

Commerce Energy Biogas/PV Mini-Grid
Renewable Resources Program

***Making Renewables Part of an Affordable and
Diverse Electric System in California***

Contract No. 500-00-036

**Co-Digestion of Dairy Manure/Food Processing
Wastes and Biosolids/Food Processing
Wastes to Energy
Evaluation Report**

Project No. 3.1 Dairy Waste to Energy

Task 3.1.11a Deliverable

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California Energy Commission
Public Interest Energy Research Renewable Program

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Introduction

In June 2001, the Commerce Energy Team (previously known as the Commonwealth Energy Team) was awarded a programmatic contract under the California Energy Commission's Public Interest Energy Research (PIER) Program to develop and carry out research strategies for making renewable energy more affordable in California. The Commerce Energy (Commerce) approach involved assessing the combined potential of biogas and photovoltaic (PV) resources in a defined study area and identifying how these resources could be developed in a complementary and cost-effective manner. The Commerce Energy Team conducted this research in a real world setting so that the findings could be applied in other parts of California. The Chino Basin, an area centered southeast of Los Angeles that is rich in PV and biogas resources, was the selected location for the Commerce program.

An important element of the Commerce PIER Renewables Mini-Grid Program is a project devoted to implementation of research and demonstration activities for converting dairy waste to energy. Measurement and evaluation (M&E) of this Commerce project, often referred to as "Project 3.1", is the subject of this evaluation report. Approximately 20 individuals employed by the regional waste water and electric utilities, and the dairy, renewable energy, and environmental industries were interviewed about their experience with the Commerce Project 3.1 and other similar projects related to the conversion of dairy waste to energy. Commerce PIER project participants, as well as non-PIER participants, were interviewed for this assessment to determine if there are differential views of Project 3.1 results by those who were directly involved relative to those who were not.

The purpose of this assessment is to determine how well the Project 3.1 goals and objectives were met and how effective this project has been in meeting the overall goals of the PIER Program. This M&E effort focuses on the following dairy waste to energy systems issues:

- Were the *pilot system performance* and *reliability testing criteria* appropriate and sufficiently comprehensive? The focus here is on the evaluation of environmental, economic, and engineering performance.
- Were *Technology Transfer* effectiveness goals met?
- How well did the Project perform in meeting its *Market Impact* goals?

1.1 Purpose of the Dairy Waste to Energy Project

The primary goals of the Commerce Project 3.1 were to:

- Develop technologies that can be used to maximize the energy production and recovery from animal waste,
- Develop and evaluate different pilot projects that include facilities at existing treatment plants and/or at individual and clusters of dairies, and
- Evaluate and test the effectiveness of low and high technologies developed in North America and Europe for the collection, processing, and energy recovery from animal waste.

In the process of meeting these goals, the currently available technologies to convert dairy waste to energy were assessed. Several project test sites were considered and a final site (IEUA Regional Plant No. 1) was selected by the Project 3.1 Team. The waste treatment and processing technologies evaluated for this project include covered lagoons, North American high-rate phased digestion, European manure digestion, thermal hydrolysis, pyrolysis, and heat drying. Upon the completion of a multi-year process of technology and site selection followed by pilot testing of various codigestion and biogas cleaning techniques, the project then continued with the codigestion system design and construction modifications at a full-scale digester plant. This was followed by an assessment of the cost-effectiveness and non-energy benefits resulting from this project.

A number of key findings were reached through the research that examined the conversion of dairy waste to energy. The Task 3.1.1 *Digester Comparison Study* that examined dairy waste anaerobic digesters concluded that dairy manure projects that included co-digestion with certain types of processed food waste produced more biogas than anticipated and were much more cost effective than those that did not. A codigestion *Tactical Marketing Plan* was developed that focused on the dairy waste and biosolids codigestion and biogas to electric power markets throughout California. The market assessment and implementation plan concluded that a number of sewage treatment plants with available existing digester capacity could be used for dairy related codigestion projects and that the benefits of codigestion of sewage sludge with food waste could also likely be realized at these same facilities as well as other larger waste water treatment plants that are located in close proximity to food only processing wastes.

Based upon the research carried out under Project 3.1, a model was developed to predict biogas production for use in a number of future codigestion projects. This model can help planners acquire those quantities of codigestion feedstocks for optimal biogas production. In addition, a separate model was developed by team members to quantify potential environmental benefits of dairy waste to energy, as a way to increase overall project benefits

by aiding the monetization and sale of renewable energy credits, greenhouse gas (GHG) credits, criteria emission reduction, including nitrogen oxides (NO_x) and particulate matter (PM) emissions reductions credits.

1.2 Project 3.1 Relationship to Overall Goals of the Commerce PIER Program

The overall goals of the Commerce Energy PIER Program are to:

- Develop and implement an approach for tailoring resource development to the specific needs and resources of local areas, or “mini-grids”;
- Develop means of increasing landfill gas production and collection, accelerating biodegradation and decreasing landfill generation lifecycle costs;
- Improve the affordability of renewable energy produced from digester gas at sewage treatment plants;
- Improve the economics of producing energy from animal waste;
- Demonstrate the potential for the use of advanced gasification processes to reduce the cost of residual and/or sludge disposal;
- Demonstrate the use of proper systems integration to enhance the performance of photovoltaic systems;
- Demonstrate and update the application of a performance evaluation rating system for building integrated systems; and to improve the transfer of this information on system and module performance to consumers and the supply channel stakeholders; and
- Illustrate the potential for demonstration applications that add substantial value to building integrated PV technology, and simultaneously take advantage of economies of scale by installing larger PV systems under various targeted arrangements (i.e., dual/tri-use facilities, common ownership and ESP power purchase/billing, PV/Biogas hybrid facilities, DC direct drive applications, etc).

