Arnold Schwarzenegger
Governor

COMMERCE ENERGY BIOGAS/PV MINI-GRID RENEWABLE RESOURCES PROGRAM

PROJECT 3.1 CO-DIGESTION OF DAIRY MANURE/FOOD PROCESSING WASTES AND BIOSOLIDS/FOOD PROCESSING WASTES TO ENERGY

PIER FINAL PROJECT REPORT

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Preface

The Public Interest Energy Research (PIER) Renewable Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER program, managed by the California Energy Commission (Energy Commission), annually awards up to $62 million to conduct the most promising public interest energy research by partnering with research, development, and demonstration (RD&D) organizations, including individual, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following six RD&D program areas:

- Buildings End-Use Energy Efficiency
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy
- Environmentally-Preferred Advanced Generation
- Energy-Related Environmental Research
- Strategic Energy Research

What follows is the final report for the PIER Commonwealth Biogas/PV Mini-Grid Renewable Resources RD&D Program, Contract Number 500-00-036, conducted by the Commerce Energy Team. The team consists of Commerce Energy; RER, Inc. (a wholly owned subsidiary of Itron, Inc.); CH2M HILL; Endecon Engineering; Renewable Energy Development Institute (REDI); and Zaininger Engineering, Inc (ZECO). The report is titled *Task 3.1.7.c – Final Report for Project 3.1*. This project contributes to the PIER Renewable Energy Program.

For more information on the PIER Program, please visit the Energy Commission's website at http://www.energy.ca.gov/research/index.html or contact the Energy Commission's Publications Unit at 916-654-5200. Alternatively, you may review the PIER Commerce Energy website at http://www.pierminigrid.org, which was created for this contract and provides a summary of each project of the contract.

Abstract

Project Purpose

Project 3.1, Co-Digestion of Dairy Manure/Food Processing Wastes and Biosolids/Food Processing Wastes to Energy demonstrates and advances the use of co-digestion with (1) manure and food processing waste and (2) biosolids produced in sewage treatment plants and food processing waste, to generate renewable energy. Using co-digestion, biogas production can increase by 10 to 40 percent in anaerobic digesters. This additional gas can be used to generate electricity, making such renewable energy more affordable in California.

Project Objectives

The objectives of Project 3.1 are to:

- Develop and demonstrate technologies that can be used to maximize energy recovery from dairy waste.
- Develop and evaluate pilot projects at existing treatment plants or at California dairies.
- Evaluate the effectiveness of technologies developed in North America and Europe for the collection, processing, and energy recovery of dairy waste.
- Quantify potential environmental benefits of dairy waste to energy projects.

Actual Project Outcomes

1. Developed operational pilot plants to test the co-digestion of dairy manure/food processing wastes, co-digestion of biosolids/food processing wastes, and biological cleaning of digester gas (removal of hydrogen sulfide).
2. Performed economic and technical analyses of the co-digestion projects.
3. Developed a model to predict gas production from co-digestion projects.
4. Prepared reports documenting the environmental benefits of co-digestion and the performance and results from the testing of (1) co-digestion of dairy manure/food processing wastes, (2) co-digestion of biosolids/food processing wastes, and (3) biological gas cleaning of biogas produced from these processes.
5. Presented the results of project activities at technical and professional meetings.

Project Conclusions

Pilot projects and analysis of statewide dairy operations, sewage treatment plants, and food processing facilities have shown that significant opportunities exist to implement co-

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digestion projects with environmental and economic benefits by both increasing renewable energy production and improving waste management practices.

Environmental benefits in the areas of greenhouse gas emission reductions credits, renewable energy credits, and particulate matter $(PM)_{10}$ emissions reductions can be obtained on similar statewide projects.

The economics of both manure/food processing waste and biosolids/food processing waste co-digestion projects were demonstrated to be favorable at the demonstration-scale project, and activities are underway to implement the project at full scale.

Key findings are as follows:

1. Co-digestion of food waste and manure produces more biogas than anticipated from adding the gas yields of manure and food waste alone.
2. The added gas production from co-digestion requires evaluation and potential upgrade of the gas handling system for safety and environmental reasons.
3. A model to predict gas production was developed based on the testing conducted under PIER program.
4. Environmental benefits from manure digester gas projects are important, particularly as related to air and water quality.
5. Co-digestion potential is significant in California, the economics of projects appear to be favorable, and projects are actively being planned in the state.

Executive Summary

Introduction

This final report for Project 3.1 summarizes the work and findings of the Commerce Energy Team in the area of dairy waste to energy from 2001 to 2005. During this time, the team explored a number of different technologies available for improving dairy waste to energy projects, selected technologies to pilot and a host site at which to implement a pilot study, designed and implemented a pilot test regime, and established and quantified environmental and economic benefits that could be gained by implementing the selected technology around the state.

The selected technology was co-digestion of manure with food waste. This technology was expanded to include co-digestion of biosolids sludge with food waste at sewage treatment plants. Co-digestion involves combining food waste and manure in anaerobic digesters and subjecting them to the same biological activity. The result is a substantial increase in biogas production over manure alone. An additional benefit is the removal of a food waste management problem.

Purpose of Project 3.1

Project 3.1, Co-Digestion of Dairy Manure/Food Processing Wastes and Biosolids/Food Processing Wastes to Energy (or "dairy waste to energy"), is intended to demonstrate and advance the use of (1) manure and food processing waste and (2) biosolids produced in sewage treatment plants and food processing waste in processes involving co-digestion to produce more renewable energy. Using co-digestion, biogas production can increase by 10 to 40 percent in anaerobic digesters. This additional gas can be used to generate electricity, resulting in both economic and environmental benefits. Overall, this project will use co-digestion to produce more biogas and then use the biogas to produce electricity, making renewable energy more affordable in California.

At the outset of Project 3.1, the focus was on dairy waste to energy projects. As the project progressed, the focus expanded. It became clear that the best opportunity for increasing the number and size of dairy waste-to-energy project opportunities in California would be to focus on co-digestion. Key components of the Project 3.1 tasks that led to this decision were:

- A digester comparison study conducted under Task 3.1.1, which compared performance of dairy waste anaerobic digesters in the United States and Europe and evaluated their cost effectiveness. This study concluded that dairy manure projects that included co-digestion with food processing waste produced more biogas, generated more electricity, and were more cost-effective than those that did not.
- A tactical marketing plan developed under Task 3.1.2, which focused on developing the dairy waste-to energy market in California and concluded that a number of wastewater treatment plants with existing available digester capacity could be used for co-digesting

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food processing waste with both manure and sewage biosolids sludge (referred to as "biosolids" in this report).

Project 3.1 Objectives

Based on the results of the digester comparison study and the tactical marketing plan, the project goals were refined as follows:

- Develop technologies that will address the lack of knowledge of the relationship between various co-digestion feedstocks and gas production. Pilot-scale (demonstration) systems will be developed to yield information on the direct relationship among the physical and chemical characteristics of the feedstocks and the operating parameters of the co-digestion system and the increase in gas production associated with their co-digestion.
- Provide information for future users when developing optimal blends or "cocktails" for co-digestion projects.
- Quantify potential environmental benefits of dairy waste to energy projects so that their values can be identified as the individual projects are being implemented.
- Report the results of studies conducted that led to the establishment of the goals listed above.

Project activities were then conducted to achieve these goals.

Actual Project Outcomes

The projected and actual outcomes for each objective are summarized in Table ES-1. These outcomes are discussed further in Sections 3 and 4 of this report.

TABLE ES-1
Project 3.1 Objectives, Projected Outcomes, and Actual Outcomes

Objective	Projected Outcome	Actual Outcome
Develop technologies that will address the lack of knowledge of the relationship between various co-digestion feedstocks and gas production. Pilot (demonstration) scale systems will be developed to yield information on the direct relationship among the physical and chemical characteristics of the feedstocks and the operating parameters of the co-digestion system and the increase in gas production associated with their co-digestion. Provide information for future users when developing optimal blends or "cocktails" for co-digestion projects.	The following pilot plants will be developed: • An operational pilot plant of co-digestion of dairy manure/food processing wastes using existing Digester No. 4 at Regional Plant 1 (RP-1) of the Inland Empire Utilities Agency (IEUA). Currently, this digester is used to process about 14 tons/day of dairy manure at an average flow of 35,000 gal/day with a total solids content of 9 percent. Food processing wastes will be added to the existing digester for co-digestion with the dairy manure. The feeding ratio of the dairy manure/food processing wastes to the digester will be tested and optimized. The expected incremental biogas production for co-digestion of manure and food processing wastes for the range of food processing wastes to be tested is expected to be from 15,000 to 25,000 cubic feet per day (cf/d).	The following pilot plant were developed: • An operational pilot plant of co-digestion of dairy manure/food processing wastes using existing Digester No. 4 at RP-1. Food processing wastes were added to the existing digester for co-digestion with the dairy manure. The feeding ratio of dairy manure/food processing wastes to the digester was tested and optimized. Dairy manure co-digestion tests with food processing wastes exhibited higher-than-expected increases in gas production. • An operational pilot plant of co-digestion of biosolids/food processing wastes using existing digesters 6 and 7 at RP-1 of the IEUA. Food processing

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TABLE ES-1
Project 3.1 Objectives, Projected Outcomes, and Actual Outcomes

Objective	Projected Outcome	Actual Outcome
	The expected additional power generation using the extra biogas generated from co-digestion is 25 to 55 kW. • An operational pilot plant of co-digestion of biosolids/food processing wastes using existing Digesters 6 and 7 at RP-1 of the IEUA. Currently, these two digesters are used to process about 42 tons/day biosolids at an average flow of 300,000 gal/day with a total solids content of 4 to 5 percent. Food processing wastes will be added to the existing digesters for co-digestion with biosolids. The feeding ratio of the biosolids/food processing wastes to the digesters will be tested and optimized. For the ranges of food processing wastes being tested, the expected incremental biogas production for co-digestion of biosolids and food processing wastes is expected to be from 180,000 to 270,000 cf/d. The expected additional power generation using the extra biogas generated from co-digestion is 400 to 600 kW. • An operational pilot plant for biological gas cleaning at a maximum design capacity of 140 CFM for biological hydrogen sulfide (H_2S) removal system, and 120 CFM maximum for the moisture and siloxane removal system. The typical operation would be in the range of 20 to 70 percent of the design capacity.	wastes were added to the existing digesters for co-digestion with biosolids. The feeding ratio of the biosolids/food processing wastes to the digesters were tested and optimized. Co-digestion of biosolids/food processing wastes did not result in a measurable increase in gas production. • An operational pilot plant for biological gas cleaning (H_2S removal) of digester gas from Digester 4. In addition to the pilot plants that were tested, a model to predict gas production was developed based on the testing conducted under the Commerce Energy PIER program. Economic and technical analyses of co-digestion projects were performed.
Quantify potential environmental benefits of dairy waste to energy projects so that their values can be identified as the individual projects are being implemented.	Reports documenting environmental benefits will be prepared.	The model to predict gas production was used to quantify emission reductions for the pilot (as-tested) and full-scale projects for manure and biosolids co-digestion at RP-1. Reports documenting environmental benefits were prepared.
Report the results of studies conducted that led to the establishment of the goals listed above.	Reports documenting the performance and results from the testing of (1) co-digestion of dairy manure/food processing wastes, (2) co-digestion of biosolids/food processing wastes, and (3) biological gas cleaning for biogas produced from these processes will be prepared. Marketing of co-digestion to targeted opportunities in California, including both dairy waste/food processing wastes and biosolids/food processing wastes.	A report documenting the performance and results from the testing of (1) co-digestion of dairy manure/food processing wastes, (2) co-digestion of biosolids/food processing wastes, and (3) biological gas cleaning for biogas produced from these processes was prepared. The activities of the project were presented at technical and professional meetings.

Conclusions

Pilot projects for biosolids and food waste co-digestion at the Inland Empire Utilities Agency (IEUA) RP-1 facility and research into dairy operations, sewage treatment plants, and food processing facilities around the State of California have shown that significant

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opportunities exist to implement co-digestion projects at these facilities and realize both environmental and economic benefits, including increased renewable energy production and improved waste management practices.

Environmental benefits in the areas of greenhouse gas emission reductions credits, renewable energy credits, and potentially PM_{10} emissions reductions can be obtained on future similar projects around the state. Water quality benefits cannot be monetized at this time because there are no existing markets where emission reductions can be traded. However, these benefits are important from a water quality standpoint in the areas where the dairies are located.

The economics of both manure/food processing waste and biosolids/food processing waste co-digestion projects were demonstrated to be favorable at the demonstration-scale project at IEUA RP-1, and activities are underway to implement a full-scale project at RP-1 and other IEUA facilities.

The key findings from Project 3.1 are summarized in the following list. These findings are discussed further in Section 4 of this report.

1. Co-digestion of food waste and manure produces more biogas than anticipated from adding the gas yields of manure and food waste alone.
2. The added gas production resulting from co-digestion of manure and food processing waste or biosolids and food processing wastes requires careful evaluation and potential upgrade of the gas handling system for safety and environmental reasons.
3. A model to predict gas production was developed based on the testing conducted under the Commerce Energy PIER program.
4. Environmental benefits from manure digester gas projects are important, particularly as related to air and water quality.
5. Co-digestion potential is significant in California, the economics of projects appear to be favorable, and projects are actively being planned in Southern California and the Central Valley.
6. The wastewater treatment community is increasingly interested in co-digestion, and the PIER Renewable Program is contributing to increased knowledge and interest in co-digestion.

Recommendations

The following are recommendations from Project 3.1:

- Establish a technology transfer program to disseminate information about the benefits of co-digestion so that proponents can initiate co-digestion at facilities around the state of California. This includes co-digestion projects involving manure and food processing waste and biosolids and food processing waste. It also includes describing the opportunity to use available digester capacity at existing wastewater treatment plants.

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- Along with the technology transfer program described above, use the co-digestion model produced under this project to estimate gas production rates for potential future projects. This model has safety factors built into it, and they should be reviewed on a case-by-case basis on future projects.
- When considering and evaluating individual co-digestion projects, address revenue streams from both increased energy production and environmental benefits, including renewable energy credits when evaluating the economics of individual co-digestion projects.
- Carefully review food waste addition practices and gas system capacities for each project to make sure they are compatible with the anticipated gas production increases.

Benefits to California

A statewide location analysis was done for California and showed that there are a number of areas around the state where sewage treatment plants, large dairies and other animal feed operations, and food processing facilities are located close to each other and would be candidate sites for implementing co-digestion and realizing both environmental and economic benefits. Figure ES-1 shows the results of that analysis.

The technical and marketing potential for new generation from biosolids co-digestion in California is significant in both the mid-term (next five years) and long-term (next 10 to 15 years). Furthermore, with the addition of monetized environmental benefits, the economic performance of these projects can be attractive, with projected rates of return up to 25 percent on initial investment, as shown in Table ES-2.

TABLE ES-2
Technical and Market Potential for New Renewable Power (MW) in California from Co-Digestion of Food Waste with Dairy Manure and Biosolids

	Technical Potential (MW)		Market Potential (MW)	
	Long-Term	Mid-Term	Long-Term	Mid-Term
Dairy Manure Co-Digestion	334	110	250	82
Biosolids Co-Digestion	129	59	97	44

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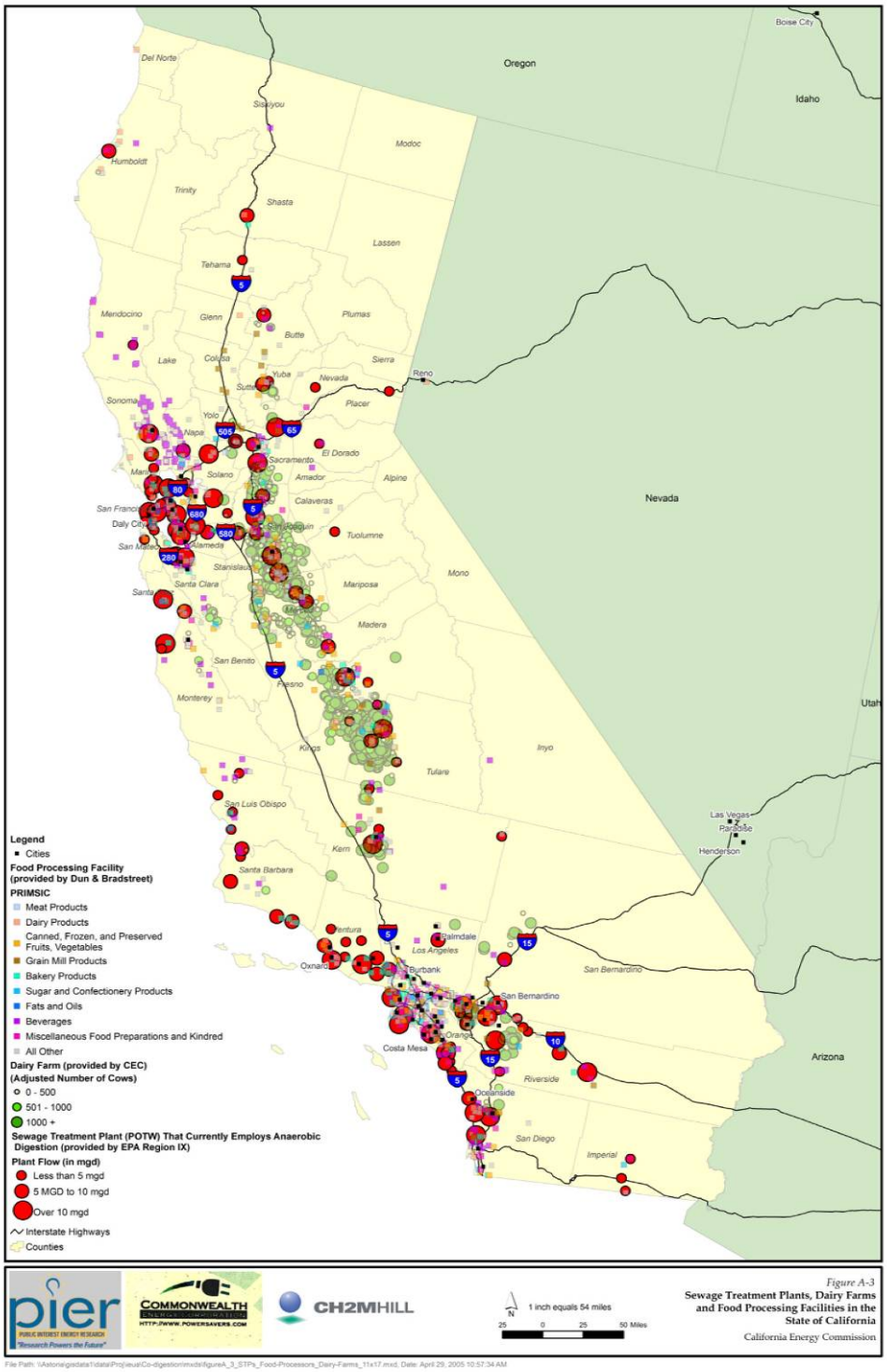

FIGURE ES-1
Statewide Locations of Large Sewage Treatment Plants, Dairy Operations, and Food Processing Facilities

SECTION 1

Introduction to the Commonwealth Program Project 3.1

In June 2001, the Commerce Energy Team was awarded a program contract under the California Energy Commission's (Energy Commission's) Public Interest Energy Research (PIER) Renewable Program to conduct research on strategies for making renewable energy more affordable in California. The team devised an approach that consisted of the following steps: (1) Assess the combined potential of biogas and photovoltaic (PV) resources in a defined study area, and (2) Identify how these resources can be developed in a complementary and cost-effective manner. Research was conducted in a practical, real-world setting so that the findings could be applied elsewhere in California and thereby benefit more California ratepayers. The local area selected for renewable energy research activities is the Chino Basin, referred to in this report as the "study area."

1.1 Background

The Chino Basin is rich in PV and biogas resources. Moreover, it is a rapidly growing area with substantial and increasing electrical loads. The underlying goal of the PIER Renewable Program is to identify potential building integrated PV (BIPV) and biogas energy projects, bring innovative technologies and business practices to these projects, assess the benefit to the local electricity distribution system (the "mini-grid"), and then use the findings to develop a business model for siting cost-effective, renewable energy projects. A description of the PIER Renewables Program, including the results of some of the work undertaken to date, is presented on the project website: http://www.pierminigrid.org.

As part of the PIER Renewables Program, candidate demonstration projects that advance the understanding of the use of biogas to reduce the need for improvements to the existing study area electrical power distribution system were selected from the mini-grid study area for analysis. This report documents the process involved in the assessment, evaluation, and selection of dairy waste to energy technologies as candidate projects. The technologies selected and possible demonstration projects will be further compared and evaluated against other demonstration projects identified in Project 2.1, Enhanced Landfill Gas Production Using Bioreactors; Project 2.2, Enhanced Energy Recovery Through Optimization of Anaerobic Digestion and Microturbines Project; Project 3.2, Building Integrated PV Testing and Evaluation Report; and Project 3.3, Building Integrated PV on Public Facilities Project.

1.2 Overview of Project 3.1—Dairy Waste to Energy

The primary objectives of Project 3.1, Co-Digestion of Dairy Manure/Food Processing Wastes and Biosolids/Food Processing Wastes to Energy (referred to in this report as the dairy waste to energy project), are to:

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

The Chino Basin is an ideal location for undertaking these projects. It has one of the largest concentrations of dairy cows in the world, with more than 300,000 cows located within a 50 square mile area. It is also well-suited for PIER research because Inland Empire Utilities Agency (IEUA), the local water basin entity responsible for treating wastewater, has led the region in its efforts to better manage the waste from the dairies and to explore alternatives to use it to produce energy. IEUA is a partner in the PIER Program. Recognizing the opportunity created by IEUA's program in converting manure to energy, the Energy Commission authorized the Commerce Energy Team to evaluate the performance of anaerobic digestion projects to convert dairy manure to energy. The purpose of this evaluation was to provide a baseline against which the performance of dairy waste digester projects at IEUA facilities could be effectively compared to other digesters.

As work on Project 3.1 progressed, important findings were reached that helped narrow the focus of Project 3.1 to those areas that offered the greatest opportunity for improving the performance and economic viability of various dairy waste to energy projects and technologies. Most notably, Project 1.1 and early Project 3.1 work brought to light the opportunity of co-digestion of dairy waste and other feedstocks such as food processing waste and municipal biosolids to improve the performance of digesters. By looking at the processes involved and the European experience in this field, it was evident that co-digestion, if properly employed, would substantially increase gas production and improve the overall performance of digester projects. This would be accomplished while at the same time improving waste management practices in food processing and other sectors that would provide their available wastes as feedstocks for co-digestion with dairy manure.

The Commerce Energy Team also recognized an opportunity to use available digester capacity at wastewater treatment plants in the Chino Basin and elsewhere in California, making the co-digestion efforts proposed at RP-1 more relevant throughout the state. An additional finding was that co-digestion of biosolids and food processing waste also represents an important opportunity to increase renewable fuel and energy production that is closely aligned with the manure co-digestion work of this program. This led to the incorporation of a biosolids co-digestion element into the program, making the findings of this technology assessment even more broadly applicable to the California market.

Project 3.1 now offers a strong focus on projects incorporating both dairy manure co-digestion and biosolids co-digestion that can be successfully implemented throughout the State of California.

