegroup.us
scotts@wallacegroup.us
Swanson Advanced Integrated Ponds Systems multi-stage biological reactors to remove nutrients, pathogens, and organics and produce recoverable biogas and effluent for irrigation and stall flushing

➢ **Waste Technology Transfer**
Robert G. Hennkens
1701 East Orange Grove Road
Tucson AZ 85718
Phone: 810 623 2405
Fax: 520 621 6044
Email: newfrontier@earthlink.net
Bio-crude oil from organic waste

Water Pure Technologies
Craig Waterman, CEO
Martin Hansen, General Manager
245 Industrial Street
Bakersfield CA 93307
Phone: 661-327-9656
Email: waterpure@cox.net
craigwnc@lightspeed.net
Web: www.waterpuretech.com
An aerobic/microbial digestion system using proprietary materials

➢ **Western Milling**
Warren Hutchings
P.O. Box 1029
Goshen CA 93227
Phone: 800-549-5999
Fax: 559-651-0246
Web: www.advancedaeration.com
Aeration and wet combustion systems

➢ **Wildcat Manufacturing**
Tim O'Hara
420 South Hwy 81 / P.O Box 1100
Freeman SD 57029
Phone: 1-800-627-3954 / 605-925-4512
Fax: 605-925-7536
Email: wildcat@wildcatmfg.com
timo@wildcatmfg.com
Web: www.wildcatmfg.com
Windrow composting

Williams Engineering Associates
Doug Williams, P.E.
2073 Buckskin Dr.
Los Osos CA 93402
Phone: 805-528-0131
Email: wmsengre@thegrid.com
Consultant for anaerobic digestion, biogas energy utilization, and energy conservation systems

Wright Environmental Management, Inc.
9050 Yonge St., Suite 300
Richmond Hill, Ontario L4C 9S6
Canada
Phone: 905-881-3950
Fax: 905-881-2334
Email: russ.blades@environmental.com
Web: www.wrightenvironmental.com
In-vessel composting systems

Appendix 3: General References on Managing and Treating Dairy Manure

Aillery, M. N. Gollehon, R. Johansson, J. Kaplan, N. Key, and M. Ribaudo. 2005. Managing Manure to Improve Air and Water Quality. Economic Report 9. United States Department of Agriculture, Economic Research Service, Washington, DC. 47 pp.

Beatty G. and H. Zygmunt, eds. 2005. "Alternative Technologies/Uses for Manure (draft)." United States Environmental Protection Agency, Office of Wastewater Management, Washington, DC. 35 pp. http://www.epa.gov/npdes/pubs/cafo_report.pdf

Burton, C.H., and C. Turner, 2003. *Manure Management: Treatment Strategies for Sustainable Agricultu*re, 2nd edition. Silsoe Research Institute, Silsoe, UK. 451 pp.

Hughes, K. and A.C. Wilkie, editors. 2005. *Cost-effective and Environmentally Beneficial Dairy Manure Management Practices*. National Dairy Environmental Stewardship Council. Sustainable Conservation, San Francisco. 28 pp. http://www.suscon.org/dairies/pdfs/COSTEFFECTIVEANDENVIRONMENTALLY.pdf

Humenik, F. 2001. *Lesson 25: Manure Treatment Options. In: Livestock and Poultry Environmental Stewardship Curriculum.* Midwest Plan Service, Iowa State University, Ames, IA.

Krich, K. et al. 2005. *Biomethane from Dairy Waste: A Sourcebook for the Production and Use of Renewable Natural Gas in California*. Sustainable Conservation, San Francisco, CA. http://www.westernuniteddairymen.com/USDA%20Grant/USDAgrantfinalreport.htm

Robbins, J.H. 2005. *Understanding Alternative Technologies for Animal Waste Treatment: A Citizen's Guide to Manure Treatment Technologies*. Waterkeeper Alliance, Tarrytown, NY. 154 pp.

Roos, K.F., and M.A. Moser. 1997. *A Manual for Developing Biogas Systems at Commercial Farms in the United States.* AgStar Handbook. U.S. Environmental Protection Agency, Washington, D.C. EPA-430-B-97-015.

San Joaquin Valley Unified Air Pollution Control District, Preliminary Draft Staff Report, Rule 4570 (Confined Animal Facilities), April 12, 2005. See especially pp. 12-25 for short descriptions of various types of technologies. http://www.valleyair.org/Workshops/postings/4-19-05/R4570_report_SM.pdf

Ungvarsky, J. 2004. Agriculture and the Environment: A Look at the Environmental Impacts of Animal Feeding Operations. *EM* (July):18-24.

US EPA. 2003. EPA AgSTAR Industry Directory for On-Farm Biogas Recovery Systems, 2nd Edition. United States Environmental Protection Agency, Office of Air and Radiation, Washington, DC. 22 pp. http://www.epa.gov/agstar/pdf/techdir.pdf