Work conducted under Project 3.1 directly relates to the goal of improving the economics of producing energy from animal waste by carrying out research and demonstration efforts that found synergistic benefits from co-digestion of dairy waste and processed food waste. A direct result of this research was a more efficient manner to produce biogas. The environmental benefits model developed to measure the value of the reduced emissions also has a direct bearing on improving the economics of dairy waste to energy by allowing for the quantification of the benefits to be traded in the environmental credit markets.

Project 3.1 also furthers the goal to develop and implement an approach for tailoring resource development to the specific needs and resources of local areas, or mini-grids.

1.3 Organization of the Report

This remainder of this report is organized as follows:

- **Section 2** presents economic, environmental, and engineering assessments of dairy waste to energy conversion and dairy waste co-digestion with food processing waste. PIER and non-PIER participants were interviewed about the economic and environmental drivers, the project costs and funding, and equipment installation, operation, and performance. An evaluation of the test plan is also included.
- **Section 3** describes the success of technology transfer activities by presenting the groups and communities the data and project results were discussed with, how this information was communicated with the dairy and wastewater treatment plant operators, and how aware non-PIER participants are of the dairy waste to energy conversion project.
- **Section 4** measures and evaluates the potential market impacts arising from an advancement of dairy waste energy generation within the mini-grid area as well as throughout California as a whole.
- **Section 5** examines whether this project has contributed to producing affordable electricity and increased reliability, how well this project met the overall goals of the PIER program, and whether this project will help to increase market penetration.

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Pilot Performance Finance and Development

This section will evaluate the performance of the effectiveness of enhancing energy recovery at the host facilities, as indicated by the specific performance metrics. The primary emphasis here is on the increased output of energy, the effects on cost-effectiveness, and the environmental impacts relative to conventional approaches. Initially developed estimates of environmental and economic performance will be compared to those based on actual pilot project results. Data on these performance aspects have been collected and analyzed by the project team under Task 3.1.3, and these results are further assessed here.

This evaluation examines how effectively the test sites were monitored for performance. Included is an assessment of 1) how well designed the monitoring system was in capturing all relevant aspects of system performance, 2) how well the monitoring was executed, and 3) how thoroughly the performance data were analyzed and evaluated.

2.2 Evaluate Test Plan

This section evaluates how well the Task 3.1.3 *Dairy Waste to Energy Test Plan* was carried out by IEUA and CH2M Hill employees. The *Dairy Waste to Energy Test Plan* presents a protocol for testing of food waste-manure and food waste-biosolids co-digestion at IEUA RP-1. The test plan called for establishment of a baseline for food waste-manure and food waste-biosolids co-digestion, full-scale co-digestion testing, and data evaluation. The impacts of co-digestion on gas quality, dewatering, and recycle streams were to be measured and evaluated as well.

Sludge & Biogas Sampling & Analysis

Three project participants answered questions about the sludge and biogas sampling and analysis that took place at IEUA. All respondents replied that the sampling rate was adequate and that no other biogas or sludge constituents needed to be measured. IEUA and CH2M Hill employees collected the samples, and the sampling plan was not modified from the original Task 3.1.3 *Test Plan*. The samples were sent to three laboratories for analysis: Western Analytical, Environmental Management Services, and Environmental Analytical. One respondent stated that samples were consistently taken on time, while the other respondent stated that the samples were generally taken on time, however, plant operators

sometimes had higher priority tasks that needed to be addressed before collecting samples. All respondents reported that there were no other problems with collecting the samples. Although use of the enhanced iron sponge and the food waste co-digestion activities will likely continue, internal lab analyses will be less frequent and IEUA has now purchased gas testing instrumentation to assess gas quality. Samples will no longer be sent to an outside lab. The data for this project was analyzed by a team at CH2M Hill.

One TAC member was interviewed and expressed concern that the protocol for testing was not adequate. This respondent was disappointed in the level of measurement and didn't think it was a good test. The TAC member was also disappointed that the pilot did not pay much attention to what happens to the waste after it leaves the digester.

2.3 Engineering Assessment

This section evaluates the performance of the food waste co-digestion and the enhanced iron sponge tested under this Commerce PIER Mini-Grid Project 3.1 and the related experiences that non-project participants have had with other co-digestion related activities.

Table 2-1: Performance of Co-Digestion Systems

ENGINEERING/ECONOMIC CONSIDERATION	EXISTING FACILITY AT IEUA REGIONAL PLANT NO. 1 (BASE CASE)	DAIRY MANURE ONLY AT IEUA REGIONAL PLANT NO. 1	CO-DIGESTION OF DAIRY MANURE / FOOD PROCESSING WASTE AT REGIONAL PLANT NO. 1 - AS TESTED -	CO-DIGESTION OF DAIRY MANURE / FOOD PROCESSING WASTE AT REGIONAL PLANT NO. 1 - FULL-SCALE -
Electricity production				
Total capacity (kW)	0	200	223	269
		Based on gas production of manure only	Based on gas production of manure and food processing waste co-digestion -	
Average annual output (\$)				
Gas Production (cfd as biogas (60% CH ₄))	0	112,860	126,420	146,900
Gas Production (MMBtu/year)	0	24,716	27,686	32,171
Power Generation (kWh/year) (90% availability)	0	1,576,800	1,758,132	2,120,796