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1.3 Project 3.1 Tasks

Project 3.1 includes the following tasks:

- 3.1.1 Assess, Evaluate, and Select Dairy Waste to Energy Technology.
  - 3.1.1.a Assess, Evaluate, and Select Dairy Waste to Energy Technology—Phases 1 through 3.
  - 3.1.1.b Assess, Evaluate, and Select Dairy Waste to Energy Technology—Final Report (with detailed system design, energy, and material balances for the identified processes).
- 3.1.2 Site Selection and Tactical Marketing Plan.
  - 3.1.2.a Site Selection.
  - 3.1.2.b Tactical Marketing Plan.
- 3.1.3 Design the Pilot Plant(s) and Prepare Test Plans on Co-digestion of: 1) Dairy Manure with Food Processing Waste, and 2) Biosolids and Food Processing Waste.
  - 3.1.3.a Develop Bench Scale Test Plan.
  - 3.1.3.b Conduct Bench Scale Tests.
  - 3.1.3.c Design the Pilot Plants and Develop Pilot Scale Test Plans.
- 3.1.4 Construct Pilot (Demonstration) Plant(s).
- 3.1.5 Operate and Test Pilot (Demonstration) Plant(s).
- 3.1.6 Conduct Economic and Environmental Assessment.
- 3.1.7 Prepare Final Report for Project 3.1.
- 3.1.8 Coordinate with Renewables Project Advisory Committee.
- 3.1.9 Perform Detailed Distribution Interconnection Study.
- 3.1.10 Dynamic Study of Three BI-PV and Biogas High-Penetration Scenarios.
- 3.1.11 Evaluate Project 3.1.

1.4 Objectives of Task 3.1.7 report:

To fulfill the scope of Task 3.1.7, the objectives of this report are to:

- Provide a summary of Tasks 3.1.1 through 3.1.6 (Section 2).
- Present the results and analyses of the pilot demonstration tests (Section 3).
- Describe the economics of each project, including the installation, operation, maintenance costs, and value of any environmental benefits achieved (Section 3).

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- Include additional information such as changes in greenhouse gas emissions that can be quantified but not as easily monetized (Section 3).
- Present conclusions and recommendations derived from the pilot tests, include the identification of pilot tested technologies that achieve the goal of maximizing energy recovery, the cost-effectiveness of centralized versus farm-based treatment facilities, and additional testing requirements (Section 4).

1.5 Project Report Organization

This report is organized as follows:

- **Section 1, Introduction,** provides background and overview information on Project 3.1, Dairy Waste to Energy, and Project 3.1 tasks. Project objectives are identified.
- **Section 2, Project Approach,** discusses the approach, or methodology, followed to accomplish Project 3.1 objectives. Seven primary subtasks are identified.
- **Section 3, Project Outcomes,** presents results. Results are organized according to the subtasks identified in Section 2.
- **Section 4, Conclusions and Recommendations,** draws on evidence documented in Sections 2 or 3 to summarize Project 3.1 activities. Specific recommendations for additional research are made.
- **Section 5, References**, provides a bibliography of documents cited in text or drawn on to write this final report.
- **Section 6, Glossary**, defines the various acronyms used throughout this report.
- **Appendix A, Co-Digestion Model.**

SECTION 2

Project Approach

The approach to conducting Project 3.1 activities was organized under seven primary tasks (Task 3.1.1 though 3.1.7 as listed in the previous section). These seven tasks are listed and further described below.

2.1 Task 3.1.1: Assess, Evaluate, and Select Animal Waste to Energy Technology

2.1.1 Phase 1: Compare Plug Flow and Complete Mix Digesters in United States and Europe

To gain a better understanding of comparative field performance of different types of digesters and specifically to compare the performance of an animal waste digester used in the Chino Valley to that of other animal waste digesters, a study was done that assembled and analyzed available performance data for manure digesters in the United States and in Denmark.

The methodology consisted of a series of steps, as follows:

- Compare digester attributes.
- Select digesters for comparison.
- Compare performance vectors.
- Generate analysis output: Performance Graphs.
- Conduct economic analysis, including monetized environmental benefits.

Steps performed are described below.

Compare Digester Attributes

The plug-flow digester at IEUA's Regional Plant #5 (RP-5) was chosen to compare with other manure digesters. The initial comparison was to be plug-flow versus complete mix design configurations. However, early in the study, it became evident that direct comparisons between plug-flow and complete-mix digester designs could not be made without considering several other factors, including:

- Operating temperature (mesophilic or thermophilic range).
- Centralized digesters (taking in waste from several farms) versus on-farm digesters.
- Differences in economic and regulatory environments between America and Europe.
- Small-scale digesters (under 1,000 cows) versus large-scale digesters (over 1,000 cows).

Therefore, each of these vectors was considered when comparing performance between digesters.

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Select Digesters for Comparison

The RP-5 digester is the one of the first documented centralized digesters in the United States. Of the facilities it was compared to, the digesters in the United States have grown out of individual initiative on the part of farmers, which has resulted in a wide variety of designs and wide variation in success rates of projects. All of these digesters are single-farm units, and they are smaller in scale than the RP-5 digester. In Denmark, there h as been an evolution to a more consistent base design for centralized digesters; however, all of these digesters are different in design from the RP-5 digester. Thus, there are no digesters exactly comparable to the digester at RP-5; all digesters compared in the study had some unique circumstances. Where data were available to make a more direct comparison, adjustments were made to do so and documented in the report.

Compare Performance Vectors

For both the U.S. and Danish digester datasets, two aspects of digester performance were compared:

- Biogas Yield—defined as biogas output per unit of manure slurry input. Different units were used for the U.S. and the Danish digesters owing to the data available. For the U.S. digesters, the units used were [cubic feet per day (cfd) biogas output]/[dry lbs. per day slurry input]. For the Danish digesters, the units used were [cubic meters (m^3) biogas output]/[cubic meters (m3) slurry input].
- Capital cost per unit output rate—for both U.S. and Danish digesters, the units used were [$ per cfd of biogas output].

Generate Analysis Output: Performance Graphs

Performance graphs were generated for performance of all digesters in both datasets, (one for U.S., one for Danish, four graphs total). Because extensive data was available for performance of the RP-5 manure digester, it was possible to superimpose RP-5's performance numbers onto all of the graphs. Thus, RP-5 was compared directly to all of the digesters in the study. An "average performance line" appears in each graph, so that performance of any digester can be compared to the average across all of them. The output graphs are shown in Figures 3-3 and 3-4 of Section 3.

Conduct Economic Analysis, Including Monetized Environmental Benefits

An economic analysis of the RP-5 digester was done, including monetized environmental benefits that accrue from its operation, and a framework for evaluating impact of potential research modifications to the digester. The framework accounts for environmental benefits that accrue from the practice of using anaerobic digestion for management of animal waste. These include:

- Air quality improvement, owing to reduction of ammonia and odor emissions
- Water quality improvement, owing to capture and diversion of nitrates and salts that would otherwise enter the Santa Ana watershed

- Greenhouse gas reduction, through capture of methane and nitrous oxide emissions
- Solid waste management, through reduction of manure to a usable compost material

2.1.2 Phase 2: Assess and Evaluate Animal Waste to Energy Technologies

A number of available technologies in the U.S. and other countries were evaluated for improving animal waste-to-energy efficiency and economics. The methodology consisted of a series of steps, as follows:

- Develop regulatory and situational background
- Provide opportunities for energy production from animal waste
- Select best opportunity and list technologies to improve performance

Steps performed are described below.

Develop Regulatory and Situational Background

A context was developed for assessing potential animal waste-to-energy technologies. In the Chino Valley, there are significant regulatory constraints and drivers that will affect dairy operations. The set-up of a typical Chino Basin dairy operation is described in order to show how manure is handled, what emission sources result, how those sources are regulated and what energy recovery opportunities may exist in the disposal stream.

Provide Opportunities for Energy Production from Animal Waste

Several processes for handling dairy manure were examined and assessed based on relevance to Chino Valley operations, amount of energy produced, economics and existence of successful examples of the process. Processes considered were:

- Anaerobic Digestion
- Direct Burning of Manure
- Pyrolysis/Gasification of Manure
- Composting (Various types)

Select Best Opportunity and List Technologies to Improve Performance

Of the above, anaerobic digestion was chosen as the best opportunity for applying technologies to improve performance and economics. Anaerobic Digestion is used at two centralized facilities operated by Inland Empire Utilities Agency (IEUA) in the Chino Valley. Study of industry practices and collaboration with IEUA personnel resulted in the following list of technologies to evaluate for improving performance of anaerobic digestion facilities used in the Chino Valley:

- Cellulose Destruction (using either ultrasound or thermal hydrolysis)
- Co-Digestion
- Acid-phased-digestion/thermophilic digestion (RP-1 Digester)
- Thermophilic/temperature-phased anaerobic digestion (TPAD) (RP-5 Digester)
- Dewatering Improvement (Residuals Management)
- Recycle Stream Management
- Biological Gas Treatment to remove hydrogen sulfide (H_2S) (a European-sourced technology)

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2.1.3 Phase 3: Technology Selection

The selection of technologies for improving animal waste-to-energy efficiency and economics occurred in the following steps:

- Develop Selection and Ranking Criteria for Technologies
- Select Top Two Technologies

The steps are described below.

Develop Selection and Ranking Criteria for Technologies

These technologies were evaluated (scored) against a set of 17 criteria. The weighting applied to each criterion is shown in parentheses.

- Enhanced gas production (10 percent)
- Consistency with environmental regulations (10 percent)
- Level of technical sophistication required (10 percent)
- Reduced capital cost (8 percent)
- Reduced operating cost (8 percent)
- Increased electricity generation (8 percent)
- Demonstrates European practice in the U.S. (5 percent)
- Improved gas utilization (5 percent)
- Technology maturity (5 percent)
- Statewide applicability (5 percent)
- Ability to scale up or down (5 percent)
- Affordable within the PIER budget (5 percent)
- Lead-time (5 percent)
- New technology versus Application of existing technology (3 percent)
- Sources of matching funds (3 percent)
- Reduced disposal costs (3 percent)
- Vendor/Supplier Interest and Support (2 percent)

All of these attributes are scored on a 1-3 scale, with 1 being the "worst" (lowest positive impact or highest negative impact) and 3 being the "best" (highest positive impact or lowest negative impact).

Select Top Two Technologies

Using the above criteria, the technologies were evaluated as shown in Table 2-1. Each technology was scored for the criteria; the scoring was done on a comparative basis, technology to technology.

Using the criteria weighting factors shown in the third column of Table 2-1, the weighted individual criteria scores were computed and totaled for each technology. The total weighted scores were then indexed to 1.00, with the highest score receiving 1.00. The bottom row of the table is the ordinal ranking of the technologies, with the highest ranking technology being 1, progressing down to the lowest ranked technology at 13.

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TABLE 2-1
Evaluation of Dairy Waste to Energy Technologies

Attribute	Scale	Weighting	Project 3.1 - Dairy Waste to Energy Technology										Composting	Direct Burn	Pyrolysis/ Gasification	Heat Drying
					Gas Production Enhancement				Residuals Management							
					Cellulose Destruction						Gas Treatment					
			Foreign Material Removal (bar screens, grit channels, tanks, grinders)	Co-Digestion	Ultrasound	Thermal Hydrolysis	Acid Phased Digestion	Thermophilic Digestion	Dewatering Improvement (Laboratory testing/ bench scale tests)	Recycle Stream Management	Chemical	Biological				
Technical																
Enhanced Gas Production	1-3 (1 = Low, 3 = High)	**10%**	1	3	2	2	2	2.5	1	1	1	1	1	1	3	1
Consistency with Environmental Regs.	1-3 (1 = Low, 3 = High)	**10%**	3	3	3	3	3	3	3	3	3	3	2.5	1	1.5	2
Level of Tech Sophistication Required	1-3 (1 = Low, 3 = High)	**10%**	3	1.5	2	2	1.5	1.5	2	1.5	2	1.5	1	1	1	2
Reduced Capital Cost	1-3 (1 = Low, 3 = High)	**8%**	1	3	2	2	2	1.5	2.5	2	2	3	2	1	1	1.5
Reduced Operating Cost	1-3 (1 = Low, 3 = High)	**8%**	2	2	2	2	2	2	1	2	2	3	2	1	1	1
Increased Electricity Generation	1-3 (1 = Low, 3 = High)	**8%**	1	3	2	2	3	3	1	1	3	3	1	1	1.5	1
Demonstrates European Practice in U.S.	1-3 (1 = Low, 3 = High)	**5%**	1	3	1	1	1	2	1	1	1	3	1	1	1	1
Improved Gas Utilization	1-3 (1 = Low, 3 = High)	**5%**	1	3	1	1	2	2	1	1	2.5	3	1	1	1.5	1
Technology Maturity	1-3 (1 = Low, 3 = High)	**5%**	3	3	2	2	2	2.5	2.5	1	2	1.5	3	2	1	2
Statewide Applicability	1-3 (1 = Low, 3 = High)	**5%**	3	3	3	3	1.5	1.5	3	3	3	3	3	1	1	1.5
Ability to Scale Up or Down	1-3 (1 = Low, 3 = High)	**5%**	2	3	3	3	1.5	1.5	3	3	3	3	3	1	1	2
Affordable within PIER Budget	1-3 (1 = Low, 3 = High)	**5%**	1	3	3	3	3	3	2	2	3	3	3	1	1	1
Lead Time	1-3 (1 = Low, 3 = High)	**5%**	1	3	3	3	3	2.5	2	2	3	2.5	2	1	1	2
New Tech vs. Application of Existing Tech	1-3 (1 = Low, 3 = High)	**3%**	1	1	2	2	1.5	1.5	1	3	1.5	3	1	1	1	1
Sources of Matching Funds	1-3 (1 = Low, 3 = High)	**3%**	2	1	3	3	3	3	2	2	2	3	1	1	1	1
Reduced Disposal Costs	1-3 (1 = Low, 3 = High)	**3%**	2	3	2	2	1.5	1.5	3	2.5	1	3	1	2	2	1
Vendor/Supplier Interest and Support	1-3 (1 = Low, 3 = High)	**2%**	1	1	3	2	1	1	1.5	2	1	3	2	1	2	2
Total Weighted Score		**100%**	1.79	2.61	2.25	2.23	2.11	2.17	1.895	1.865	2.19	2.55	1.78	1.08	1.365	1.435
Indexed to 1.00			0.69			0.85	0.81	0.83	0.73	0.71	0.84		0.68	0.41	0.52	0.55
Indexed to 1.01				1.00	0.86							0.98				
Ranking			**9**	**1**	**3**	**4**	**6**	**5**	**7**	**8**	**4**	**2**	**10**	**13**	**12**	**11**

2.2 Task 3.1.2: Select Sites and Prepare Preliminary Plans for Projects to Implement the Selected Technologies

2.2.1 Site Selection

The following criteria were used to evaluate the three potential sites:

- Site suitability for demonstrating technology
- Support of host site
- Capital cost
- Reduced operating cost
- Lead-time
- Sources of matching funds
- Increased electricity generation
- Consistency with environmental regulations
- Improved gas utilization

These are site attributes that influence site selection for demonstration projects. All of these attributes are scored on a 1-3 scale, with 1 being the "worst" (lowest positive impact or highest negative impact) and 3 being the "best" (highest positive impact or lowest negative impact).

Based on these criteria and discussions with IEUA and Burrtec, Table 2-2 presents scoring of the three sites relative to one another, with the score for each criterion weighted as indicated in the third column from the left and then indexed to 1.00, with the highest ranked site receiving a score of 1.00. The sites are ranked as follows:

1. RP-1 1.00
2. RP-5 0.85
3. Burrtec 0.51

TABLE 2-2
Site Evaluation and Scoring

Site Attribute	Scale	Weighting	RP-1	RP-5	Burrtec
Site Suitability for Demonstrating Technology	1-3 (1 = Low, 3 = High)	15%	3	2	1
Support of Host Site	1-3 (1 = Low, 3 = High)	15%	3	3	2
Capital Cost	1-3 (1 = Low, 3 = High)	15%	3	2	1
Reduced Operating Cost	1-3 (1 = Low, 3 = High)	10%	3	2	1
Lead Time	1-3 (1 = Low, 3 = High)	10%	3	2	1
Sources of Matching Funds	1-3 (1 = Low, 3 = High)	10%	3	3	1
Increased Electricity Generation	1-3 (1 = Low, 3 = High)	10%	3	3	3
Consistency with Environmental Regs.	1-3 (1 = Low, 3 = High)	10%	3	3	2
Improved Gas Utilization	1-3 (1 = Low, 3 = High)	5%	2	3	2
Weighted Score	Total	100%	2.95	2.50	1.5
Indexed to Highest Score			1.00	0.85	0.51

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RP-1 had the highest score. Specific equipment location selections are shown in Section 3.2.

2.2.2 Tactical Marketing Plan

As the work was being done to select technologies and sites for test projects for projects 3.1 and 2.2, it became apparent that conditions existed around California for development of a significant market around co-digestion of food waste with both manure and municipal biosolids sludge. Because an important part of the PIER program is to develop technologies that can be applied throughout the state, it was decided to investigate and quantify this market opportunity.

Overview of Methodology

A study was done to investigate the following with regards to co-digestion in California:

- Current Situation, Opportunity, and Trends
- The Value Proposition
- Market Opportunity Overview
- Marketing Approach
- Financial Plan: Sample Project
- Detailed Market Size Analysis: Technical and Market Potential
- Detailed Analysis for Three STPs Selected of Different Types and Opportunities

2.3 Task 3.1.3: Design the Pilot Plant(s) and Prepare Test Plans on Co-Digestion of (1) Dairy Manure with Food Processing Waste, and (2) Biosolids and Food Processing Waste

Test plans were developed for bench scale and pilot scale testing of dairy manure/food processing wastes and biosolids/food processing wastes co-digestion. The test plans included discussion of the following elements:

- Potential sources of food waste
- Experimental setup
- Pre-test baseline conditions
- Test procedures and test parameters to be measured for the tests.

Bench-scale tests and pilot scale tests were conducted as outlined in the plans.

2.4 Task 3.1.4: Construct Pilot (Demonstration) Plant(s)

2.4.1 Overview of Methodology

In this task, the construction activity for the Project was completed in accordance with design activity completed under Task 3.1.3 and the related matching fund design effort. The construction involved installation of the co-digestion system for the dairy manure/food

processing waste system, the biosolids/food processing waste co-digestion system, and gas cleaning and related infrastructure systems. The construction tasks were divided into subtasks:

- **3.1.4(a)1: Construct Pilot (demonstration) Plant's Materials Handling System**. Install pumps, storage tanks, valves, metering, electrical and instrumentation and control systems, sampling ports, and related equipment in accordance with the design completed under Task 3.1.3.
- **3.1.4(a)2: Construct Pilot (demonstration) Plant's Digesters Gas Cleaning, and Gas Collection, Piping, and Safety Systems Upgrade**.

  Conduct the following four activities:

  - Installation of new physical-chemical processes for H2S treatment in close coordination with activities under Project 2.2. This will involve new sponge media for H2S absorption under anaerobic conditions and oxygen injection for operating the system under aerobic conditions.
  - Expansion of gas collection system to accommodate increased gas production
  - Safety system upgrades to the existing piping systems
  - Piping modifications to connect the modified digesters with the existing gas distribution system.
- 3**.1.4.(b): Construct Pilot (demonstration) Plant—Startup Activities**. Conduct startup activities and initial testing of the materials handling system and gas cleaning, and gas collection, piping and safety systems upgrades. This startup testing and commissioning activity assures that the system meets the performance requirements.
- 3**.1.4.(c): Construct Pilot Plants—Specifications, As-Built Drawings, and Initial Performance Report.** Prepare specifications, as-built drawings, and a summary report documenting performance versus design during startup and initial operation.

2.5 Task 3.1.5: Operate and Test Pilot (Demonstration) Plant(s)

This task consisted of operating the dairy manure/food processing and biosolids/food processing plants and conducting tests in accordance with the test plan. Under this task, equipment was operated and the performance data collected and compiled for each condition and process configuration tested. Additional information was compiled on construction/installation and operation and maintenance costs. Data were collected on biogas generation rate (ft^3/day/lb TS), volatile solids reduction, and biogas composition, including CH_4, CO_2, and H_2S. Testing was undertaken with different blends of foodwaste and manure and different blends of food waste and biosolids.

Monthly plant operating data reports verified that the pilot plants met performance requirements (e.g., throughput, environmental requirements, waste processing, and gas production/energy recovery). Tests were conducted for each co-digestion condition or process tested over a 3-month period.

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During this operation and test phase, close coordination was required between the project's engineering staff and the plant operators to ensure that the co-digestion activities did not affect other activities at RP-1 while providing the desired results from the testing program. Weekly coordination meetings were held involving engineering, construction and operations staff to ensure that any issues that arose were addressed appropriately. One example of an issue requiring the attention of the team was the spike in gas production which occurred as a result of slug feeding of the digesters. As the testing progressed, the approach was adjusted so that safety and environmental concerns could be addressed while allowing key testing activities to proceed.

2.6 Task 3.1.6: Conduct Economic and Environmental Assessment

2.6.1 Environmental Benefits of Anaerobic Digesters (Tasks 3.1.6.0 through 3.1.6.6)

Overview of Methodology

The IEUA Digestion Project serves as a reference project that is relevant for PIER and other Projects around the State of California. The project's prototype nature has generated significant ongoing interest from EPA, the Energy Commission, and many environmental, agricultural and governmental entities in this subject area. Going forward, the quantification of environmental benefits from the project will be key to developing interest in further projects. This task was useful in identifying issues that should be considered by various stakeholders when determining economic value of environmental benefits from these projects.

An outline of the work and a peer group for review were established. The first meeting of the peer group was on February 5, 2004. The study approach and goals were reviewed at that time. They form the framework of the final report. The approach was to (a) establish the peer group, (b) solicit input from experts, (c) investigate the six key areas listed below, (d) report findings to the peer group and others and (e) prepare a final report

The sequence of analysis efforts was as follows:

- Identify Peer Review Group to Review Environmental Benefits Work
- Develop Baseline Analysis Associated with the Implementation of Anaerobic Digester projects
- Evaluate Reductions in Greenhouse Gas Emissions and Define Strategy to define the benefits resulting from these reductions
- Evaluate Reductions in Air Emissions for Criteria Pollutants and Define Strategy to maximize the value resulting from these reductions.
- Evaluate Effect of the Reduction of Emissions on Water Quality and define potential benefits resulting from these reductions.

- Evaluate Opportunity to define Renewable Energy Attributes, or "Green Tags," from Manure Digestion Projects
- Develop a Monitoring, Reporting and Verification Protocol for the Digester Projects.

SECTION 3

Project Outcomes

As discussed in sections 1 and 2, several different tasks were completed as part of Project 3.1, with the overall goal of advancing the use of co-digestion with (1) manure and food processing waste, and (2) biosolids produced in sewage treatment plants and food processing waste, to generate renewable energy. Section 2 discussed the approach that was taken to complete tasks 3.1.1 through 3.1.6. This section discusses the specific project results and outcomes associated with these tasks and in turn the project objectives. Project objectives and projected outcomes were presented to the Energy Commission at the beginning of the project. Results obtained through the research conducted during the project formulated the actual project outcomes. Table 3-1 shows the relationship between objectives, projected outcomes, actual outcomes, and the associated tasks that were completed in order to satisfy each objective.

Additional discussion regarding the specific outcomes associated with each task are included below.

3.1 Outcomes of Task 3.1.1: Assess, Evaluate, and Select Animal Waste to Energy Technology

3.1.1 Phase 1: Comparison of Plug Flow and Complete Mix Digesters in U.S. and Europe

Outcomes

Plug-Flow Design (RP-5 Facility) Versus Complete Mix Design (Danish Centralized Digesters). The plug-flow configuration is the simplest, least expensive design for anaerobic digesters. The typical design consists of a horizontal trough. Waste slurry enters at one end of the trough and exits from the other end. The trough is covered with either a fixed (concrete) or flexible (hypalon or polypropylene) cover, which collects the biogas. The biogas is then piped off to a flare, or an engine generator. Temperature control (heating to 95°F) is achieved by circulating hot water through pipes that run through the trough. Waste heat from an engine generator can be used to provide the hot water. Figure 3-1 shows a simplified flow diagram for a plug-flow digester.

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TABLE 3-1
Project 3.1 Objectives, Projected Outcomes, Actual Outcomes, and Associated Tasks

Objective	Projected Outcome	Actual Outcome	Associated Tasks
Develop technologies that will address the lack of knowledge of the relationship between various co-digestion feedstocks and gas production. Pilot (demonstration) scale systems will be developed to yield information on the direct relationship between the physical and chemical characteristics of the feedstocks and the operating parameters of the co-digestion system and the increase in gas production associated with their co-digestion. Provide information for future users when developing optimal blends or "cocktails" for co-digestion projects.	The following pilot plants will be developed: • An operational pilot plant of co-digestion of dairy manure/food processing wastes using existing Digester No. 4 at Regional Plant 1 (RP-1) of the Inland Empire Utilities Agency (IEUA). Currently, this digester is used to process about 14 tons/day of dairy manure at an average flow of 35,000 gal/day with a total solids content of 9 percent. Food processing wastes will be added to the existing digester for co-digestion with the dairy manure. The feeding ratio of the dairy manure/food processing wastes to the digester will be tested and optimized. The expected incremental biogas production for co-digestion of manure and food processing wastes for the range of food processing wastes to be tested is expected to be from 15,000 to 25,000 cubic feet per day (cf/d). The expected additional power generation using the extra biogas generated from co-digestion is 25 to 55 kW. • An operational pilot plant of co-digestion of biosolids/food processing wastes using existing Digester 6 and 7 at RP-1 of the IEUA. Currently, these two digesters are used to process about 42 tons/day biosolids at an average flow of 300,000 gal/day with a total solids content of 4 to 5 percent. Food processing wastes will be added to the existing digesters for co-digestion with biosolids. The feeding ratio of the biosolids/food processing wastes to the digesters will be tested and optimized. For the ranges of food processing wastes being tested, the expected incremental biogas production for co-digestion of biosolids and food processing wastes is expected to be from 180,000 to 270,000 cf/d. The expected additional power generation using the extra biogas generated from co-digestion is 400 to 600 kW. • An operational pilot plant for biological gas cleaning at a maximum design capacity of 140 CFM for biological hydrogen sulfide (H_2S) removal system, and 120 CFM maximum for the moisture and siloxane removal system. The typical operation would be in the range of 20 to 70 percent of the design capacity.	The following pilot plant were developed: • An operational pilot plant of co-digestion of dairy manure/food processing wastes using existing Digester No. 4 at RP-1. Food processing wastes were added to the existing digester for co-digestion with the dairy manure. The feeding ratio of dairy manure/food processing wastes to the digester was tested and optimized. Dairy manure co-digestion tests with food processing wastes exhibited higher-than-expected increases in gas production. • An operational pilot plant of co-digestion of biosolids/ food processing wastes using existing digesters 6 and 7 at RP-1 of the IEUA. Food processing wastes were added to the existing digesters for co-digestion with biosolids. The feeding ratio of the biosolids/food processing wastes to the digesters were tested and optimized. Co-digestion of biosolids/food processing wastes did not result in a measurable increase in gas production. • An operation pilot plant for biological gas cleaning (H_2S removal) of digester gas from Digester 4. In addition to the pilot plants that were tested, a model to predict gas production was developed based on the testing conducted under the Commerce Energy PIER program. Economic and technical analyses of co-digestion projects were performed.	Task 3.1.1 Assess, Evaluate, and Select Dairy Waste to Energy Technology Task 3.1.2 Site Selection and Tactical Marketing Plan Task 3.1.3 Design the Pilot Plant(s) and Prepare Test Plans on Co-digestion of: 1) Dairy Manure with Food Processing Waste, and 2) Biosolids and Food Processing Waste Task 3.1.4 Construct Pilot (Demonstration) Plant(s) Task 3.1.5 Operate and Test Pilot (Demonstration) Plant(s) Task 3.1.6 Conduct Economic and Environ-mental Assessment
Quantify potential environmental benefits of dairy waste to energy projects in such a way that their values can be identified as the individual projects are being implemented	Reports documenting environmental benefits will be prepared.	The model to predict gas production was used to quantify emission reductions for the pilot (as-tested) and full-scale projects for manure and biosolids co-digestion at RP-1. Reports documenting environmental benefits were prepared.	Task 3.1.6 Conduct Economic and Environ-mental Assessment
Report the results of studies conducted that led to the establishment of the goals listed above.	Reports documenting the performance and results from the testing of 1) co-digestion of dairy manure/food processing wastes, 2) co-digestion of biosolids/food processing wastes, 3)biological gas cleaning for biogas produced from these processes will be prepared.	A report documenting the performance and results from the testing of 1) co-digestion of dairy manure/food processing wastes, 2) co-digestion of biosolids/food processing wastes, 3)biological gas cleaning for biogas produced from these processes was prepared.	Task 3.1.7 Prepare Final Report for Project 3.1

TABLE 3-1
Project 3.1 Objectives, Projected Outcomes, Actual Outcomes, and Associated Tasks

Objective	Projected Outcome	Actual Outcome	Associated Tasks
	Marketing of co-digestion to targeted opportunities in California, this includes both dairy waste/food processing wastes and biosolids/food processing wastes.	The activities of the Project were presented at technical and professional meetings.	

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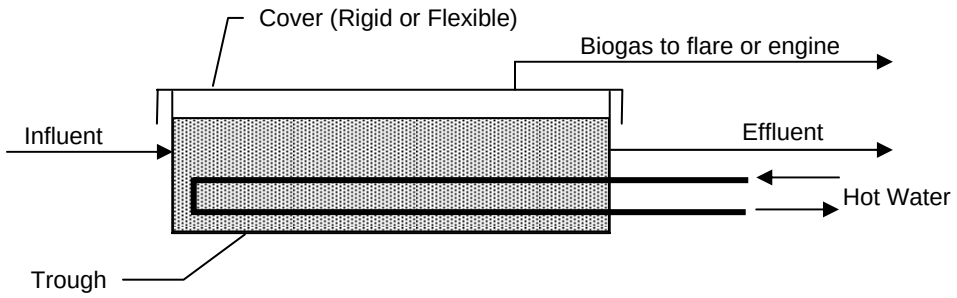

FIGURE 3-1
Flow Diagram for Plug-Flow Digester

The complete mix digester consists of a tank that is heated and mixed. A typical design is a round tank that is stirred with a mechanical mixer. Recirculating pumps can also be used for mixing. In most units, temperature control is achieved using a spiral-flow heat exchanger. Complete mix digesters can operate at mesophilic (90 to 95°F) or thermophilic (140 to 145°F) temperatures, and operational experience exists for both. Figure 3-2 shows a simplified flow diagram for a complete mix digester.

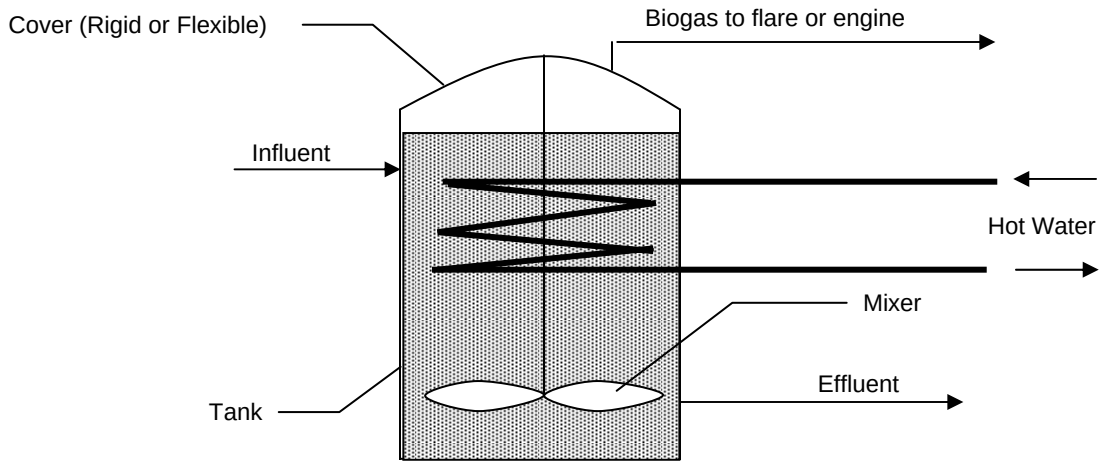

FIGURE 3-2
Flow Diagram for Complete Mix Digester

Performance Comparisons. There are no digesters exactly comparable to the digester at RP-5; all digesters compared in the study had some unique circumstances. Where data were available to make a more direct comparison, adjustments were made to do so and documented in the report. In all, 15 on-farm digesters in the U.S. and 18 centralized digester facilities in Denmark were chosen based on attributes and availability of operating data for comparison to RP-5.

The RP-5 digester's performance with respect to biogas production was compared to that of U.S. on-farm plug-flow digesters and Danish complete mix digesters (Figures 3-3 and 3-4). The comparisons show that against the other plug-flow digesters, RP-5's performance is approximately on par with the benchmark set by other plug-flow units. The gas production performance of the Danish compete mix units was on average better than that of the RP-5 digester, for the following reasons:

- The Danish units are configured as complete mix units and some of them are thermophilic (higher operating temperature than the digester at RP-5).
- Operating practices and pretreatment have been optimized for steady, consistent operation of the digester.
- Most importantly, they all practice some amount of co-digestion of other wastes, typically food wastes, which produce higher amounts of methane than manure. The data suggest that co-digestion at the RP-5 plant has a potential for significant increase in performance. A Danish report suggests that on average, adding 24 percent co-digested waste to the manure stream may be increasing gas production at some facilities by up to 50 to 85 percent over manure use alone.

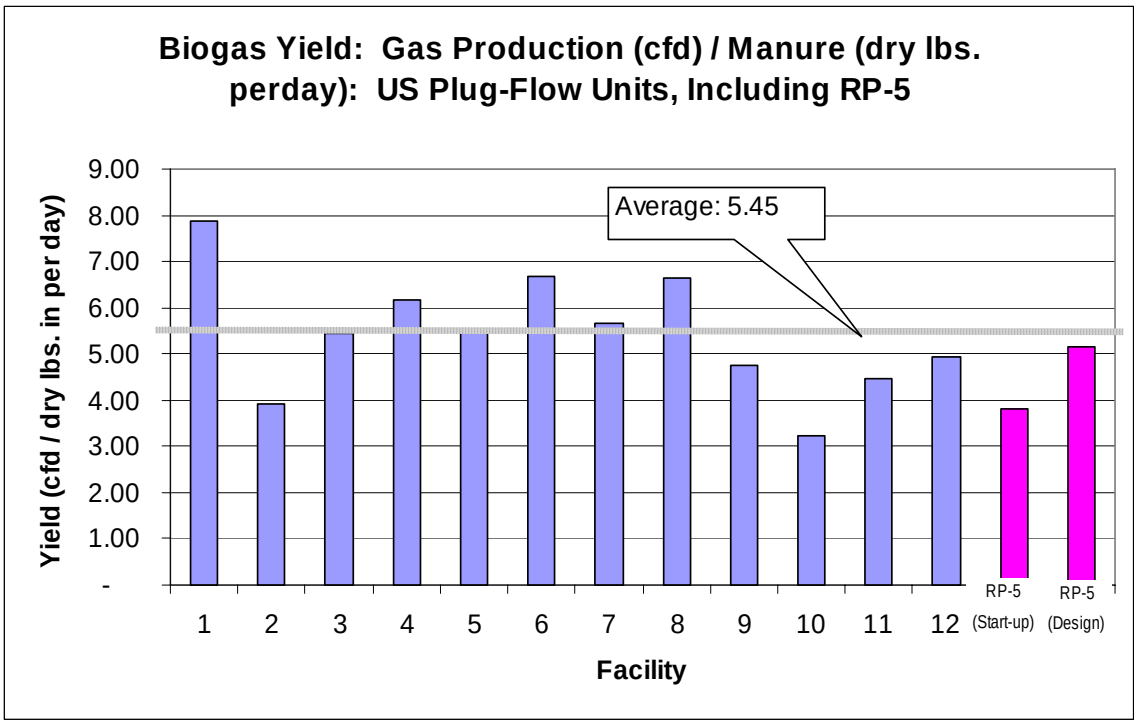

FIGURE 3-3
Biogas Yield: Production PER Manure Input (Dry lbs/day)—U.S. Plug-Flow Digesters

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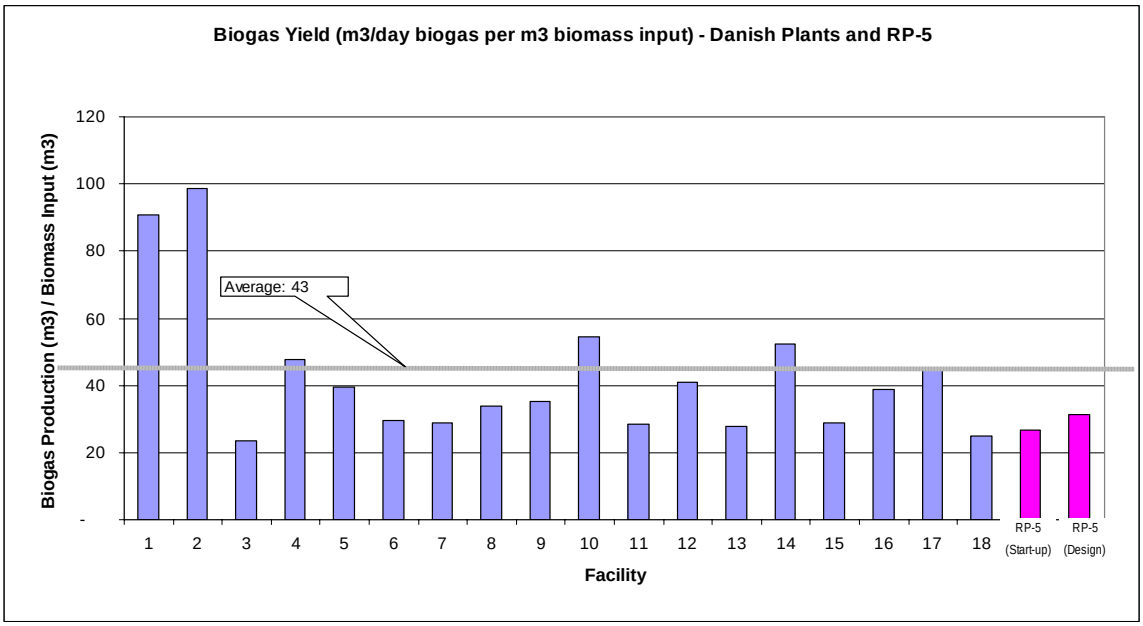

FIGURE 3-4
Biogas Yield per Manure Slurry Input—RP-5 Digester and Danish Centralized Units

The RP-5 digester's capital cost, per unit of biogas produced, was compared with U.S. on-farm plug-flow digesters, and with Danish centralized complete mix digesters.

With respect to the U.S. digesters, the cost per unit of biogas for RP-5 was higher than the average, for the following reasons:

- Labor and overhead costs associated with construction are fully reported for RP-5, whereas the on-farm units would contain unreported costs for time spent by the farm owner or other farm employees on the system.
- The RP-5 digester is constructed to all applicable codes and building practices, using durable materials with operating lives of 20 years or more, whereas many on-farm units are not built to the same code standards, using less durable materials (such as flexible fabric covers), which require replacement in less than 20 years.
- The RP-5 digester was subjected to a full design and permitting process, whereas many on-farm digesters have not been in the past.

With respect to the Danish digesters, the RP-5 unit's comparable capital cost per unit of biogas produced fell close to the average. Figures 3-5 and 3-6 compare U.S. and Danish capital costs.

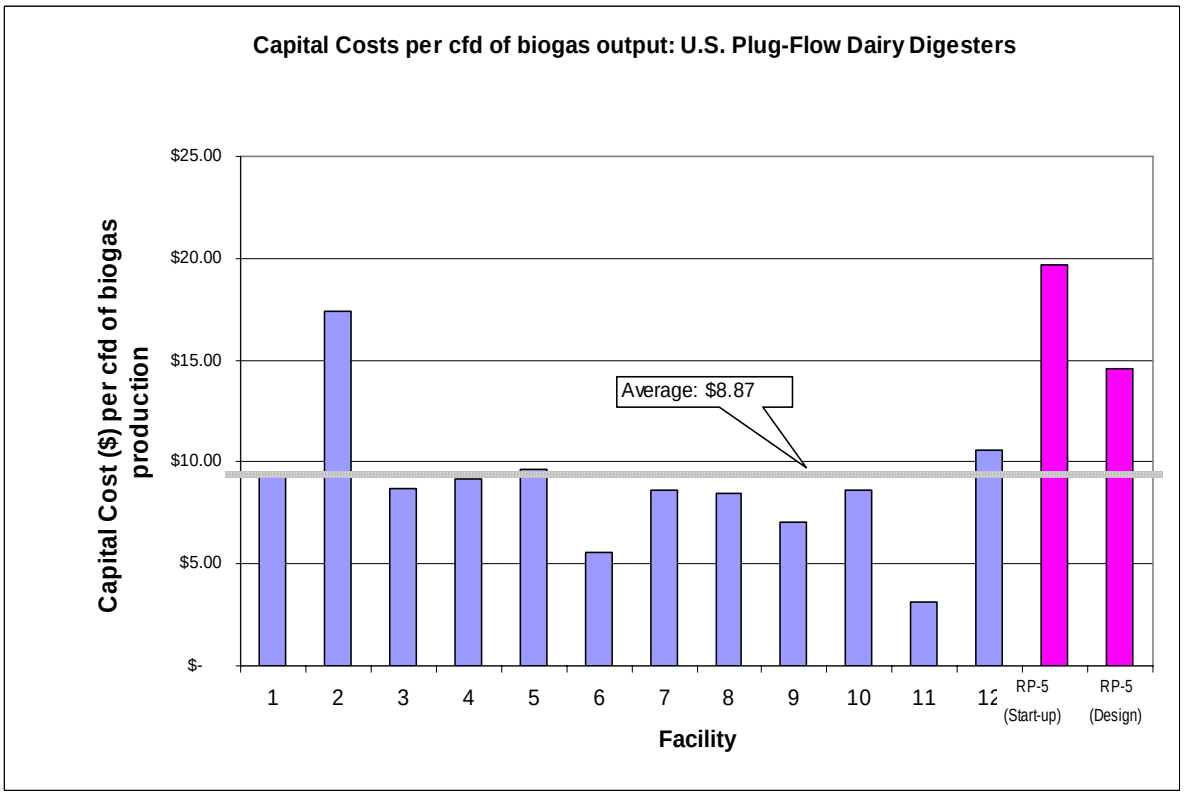

FIGURE 3-5
Capital Cost per CFD of Biogas—U.S. Plug-Flow Digesters

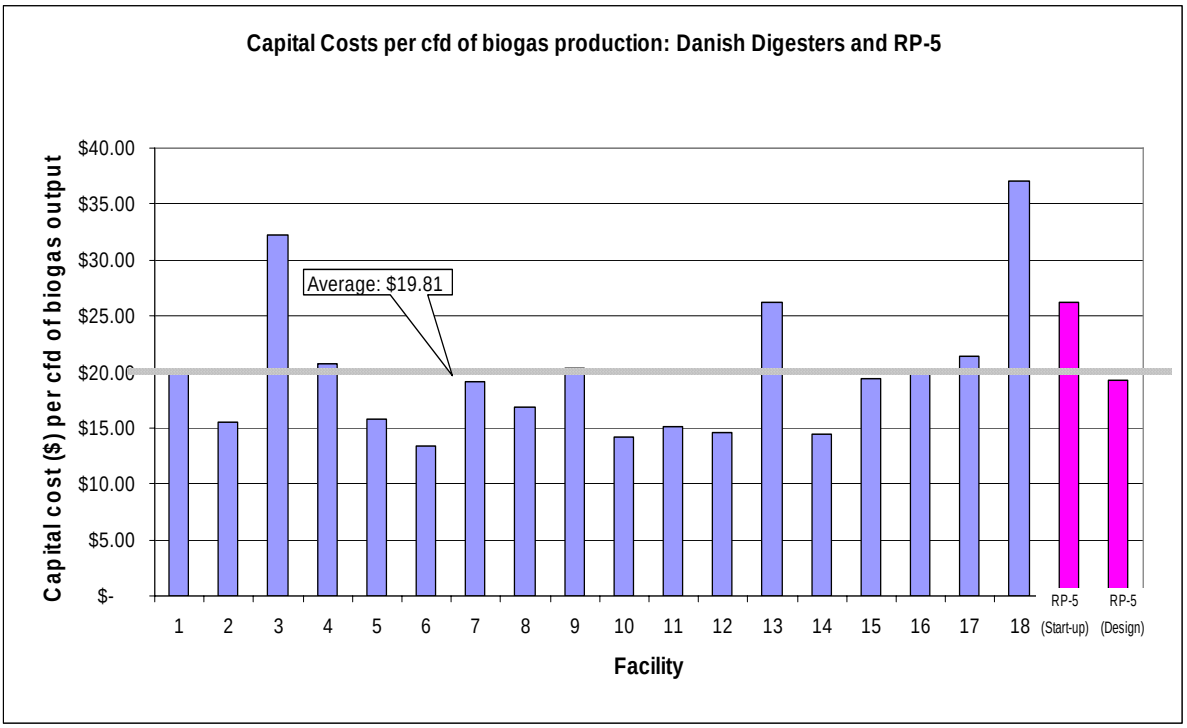

FIGURE 3-6
Capital Cost per CFD of Biogas Production for Danish Units and RP-5 Digester

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Conclusions

The conclusions from this comparison were as follows:

- A complete-mix design is favored over plug flow for larger centralized facilities. Although the RP-5 digester was successfully processing manure waste and performing close to its design criteria, the economic results shown above indicate that a complete-mix design is probably a better way to go for future designs of digesters of that size and larger.
- Co-digestion is key element in making projects more economically feasible. Virtually all of the Danish, centralized, complete-mix facilities used co-digestion of food waste or other similar organic material to supplement the manure input. Doing this significantly increased biogas output and improved economic performance at those facilities.
- Assigning a monetary value to these environmental benefits is an emerging practice. Some of these values have assignable credits that can be traded in a market, though these types of trades are relatively new. Estimates are given in the report for what some of these values could be, subject to further review. Some of these values may have significant positive effect on the economic analysis of the RP-5 and other digesters going forward.

3.1.2 Phase 2: Assess and Evaluate Animal Waste to Energy Technologies

The results of Phase 1, which compared the technical and performance and economics of plug flow digesters to complete-mix digesters in the U.S. and Europe, were supplemented by a review of the regulatory framework and an evaluation of dairy waste processing technologies in Phase 2. The regulatory framework described the role of the South Coast Air Quality Management District and particularly Rule 1127, which required that certain manure management practices be followed. It also reviewed the requirements of the Santa Ana Regional Water Quality Control Board and its order 99-11, which related to concentrated animal feeding operations. Together, these rules require certain management practices be followed and favor technologies such as anaerobic digestion for manure treatment.

Phase 2 also involved the evaluation of waste processing technologies. The waste processing technologies were considered and evaluated in light manure collection and management options. These options are shown in Figure 4-1 of *Task 3.1.1.b, Final Report: Assessment, Evaluation, and Selection of Dairy Waste to Energy Technology* (CH2M HILL, 2005).

The waste management technologies considered include, thermal hydrolysis, direct combustion, pyrolysis, and gasification. In general, the technology evaluation concluded that all of these technologies were less proven, less economical, and posed greater environmental risks than anaerobic digestion. Therefore, future evaluations in Phase 3 focused on anaerobic digestion and gas cleaning of biogas produced in anaerobic digesters. With a focus in these areas, the potential for improving the economic and environmental performance dairy waste anaerobic digesters was significantly improved.