PIER Participants - Co-Digestion

Three project participants answered questions about co-digestion operational issues. Two participants commented that problems were encountered with manually feeding the food waste to the digester because it was not done continuously and this was causing rapid increases (e.g., spikes) in biogas volumetric production and inconsistent biogas quality. Due to safety and air emission concerns, the problem was solved by installing an automated feeder. Once the correct automatic feed rate was found, biogas production was more stable and the quality was more consistent. This problem could have also been solved manually by gradually increasing the amount of food waste being fed to the digester or by investing in an adequately sized gas storage tank. The automated feed method is recommended by all respondents, however, because it is more consistent and it also will free up the plant operators to work on other tasks. The food waste was consistently available, but IEUA used lesser volumes than originally expected. When IEUA was not able to accept the food waste, the providers were contacted soon enough in advance so that they could properly dispose of their waste through an alternate method. Another obstacle for implementing co-digestion is that it creates extra work for the plant operators. Despite a few problems, all respondents felt that overall co-digestion was a success and biogas production was increased more than expected; IEUA will expand co-digestion to RP-2 and RP-5.

PIER Participants Enhanced - Iron Sponge

Three project participants answered questions about the operational issues of the modified iron sponge. This technology looked promising to all project participants, although there were initial problems which prevented testing to be completed before the end of the PIER program. Two respondents said that the iron sponge was easy to modify, while the third commented that the modification required shutting down the system, but was otherwise it was easy to install. One respondent reported that a line was used to inject lyme in order to control the pH, and the lyme caused the air injectors to clog. This issue is currently under investigation and will most likely result in replacing the lyme with a different basic chemical. All respondents expected the enhanced iron sponge to extend the life of the media by one to two months. One respondent recommended this technology to other treatment plants that already have an iron sponge. The enhanced iron sponge will continue to be used at IEUA.

PIER Non-Participants - Co-Digestion

Only three non-participant respondents had used co-digestion. One had co-digested dairy wastewater with cheese waste and did not have any major problems. The second had co-digested manure with cheese waste and commented that permitting co-digestion projects can be difficult because the food waste is often considered industrial waste. One respondent who had not participated in a co-digestion project commented that because the food waste has a much higher energy value than the manure, higher and higher food waste to manure ratios are

being used, and this becomes less beneficial to the dairies. He added that transport distances can also be an issue. The third respondent had tried co-digestion with many different organic wastes, but would not comment on what had been successful.

2.1 Environmental Assessment

This section will evaluate the environmental assessment of Project 3.1. Five project participants and twelve non-participants answered questions about what the most important environmental drivers are for dairy waste to energy projects and co-digestion projects and their responses corresponded with what was measured by the Project 3.1 Team. Project participants and non-participants were also asked about the usefulness and future applicability of the environmental benefits model, developed under Task 3.1.6.

Environmental Drivers Participant Responses

The Project 3.1 Team quantified the environmental benefits for the co-digestion of manure with food waste and biosolids with food waste in the tables below.

Table 2-2 IEUA RP-1 Manure Baseline and Co-Digestion Environmental Benefits

ENVIRONMENTAL BENEFITS	IEUA REGIONAL PLANT #1 WITHOUT MANURE (BASE CASE)	IEUA REGIONAL PLANT #1 WITH MANURE	IEUA REGIONAL PLANT #1 WITH MANURE AND FOOD PROCESSING WASTE (AS TESTED)	IEUA REGIONAL PLANT #1 WITH MANURE AND FOOD PROCESSING WASTE (FULL SCALE)
GHG Reductions (metric tons/year)				
Reductions From Manure Management				
Methane (CH ₄) reduction (tons/year)	0	25.8	25.8	25.8
CO ₂ equivalent of CH ₄ reduction (tonsCO ₂ E/year)	0	542.8	542.8	542.8
Nitrous Oxide (N ₂ O) reduction (tons/year)	0	8.6	8.6	8.6
CO ₂ equivalent of N ₂ O reduction (tonsCO ₂ E/year)	0	2,658.7	2,658.7	2,658.7
Reductions From Food Waste Management				
Methane (CH ₄) reduction (tons/year)	0	0.0	Up to 60	Up to 140
CO ₂ equivalent of CH ₄ reduction (tonsCO ₂ E/year)	0	0.0	Up to 1,190	Up to 3,000

ENVIRONMENTAL BENEFITS	IEUA REGIONAL PLANT #1 WITHOUT MANURE (BASE CASE)	IEUA REGIONAL PLANT #1 WITH MANURE	IEUA REGIONAL PLANT #1 WITH MANURE AND FOOD PROCESSING WASTE (AS TESTED)	IEUA REGIONAL PLANT #1 WITH MANURE AND FOOD PROCESSING WASTE (FULL SCALE)
Reductions From Reduced truck traffic				
Methane (CH ₄) reduction (tons/year)	0	0.0006	0.00036	0.0001
CO ₂ equivalent of CH ₄ reduction (tonsCO ₂ E/year)	0	0.012	0.0076	0.0024
CO ₂ emissions (tons/year)	0	9.6	4.4	(2.5)
Increases from Combustion (Energy Recovery)				
Methane (CH ₄) (tons/year)	0	2.4	2.7	3.1
CO ₂ equivalent of CH ₄ emissions increase (tonsCO ₂ E/year)	0	50.5	56.6	65.7
CO ₂ (tons/year)	0	0.0	0.0	0.0
Net GHG emissions reductions (Reductions from manure management & truck traffic less increases from combustion), (tons CO ₂ E/year)	0	3,200	3,100 - 4,300	3,100 - 6,100
NOx emissions (tons/year)				
Increases from Combustion (Energy Recovery)	0	0.86	1.0	1.1
Less: Reductions (Increase) From truck traffic	0	0.08	0.03	(0.05)
Net NOx Emissions Increase (Reduction)	0	0.78	0.94	1.2
SOx emissions (tons/year)				
Increases from Combustion (Energy Recovery)	0	0.24	0.27	0.31
Less: Reductions (Increase) From truck traffic	0	0	0	0
Net SOx Emissions Increase (Reduction)	0	0.24	0.27	0.3
Ammonia emission reductions (tons/year)				
Reduced from dairy stockpiles	0	58	58	58
TDS reduction in groundwater	0	5.2	5.2	5.2