3.1.3 Phase 3: Technology Selection

Based on the finding that the best technology to consider for dairy waste management was anaerobic digestion, a more detailed assessment was undertaken to identify the following important planning considerations:

- **Environmental regulations** are becoming more stringent, requiring improved manure collection and management. The compliance costs may adversely affect the smaller dairy's economic viability; there is a strong trend toward larger and larger diary operations.
- **Anaerobic digestion** is the best approach to energy recovery from dairy manure. It also provides the added benefits of odor control, volatile solids destruction, pathogen and seed destruction, and waste volume reduction. It also helps to concentrate nutrients into more usable forms for use as a fertilizer.
- **Strong economies of scale** for AD digestion installations indicate that centralized AD installations are more likely to be economically viable. U.S. dairy farmers face a challenging business environment because of low milk prices and increasing environmental regulation. Individual farmers have a difficult time making large long-term investments in waste treatment facilities. For most individual dairies in the Chino Basin, it is uncertain how development pressures will affect their long-term future.
- **A centralized approach** also allows for expert operation and maintenance of the facility with an emphasis on stable operation and biogas production and allows the dairy farmer to focus on operating a dairy. It also disperses the risk associated with the financial integrity of individual dairies; long-term capital investment can be made independent of the fortunes of a particular dairy.
- **Co-digestion** of higher gas value wastes significantly increases the biogas production and improves the economics of the operation. Again, a centralized approach expedites the collection of other waste streams for co-digestion.
- **Complete mix digesters** provide higher levels of VS destruction and biogas production. European practice has standardized on complete mix digesters using co-digestion.
- **Improved methods of manure collection and/or pretreatment** processing to remove foreign materials will reduce the costs of digesting manure. IEUA's experience with grit, rocks, and other foreign materials indicate that their removal can be a significant part of the cost to anaerobically digest dairy manure.

Dairy manure biogas must be cleaned before being used in prime movers for electricity generation. Without cleaning (for example, moisture removal, H_2S removal), the gas is hard on the equipment, resulting in significantly increased maintenance and maintenance cost and much shorter operational life for the equipment. Each installation's biogas can have unique characteristics. In the U.S., this has led to installation specific mechanical or chemical solutions to the problem; none of which have been developed into more standardized commercial packages. In Europe, **biological gas cleaning**, primarily for H_2S is widely used; it has not been applied in the U.S.

The analysis of anaerobic digestion applications, conducted in light of the themes listed above concluded that the best near term opportunity to increase the affordability of biogas

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from dairy manure was through co-digestion involving manure and food processing wastes. It was also recognized that co-digesting biosolids with food processing waste would be similarly advantageous because it could significantly increase gas production with the addition of relatively little additional waste material. With this finding the last portion of the effort on this task focused on co-digestion. The objectives of the review were to:

- Determine the appropriate approached to co-digestion at RP-1
- Identify suitable food waste types for co-digestion
- Determine suitable mixture compositions for:
  - Wastewater solids plus food waste
  - Cow manure plus food waste
- Determine optimum conditions for co-digestion operation, including carbon:nitrogen ratio, organic loading rate, total solids (TS) content of the feed stream, and hydraulic retention time (HRT)

In light of these objectives, previous studies of co-digestion were carefully reviewed and compiled so the findings could be applied to the selected site, at Regional Plant No. 1. Table 12-2 in *Task 3.1.1.b, Final Report: Assessment, Evaluation, and Selection of Dairy Waste to Energy Technology* (CH2M HILL, 2005) summarizes the results of this review.

After analyzing these findings from previous studies, reviewing the objectives of this task, and considering the conditions at the test site, the following key parameters/suggested values for RP-1 were established:

- C:N ratio in mixture/20:1
- Temperature/Mesophilic or thermophilic
- HRT/15 to 20 days
- Organic Loading Rate/0.094-0.19 lb VS/cf-day
- Percent TS/5 to 8 percent

These suggested values for the key parameters to be applied at RP-1 provided the basis for the design and test plan outlined in the subsequent tasks.

3.2 Outcomes of Task 3.1.2: Site Selection and Tactical Marketing Plan

3.2.1 Site Selection

Outcomes

IEUA's RP-1 facility was chosen as the host facility using the process described above in Section 2.2. RP-1 is located in the City of Ontario, California, near the intersection of Highway 60 and Archibald Avenue. The plant treats an average daily wastewater flow of 44 million gallons per day (mgd). The plant's liquid treatment processes are designed to

meet Title 22 requirements for nonrestricted recreational use of effluent water. Figure 3-7 illustrates the location of the RP-1 project site in the Chino Basin area.

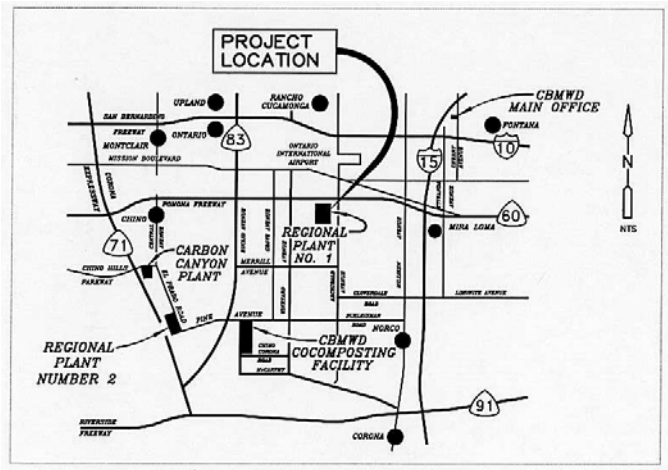

FIGURE 3-7
Site Location

Figure 3-8 illustrates the current RP-1 process for manure at Digester 4.

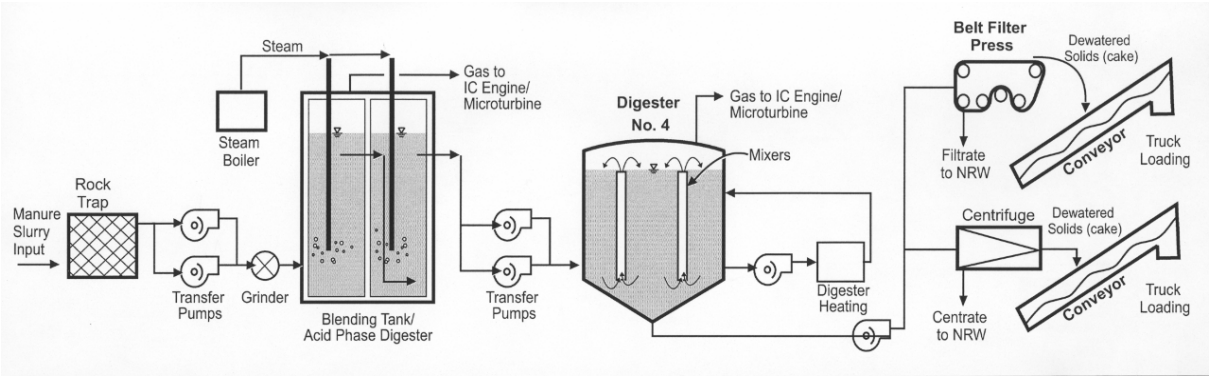

FIGURE 3-8
RP-1 Digestion Process Schematic for Digester 4 Operations

As Figure 3-8 indicates, the project sites chosen for the various equipment sets are at different locations across the RP-1 facility, based on space availability and interconnection to nearby processes. The main site locations are as follows:

- **Holding tanks and pumps for co-digestion food waste:** Four holding tanks and transfer pumps for food waste are to be located in an available space to the north of Digester 3. This equipment feeds food waste into digesters 3, 4, 5, 6, or 7 for co-digestion with biosolids (digesters 3, 5, 6, 7) or cow manure (Digester 4).
- **Biological gas treatment system:** The pilot system for biological treatment to remove H_2S from biogas is to be located in an available space to the north of Digester 4. This equipment will treat biogas from Digester 4.
- **Power generation equipment:** Up to 500 kilowatts (kW) of new power generation equipment to convert extra biogas from co-digestion into power is to be located in one of

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several potential locations just east or southeast of the energy recovery building. Three potential siting locations for this equipment were mapped, examined, and photographed. All of these locations are outdoors. Figure 3-9 shows the area around the energy recovery building in greater detail, with potential sites highlighted.

The equipment and project sites for the co-digestion holding tanks and pumps and the biological gas treatment system are well-defined. The project site for the power generation equipment is less defined. However, an area close to the energy recovery building, where the delivery piping for treated biogas from storage tanks is located and where some power equipment already exists, is a logical choice.

3.2.2 Tactical Marketing Plan

Outcomes

Market Opportunity. The factors in California's power markets and regulatory environment that provide a market opportunity for economic co-digestion projects include:

- Deregulation of power markets, which though not complete, has allowed some amount of open competition in certain areas for potential energy service providers.
- High prevailing retail electric rates, which in many areas of the state can allow a potential energy provider to profitably sell electricity generated on-site.
- Volatility of electric rates, which will prompt facilities that consume energy, such as dairies and STPs, to seek ways to self-generate power to cover part or all of the power needs, as protection against price shocks.
- Increasingly stringent environmental regulations, which will drive process changes at dairies, STPs and food processors in order to better manage waste and reduce air and water emissions.
- Opportunities for financial gain from environmental benefits from renewable energy projects, such as renewable energy credits ("green tags"), tax credits, emission reductions credits, and other state or locally-sponsored incentives, such as the California Public Utility Commission's (CPUC's) Self-Generation Incentive Program (SGIP) in California.

Marketing Approach. Members of the marketing team would include:

- A developer, who would market this service as part of a full suite of energy services and secure investment funds for developing the projects
- CH2M HILL, who would assist the developer in marketing these services, provide access to its existing customer base, and provide technical input and design engineering for system installation
- Host facilities, consisting of the municipal sewage treatment plants, centralized digester facilities, and mega-dairies that have a biosolids or manure waste stream to be processed

- Food waste producers, who will deliver their waste streams to the digester facilities on a regular schedule for co-digestion with the main waste stream

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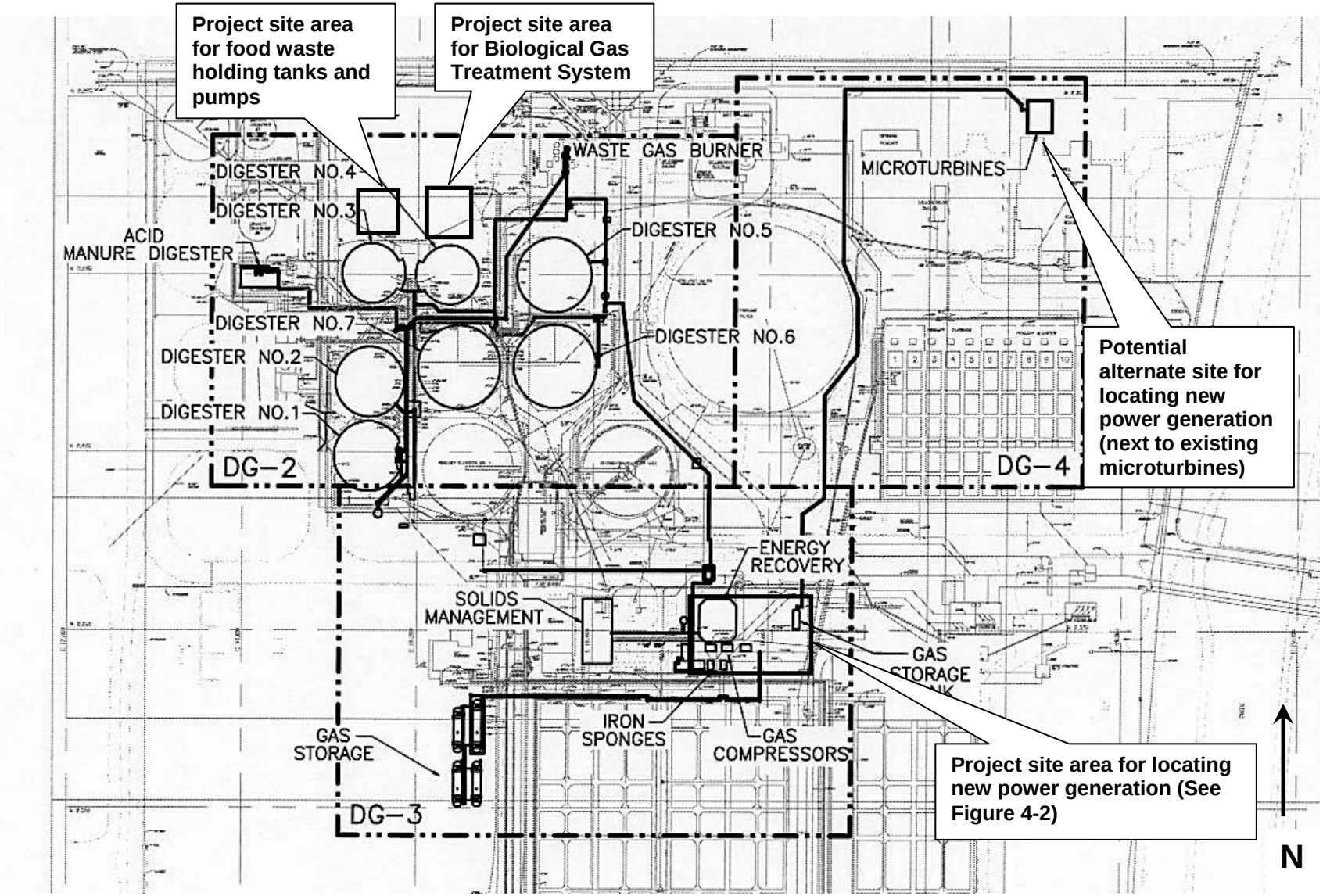

FIGURE 3-9
RP-1 Site Overview with Project Locations

There are two sets of focus customers:

- Dairy Waste Customers—the first targets would be the IEUA centralized dairy manure facilities, which are already starting to experiment with co-digestion. The next set of customers would be the mega-dairies (10,000 head of cattle and up) and new centralized manure digesters as they come on line.
- Sewage Treatment Plants—the first targets would be the IEUA regional facilities, and plants at the Cities of Stockton and Riverside. From there the primary target list would expand to cover at least 114 plants with design flows of 1 MGD or more that already have digester capacity installed.

The channels to market considered for reaching consist of two main access paths, one for each set of focus customers listed above:

- Dairy Waste Customers—In the Chino Valley, CH2M HILL and Commonwealth have already been working with IEUA on digester projects. Since these are some of the first centralized dairy digesters in the U.S., avenues to other potential customers have not yet been forged, but are available, through presentations by IEUA in conjunction with CH2M HILL and Commonwealth, and through other programs such as EPA's AgSTAR program and conferences such as the Biogas Summit held in 2003.
- Sewage Treatment Plants—CH2M HILL works with many of the sewage treatment plants over 1 MGD in California already, thus access to these clients can be achieved through existing client contacts and ongoing work. This will allow Commonwealth and CH2M HILL to effectively present to these facilities as a team, with credibility already established.

Financial Plan: Sample Project. A financial analysis was developed for a hypothetical 1-MW project from the perspectives of both the Developer and the Host Facility. The developer is a *for-profit* entity; it is assumed that the developer needs approximately a 15 to 25 percent rate of return for investments. Table 3-2 shows inputs and results for the developer from the financial analysis. The analysis shows that the developer can make a sufficient rate of return from such a project to justify the investment.

The sample project was also analyzed from the perspective of the host facility. The host facility takes advantage of power savings resulting from the project. Table 3-3 shows inputs and results for the host facility from the financial analysis.

The analysis shows that both the host facility and the developer benefit from these projects, and that the business opportunity as described in this plan is economically viable for both parties.

Market Size Analysis: Technical and Market Potential. Both dairies and STPs represent significant market opportunities for this business plan in California. In the case of dairies, the immediate locations are fewer, but the potential future market size is greater. STPs present less total potential market size (in terms of new power generated), but many more immediate locations at which this business might be implemented. Both markets were defined in terms of technical potential and market potential of electric power generation capacity (MW).

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TABLE 3-2
Sample Project—Conditions and Results for the Developer

Inputs		
Nominal Generation Capacity Installed	1,000	kW
Installed cost of generation (per kW)	$2,000	per kW
Total design and project management costs	20%	of generation installed cost
Availability of power generation equipment	90%	
Selling price for electricity to host facility ($/kWh)	$0.090	per kWh
Green Tag Value (increases revenues)	$0.002	per kWh
Annual O&M costs	$0.025	per kWh nominal
Self Generation Incentive	40%	Of total investment costs, rebated upon startup
Corporate Tax Rate	40%	
Investment Hurdle Rate	15%	
Results		
Net Electricity Generated/year	7,884,000	kWh per year
Annual O&M costs (over 5 years)	$219,000	
Total 5-year revenues (not discounted):	$3,626,640	
Total investment without self-gen incentive:	$2,400,000	
Total investment with self-gen incentive:	$1,440,000	
6-year NPV of project	$62,250	
Payback Year	4	
Project rate of return (IRR)	16.96%	(with self-gen. Incentive)

TABLE 3-3
Sample Project—Conditions and Results for the Host Facility

Inputs		
Nominal Generation Capacity Installed	1,000	kW
Installed cost of ancillary equipment	$1,000	per kW
Total design and project management costs	20%	of equipment installed cost
Availability of power generation equipment	90%	
Purchase price for electricity from developer ($/kWh)	$0.090	per kWh
Annual O&M costs (1st 5 years of operation)	$0	per kWh nominal
Annual O&M costs (after year 6)	$0.025	per kWh nominal
Prevailing Retail Blended Electric Rate	$0.120	per kWh
Tax Rate	0%	
Investment Discount Rate	6%	
Results		
Total Capital costs borne by Host Facility	**$1,200,000**	
Annual O&M costs (1st 5 years)	$0	Per year
Annual O&M costs (remaining years, after buyout)	$219,000	Per year
Equipment overhaul costs in years 7 and 12:	$250,000	Years 7 and 12 only
Annual energy savings by paying $.09 per kWh vs. $.12 per kWh (1st 5 years of operation)	$236,520	Per year
Annual savings after buyout of equipment	$727,080	Per year
15-year NPV for project	**$3,182,531**	
Payback Year	7	
15-year IRR	**27.99%**	

To estimate technical potential for dairies, previous studies by the Commonwealth team and information from the State of California and USDA provided an inventory of dairy cattle in the entire state, which in 2002 included about 1.62 million dairy cows. Using experience from dairy operations in the Chino Valley, it was estimated that capturing 34 percent of the manure from all of these cows would provide a waste stream to generate approximate 130 MW of renewable power through anaerobic digestion. If food waste were then added to this dairy waste stream at a ratio of 80 percent manure to 20 percent food waste, another 98 MW could be developed. The median technical potential estimated from this business, if implemented everywhere in California is 98 MW. The immediate locations where co-digestion could be implemented are six dairy digesters around the state, including two centralized facilities.

To estimate technical potential for STPs, lists were obtained from the State of California of all STPs in the state with average annual design flows over 1 MGD, (there are 312 on the list) and those STPs over 1 MGD design flow that have anaerobic digestion facilities installed (there are at least 114). A practical estimation of technical potential was done using the 114

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potential sites with existing digesters. These sites with existing digesters combine for about 2,505 MGD average dry weather flow rate. Not all of these sites use the biogas from their current digesters for power generation, but if they all did, that would represent approximately 102 MW of power as a baseline, on the existing waste streams. Implementing co-digestion with food waste at all of these plants results in an estimated increase of 59 MW. Thus, this incremental 59 MW is taken as a practical technical electric potential for co-digestion of food waste with biosolids at existing STPs.

Market potential was estimated by varying inputs to the financial analysis with a range and determining the percentage of scenarios resulting in acceptable rates of return, based upon a given hurdle rate distribution for self-generation technology. This analysis yielded a 75 percent market acceptance rate, (i.e., 75 percent of these projects would provide an acceptable rate of return based on the range of input assumptions used). This acceptance rate, when applied to the technical potential estimates listed above, results in a market potential for dairy waste applications of 73 MW, and for biosolids STP applications of 44 MW.

Facility Statewide Location and Proximity Assessment for Sewage Treatment Plans, Dairy Facilities, and Food Processing Facilities. In many local areas throughout the state of California, sewage treatment plants are located close to dairy farms and food processing facilities (see Figures ES-1 and 4-1). This observation is consistent with the findings presented in the *Co-Digestion Tactical Marketing Plan*, which identified the market potential to increase biogas generation by over 100 megawatts (MW) through the use of co-digestion at existing STPs and dairy facilities. The proximity review provided an important link between the market potential described in the *Co-Digestion Tactical Marketing Plan* and stakeholder implementation of the concept, because it demonstrates that the dairies, food processing facilities, and sewage treatment plants are located close enough to each other to support the concepts of the *Co-Digestion Tactical Marketing Plan*. The location and proximity assessment selected 20 treatment plants and tabulated the dairies and food processing facilities within 25 and 50 miles of these plants, respectively. For an additional five plants, maps were prepared showing the dairies and food processing facilities located within these zones.

The overall conclusion of the proximity analysis was that an adequate number of dairies and food processing facilities do in fact occur in the vicinity of the sewage treatment plants to support the co-digestion processes described in the *Co-Digestion Tactical Marketing Plan*. All of the treatment plants considered here have anaerobic digestion as part of their existing processes. A broader review of the results as presented in Figures ES-1 and 4-1 demonstrates that there are many other opportunities for co-digestion of: (1) manure and food processing waste, and (2) biosolids and food processing waste at locations throughout the state of California.

3.3 Outcomes of Task 3.1.3: Design the Pilot Plant(s) and Prepare Test Plans on Co-Digestion of (1) Dairy Manure with Food Processing Waste, and (2) Biosolids and Food Processing Waste

3.3.1 Bench Scale Test Results

Digestibility Testing

The bench-scale tests included the easy to digest and moderate to digest food waste groups as listed in Table 3-4.

TABLE 3-4
Food Waste Used in Digestability Testing

Bottle No.	Food Waste Type	Digestibility Category	Mesophilic	Thermophilic
1	Control—Biosolids Only (100%)	N/A	Triplicate	Duplicate
2	Unilever Best Food/Tomato Sauce and Mayonnaise and Biosolids (50:50)	Easy to digest	Triplicate	Duplicate
3	GFF/Salad dressing and Biosolids (50:50)	Easy to digest	Triplicate	Duplicate
4	Golden Cheese Company/ Cheese and Biosolids (50:50)	Moderately easy to digest	Triplicate	Duplicate

Triplicate: Three identically prepared bottles of indicated sample.
Duplicate: Two identically prepared bottles of indicated sample.

The digestibility tests were conducted at the Orange County Sanitation District (OCSD) Plant No. 2 Laboratory. Digestion bottles were incubated in temperature-controlled water baths equipped with shaker tables, at mesophilic (98°F) and thermophilic (128°F) temperatures. Mesophilic digestion bottles were set up in triplicates and thermophilic bottles were set up in duplicates, as indicated in Table 3-4.

The bench-scale digestion setup used throughout this study is shown in Figure 3-10. Eight bottles in the water bath contained the test mixtures, as indicated in Table 3-4. Eight bottles outside the water bath were used for gas collection and gas generation measurement via volume displacement. Each digestion bottle was connected to one gas collection bottle. All bottles were sealed to achieve gas-tight conditions for accurate gas measurements. Gas generation quantity was monitored each day by taking level readings from the gas collection bottles. Gas quality and chemical content were not analyzed in this test.

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FIGURE 3-10
Bench-Scale Digestion Setup Showing the Digestion and Gas Collection Bottles

Cumulative gas generation results collected over the digestion period are summarized in Figures 3-11 and 3-12 for mesophilic batches. The results indicate that the easy and moderate to digest food waste groups have the potential to generate more gas more rapidly relative to the control under mesophilic conditions. The total gas generation with food waste was 26 percent greater compared to the control bottles under the bench-scale test conditions. All mesophilic bottles showed biological activity, indicating no loss of activity during transfer or test set up. As indicated above, high acetic acid values observed in the cheese waste bottles could explain the cessation of gas generation after the 18th day of digestion.

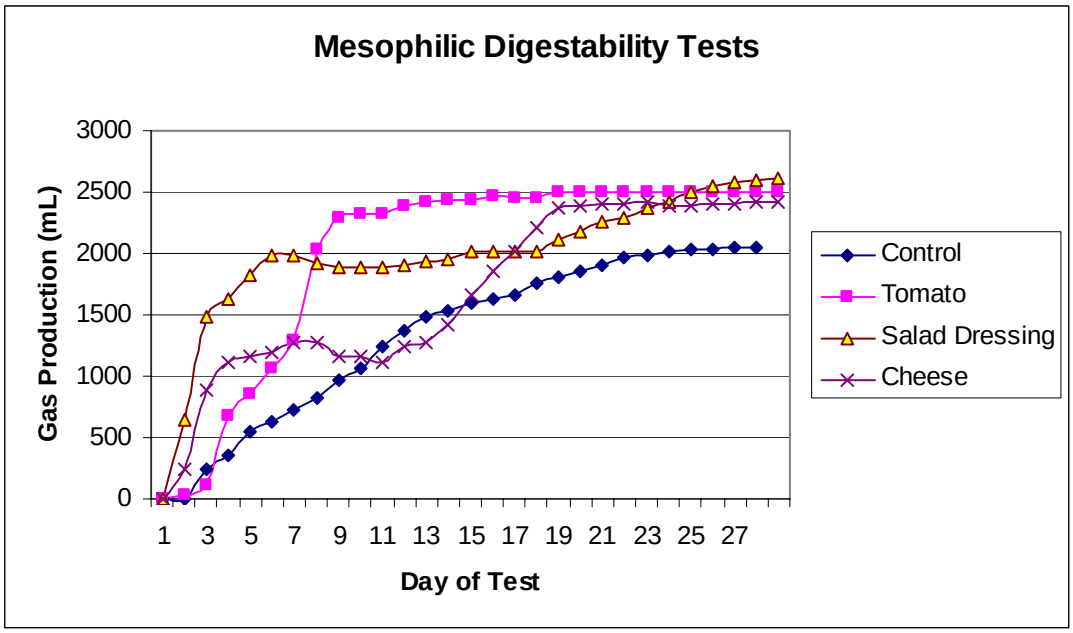

FIGURE 3-11
Mesophilic Gas Generation Values

Acid Digestion Testing

Bench-scale mesophilic acid-gas phase digestibility tests were started on December 27. Biosolids samples collected from IEUA RP-1 Digester 1, and dairy cow manure and cheese waste samples were mixed at 80:20 volume ratios in 2-liter bottles, and were then incubated in temperature-controlled water baths at 98°F. One set of control bottles with biosolids without waste addition was also included.

Table 3-5 lists the waste types used in this phase of testing. Cheese waste was selected, since it was found to be relatively difficult to digest compared to the other food wastes used. Due to the relative complexity of the cheese waste matrix (fat, protein and carbohydrate contents as reflected in high TOC values), acid digestion was considered to have the potential to increase the hydrolysis rate, improving the solids reduction in the gas phase.

TABLE 3-5
Waste Types Used in Acid-Gas Digestibility Testing

Food Waste Type	Digestibility Category	Comment
Golden Cheese Company/Cheese	Moderately easy to digest	Used as is
Dairy Manure	N/A	Diluted at 1:1 volume ratio

Gas generation results are summarized in Figure 3-12 for the gas phase digestion of these mesophilic batches. The results indicate that the cheese waste has the potential to generate more gas more rapidly relative to the control and manure fed digester under mesophilic conditions. The total gas generation with food waste was 15 percent greater compared to the control bottles under the bench-scale test conditions. All bottles showed biological activity without any potential signs of inhibition. For monitoring the performance of the acid-gas digestion, samples were sent out at the start of the test, as well as on the 2nd (end of acid digestion) and 14th days of testing.

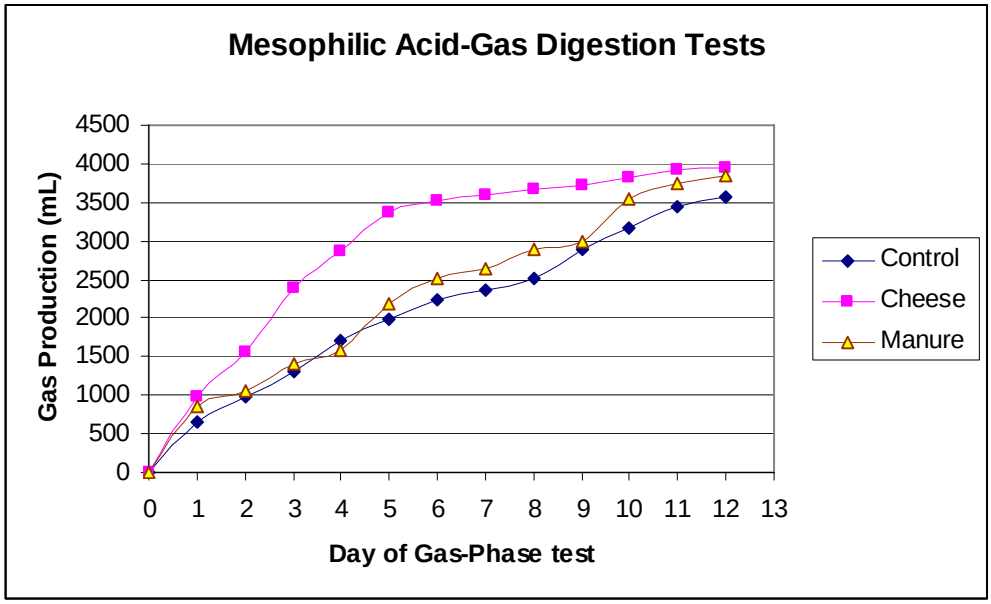

FIGURE 3-12
Gas Generation During the Gas-Phase of the Mesophilic Acid Digestion Testing

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Co-Digestion Blends Testing

Bench-scale mesophilic blend tests were started on December 27, 2004. Biosolids samples collected from IEUA RP-1 Digester 6 and food waste samples were mixed at 80:20 volume ratios in 2-liter bottles, and were then incubated in temperature-controlled water baths. One set of control bottles with biosolids without food waste addition was also included. When the biosolids seeds for the testing were obtained from RP-1 Digester 6 (mesophilic), the digester temperature was at 98°F. Table 3-6 lists the food waste types used in this phase of testing.

TABLE 3-6
Food Wastes Used in the Co-Digestion Blends Testing

Food Waste Type	Digestibility Category	Comment
GFF/Salad dressing	Easy to digest	
Unilever Best Food/Tomato Sauce and Mayonnaise	Easy to digest	
Golden Cheese Company/Cheese	Moderately easy to digest	

Table 3-7 lists the blend ratios tested in this phase of testing. Percentages listed for each food waste type make up the 20 percent total food waste content in the final digestion volume. For example, the total digestion volume was 1,600 mL in each bottle. Twenty percent of this volume (320 mL) was food waste comprising either one of the two blends listed in Table 3-7, while the total seed volume was 1,280 mL.

TABLE 3-7
Food Waste Blends (20% Total Food Waste Volume) Used in the Co-Digestion Blends Testing

Food Waste Type	Blend 1	Blend 2
GFF/Salad dressing	25%	10%
Unilever Best Food/Tomato Sauce and Mayonnaise	25%	10%
Golden Cheese Company/Cheese	50%	80%

For monitoring the performance of the blends digestion, samples were sent out at the start of the test and on the 14th day of testing. Due to limitations at the OCSD Plant No. 2 laboratory, the test was conducted up to 14 days. Gas generation results are summarized in Figure 3-13 from digestion of these mesophilic batches. The results indicate that at both blend ratios there is potential to generate more gas more rapidly relative to the control under mesophilic conditions. The total gas generation with food waste was 15 percent greater compared to the control bottles under the bench-scale test conditions. All bottles showed biological activity without any signs of inhibition.

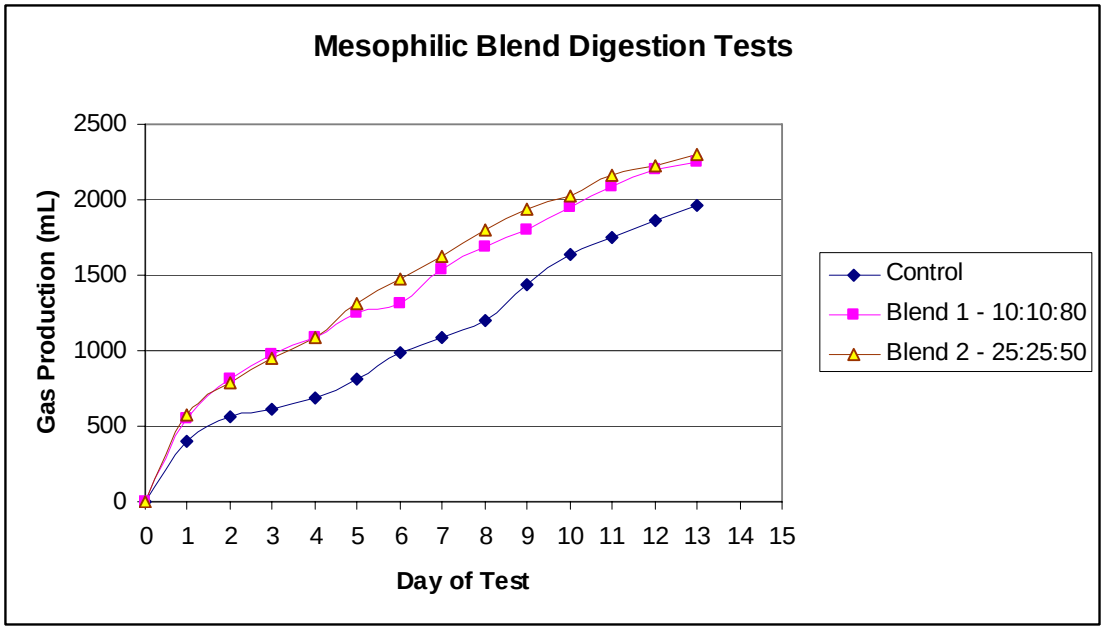

FIGURE 3-13
Gas Generation During the Mesophilic Blend Digestion Testing

Bench-Scale Test Findings Summary

The results showed that by implementing co-digestion, it is possible to obtain significant gas generation and full scale testing is warranted to be able to assess the gas generation under continuous food waste and seed (biosolids or manure) feed conditions. Depending on test conditions, a 15 to 26 percent increase in gas production was observed in tests using co-digestion with food waste as compared to control tests without. It was recommended that full-scale testing be conducted at mesophilic temperatures for co-digestion of food waste with manure and biosolids. It was determined that food waste feed should start at a low rate relative to manure or biosolids, to allow the populations in the digesters to acclimate, then be increased slowly to 90:10 (10 percent food waste), and then to 80:20 (20 percent food waste), if no adverse operational or quality impacts are experienced at 90:10 ratio.

3.3.2 Pilot Plant Design and Testing

The final activity in Task 3.1.3.c was to use the results of the bench scale testing to complete the final design of the co-digestion facility and to develop the test plan for the development of the demonstration projects. The results of these activities were presented in the Task 3.1.3.c report, which included the schematic shown below as Figure 3-14. This figure provides an overview of the process schematic for co-digestion at RP-1.

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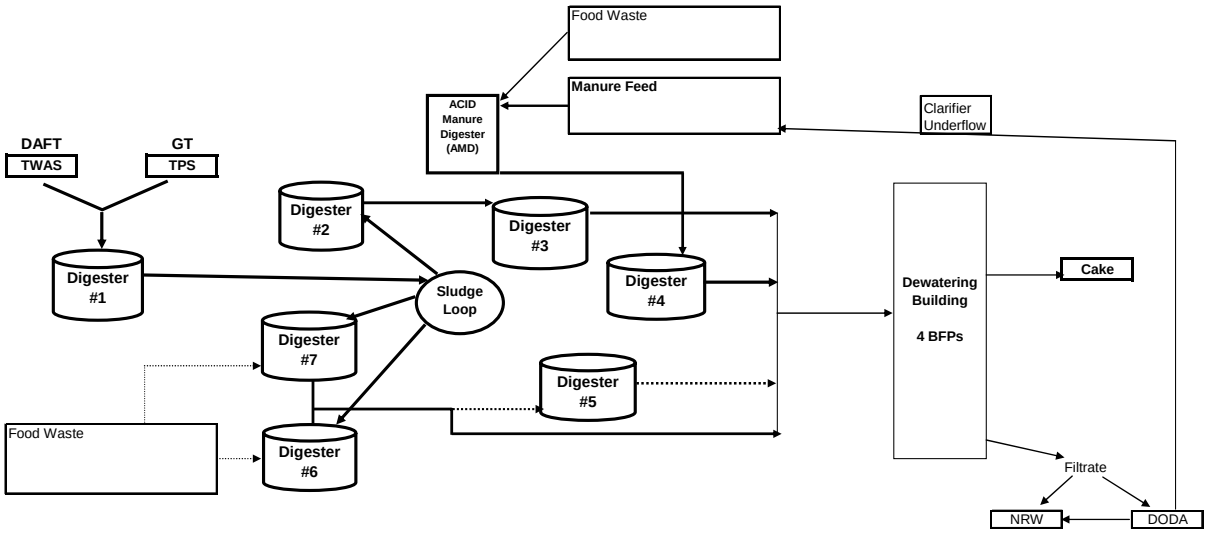

FIGURE 3-14
Overview Process for Co-Digestion at RP-1

Detailed schematics of the tanks to be installed and the piping modifications to be implemented also were provided in Appendix B, Detailed Drawings for Co-Digestion Equipment at RP-1, for the Task 3.1.3.c Test Plan. A general site overview showing the locations of the food waste holding tanks and the existing digesters 1 to 8 is shown in Figure 3-9 earlier in this section.

The Task 3.1.3.c report also identified potential sources of food waste to be used in the co-digestion of manure and food processing waste and biosolids and food processing waste. Contacts were made with food waste suppliers to make sure they could provide enough waste for testing and for full-scale implementation. A summary of the short-listed food waste providers included in the Task 3.1.3.c report is presented in Table 3-8. From this list, the final list of food waste providers was selected. The wastes selected for co-digestion testing included cheese whey, salad dressing waste, and ice cream waste.

TABLE 3-8
Short-Listed Food Waste Producers Located Within 50 Miles of RP-1 and Initially Available Delivery Information

					Waste Volume Available for Co-Digestion			
					80:20 Feed		90:10 Feed	
Waste Digestibility	Producer	Type of Food Waste	Waste Production gpd	Waste Production gal/wk	% of Daily Total Needed	Amount Needed, gpd	% of Daily Total Needed	Amount Needed, gpd
Easy	Unilever Best Food (UBF)	Tomato Sauce and Mayonnaise	720	5,000 [1]	1.28	1,000	2.56	1,000
Medium	Cacique Inc.	Cheese	20,000-30,000		38.5	30,000	76.9	15,000
Medium	Golden Cheese Company	Cheese	25,000 +		32.1	35,000	64.2	18,000
Easy	GFF Inc.	Salad Dressing	720-1400	5,000-10,000	1.79	1,400	3.59	1,400

TABLE 3-8
Short-Listed Food Waste Producers Located Within 50 Miles of RP-1 and Initially Available Delivery Information

					Waste Volume Available for Co-Digestion			
					80:20 Feed		90:10 Feed	
Waste Digestibility	**Producer**	**Type of Food Waste**	**Waste Production gpd**	**Waste Production gal/wk**	**% of Daily Total Needed**	**Amount Needed, gpd**	**% of Daily Total Needed**	**Amount Needed, gpd**
Hard	Calmeco	Meat Processing	2,000		2.56	2,000 [3]	5.13	1,000 [3]
Hard	Corona Cattle	Meat Processing	2,000-3,000		3.85	2,000 [3]	7.70	1,000 [3]
Easy	Mizkan Americas Inc.	Vinegar	10,000 (Potential Filler)		12.8	10,000	25.6	5,000
Easy	Alta Dena[4]	Ice Cream	2,140	15,000	2.7	2,140	5.5	1,070
Total			**74,540[2] gpd+ Available**		**78,000 gpd Needed for Full-Scale Implementation**		**39,000 gpd Needed for Full-Scale Implementation**	

[1] Producer prefers one weekly delivery.

[2] May need to arrange for more Golden Cheese waste. Their total production is 70,000 gpd.

[3] Meat processing waste can be part of the biosolids co-digestion to prevent pH suppression in the gas digesters (digesters 2, 6, and 7) since they have pH values higher than other available food wastes and contain alkalinity.

[4] Ice cream waste is newly identified, and was not part of the initial evaluation.

This design and test plan information was then used to construct and operate the co-digestion projects for dairy manure and food processing waste and biosolids and food processing wastes under Tasks 3.1.4 and 3.1.5.

3.4 Outcomes of Task 3.1.4: Construct Pilot (Demonstration) Plant(s)

The construction tasks were categorized into four subtasks:

- 3.1.4(a)1: Construct Pilot (demonstration) Plant's Materials Handling System
- 3.1.4(a)2: Construct Pilot (demonstration) Plant's Digesters Gas Cleaning, and Gas Collection, Piping and Safety Systems Upgrade
- 3.1.4.(b): Construct Pilot (demonstration) Plant—Start-Up Activities
- 3.1.4.(c): Construct Pilot Plants—Specifications, As-Built Drawings, and Initial Performance Report

The activities conducted under each of the four subtasks are described below.

3.4.1 Materials Handling System

This task involved installing pumps, storage tanks, valves, metering, electrical and instrumentation and control systems, sampling ports and related equipment in accordance with the design for the Materials Handling Systems in accordance with the design completed under Task 3.1.3.

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As part of this task, a letter was provided to the Energy Commission stating that the materials handling system had been successfully installed, including all pumps, storage tanks, valves, metering, electrical and instrumentation and control systems, sampling ports, and related equipment. As stated in the letter, the installation was completed in accordance with the design completed under Task 3.1.3. Photographs showing system completion were included with the as-built drawings. A photograph showing the food waste receiving system and piping modifications also was included (Figure 3-15).

FIGURE 3-15
Food Waste Receiving System and Piping Modifications for Co-Digestion System at RP-1

3.4.2 Gas Cleaning, Gas Collection, Piping and Safety Upgrade Systems—Iron Sponge Modifications

Iron sponges are used remove H_2S from digester gas. IEUA RP-1 has four units. Two are used for polishing the removal of H_2S from approximately a few hundred ppm to less than 30 ppm prior to the engine generators and the microturbines. The other two iron sponges are used for removing H_2S prior to disposing the digester gas to the waste gas burner. To make sure the iron sponges can provide removal of H_2S, the media in all the units is replaced every 6 months.

There are several studies that suggest that adding air to an iron sponge can increase the life of its media. The amount of air that needs to be added for iron sponge media regeneration is less than 10 percent of the digester gas flowing to the iron sponge. Adding air to the media causes an exothermal reaction, which requires the addition of water to maintain the temperature in the iron sponge below 120°F. The system is also more effective if the pH in the iron sponge is maintained in the basic side of the scale.

The two iron sponges upstream of the engine generators and the microturbines at RP-1 have been selected for the pilot study. Each of these iron sponges consists of two compartments totally isolated from each other. Digester gas flows into each of these compartments from a common header and can be isolated by a manual valve (see Figure 3-16).

FIGURE 3-16
Iron Sponge System Prior to Modifications

To conduct the iron sponge pilot test, the two iron sponges by the Energy Recovery Building (ERB) required piping modifications. The iron sponge located southwest was selected as the pilot unit and the one located southeast was selected as the control unit. Figure 3-17 shows the modifications needed at each iron sponge and Figure 3-18 shows the implemented modifications. The existing header and the piping feeding each iron sponge had to be reconfigured to allow the installation of a flowmeter and sample point on each branch. The branch feeding the southwest iron sponge also included an injection point. The modifications also included adding a sample point on the discharge branch of each iron sponge, a temperature switch on the discharge of the southwest branch, an air pipe with a modulating valve and flowmeter, and the required control and electrical systems.

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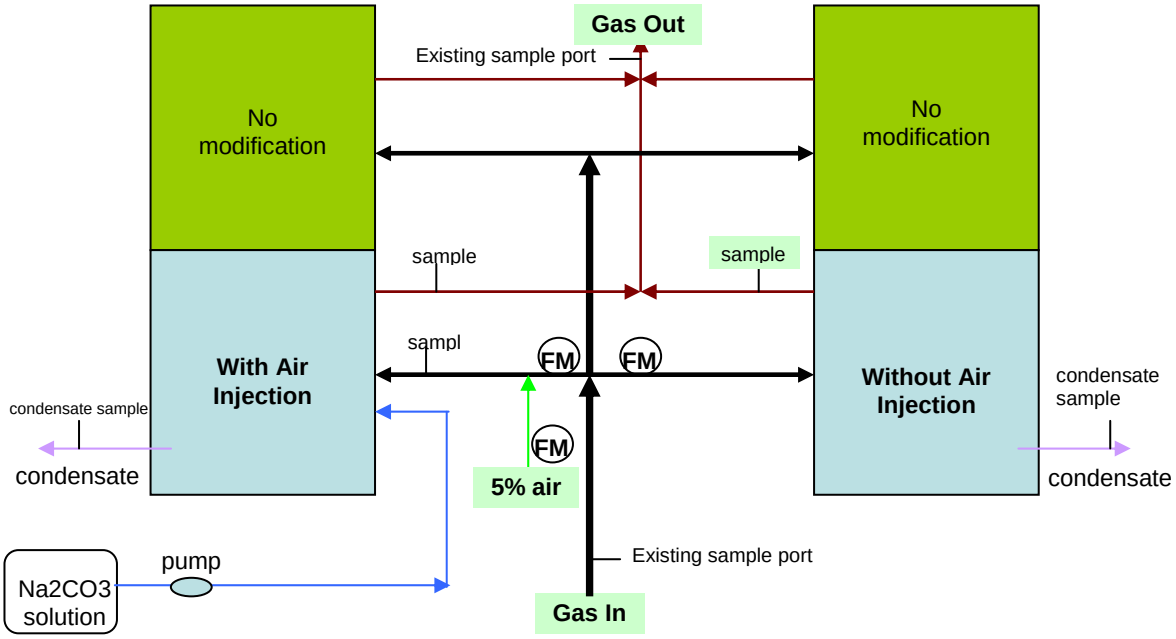

FIGURE 3-17
Iron Sponge System Modifications

FIGURE 3-18
Implemented Iron Sponge System Modifications: 1

3.4.3 Plant Startup Activities

This task involved conducting startup activities and initial testing of the materials handling system (Task 3.4.(a) 1) and gas cleaning, and gas collection, piping and safety systems upgrades (Task 3.4(a).2).

As part of this task, a letter providing notification that start-up and commissioning has been completed for RP-1 systems and that initial operating data meet performance requirements was submitted. This notice pertained to start-up activities and initial testing of the materials handling system (Task 3.4.(a) 1) and gas cleaning, gas collection, piping and safety systems upgrades (Task 3.4(a).2).

Also as part of this task, a letter stating that the as-built drawings had been completed was submitted. It was noted that specifications are found in drawings submitted previously under Task 3.1.3.c and that initial performance is documented in the reports under Task 3.1.5.

3.4.4 Specifications, As-Built Drawings, and Initial Performance Report

As-built drawings for materials handling, co-digestion, and digester gas cleaning (iron sponge) are listed in Tables 3-9, 3-10, and 3-11, respectively.