ENVIRONMENTAL BENEFITS	IEUA REGIONAL PLANT #1 WITHOUT MANURE (BASE CASE)	IEUA REGIONAL PLANT #1 WITH MANURE	IEUA REGIONAL PLANT #1 WITH MANURE AND FOOD PROCESSING WASTE (AS TESTED)	IEUA REGIONAL PLANT #1 WITH MANURE AND FOOD PROCESSING WASTE (FULL SCALE)
(tons/year)				
Nitrate reduction in groundwater (tons/year)	0	0.22	0.22	0.22

Table 2-3 IEUA RP-1 Biosolids Baseline and Co-Digestion Environmental Benefits

ENVIRONMENTAL BENEFITS	RP-1 BASE CASE	RP-1 WITH BIOSOLIDS AND FOOD PROCESSING WASTE - AS TESTED	RP-1 WITH BIOSOLIDS AND FOOD PROCESSING WASTE - FULL SCALE
GHG Reductions (metric tons/year)			
Reductions From Food Waste Management			
Methane (CH ₄) reduction (tons/year)	0	Up to 520	Up to 1,080
CO ₂ equivalent of CH ₄ reduction (tonsCO ₂ E/year)	0	Up to 10,900	Up to 22,730
Increases From truck traffic			
Methane (CH ₄) reduction (tons/year)	0	0.0004	0.002
CO ₂ equivalent of CH ₄ reduction (tonsCO ₂ E/year)	0	0.008	0.049
CO ₂ emissions (tons/year)	0	12.6	76.7
Increases from Combustion (Energy Recovery)			
Methane (CH ₄) (tons/year)	0	4.7	5.5
CO ₂ equivalent of CH ₄ emissions increase (tonsCO ₂ E/year)	0	99.1	115.5
CO ₂ (tons/year)	0	0.0	0.0
Net GHG emissions reductions (Reductions from manure management & truck traffic less increases from combustion), (tons CO ₂ E/year)	0	Up to 10,790	Up to 22,540
NOx emissions (tons/year)			

ENVIRONMENTAL BENEFITS	RP-1 BASE CASE	RP-1 WITH BIOSOLIDS AND FOOD PROCESSING WASTE - AS TESTED	RP-1 WITH BIOSOLIDS AND FOOD PROCESSING WASTE - FULL SCALE
GHG Reductions (metric tons/year)			
Reductions From Food Waste Management			
Increases from Combustion (Energy Recovery)	0	1.7	2.0
Less: Reductions (Increase) From truck traffic	0	0.1	0.9
Net NOx Emissions Increase (Reduction)	0	1.8	2.9
SO₂ emissions (tons/year)			
Increases from Combustion (Energy Recovery)	0	0.5	0.5
Less: Reductions (Increase) From truck traffic	0	0.0	0.0
Net SOx Emissions Increase (Reduction)	0	0.5	0.5
Ammonia emission reductions (tons/year)			
Reduced from dairy stockpiles	N/A	N/A	N/A
TDS reduction in groundwater (tons/year)			
	N/A	N/A	N/A
Nitrate reduction in groundwater (tons/year)			
	N/A	N/A	N/A

Five project participants considered additional environmental benefits as important, including manure management, greenhouse gas and renewable energy credits, decreased residuals, decreased chemical usage when the biological hydrogen sulfide removal system is used - as opposed to the ferric feed/iron sponge method, healthier cows, reduction in use of natural gas, and a reduction in waste entering the landfills.

Environmental Drivers Non-Participant Responses

Thirteen non-participants answered questions about the most important environmental drivers for this project. Most responded that air quality benefits and renewable energy were the most important environmental drivers for dairy waste to energy projects. Other benefits that were mentioned included manure management, reduction in greenhouse gas emissions, less waste entering the landfills, and possibly a reduction in volatile organic compounds (VOCs) emissions. One respondent noted that the most important environmental benefits for dairies are not water quality related, however, water quality is currently regulated more so than air quality for agricultural industries. Most respondents replied that water quality benefits from dairy waste to energy projects are minimal. Another respondent replied that

the drivers for dairy waste to energy projects are economic, and are not due to environmental concerns.

Environmental Benefits Model

Eleven non-participants answered questions about the environmental benefits model. All six respondents from the dairy industry were unfamiliar with the details of the environmental benefits model and expressed an interest in using or reviewing the model and its results. One respondent did not believe that the dairy industry would be interested in the model, while two respondents were unsure. One project participant thought that certain dairies would be interested in the project, depending on their location and particular situation with methane control and nutrient loading. One of the air quality respondents also mentioned an interest in reviewing and/or using the model. A project participant mentioned that the model has been updated throughout the duration of the project. He believes the model is very useful and added that they have received a grant to continue researching the ammonia to PM₁₀ conversion factor so that ammonia emissions can be traded. Another project participant mentioned that the industry is very interested in the methodology for calculating baseline conditions.