TABLE 3-9
Regional Plant No. 1 Materials Handling Drawings

Drawing Number	Drawing Title
T-1	Cover Sheet and Drawing Index
G-1	Mechanical Legend
DG-1	Food Waste Receiving Area and Piping Modifications
F-1	Process Flow Legend and Symbols
F-2	Foodwaste Receiving and Food Systems

TABLE 3-10
Regional Plant No. 1 Co-Digestion Drawings

Drawing Number	Drawing Title
T-1	Cover Sheet and Drawing Index
G-1	Mechanical Legend
DG-1	Foodwaste and Piping Modifications
DG – 2	Foodwaste Piping at Digesters
F-1	Process Flow Diagram Legend and Symbols
F-2	Foodwaste Receiving and Feed Systems
F-3	Foodwaste Mixing AMD Area

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TABLE 3-11
Regional Plant No. 1 Digester Gas Cleaning (Iron Sponge)

Drawing Number	Drawing Title
T-1	Cover Sheet and Drawing Index
G-1	Mechanical Legend
DG-1	Iron Sponge Air Injection
F-1	Process Flow Diagram Legend and Symbols
F-2	Process Flow Diagram Iron Sponge Air Injection

3.5 Outcomes of Task 3.1.5: Operate and Test Pilot (Demonstration) Plant(s)

The results of the monthly reports done under Task 3.1.5 showed that biogas production increased at both Digester 4 and the biosolids digester train (digesters 1, 2, 3, 6, and 7) at RP-1 when food waste was added to the input stream. Furthermore, manure co-digestion tests with food waste exhibited higher-than-expected increases in gas production. Specific observations and conclusions from the testing period (July to December, 2005) are:

On average, approximately 12 percent more biogas was produced from manure co-digestion than our original analysis predicted. This was indicated by:

- Volatile solids reduction in Digester 4 during the July-December co-digestion test period improved by about 11 percent over the baseline performance prior to April 2005, as illustrated in Figure 3-19:

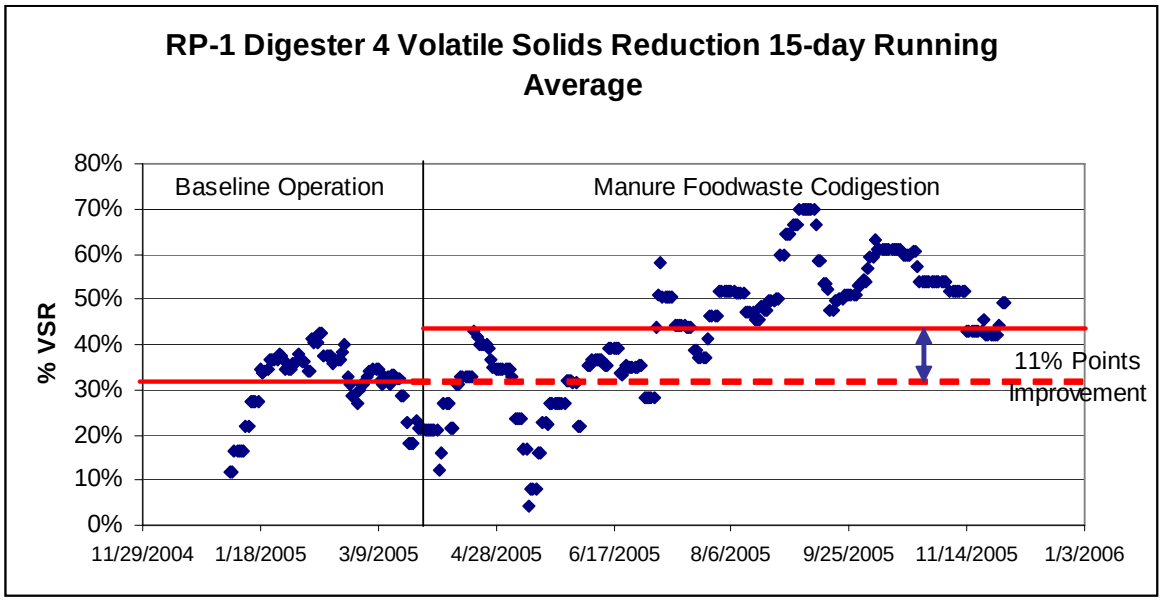

FIGURE 3-19

Implemented Iron Sponge System Modifications: 2

- After acclimation, the measured biogas produced from co-digestion was not only higher than baseline without co-digestion, but also about 12 percent higher than the expected amount. Thus, the increase was higher than expected, as illustrated in Figure 3-20:

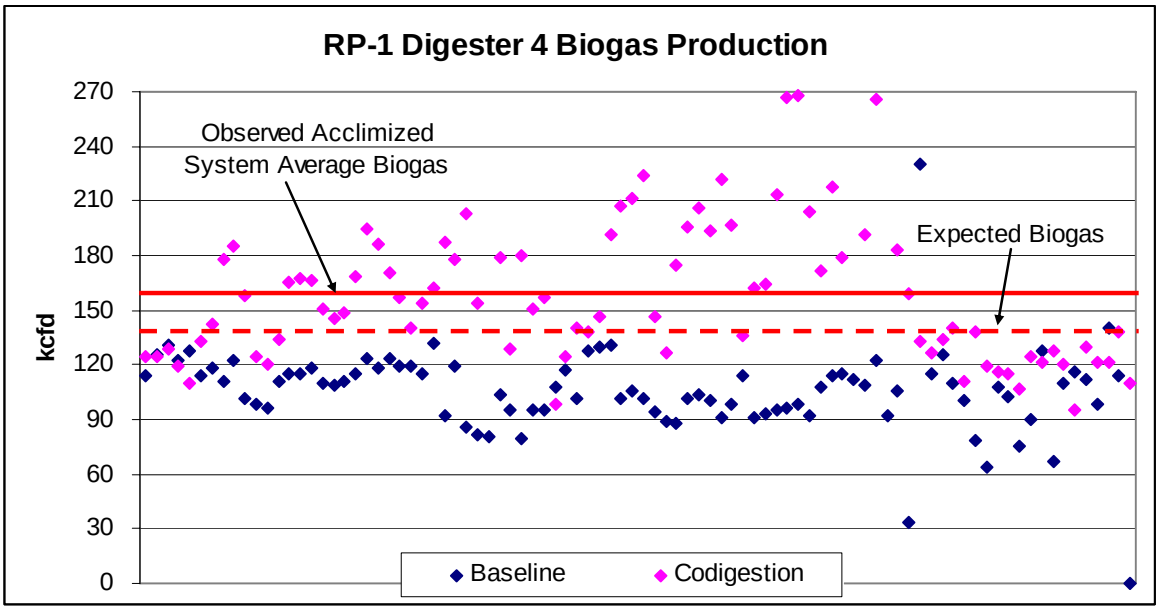

FIGURE 3-20
Implemented Iron Sponge System Modifications: 3

- The reason for this appears to be a synergistic effect between the two materials being co-digested. A possible reason is that the addition of food waste added nutrients that were naturally deficient with manure alone. Therefore, the bacteria community inside the digester may have been stronger and digested the manure better with food waste addition. This would explain the higher VSR observed as well as spikes in gas production when food waste was added.

- This phenomenon was not observed in a measurable way for co-digestion with biosolids, which have higher nutrients than dairy manure.

Large spikes were experienced during the testing when food waste was added in a "slug" fashion, meaning that an entire delivery of food waste was added to the digester at once, rather than being metered into the digester over a day.

- Data and observations made during transfer of food waste from the holding tanks into the digesters show that food waste was added all at once – an entire tank would be emptied into the digesters over a period of 1-2 hours, rather than over a day. This "slug-feed" situation was observed to cause immediate spikes in gas production. Figures 3-21 and 3-22 illustrate what happened:

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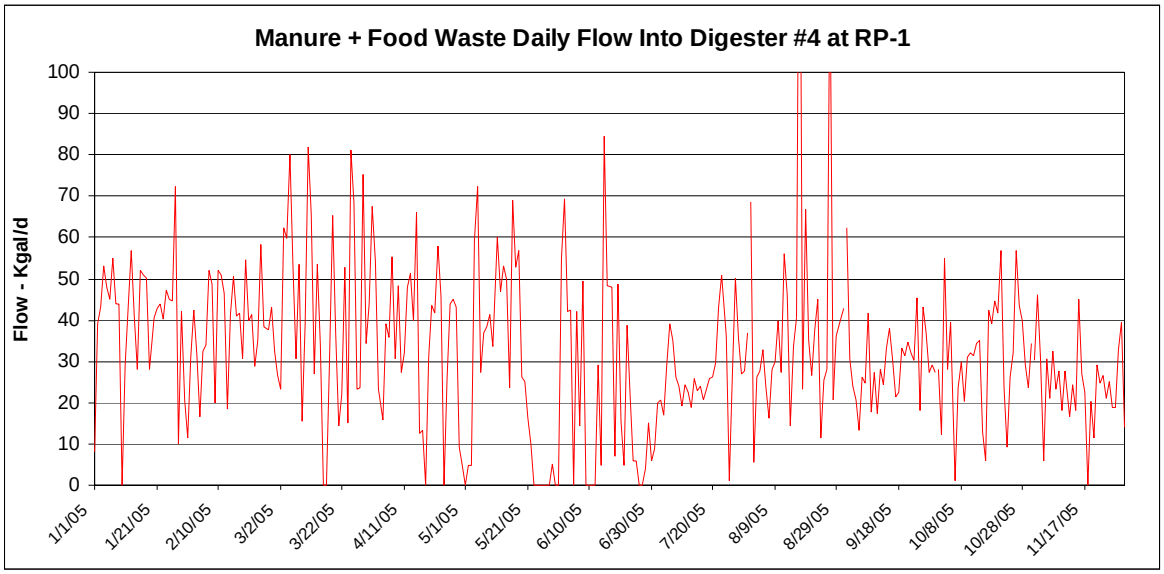

FIGURE 3-21
Implemented Iron Sponge System Modifications: 4

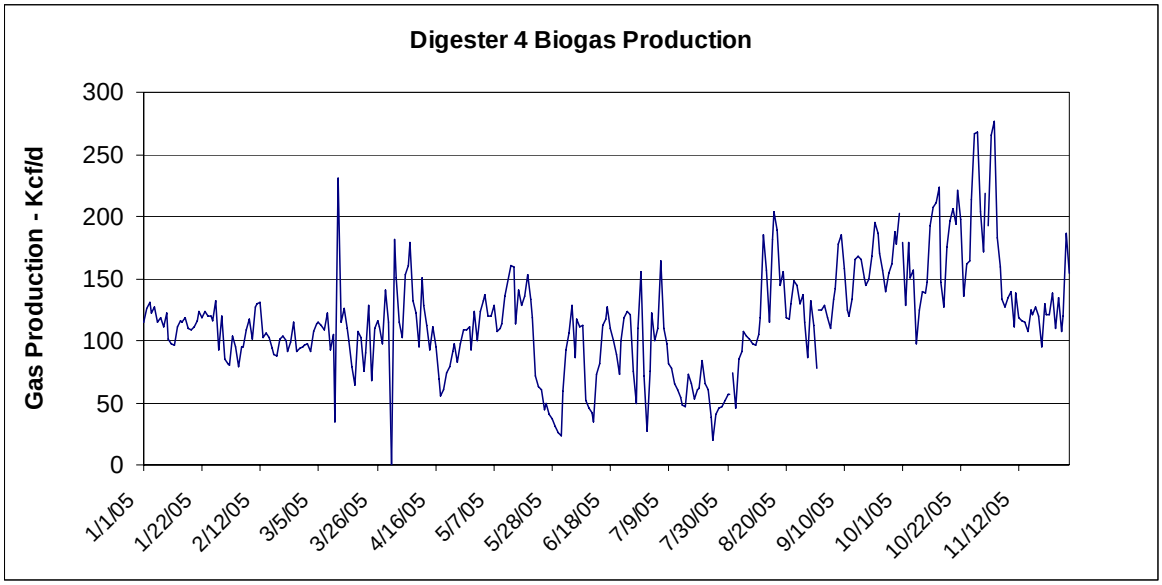

FIGURE 3-22
Implemented Iron Sponge System Modifications: 5

These spikes would at times overload the gas handling and storage system, causing unplanned release of biogas. During these times, most of the gas had to be sent to the flares, and at times even these were overload. At times, it was necessary to shut down the biogas-to-energy operations temporarily in order to prevent exceed air emissions limits. These episodes made it hard to manage biogas production to consistent levels.

Partially because of the spikes in gas production, the feed rate of food waste was reduced, therefore performance summary tables in the conclusions section (Section 4) of this report

include data for the systems *as tested*, and data for *full-scale*, with the planned food waste feed rates.

Lessons Learned from Co-Digestion Testing

The major lessons learned from the co-digestion testing are that biogas production may be up to 12 percent higher than expected when co-digesting manure with food waste, and planning needs to be done for the extra biogas. During this project, IEUA upgraded several parts of their biogas handling system, for both regulatory and safety reasons.

Also, food waste input into the digesters needs to be metered at a steady rate. "Slug-feeding" large amounts of food waste all at once can cause immediate spikes of gas production which can overwhelm existing gas systems. Associated with this, the food waste receiving and holding equipment should be sized carefully to be able to receive deliveries and hold enough food waste to meter it in gradually to the digesters.

Gas storage should also be carefully considered and sized for these systems when considering co-digestion with food waste, so that there is enough storage in the system to absorb temporary increases and fluctuations in gas supply without releasing biogas or affecting power system operations.

3.6 Outcomes of Task 3.1.6: Conduct Economic and Environmental Assessment

3.6.1 Formation of Peer Group

A key part of the effort to identify and evaluate the environmental benefits of dairy manure anaerobic digestion projects was to form a peer review group. The group was established to provide input at the outset of the project and to help shape the direction and to provide guidance on the key areas of focus. The group was also asked to participate in a workshop in February of 2004 prior to which the members were provided preliminary information about the anticipated findings and overall work approach. Comments from this workshop were considered during the course of the study.

The peer review group consisted of industry, agency and other recognized experts. Report authors also participated in the peer review reviewing sections written by other authors. Individuals on the peer review group are shown in Table 3-12.

TABLE 3-12
Peer Review Group for Evaluating Environmental Benefits of Dairy Waste Anaerobic Digester Projects

Name	Organization
Barbour, Wiley	Environmental Resources Trust
Bartam, Deborah	Eastern Research Group
Bose, Laura	U.S. EPA Region IX
Camp, Robyn	California Climate Action Registry
Clifton, Neil	Inland Empire Utilities Agency
Davis, Martha	Inland Empire Utilities Agency

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TABLE 3-12
Peer Review Group for Evaluating Environmental Benefits of Dairy Waste Anaerobic Digester Projects

Name	Organization
DeBoom, Nathan	Milk Producers Council
Drake, D. Kerry	U.S. EPA Associate Director
Dusault, Allen	Sustainable Conservation
Feenstra, Robert	Milk Producers Council
Gaffney, Patrick	California Air Resources Board
Gravender, Jill	California Climate Action Registry
Gundlach, John	Inland Empire Utilities Agency
Jones, David B	EPA Waste Management
Kashak, Edward	Regional Water Quality Control Board
Kitto, Bill	CH2M HILL
Krich, Ken	Sustainable Conservation
Lester, Julia	South Coast Air Quality Management
Lindgren, Glen	CH2M HILL
Lowry, Polly	Central Valley Regional Water Quality Control Board
Lorang, Phil	EPA/OAR (RTP) - Ammonia NEI - Livestock Ops.
Martin, Paul	Western Untied Dairymen
Mayville, Steve	State Water Resources Control Board (Riverside)
Menke, John	State Water Resources Control Board
Pajarillo, Jovita	U.S. EPA Region IX
Pena, Naomi	PEW
Phillips, Kathryn	Center for Energy and Environmental Research and Technology
Roos, Kurt	U.S. EPA AgStar Program
Salas, Bill	
Spurgin, Bob	Spurgin Associates
Summers, Matt	California Department of Food and Agriculture
White, Heather	U.S. EPA Region IX
White, John	Center for Energy and Environmental Research and Technology
Wilkinson, Robert	UC Santa Barbara
Wong, Lily	U.S. EPA Region IX
Zhang, Jessica	California Energy Commission

3.6.2 Baseline Analysis

The baseline analysis is a necessary element for quantifying emission reductions. It provides a description of the conditions and practices found on the dairy farms that currently supply manure to the digesters. The results of the baseline analysis quantify a range of predicted emissions resulting from the operation of the identified dairies that currently supply

manure to RP-1 and RP-5 digesters both before and after the implementation of the digester projects, based on best available data from the farms.

The analysis quantifies a range for all criteria pollutant emissions and greenhouse gases (GHG) (notably methane, nitrous oxide, and carbon dioxide) and ammonia emissions related to the identified dairy operations prior to the establishment of RP-1 and RP-5 anaerobic digesters. This establishes a baseline level of emissions that occurred before the IEUA Digester Project. An estimate is then made of emissions with the Digester Project, so that a comparison may be made, and reductions determined.

3.6.3 Scope

Methane and ammonia emissions from the following operations are included in the analysis: dairy cattle enteric fermentation (methane only), manure management in the corral and anaerobic lagoon, offsite composting, and land spreading. Nitrous oxide emission estimates include: (1) direct emissions from manure management at the dairy and manure nitrogen applied to soil and (2) indirect emissions from volatilization and subsequent deposition of nitrogen and leaching and runoff of applied nitrogen. Indirect emissions of N_2O associated with leaching at the dairy are not included in the estimates.

3.6.4 Chino Dairy Manure Management

The baseline analysis describes dairy manure management methods both before and after implementation of the Digester Project. At most dairies in the Chino Valley, the cattle are fed along a concrete feed lane and about 85 percent of the daily manure excreted is deposited throughout the corral and feed lanes. Before the Project, manure was scraped from the feed lanes into the corral weekly and either spread out or stacked. Two to three times a year, the manure would be hauled locally for direct land application on neighboring farms or for composting, or hauled to neighboring counties, such as Riverside County or beyond.

With the Digester Project, each participating dairy now uses a “honey vac” vacuum tanker truck to collect fresh manure along the feed lanes daily. Manure must be collected within 24 hours of being excreted. The honey vac truck is run several times per day for each group of cows fed. The manure is then transported to an “end dump” truck, or in some cases a nurse tank truck, which resides at the dairy. Throughout the day, the dairy collects manure from the feed lanes into these holding areas. Once per day, a manure hauler arrives and transports the manure to either RP-1 or RP-5, depending on the dairy’s location and the capacity of the digesters. The collected manure is transported locally to either RP-1 or RP-5, where it is anaerobically digested, a process that breaks down volatile solids into methane and carbon dioxide, leaving the remaining solids as compost. This is transported to a co-composting facility, where the compost is sold.

3.6.5 Baseline Methodology

A model was developed to quantify and verify methane and other GHG emission reductions and the environmental benefits of renewable energy produced by the digesters. Baseline emissions of methane (CH_4), nitrous oxide (N_2O), and ammonia (NH_3) associated with dairy manure management, including land application, prior to implementation of the

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digester project were estimated using farm-specific operational data. Post-digester emissions associated with the transportation of manure were also calculated.

Estimates of methane and nitrous oxide emissions are based on the methodology used by EPA to generate the annual *Inventory of U.S. Greenhouse Gas Emissions and Sinks*. In some cases, Eastern Research Group (ERG) used location-specific data to calculate emission factors.

3.6.6 Parameters Used for Sensitivity Analysis

The following assumptions were used for estimating parameters that drive the sensitivity analysis:

- Amount of Manure Processed
- Manure Total Solids (TS)
- Manure Volatile Solids (VS)
- Maximum Methane Producing Capacity
- Manure Transported from Corrals in Runoff
- Manure Land Applied
- Percent of Nitrogen that Leaches and Runs Off from Land Application
- Manure Shipped to Co-Composting
- Corral Methane Conversion Factor
- Nitrogen Excreted
- Manure Production
- Typical Dairy Cattle Mass

3.6.7 Results

A model was developed to estimate emissions using the input parameters above. Specific calculations within the model are described in the full report. A summary of the estimated baseline and Digester Project air emissions using the model is shown in Tables 3-13 and 3-14.

TABLE 3-13
Emissions Related to Dairy Manure Management (including Composting and Land Application)

Pollutant	Methane		Nitrous Oxide		Ammonia	
Baseline Emissions	336.5	tons CH_4 /yr.	23.2	tons N_2O /yr.	227.2	tons NH_3/yr
Post-Digester Emissions	261.9	tons CH_4 /yr.	1.1	tons N_2O /yr.	56.1	tons NH_3/yr
Reductions	74.6	tons CH_4 /yr.	22.1	tons N_2O /yr.	171.1	tons NH_3/yr

TABLE 3-14
Emissions Related to the Transportation of Manure

Pollutant	VOC		CO		NO_x	
Baseline Emissions	213.7	lbs VOC/yr.	803	lbs CO/yr.	2,715	lbs NO_x/yr.

TABLE 3-14
Emissions Related to the Transportation of Manure

Post-Digester Emissions	94.9	lbs VOC/yr.	432.3	lbs CO/yr.	1,366	lbs NO_x/yr.
Reductions	118.8	lbs VOC/yr.	371	lbs CO/yr.	1,348	lbs NO_x/yr.

Pollutant	CO_2		Methane	
Baseline Emissions	274,683	lbs CO_2/yr	10.0	lbs CH_4/yr
Post-Digester Emissions	134,277	lbs CO_2/yr	4.4	lbs CH_4/yr
Reductions	140,405	lbs CO_2/yr	5.55	lbs CH_4/yr

3.6.8 Reductions in Greenhouse Gas Emissions

As part of the baseline analysis, ERG analyzed the emission of GHG associated with the management of manure at the dairy, land application of manure, offsite processing of manure (e.g., composting), and transportation of manure off the farm (onsite transportation emissions were not estimated). Emissions were estimated using farm-specific operational data, where available, coupled with pollutant-specific emission factors.

Estimates of methane and nitrous oxide emissions are based on the methodology used by EPA to generate the annual *Inventory of U.S. Greenhouse Gas Emissions and Sinks*. In some cases, ERG used location-specific data to calculate emission factors. The model developed for the baseline analysis was used to quantify and verify methane and other GHG emission reductions and the environmental benefits of renewable energy produced by the digesters. Baseline emissions of methane (CH_4), nitrous oxide (N_2O), and ammonia (NH_3) associated with dairy manure management, including land application, prior to implementation of the Digester Project were estimated using farm-specific operational data.

Post-Digester Project emissions associated with the transportation of manure were also calculated. Post-Digester Project emissions include an estimate of emissions from the digesters themselves.

A summary of GHG emissions results is shown in Table 3-15.

TABLE 3-15
Summary of Baseline and Post-Digester GHG Emissions

Pollutant	GHG Emissions (CH_4+N_20)	
Baseline Emissions	14,245	tons CO_2-eq /yr.
Post-Digester Emissions	6,221	tons CO_2-eq /yr.
Reductions	8,023	tons CO_2-eq /yr.

It should be noted that the market for GHG reduction credits is nascent, and has been dependent on international acceptance and ratification of the Kyoto Protocol on GHG reductions. This market is limited, especially in the U.S. Prices in the U.S. per ton for GHG reductions have been around $1 per ton, but forward pricing is around $2.00 to $2.50 per ton. To compare with other locations, the European Union started a real trading system for

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GHG emissions credits in 2005, and those credits were trading around $25 per ton (metric) in early 2006. For economic purposes, the $1.00 to $2.50 range is used in this report.

3.7 Outcomes of Reductions in Air Emissions for Criteria Pollutants

Estimates for baseline air emissions and post-Digester Project emissions reductions from the ERG analysis were studied against the backdrop of current California regulatory requirements and EPA policy on pollutant credit trading to establish potential monetary value for the emissions reductions.

Emission Reduction Credits (ERCs) are normally sold as a permanent stream. Depending on the local air agency and the methodology used in the local NSR rule, ERCs are either issued as a ton per year stream or a pound per day stream. A rule of thumb to equate prices between these two methodologies is to multiply the pound per day stream price by 5.5 to arrive at a ton per year equivalent price. Tables 3-16 and 3-17 present current prices within the South Coast Air Quality Management District (SCAQMD) and San Joaquin Valley Air Pollution Control District (SJVAPCD), and statewide prices for ERCs. Current market prices were obtained from Cantor Fitzgerald's Market Price Index (MPI).

TABLE 3-16
South Coast Air Quality Management District Emission Reduction Credit Prices (2004)

		CO	NO_x	PM_{10}	SO_x	VOC[3]
Permanent[1]	$/lb/day	$15,000	$22,875	$31,250	$11,125	
Short Term Credits[1]	$/lb/day/year	$1,100	$1,800	$2,300	$820	
SCAQMD ERCs[2]	$/lb/day	$3,370	$7,083	$22,667	$7,233	$1,070[4]

Notes:

[1] Source—SCAQMD Rule 301(aa)—These are traded at a 1:1 ratio.

[2] Source—Cantor Fitzgerald Market Price Index, July 19, 2004—Traded within the SCAQMD NSR program at a 1.2:1 ratio.

[3] At the time that the SCAQMD was creating its ERC allowance in 2002, there was not a perceived shortage of VOC ERCs and no allowance or price was created.

[4] Based upon the economic ratio that the SCAQMD used to convert present value of ERC stream prices to an annual cost for Short Term Credits, a sale of Short Term VOC credits could be expected to be equivalent to $78/lb/day/year (Calculated as $1070 x .073).

Note that conventional ERCs are traded at a 1.2:1 ratio. For each pound of emissions that needs to be offset, 1.2 pounds of ERCs are purchased.

TABLE 3-17
San Joaquin Valley APCD and Statewide Emission Reduction Credit Transaction Prices for 2003

		CO	NO_x	PM_{10}	SO_x	VOC
San Joaquin Valley[1]	$/ton/year	[2]	$17,500-$30,000	$5,840-$30,000	$6,000-$10,000	$2,850-$11,000
San Joaquin Valley[3]	$/ton/year	n/a	$22,750	$14,750	$6,450	$10,887
Statewide[4]	$/ton/year	$16,251	$39,842	$35,797	$9,146	$9,738

Notes:
[1] Source—CARB 2004—Range of ERC trades reported for 2003
[2] No trade reported in 2003
[3] Source—Cantor Fitzgerald Market Price Index, dated Monday July 19, 2004
[4] Source—CARB 2004—Average price of all ERC trades reported within California for 2003

Note that the trading ratio for ERCs in the San Joaquin Valley is 1.3:1 for distances of less than 15 miles between the new emissions source and the source providing the emissions offsets. The ratio increases to 1.5:1 for distances beyond 15 miles.

3.7.1 Limitations to Creating Tradable Emission Reductions

Ammonia emissions from dairies, sewage plants, and industrial activities react to some extent in the atmosphere with sulfur and nitrogen compounds to form sulfate and nitrate aerosols. Modeling conducted by the SCAQMD shows that peak ambient air quality PM_{10} emissions occur in the immediate area of the dairy industry in the Chino Basin. In addition, particulate ammonia has been shown to amount to as much as 27 percent of the total winter San Joaquin Valley PM_{10} concentration. Because of this relationship, the SCAQMD developed strategies and is in the process of adopting Rule 1127, which will affect manure management practices and will lead to reductions in dairy-related ammonia emissions. Unfortunately, the state-of-the-art in atmospheric or air quality planning models is not yet at the stage where direct conversion ratios between the mass of ammonia emitted and the mass of resulting nitrate or sulfate aerosol formed as a result can be assessed. Research being conducted in the San Joaquin Valley should yield sufficient data within about 2 years such that mass conversion ratios will be available.

3.7.2 Reduction of Emissions Affecting Water Quality

Baseline Water Quality Evaluation ("Without Digester Project")

Current Groundwater Quality. Current levels of nitrates and TDS in local groundwater were assessed using data from two sources: (1) Annual reports from the Chino Basin Watermaster's Optimum Basin Management Program, and (2) Groundwater quality evaluations completed in 1999 as part of the development phase of the IEUA Desalter project.

Effects of Manure Management and Dairy Operations

Dairy waste management practices have direct impacts on quality of the nearby and neighboring surface and ground waters. The main sources of water in most dairy operations are the cattle excretions and the water used for manure flushing and dust control. Rainfall also contributes to the overall water budget by washing off the surfaces. Water losses from

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the farms occur in the form of seepage through the soil, evaporation, overflows from lagoons and runoff into the holding ponds. In many cases, the lagoons are not lined or the linings are not watertight and allow seepage to occur.

The stocking rate (animal density) has a significant impact on the manure compaction and evaporation rates that in turn impact the moisture retained in the manure. For the model farm developed for this evaluation, the stocking rate of the farm was assumed to be sufficient to minimize water usage on the farm, and allow for dry-removal of the manure. The runoff is assumed to contribute to the anaerobic lagoon water budget, washing a certain amount of manure solids and excrement into the lagoon.

Mass Balance Model—"Without Project"

A "Without Project" mass balance model was developed based on the model farm assumptions and manure generation rates. The model is based on the complete Nitrogen cycle (simplified in Figure 3-23). The results are used to assess water quality impacts/benefits of the Digester Project.

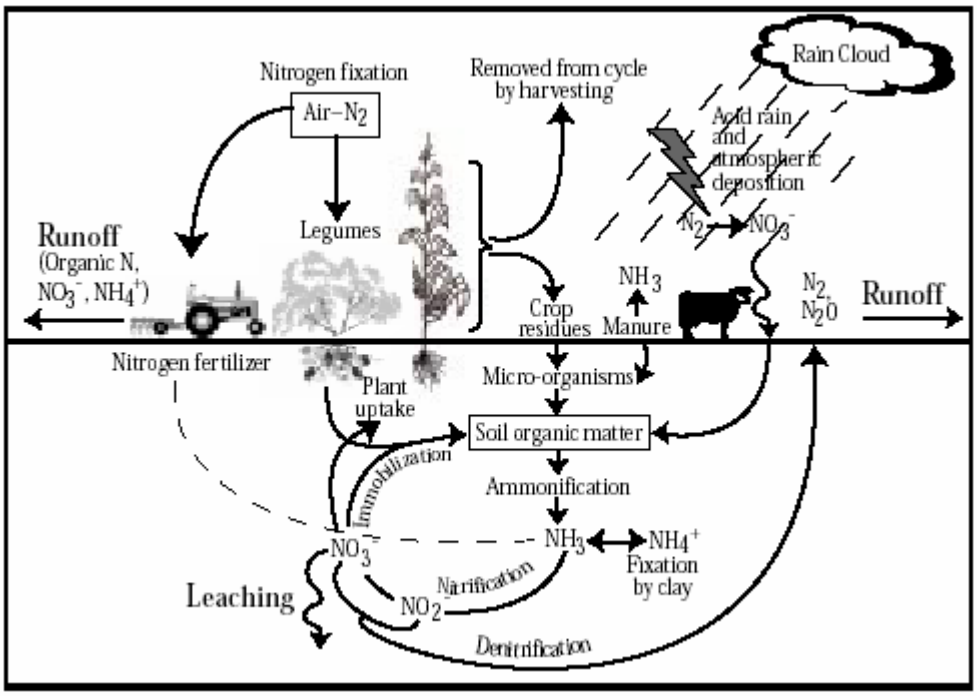

FIGURE 3-23
Nitrogen Cycle in Agricultural Areas

Manure Management and Mass Balance Model with Project

With the Digester Project, the manure is assumed to be dry-collected from the corrals within 24 hours of excretion and transported to the digester site. It was assumed that the digested biosolids are dewatered and either land applied or composted. For the mass balance calculations, the land-applied fraction was assumed to be 50 percent. A "With Project" mass balance model was developed based on the model farm assumptions, manure generation

rates and current digestion practice at the RP-1 and RP-5 manure digestion facilities. RP-1 and RP-5 digester volatile solids destruction rates, dewatered biosolids solids content and centrate quality values were used. The model results are used in assessment of water quality impacts/benefits of the digester projects.

Impacts of the Project

The Project water quality impact is based on two considerations:

1. Water quality ERCs, above and beyond base reduction requirements set forth by the EPA, which may be able to be traded in a market.
2. Reduced load on the IEUA desalting facility, which treats nitrates and TDS salts in the groundwater using reverse osmosis. To the extent that the dairy manure is captured and processed, these contaminants are reduced, offsetting operating costs, and/or deferring expansion of desalting plant capacity. These reductions or deferments may accrue as monetary benefits.

Groundwater Quality Impacts

For the 18-acre Model Farm area, the underlying groundwater directly impacted from the farm activities was calculated as 22 Ac-ft/yr. Assuming zero background nitrogen, it was calculated for the groundwater underlying the farm area that a 54 percent reduction in nitrogen load can be achieved by the Project. Assuming that the blend water used at the Desalter will continue to have the same quality and with the reduced TDS load, the RO units can be operated at 90 percent recovery rates. A 16 percent reduction in RO feed and a 63 percent reduction in RO brine generation were calculated for the "With Project" conditions.

Monetary Impacts/Benefits

Pollutant Trading. For water emissions, it was determined that there is not yet a market for trading emissions, so there is not financial benefit from credits trading for water emissions.

Desalter Operation. Information provided on desalter operation and maintenance costs currently being accrued by IEUA show that $668 is spent per acre-foot of treated groundwater. This value corresponds to $6 Million for 2,894 million gallons (MG) of annual groundwater volume treated. The beneficial effects of reduced salt and nitrogen loads reach the groundwater after implementation. These impacts are expected to translate into cost savings because:

1. The reduced TDS load to the desalter membrane elements reduces the frequency of membrane replacement and other maintenance needs to control fouling.
2. The reduced TDS load can increase the recovery rate of the desalter membranes from the current 80 percent potentially up to 90 percent, increasing the product water quantity.
3. The increased recovery results in reduced brine generation, and reduced SARI fees (lumped into the cost of $668/AF).
4. The improved groundwater quality reduces the volume that needs to be treated to meet the blend water quality and quantity requirements.

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It must be emphasized that benefits seen in the groundwater coming into the desalter would accrue over time as more and more dairy farms went to collecting manure for digestion. There are 10,000 to 15,000 acres of dairy farms in the Chino Basin. If one 18-acre model farm does the project, the nitrogen and salt reduction in the ground water effluent *from that farm* will be as shown in the "w/project" mass balance; however, the reduction in groundwater *at the desalter* would barely be noticeable, since it includes effluent from all of the surrounding farms. If *all* of these farms execute the project, then groundwater at the desalter should over time experience nitrogen and salt reductions.

Table 3-18 lists potential financial benefits due to reduced operating costs at the desalter if *all* dairies implemented the project.

TABLE 3-18
Project Benefits on Desalter O&M Costs if all Chino Basin Dairies Implemented Manure Digester Projects

Annual O&M Costs without Project		Annual O&M Costs with Project		Annual Savings	
5,932,900	$/yr	3,669,500	$/yr	2,263,400	$/yr[1]
2,050	$/MG	1,500	$/MG		
12,688	$/ton NO_3-N	15,559	$/ton NO_3-N		
516	$/ton TDS	610	$/ton TDS		
470	ton NO_3-N removed	240	ton NO_3-N removed		
11,490	ton TDS removed	6,020	ton TDS removed		

Note:
[1] $2,263,400/yr assumes *all* Chino Basin Dairies implement the project. For the "Project" as implemented at dairies served by RP-1 and RP-5, savings in desalter operation costs were estimated at $40,300 per year.

Applicability of Desalter Operations Savings and Water Emissions Reductions to Other Areas. The use of the IEUA desalter facility to reduce salts and nitrates in groundwater before use is a situation unique to the Chino Basin. Faced with the existing groundwater problems of high nitrates and salts from years of this type of agriculture in the area, IEUA has selected the strategy of using membrane separation technology as a response for groundwater treatment. Another unique aspect of this situation is that IEUA has a pipeline directly to the ocean (the SARI line), which it can use to dispose of high salt-content brine reject from the membrane operation.

Nevertheless, it should be noted that salt and nitrate contamination of groundwater is an approaching issue for both the San Joaquin and Sonoma Valleys. If dairy agriculture increases in those areas, they will likely face the same issues. Because their situations vary from that in the Chino Basin, the strategy for groundwater treatment may be different, however it is anticipated that there will still be a cost associated with this. Therefore an environmental benefit should accrue from proactively managing animal manure in those areas through collection and digestion at facilities similar to those used by IEUA. This would have the effect of reducing groundwater emissions before they build up, and displacing the expense of future groundwater treatment.

3.7.3 Renewable Energy Attributes ("Green Tags") from Manure Digestion Projects

This evaluates opportunities to define renewable energy attributes or "green tags" from manure digestion projects. Using the IEUA dairy waste to energy project as a case study, the potential for monetary benefits from green tags created by these types of operations was reviewed.

- Definition of a "Green Tag"
- Reviewing how a green tag is created, identified, purchased, accounted, monitored and verified
- Showing the effect of various accounting methods under consideration
- Exploring ways to maximize the renewable energy benefits
- Determining the difficulties in maximizing these benefits and exploring alternatives

The analysis table identifies the range of potential values for the renewable energy generated and for the environmental benefits from reduced emissions. Because the markets for valuing emission reductions are not well developed, a strategy to realize the economic benefits of reduced emissions is also discussed.

3.7.4 Definition of Green Tag

Various definitions of the term "green tag" exist in the current literature. Some of them offer conflicting implications on how a "green tag" would be valued in the marketplace. The definition from NatSource adopted for this report is:

> "A renewable energy certificate (REC or "Green Tag") represents a contract between a generator and a purchaser representing "unique and exclusive proof that one MWh of energy was generated from a renewable resource."[1]

Environmental Resources Trust (ERT) offers a certification standard based on this definition[2] and this standard is being used throughout the U.S. to represent the identification, accounting, and transacting of RECs.

3.7.5 Creation of a Green Tag

A green tag is created when a seller certifies that one megawatt hour (MWh) of renewable energy has been created from a qualifying new renewable source. The "greenness" of that energy is then sold and the actual electricity is generically used.

The initial purpose of a "Green Tag" was to eliminate the cumbersome exercise of scheduling physical delivery of the green power to the consumer. Selling the "greenness" of the energy eliminates that need. Once the tag is sold, the electricity has lost its green quality and becomes generic, allowing for the separation of the electricity from the green tag. The green

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[1] Natsource. Williamson, Matthew, "Estimating Benefits from Renewable Energy," California Energy Commission Technical Meeting, July 17, 2003

[2] Environmental Resources Trust, Leahy, Patrick & Hathaway, Alden, "Renewable Energy Certificates and Air Emission Benefits—Developing an Appropriate Definition for a REC," April 2004

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tag ends up becoming a type of "voucher" that can be used to "green-up" commodity electricity taken off the grid from somewhere else. If a fossil fuel has been displaced, an emission reduction may be created from that displacement. The accounting of that MWh is documented as a 'green tag' so as not to be counted a second time. Once the tag is created, the transaction between buyer and seller creates a change in ownership. It is clearly the buyer who takes ownership of the *renewable energy credit*. Yet, under the present system, ownership of the *environmental benefit (*ERC) is more open to debate.

The IEUA Digester Project is an example. A study by ERT and ERG identified reductions in both methane and ammonia.[3] While ammonia is not a GHG, there is the possibility of local trading markets opening up to trade reductions in ammonia emissions. The methane is burned in the generation of electricity, yet the reduction in ammonia had nothing to do with energy development. This illustrates the debate on both accounting and ownership. Bundling the emissions benefits into the green tag serves to eliminate any credit or benefit from the reduction of the other emissions not directly connected with the production of energy. The generator of the renewable energy may therefore wish to claim the environmental credits separate and apart from the sale of the Green Tag.

When a generator claims a REC, that generator must register that REC in order to make it available for sale. The typical process goes like this:

- Complete an application
- Pay a registration fee
- Provide documentation to prospective buyers
- Submit to third-party verification
- Agree to standards and codes of conduct

Typically the application and registration involve making a claim of a set amount of renewable energy and identifying its source. The certifying agency will refer the generator to an independent third party to verify the renewable energy generation. The seller of a green tag must also agree to certain standards, sometimes known as "Codes of Conduct."[4] These standards can include the amount of the renewable energy, as minimum amounts sometimes apply; environmental benefits[5]; renewable classification status (new); and counting integrity. ERT's position paper on these standards is included as an appendix to the full report. A copy of the Green-e Code of Conduct is also included as an appendix to the full report.

3.7.6 Accounting Methods

Central to the integrity of the Green Tag approach is the accounting method to make sure that the credit is only claimed and counted once. A report from the Center for Resource Solutions to the National Renewable Energy Laboratory (NREL) highlighted the issues

[3] Environmental Resources Trust, "Monitoring, Reporting and Verification Protocol for the IUEA Anaerobic Digester Project," October 2003

[4] Green-e National Standard for TRC's Appendix B, Green-e TRC Contract

[5] Green-e National Standard for TRCs Requires "Inclusion of Environmental Benefits; ERT REC Certification does not

central for an accounting system. Note that the reference to a "TRC" stands for Tradable Renewable Credit, synonymous with a Green Tag or REC:

> "There are several key functions that each Issuing Bodies' TRC tracking system must satisfy including: (1) retirement of certificates after they have been used to meet government mandates or retail sales, (2) prevention of double counting, double sales, or double use, (3) ability to ensure the basic information (e.g. fuel type, emissions profile) and quantity of certificates is verified, (4) ability to meet a variety of regulatory objectives, such as verification of compliance with RPS or desire to increase market potential for renewables; and (5) the ability of the various issuing bodies to communicate between each other in an efficient and secure manner. The individual systems and the network should be easy to use, transparent, flexible, and have low transaction costs."[6]

California has recently developed a numbered system of accounting for such tags. Under this accounting system, suppliers complete Energy Commission electronic forms documenting the source and qualification for the renewable power and the amount declared. This information can then be tied into the recipient information insuring integrity in accounting. This concept and using the same mechanisms would appear to be applicable to buying and selling credits for individual pollutants if there were a separate accounting for emission reduction credits.

As the market for green tags matures, traders who buy and sell green tags are, in some cases, finding that they are having more difficulty selling green tags that include the environmental benefits. Whether by prohibition or complication, it is being suggested that it is in fact easier and simpler to keep the renewable energy credits separate from the environmental benefits.

It is clear that the method of accounting will have an impact on the economics in that ease of access to markets and sellers is impacted by the method of accounting. Elements necessary to an accounting system include:

- Develop a sound framework for governance
- Effective network between participating entities
- Public acceptance of the accounting system
- Secure communications between entities
- Market conditions for both supply and demand[7]

3.7.7 Maximization of Benefits

An entity generating renewable energy wants to maximize the economic benefit derived from that energy. Options that go into determining what to do with the renewable energy include:

1. Use the energy to offset what would otherwise be purchased and gain credit for self-generation and consumption of renewable energy

[6] Hamrin, Jan, PhD and Wingate, Meredith, Developing a Framework for Tradable Renewable Certificates, Final Report. May 29, 2002, updated August 2002

[7] Hamrin, Jan, PhD and Wingate, Meredith, Developing a Framework for Tradable Renewable Certificates, Final Report. May 29, 2002, updated August 2002

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2. Sell the actual energy to a qualified entity with transmission and distribution capability and sell the emission reductions separately
3. Sell the green tags, use the energy (now without the 'green' qualification) and sell the emission reductions separately
4. Sell the green tags with environmental benefit attributes as is currently being offered by the investor-owned utilities in California.

A generator of renewable energy will see pros and cons for each option. Depending on the situation, any one of the options may be most beneficial. However, Option 3 will provide the greatest flexibility for a generator to maximize value from both RECs and emission reductions. In California however, options to register green tags with Green-e and sell them are limited to Options 2 or 4 listed above.

A workshop held on October 27, 2004, at Inland Empire Utilities Agency in Chino California addresses the topics contained in this section concerning Renewable Energy Credits. This includes the definition, generation, trading, and accounting of RECs ("Green Tags"). Sponsored by the Energy Commission, with support from the California Climate Action Registry, the forum includes participants from the environmental and regulatory communities, as well as green energy service providers. The workshop facilitator is Dr. Robert Wilkinson, Professor at UC Santa Barbara, an international expert in climate change and trading programs, and a member of the Energy Commission's Scientific Review Panel. Topics include issues that impact the market for Renewable Energy Credits, and how best to certify and account for their development and trading. At the conclusion of the workshop, a report will be developed summarizing the discussion and findings.

3.7.8 Example Estimation of Monetary Benefits from Green Tags for a Project

Using data from RP-1 for the year 2002 as an example, Table 3-19 illustrates how the economic benefits could be maximized.

TABLE 3-19
Breakdown of Potential Economic Benefits (RECs and Green Tags) from Dairy Manure Anaerobic Digestion at RP-1

		Annual Value Range		
Constituent	**Amount**	**Low**	**Mid**	**High**
Renewable Energy Generation valued as a REC[8]	12,385 MWh	$12,385	$24,770	$38,115
GHG Emission Reductions CO_2 Equivalent	8,023 tons/yr.	$7,200	$8,000	$10,000
Other emission reductions:				
Ammonia (NH_3)	171.1 tons/yr.	N/A*	N/A*	N/A*
Total estimated benefit		$19,585	$32,770	$48,115

* Values for ammonia not available because a mechanism for translating these reductions to tradable credits

[8] Inland Empire Utilities Agency, Energy Production Figures for 2002 Value is limited here to sale as a green tag as opposed to actual energy.

TABLE 3-19
Breakdown of Potential Economic Benefits (RECs and Green Tags) from Dairy Manure Anaerobic Digestion at RP-1

does not yet exist.

The amounts of emission reductions were calculated by ERT and ERG in their report to IEUA.[9] Value ranges were determined using the most recent sale of emission reduction credits from the Chicago Climate Exchange (CCX) as the mid-point. Low values were calculated using the lowest sale of the constituent pollutant in the last 24 months and the higher values were determined through conversations with traders with a specific interest in the emission reduction credits IEUA will eventually make available for sale.

The amount of renewable energy generation at RP-1 comes from IEUA data for 2002. Total energy production is just over 12 million kWh per year, as shown in Table 3-20.

TABLE 3-20
kWh Energy Generation from RP-1 for 2002

Quarter	Total Production (kWh)	Digester Gas Percentage	Production from Biogas (kWh)
First	5,343,058	.62	3,312,696
Second	4,093,723	.71	2,906,543
Third	3,964,670	.75	2,973,502
Fourth	4,145,504	.77	3,192,038
Total	17,546,955		12,384,779

3.7.9 Actual Sale of Renewable Energy Credits

Commerce Energy entered into an agreement to purchase 12,000 megawatt hours (MWh) from IEUA in the form of a REC in May of 2004. This credit was sold to Commonwealth without environmental benefits or other attributes. In California terms, it is an "unbundled" green tag(s).

This renewable energy was generated in 2003, which reduced its value somewhat. RECs sold after the March 31 reporting deadline for those claiming RECs are worth less than they are for the current year. The purchase price for this sale was $1.50 per MWh, so the total value of credits was $18,000.

Commerce Energy has expressed interest in purchasing 2004 credits later this year, for a price equal to or higher than $2.00 per MWh. Because IEUA tracks its renewable energy generation on an ongoing basis, it can forecast the amount of energy for the pending sale with Commonwealth. If the total number of credits for 2004 is comparable to that for 2003 (12,000 MWh), then the total value of the sale would be $24,000 or more, which falls into the mid-range of the values for RECs shown in Table 3-20 above.

[9] Environmental Resources Trust, "Monitoring, Reporting and Verification Protocol for the IUEA Anaerobic Digester Project," October, 2003

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Tim Tutt of the Energy Commission has expressed concern that because the green tag is sold without environmental benefits it might devalue the green attributes of the RECs that Commonwealth purchased. Discussions with the Energy Commission are ongoing. In the meantime, IEUA is holding the emission reduction credits and neither claiming them nor selling them until this issue is resolved.

3.7.10 Potential for Sale of GHG Credits

Currently IEUA has received interest from several parties on the 8,023 tons of GHG credits at a price of $1.00 per ton. Both the CCX and several independent traders have indicated they would purchase the credits even though renewable energy generated from the project has been claimed in another sale. Since all necessary steps to prepare the transaction have been completed, the sale could be made at any time once the issue on the unbundled credit sold to Commonwealth is addressed to the Energy Commission's satisfaction. Ideally this transaction should be completed this year to keep the value of the credits as high as possible, as older emission reduction credits lose some value over time.

3.7.11 Summary

Total projected revenue from this project from both renewable energy and emission reduction credits ranges from $20,000 to slightly over $48,000 annually. However, based upon input received from the market it is expected that these combined credits will sell for the approximately $32,000 for both the renewable energy credit and the emission reduction credit. Disaggregating the emission reductions from the green tag maximizes the value. Buyers for the green tag without the emission reductions are willing to purchase a disaggregated tag from IEUA, and the methane reduction credit is tradable on the GHG market. Additionally, local market options for ammonia should be pursued through the cooperation of the local air quality management district (AQMD) to explore trading for that particular criteria pollutant.