2.2 Economic Assessment

The reported results from the co-digestion of dairy manure and food waste are presented in Table 2-4.

Table 2-4: IEUA RP-1 Manure Baseline and Co-Digestion Project Economics

ECONOMIC CONSIDERATION	EXISTING FACILITY AT IEUA REGIONAL PLANT NO. 1 (BASE CASE)	DAIRY MANURE ONLY AT IEUA REGIONAL PLANT NO. 1	CO-DIGESTION OF DAIRY MANURE / FOOD PROCESSING WASTE AT REGIONAL PLANT NO. 1 - AS TESTED -	CO-DIGESTION OF DAIRY MANURE / FOOD PROCESSING WASTE AT REGIONAL PLANT NO. 1 - FULL-SCALE -
Average annual output (\$)				
Total Annual Revenue from biogas power output (\$0.11/kWh)	0	\$ 173,448 ¹	\$ 193,395 ²	\$ 233,288
Capital cost (\$)				
Total Capital Investment (\$)	0	\$ 1,100,000	\$ 1,367,860	\$ 1,436,860

¹ Based on gas production of manure only.

² Based on gas production of manure and food processing waste co-digestion.

ECONOMIC CONSIDERATION	EXISTING FACILITY AT IEUA REGIONAL PLANT NO. 1 (BASE CASE)	DAIRY MANURE ONLY AT IEUA REGIONAL PLANT NO. 1	CO-DIGESTION OF DAIRY MANURE / FOOD PROCESSING WASTE AT REGIONAL PLANT NO. 1 - AS TESTED -	CO-DIGESTION OF DAIRY MANURE / FOOD PROCESSING WASTE AT REGIONAL PLANT NO. 1 - FULL-SCALE -
Annual O&M costs (\$/year)				
Total O&M cost	0	\$ 19,858	\$ 28,678	\$ 32,304
Environmental benefits (\$)				
Total Value of RECs at \$0.005 per kWh	0	\$ 7,884	\$ 8,791	\$ 10,604
Total Value of GHG emissions reductions	0	\$ 3,200	\$3,100 - \$4,300	\$7,750 - \$15,250
PM ₁₀ emissions reductions	0	Not Determined	Not Determined	Not Determined
Total Monetized Environmental Benefits (\$/yr)	0	\$ 11,084	\$11,891 - \$13,091	\$18,354 - \$25,854
Total Annual Cash Flows				
TOTAL ANNUAL CASH FLOWS (=Revenues from power output + Monetized Environmental Benefits - Annual O&M Costs)	0	\$164,700	\$176,600 - \$177,800	\$219,300 - \$226,800
Lifecycle Analysis:				
Present Value of annual cash flows at 6 % discount rate, 15 year project life	N/A	\$1,599,600	\$1,715,300 - \$1,726,900	\$2,130,300 - \$2,203,100
Net Present Value of Investment	N/A	\$499,600	\$347,440 - \$359,040	\$693,440 - \$766,240
Simple Payback period	N/A	6.7 years	7.7 - 7.7 years	6.3 - 6.6 years
Rate of return (percent)	N/A	12.4%	9.7% - 9.8%	12.7% - 13.4%
Incremental rate of return: manure only to full-scale manure co-digestion				16.6%

In the initial test plan developed under Task 3.1.3, the various costs associated with co-digestion of dairy wastes and food processing wastes were not estimated. As a result, no comparison to original estimates is possible.

For the business model assumed by this project, the economics appear somewhat favorable for co-digestion but not much better than simple anaerobic digestion of dairy manure. The

estimated rate of return and simple payback are not strong enough to make either technology overly attractive and this includes potential value of emissions reduction credits. The underlying business model uses the electric power generated from the biogas generated to offset electricity purchase costs. The tactical marketing plan that was developed during this project uses a different business model where a third party developer owns the generation and sells the power back to the facility. In both cases the facility sees the value of electricity at or near full utility rates. Under a model where the facility would sell the power back to the grid, the economics would likely be different as far as the value of the electricity generated. Market rates are substantially lower than utility rates.

In addition, the economics are viewed from the perspective of the WWT facility or host facility and not from the dairy operation. The concept of a centralized co-digester in this project assumes that a host facility either a) owns the digester and the biogas to energy generation and offsets its own electricity costs by using the power itself or b) a third party owns them and sells the power to the host at a rate lower than utility rates. In both cases the benefits to the dairies and the food processors are assumed to be lower waste disposal costs.

The reported results from the co-digestion of WWT biosolids and food waste are presented in Table 2-5.

Table 2-5 IEUA RP-1 Biosolids Baseline and Co-Digestion Project Economics

ENGINEERING/ECONOMIC CONSIDERATION	EXISTING FACILITY AT IEUA REGIONAL PLANT NO. 1 (BASE CASE)	CO-DIGESTION OF BIOSOLIDS / FOOD PROCESSING WASTE AT IEUA REGIONAL PLANT NO. 1 (AS TESTED)	CO-DIGESTION OF BIOSOLIDS / FOOD PROCESSING WASTE AT IEUA REGIONAL PLANT NO. 1 (FULL SCALE)
Average annual output (\$)			
Total Annual Revenue from biogas power output (\$0.11/kWh)	\$ 1,012,936	\$ 1,243,622	\$ 1,508,130
Capital cost (\$)			
Total Capital Investment (\$)	0	\$ 1,550,640	\$ 2,008,140
Annual O&M (\$/year)			
Total O&M	\$ 126,661	\$ 182,208	\$ 206,254
Environmental benefits (\$)			
Total Value of RECs at \$0.005 per kWh	\$46,000	\$56,500	\$68,600
Total Value of GHG emissions	0	Up to \$10,800	Up to \$56,300

ENGINEERING/ECONOMIC CONSIDERATION	EXISTING FACILITY AT IEUA REGIONAL PLANT NO. 1 (BASE CASE)	CO-DIGESTION OF BIOSOLIDS / FOOD PROCESSING WASTE AT IEUA REGIONAL PLANT NO. 1 (AS TESTED)	CO-DIGESTION OF BIOSOLIDS / FOOD PROCESSING WASTE AT IEUA REGIONAL PLANT NO. 1 (FULL SCALE)
reductions			
PM10 emissions reductions	N/A	N/A	N/A
Total Monetized Environmental Benefits (\$/yr)	\$46,000	\$56,500 - \$67,300	\$68,600 - \$124,900
Total Annual Cash Flows			
TOTAL ANNUAL CASH FLOWS (=Revenues from power output + Monetized Environmental Benefits - Annual O&M Costs)	\$ 932,275	\$1,117,900 - \$1,128,700	\$1,370,500 - \$1,426,800
Lifecycle Analysis:			
Present Value of annual cash flows at 6 % discount rate, 15 year project life	\$9,054,491	\$10,857,500 - \$10,962,300	\$13,310,400 - \$13,857,600
Net Present Value of Investment	N/A	\$357,100 - \$252,300	\$2,247,800 - \$2,795,000
Simple Payback Period	N/A	7.9 - 8.4 years	4.1 - 4.6 years
Rate of return (percent)	N/A	8% - 9%	20% - 24%

In the initial test plan developed under Task 3.1.3, the various costs associated with co-digestion of WWT biosolids and food processing wastes were not estimated. As a result, no comparison to original estimates is possible.

The resulting economics for the co-digestion of WWT biosolids and food waste are slightly better than those for co-digestion of dairy manure and food waste. Here too, the underlying business model for this pilot uses the electric power generated from the biogas generated to offset electricity purchase costs. If the facility were the digester and generation owner and was looking to sell the power back to the grid, the economics would be very different.

3

Project 3.1 - Evaluation of Technology Transfer Activities

The mission of the PIER program is not only to research and develop methods of improving renewable energy production and affordability, but also to effectively demonstrate and transfer the accomplishments to the industry stakeholders so that these advances can be incorporated into California energy markets in order to benefit all its citizens. This section presents the extent to which learning and technology advancements accomplished at the dairy waste to energy host facilities were communicated to other Commerce Energy PIER participants and to members of the renewable energy community.

During the interviews with individuals from the environmental quality, utility, biogas equipment manufacturing, and dairy industries, questions were asked about whether dairy waste to energy project design information was conveyed, how data and results from digester studies were transferred, and to whom the information was communicated. Both PIER participants and non-participants were surveyed to determine how they felt about the transfer of technological information regarding the conversion of dairy waste to biogas and codigestion with food processing wastes.

3.1 Communication of Operating Data, Concerns, and Project Results

A total of five respondents answered questions about whether project information, concerns, and results were communicated effectively. Most of these respondents were directly involved with the Commerce Project 3.1. On the whole, the respondents agreed that data and results from the dairy digester comparison study and the benefits of codigestion were successfully communicated to the other PIER participants, the California Energy Commission (CEC), and the Project 3.1 Technical Advisory Committee (TAC). Three of the respondents commented on how closely engaged the project team members were about discussing the data and results. This regular communication occurred through weekly team meetings, teleconferences, and regular email communications. Only one project team member stated that operating data and results were not communicated with the CEC, Project 3.1 TAC, or system developers. This member did state, however, that system installers were involved and they did communicate project developments.

When individuals were asked about whether Project 3.1 food waste codigestion and biogas cleaning findings were discussed with energy industry members and whether energy researchers are aware of the project, fourteen interviewees replied. Half of the responses were positive, though it was clear from the collection of responses that utility and environmental industry members were less aware of the Commerce Project 3.1 details than equipment manufacturers, designers, and installers. However, it should be noted that almost all of the respondents were aware of dairy waste to energy projects in general.

Commerce Project 3.1 results and those of similar dairy waste conversion projects have been presented at conferences, authored in trade journal articles and company newsletters, and discussed with those industry members interested in renewable energy or distributed power generation. The conferences mentioned by survey respondents include those held by the Women's Engineering Society (WES), the American Water Works Association (AWWA), and the California Water Environment Association (CWEA). One respondent mentioned reading about Project 3.1 details on the Commerce PIER Mini-Grid website (www.pierminigrid.org). Another felt that while energy researchers are familiar with biogas projects, they should be more aware. One respondent indicated that the results should be presented at the annual AgSTAR National Conference in Wisconsin in April, 2006 - because this is the most important conference in the dairy industry.

CH2M Hill provided Itron with a compiled list of thirteen (13) conference papers related to biogas production, anaerobic digestion, co-digestion of dairy waste with processed food waste, and biogas cleaning. These papers were authored by six different individuals and all were presented at conferences held during 2005, providing further evidence of the technology transfer that has occurred to date. Most of these authors were involved in some way or another with Commerce Project 3.1. Conferences at which these papers were presented include the California Water Environment Association (CWEA) Annual Conference, the Residuals and Biosolids Management Conference, the Innovative Uses of Biosolids and Animal and Industrial Residuals Conference, the Water Environment Federation (WEF) Residuals and Biosolids Management Conference, and the Water Environment Federation Technical Exhibition and Conference (WEFTEC).

Twenty-three individuals responded to an inquiry as to whether there is interest in the energy community to initiate similar types of projects. Seventeen of the respondents agreed that there is interest and that this interest stems from the environmental benefits of using biogas, the reduction of waste that needs to be eliminated, and the reduced costs of energy use through self-generation. These seventeen respondents include individuals in utility, dairy, environmental quality, and equipment manufacturing industries.

Of the group of negative or neutral respondents, three stated that there is not enough interest; two respondents believe there hasn't been enough success to date and the third commented that current attitudes of investor-owned utilities prevents the development of renewable energy projects.

The remaining respondents gave mixed answers about the energy community's interest in future projects related to dairy waste conversion to energy. Some felt that while the energy community is interested, no one is willing to carry out the projects. Members of the utility industry stated that they were interested, but that they would like to see more developments in additional transmission capacity to make the most of the renewable energy generated from the dairy waste. Others said that waste water management industry members and those who operate dairies have more of an interest because both have to deal with waste volume and the impacts upon water quality in the region. Still others felt there would be more interest if the benefits related to renewable energy, greenhouse gas, and particulate emissions reduction credits were tapped into as an additional source of revenue from these types of projects.

4

Assessment of Market Impacts

This section addresses the effects of the Commerce Project 3.1 advancements on the potential market acceptance of dairy waste to energy projects. To determine the likely market impacts, an assessment is made of how well the technical and economic feasibility of centralized anaerobic digesters (CAD) for dairy waste to energy has been demonstrated. Additionally, it is based on a demonstration of the methodology used to quantify the environmental benefits of using centralized anaerobic digesters. The market impacts discussed here are based on qualitative judgments regarding the cost-effectiveness of the demonstrations as well as their effectiveness in mitigating non-cost barriers.

4.1 Obstacles

In order for future dairy waste to energy projects to be successful, it is beneficial to address the obstacles that have been faced to date when such projects have been carried out. Gathering information about these obstacles helps to ease the difficulties of implementing biogas production projects in the future. Thirteen responses from the environmental quality, waste water and electric utility, and dairy industries were recorded when interviewees were asked about the obstacles encountered when designing and implementing renewable energy conversion from dairy waste projects. Some of the general barriers cited include environmental regulations and high capital and operational costs. One respondent stated that with additional projects there are more technological transfer activities; ways to reduce these costs may be uncovered, thereby lowering these barriers. Another respondent indicated that a more important factor for a successful centralized co-digester than the power generated by the biogas was the conversion of post-digester solids into a usable product, such as turf fertilizer or cow bedding. The same respondent commented that the Federal government needs to help with the high capital costs associated with these projects or they won't happen.

Individuals in the dairy industry stated that the utilities represent a significant barrier to the implementation of dairy waste to energy projects because (1) they do not offer full retail value for the energy that is produced and (2) interconnectivity to the grid is limited. Another responder stated that on the outside, utilities encourage the pursuit of these projects, but this may not always be the case in actuality. Because utilities are often monopolies, producers of biogas for energy are seen as competitors. Utilities may therefore feel their market

advantage is being diminished. From the utility industry, one respondent made the observation that while dairy waste to energy projects may be difficult to bring online, they would be a good hedge against the rising prices of natural gas. If the price of natural gas rises over the next decade or two, the use of biogas will be looked upon more favorably.

Interviewees were asked whether the Project 3.1 pilot carried out under the Commerce PIER Program has helped to demonstrate that obstacles affecting dairy waste to energy projects can be overcome. Eight responses of mixed opinion were recorded. Most felt that while Project 3.1 results did take steps towards the acceptance of this method of energy generation, more information and successful demonstrations are needed. One interviewee mentioned the need for additional technical transfer activities to inform the energy community and dairies of the success of co-digestion and cogeneration. Two individuals said that Project 3.1 outcome was positive, but that interconnectivity to the grid and environmental consequences are still present and need to be dealt with more effectively.

4.2 Technical Feasibility and Cost-Effectiveness

Interviewees were asked whether they believe biogas to energy projects are technically feasible and cost-effective. Of the six respondents who replied to these questions, all were confident that these projects were technically feasible. However, mixed responses were recorded when these individuals were surveyed about their cost-effectiveness. Only one respondent said biogas projects are cost-effective, while the others gave more conditional responses such as “*they can be*” or “*it is still to be determined.*” Three of the respondents said they were not sure or did not know about how cost-effective are projects involving biogas to energy projects.

4.3 Environmental Benefits of Dairy Waste to Energy

One way to break down barriers to the acceptance of dairy waste to energy projects is to present the quantified environmental benefits resulting from them. To assess the impact of this information, interviewees were asked about their familiarity with environmental benefits models used to quantify benefits from biogas projects in general, and Project 3.1 in particular. Twelve respondents said that they expect dairies and other involved groups to be interested in models to assess the environmental benefits but most of them were not familiar with the environmental benefits model used to assess the impacts of Project 3.1. Most of the respondents had not used a similar model, but instead relied on cost-effectiveness measures of biogas projects. The respondents were all interested in reviewing the model to see if it would be useful to them or to those in the environmental quality, waste water and electric utility and the dairy industries.

4.4 Potential for Emissions Trading

In the process of generating biogas from dairy waste through co-digestion with processed food waste, the opportunity to generate revenues from the monetization and sale of renewable energy credits, greenhouse gas (GHG) credits, and particulate emission reduction credits arises. The economic benefits from the sale of these credits can be significant and could help increase interest in dairy waste to energy projects. To assess awareness of the opportunity to generate revenue in this manner, respondents who are familiar with environmental quality and emission trading opportunities were asked about the progress in this area specifically as it relates to Project 3.1. Two individuals responded and both stated that trading programs related to the trade of emissions from these projects are being discussed in both northern California and southern California. It was recognized that if trading infrastructures are established, it will further promote the advantages of dairy waste to energy projects.

4.5 Future Biogas Projects

The future of biogas to energy projects penetrating the market was also assessed by asking individuals if they were familiar with any other projects being planned as a result of projects implemented under the PIER Program. Of the seventeen individuals who responded, eleven were aware of related projects though they were not sure if these projects were planned as a direct result of Commerce Project 3.1. A majority of the projects described by the interviewees are related to funding and installation of digesters at dairies for the purpose of codigestion, though there was mention of projects involved in gas cleaning to remove siloxanes and carbon media for H₂S. One interviewee had spoken to a few individuals who are interested in pursuing co-digestion projects to increase biogas production for use as fuel.

5

Summary & Conclusions

5.1 Meeting the Goals of the PIER Project

Project 3.1, Dairy Waste to Energy, under the Commerce Energy Contract No. 500-00-036 had three specific goals. These were:

- Develop technologies that can be used to maximize the energy production and recovery from animal waste,
- Develop and evaluate different pilot projects that include facilities at existing treatment plants and/or at individual and clusters of dairies, and
- Evaluate and test the effectiveness of low and high technologies developed in North America and Europe for the collection, processing, and energy recovery from animal waste.

Under this project, the Commerce Energy team designed and tested a process where by dairy waste was co-digested with food wastes at a centralized facility. In addition, WWT biosolids were also co-digested with food wastes. The choice of a WWT facility to act as the centralized co-digestion facility was made because of the availability of excess digester capacity and the proximity of necessary digester feed stocks. This arrangement does not have a large potential within California, but it has the potential of being exploited more quickly than other centralized designs.

The test successfully demonstrated that centralized co-digestion of dairy waste under certain circumstances is a technically and economically viable technology for maximizing the biogas production and recovery from animal waste. The testing resulted in sufficient data that the CE team was able to develop a model for predicting the rate and timing of biogas production based on factors such as the type and amount of food waste entering the digester with the dairy waste.

The measurement and evaluation portion of this project, summarized by this report, sought to address three issues. First, were the pilot system performance and reliability testing criteria appropriate and sufficiently comprehensive? Second, were the technology transfer effectiveness goals of the project met? Third, were the project's market impact goals met?

The testing and performance criteria were found to be appropriate and sufficiently comprehensive. This is not to say that more couldn't be done, but rather given the constraints of the project, it produced sufficiently credible results. The data from the project provided sufficient information for a dairy waste co-digestion model to be developed.

In meeting the technology transfer goal, the CE team made presentations at numerous industry conferences which is viewed by many to be a very effective means of transferring the knowledge developed through the project. The WWT industry tends to be conservative in its adoption of new technologies and needs to see successes before adopting them. The general consensus among the CE team and other stakeholders is that the efforts toward technology transfer should continue.

The effect this project will have on the market within California is not yet known, but it is seen by stakeholders as being potentially very positive. The estimated potential environmental and economic benefits to the dairies, food processors and the WWT facilities as well as the communities surrounding them are seen as being significant.

5.2 Conclusions

Dairy waste co-digestion utilizing excess digester capacity at WWT facilities is ready to be taken to market. The knowledge gained through this project is sufficiently thorough to allow existing WWT facilities with excess digester capacity to consider being a host to a full scale centralized dairy and food waste co-digestion facility. Such a facility will need to have automated feed systems to control the mixing of wastes and thereby control the rate of biogas production so as not to tax the gas transport and storage systems. A good engineering review of the gas transport and storage facilities at the host site will be necessary so that the proper mix of dairy to food waste can be specified. This will help avoid leakages/releases from the system resulting from excessive biogas production and prevent environmental penalties to the host facility.

The co-digestion with WWT biosolids and food waste did not have the chance to complete its full testing and as a result the real benefits were not firmly established. Preliminary results were favorable and warrant a continuation of its testing. There is the potential that a similar co-digestion biogas model could be developed for WWT biosolids.

In order to facilitate the implementation of dairy waste to energy projects, economic barriers need to be addressed and cost-effectiveness needs to increase. Utilities have been an obstacle thus far because they do not offer full retail value for the energy that is produced and interconnectivity to the grid is limited. If the market for air emissions is expanded and a market for water quality improvements is developed, this will benefit the cost-effectiveness

of dairy waste to energy projects. Further dissemination of this project's and similar successful projects' results will encourage dairies and wastewater treatment facilities to undertake a dairy waste to energy project.

There are potentially significant market impact benefits for the Energy Commission to facilitate such a project by providing match funding to stimulate the development of a full scale dairy co-digestion implementation. These benefits include development of and investment in a renewable source of energy that could potentially off-set the rising costs of natural gas.