SECTION 4

Conclusions and Recommendations

At the outset of Project 3.1, goals were established for the Project that only focused on dairy waste to energy projects. As the project proceeded, it became clear that the best opportunity for increasing the number and size of dairy waste to energy project options in California would be to focus Project 3.1 efforts on co-digestion. Co-digestion involves placing food waste and manure in anaerobic digesters together so they can both be subject to the biological activity in the digester. The result is that much more biogas is produced than would have been with manure alone. The food waste also is treated through this process, thereby using co-digestion to solve a waste management problem, as well.

The decision to focus on co-digestion followed the completion of a digester comparison study under Task 3.1.1.(a).1 that examined dairy waste anaerobic digesters in the U.S. and Europe and evaluated their cost effectiveness. A significant conclusion from this study was that dairy manure projects that used co-digestion with food processing waste produced more biogas, generated more electricity, and were more cost-effective than those that did not. Thus it was recognized that one of the key areas of focus for dairy waste to energy projects should be on co-digestion of dairy manure and food processing waste.

Another key activity on Project 3.1 was the completion of the Tactical Marketing Plan as part of Task 3.1.2. The tactical marketing plan focused on developing the dairy waste to energy market in California. It concluded that a number of wastewater treatment plants with existing available digester capacity could be used for co-digestion projects. Because this extra capacity is available at wastewater treatment plants, it was also recognized that there is an opportunity for co-digestion involving food processing waste and sewage sludge generated as part of the wastewater treatment process. This partially treated sewage sludge, which is typically treated in an anaerobic digester, is referred to as biosolids in this project. Consequently there is also an opportunity for co-digestion biosolids and food processing waste in California.

Figure 4-1 shows the location of wastewater treatment plants, dairies, and food processing facilities in California. This map illustrates that many wastewater treatment plants are located near dairies and food processing facilities and could serve as hosts for such co-digestion facilities. A more detailed spatial analysis of the dairies, food processing facilities, and wastewater treatment plants was conducted and it was concluded that the technical and market potential for the co-digestion market in California are significant, as shown in Table 4-1.

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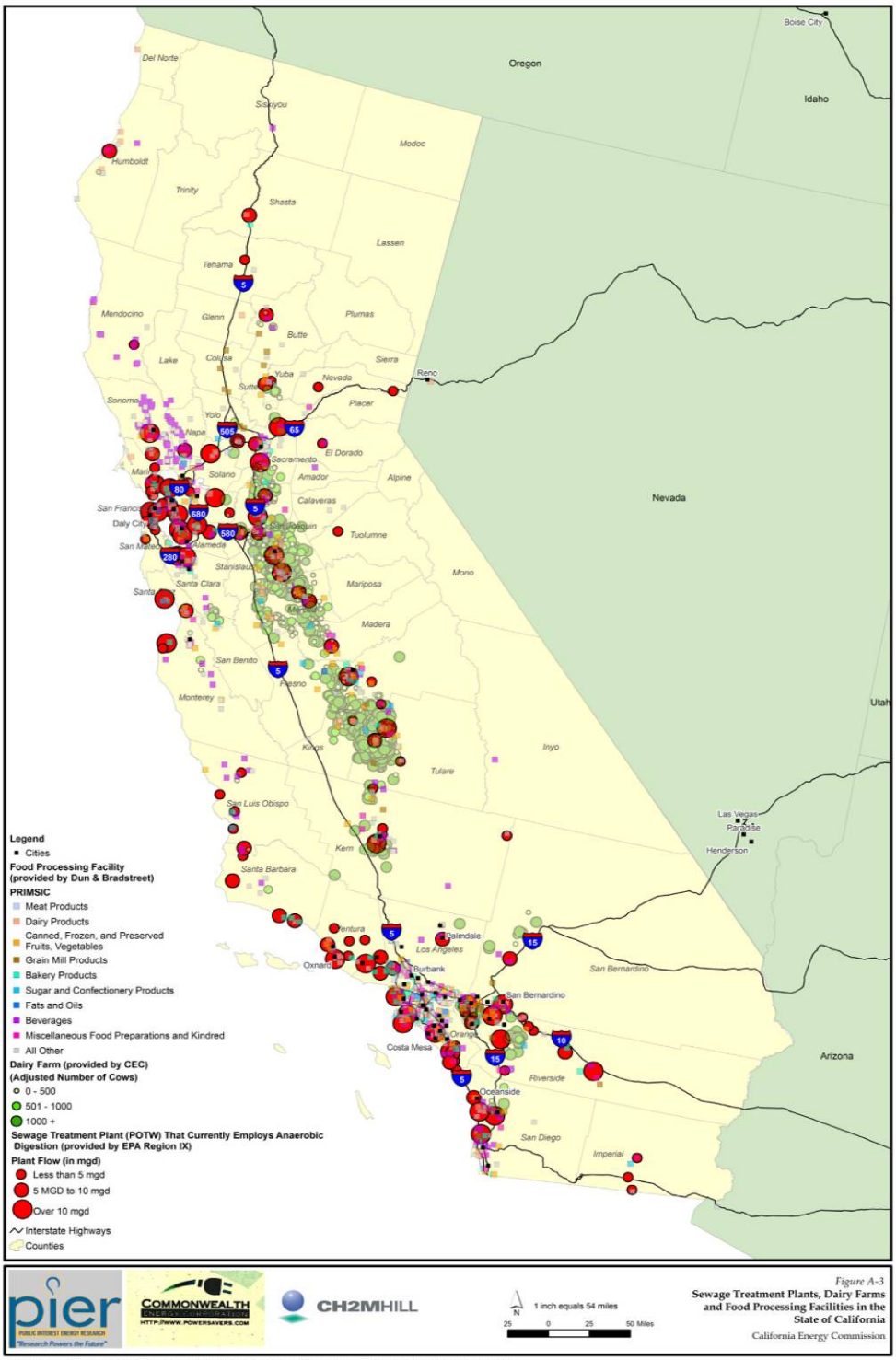

FIGURE 4-1
Statewide Locations of Large STPs, Dairy Operations and Food Processing Facilities

TABLE 4-1
Technical and Market Potential for New Renewable Power (MW) in California from Co-Digestion of Food Waste with Dairy Manure and Biosolids

	Technical Potential (MW)		Market Potential (MW)[1]	
	Long-Term	**Mid-Term**	**Long-Term**	**Mid-Term**
Dairy Manure Co-Digestion	298	98	223	73
Biosolids Co-Digestion	129	59	97	44

Note:
[1] A market potential analysis performed by RER/Itron for the Tactical Marketing Plan resulted in a market acceptance rate of 75%, meaning that 75% of the projects within the technical potential are expected to show strong enough economic performance to be accepted by potential developers. Thus, the market potential estimates are each 75% of their corresponding technical potential estimates.

Based on the results of the digester comparison report, the tactical marketing plan, and the initial results of the technology review conducted as a part of Task 3.1, the project goals were refined to those described in Section 4.1 below. Project activities were then conducted to achieve these goals.

4.1 Project Goals

The goals of the Co-digestion of Dairy Manure/Food Processing Wastes and Biosolids/ Food Processing Wastes to Energy project are to:

- ***Develop technologies that will address the lack of knowledge of the relationship between various co-digestion feedstocks and gas production. Pilot (demonstration) scale systems will be developed to yield information on the direct relationship between the physical and chemical characteristics of the feedstocks and the operating parameters of the co-digestion system and the increase in gas production associated with their co-digestion.***
- ***Provide information for future users when developing optimal blends or "cocktails" for co-digestion projects.***
- ***Quantify potential environmental benefits of dairy waste to energy projects in such a way that their values can be identified as the individual projects are being implemented***
- ***Report the results of studies conducted that led to the establishment of the goals listed above.***

4.2 Key Findings

Six key findings resulted from this project. The relationship of each finding to the relevant project goal, the related activities undertaken on the Project, results, conclusions, and application to other projects are discussed below.

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1. **Co-Digestion of Food Waste and Manure Produces More Gas than Anticipated**

Relevant Project Goal: Develop technologies that will address the lack of knowledge of the relationship between various co-digestion feedstocks and gas production. Pilot (demonstration) scale systems will be developed to yield information on the direct relationship between the physical and chemical characteristics of the feedstocks and the operating parameters of the co-digestion system and the increase in gas production associated with their co-digestion.

Description of Activities Conducted during the Project: The project involved co-digesting manure and biosolids with the following food wastes: salad oil waste, cheese whey and ice cream waste. Co-digestion testing activities were conducted over a six-month period with digester performance and biogas output being measured.

Results of Project Activities: The testing on manure co-digestion at IEUA's RP-1 facility led to increased biogas production beyond what was expected as shown in Figures 4-2 through 4-4:

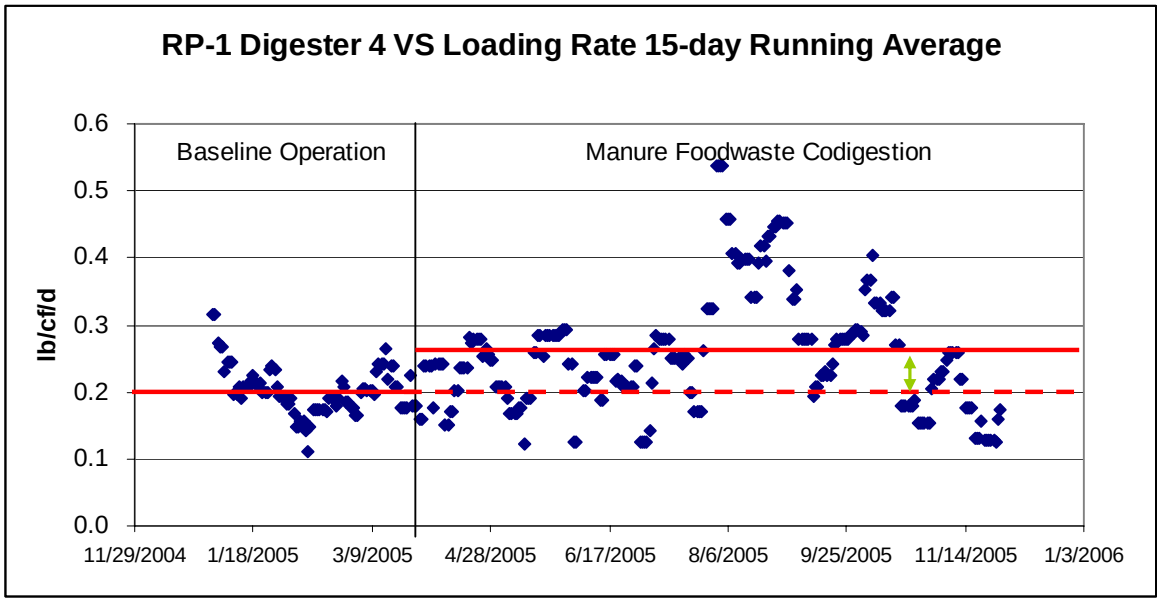

FIGURE 4-2
Manure Co-Digestion VS Loading Rate I at RP-1 Digestion Facility

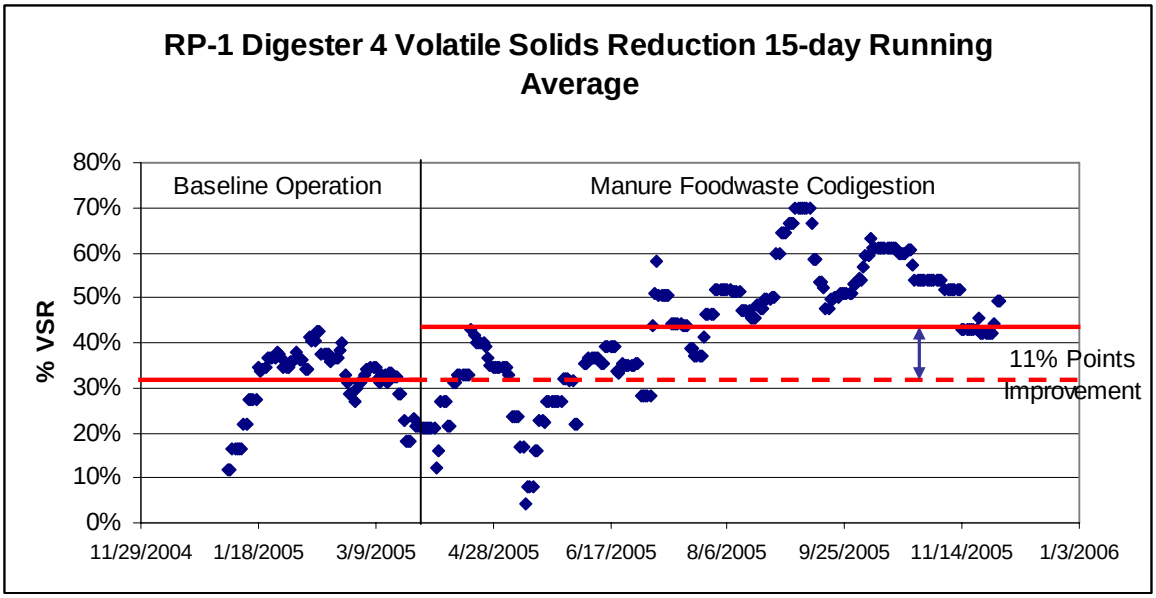

FIGURE 4-3
Manure Co-digestion VSR Improvement Observed at RP-1 Digestion Facility

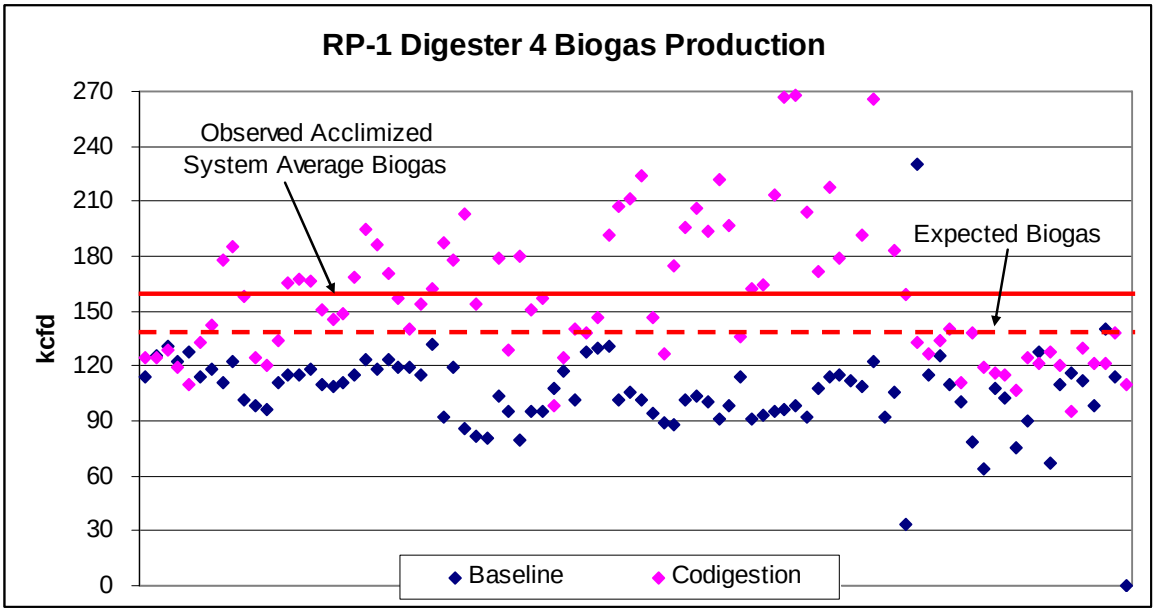

FIGURE 4-4
Manure Co-digestion Biogas Generation at RP-1 Digestion Facility

Conclusions: The amount of gas produced from co-digestion is greater than the amount that would theoretically be anticipated considering the cumulative gas generation from manure and food waste digestion. The reason for this appears to be a synergistic effect between the two materials being co-digested. Figure 4-2 illustrates the overall improvement observed during manure co-digestion. Figure 4-3 shows the biogas generation observed during baseline and co-digestion periods. The biogas generation

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observed during acclimated operation period was greater then what was anticipated as indicated.

This effect is anticipated to increase the overall technical potential of manure co-digestion energy recovery over what was originally estimated in the Tactical Marketing Plan. The same effect was not in co-digestion with biosolids.

Application of Findings to the State of California: The findings confirmed that the technical and market potential for co-digestion produced biogas is larger than anticipated. The results of the testing suggest the technical and market potential for manure co-digestion is approximately 12 percent higher than the values in Table 4-1, estimated before the testing.

2. **The added gas production resulting from co-digestion of manure and food processing waste or biosolids and food processing wastes requires careful evaluation and potential upgrade of the gas handling system for safety and environmental reasons.**

This added gas production must be carefully considered during the course of developing future projects. Added gas production increases the possibility of unplanned air emissions. Combustion of additional biogas increases air emissions from engines, boilers or flares. This could potentially result in excessive air emissions (above permit limits) and pose safety risks associated with unplanned releases.

Relevant Project Goals: Develop technologies that will address the lack of knowledge of the relationship between various co-digestion feedstocks and gas production. Pilot (demonstration) scale systems will be developed to yield information on the direct relationship between the physical and chemical characteristics of the feedstocks and the operating parameters of the co-digestion system and the increase in gas production associated with their co-digestion.

Provide information for future users when developing optimal blends or "cocktails" for co-digestion projects.

Description of Activities Conducted during the Project: The project involved co-digesting manure with the following food wastes: salad oil waste, cheese whey and ice cream waste. Co-digestion testing activities were conducted over a 6-month period. During the testing several food process wastes were fed at different rates to test the impact on gas production and gas performance.

Results of Project Activities: The testing led to increased biogas production as shown in the Table 4-1 above. During several testing sequences, large spikes in gas production were experienced, straining the gas system and causing unplanned releases of biogas. This caused suspension of some of the testing and raised concerns with the operations staff because of the potential for violations of the air permit. Observations made during operation of the system show that spikes in gas production were associated with "slug-feed" situations at the front end of the digesters, wherein new loads of food waste would be fed into the digesters all at once, rather than measured in at a constant rate over time. These "slug-feed" situations would quickly result in sharp spikes in biogas

production, which would cause the problems mentioned above. Figures 4-5 and 4-6 show the spikes in both feed rate and biogas production in Digester 4 during 2005:

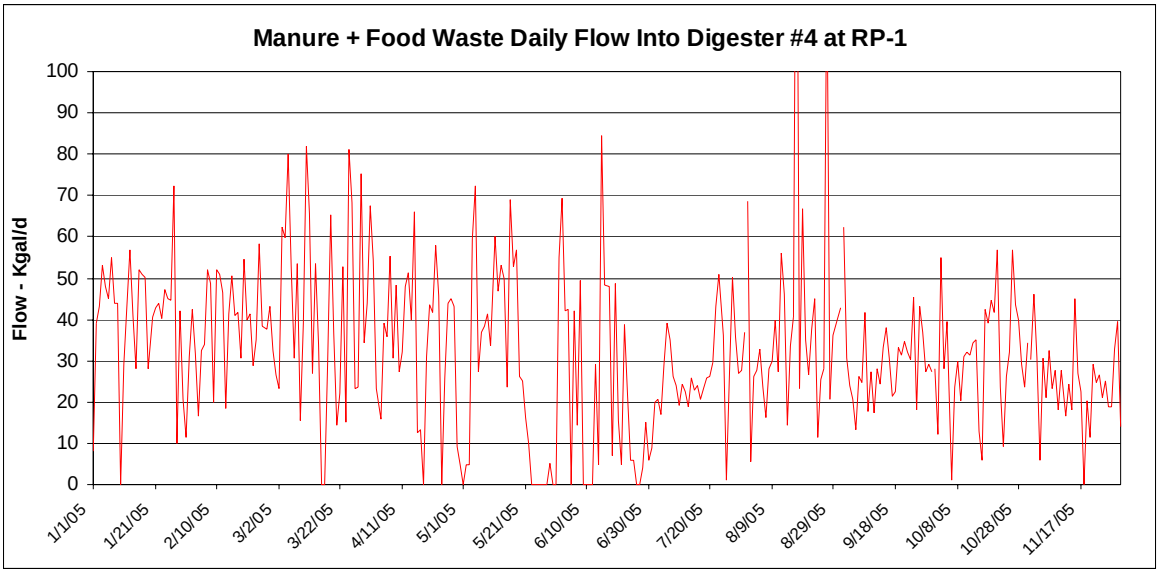

FIGURE 4-5
Manure + Food Waste Feed Rates into Digester 4 at RP-1: January – November 2005

The Sharp spikes shown above correspond to instances when an entire load of manure or food waste would be fed to the digester. The spikes below are corresponding increases in biogas production. This also happened during the biosolids testing, at digesters 1, 2, 3, 6, and 7. The biogas handling and storage capacity was at times not capable of handling these surges.

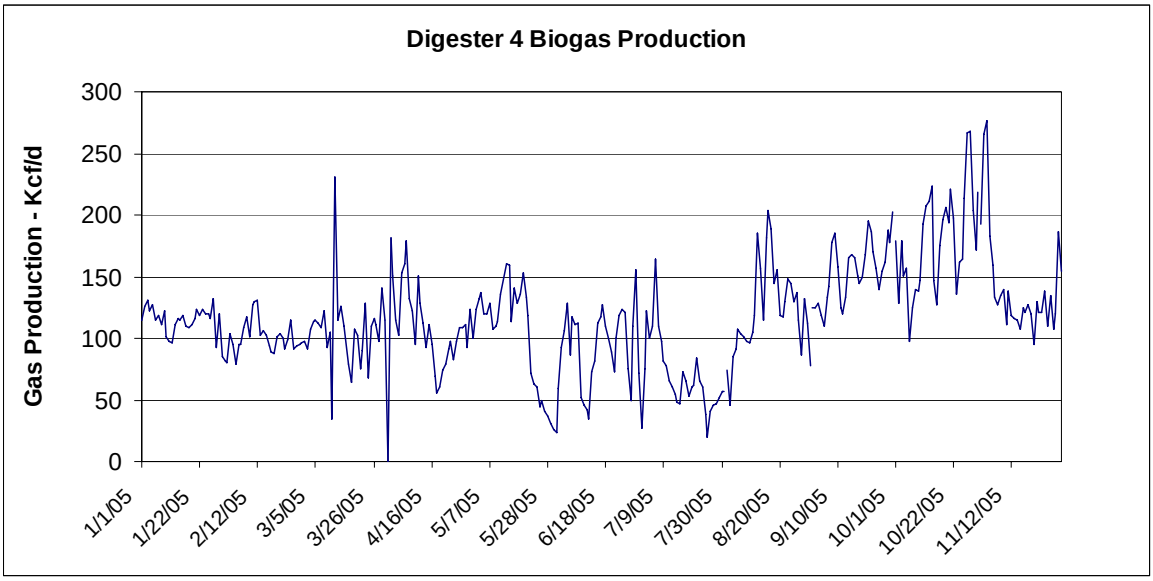

FIGURE 4-6
Biogas Production from Digester 4 at RP-1: January – November 2005

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Conclusions: The amount of gas produced from co-digestion was greater than expected in the testing on this program and significant spikes occurred during the testing. This situation can be avoided in future projects by following the following the three steps:

Use the co-digestion model produced under this project to estimate gas production rates. This model has safety factors built into it and they should be reviewed on a case-by case basis on future projects.

When adding food waste to the co-digestion process, gradually increase the amount of food waste added to the digester to a preplanned level. Avoid "slug" feeding food waste into the co-digestion process.

Review the existing gas system performance limits before starting co-digestion process to be sure it can handle the increased gas production.

Application of Findings to the State of California: The amount of biogas that can be produced through co-digestion is significant, but the lessons learned, as summarized in the conclusions summarized above should be applied**.**

3. **A model to predict gas production was developed based on the testing conducted under the Commerce Energy PIER program**.

This model is a tool that can be used on a variety of future co-digestion projects and will enable effective planning associated with the acquisition of co-digestion feedstocks and establishing feeding rates for various feedstocks used in co-digestion projects. See Appendix A for the co-digestion model.

Relevant Project Goal: Provide information for future users when developing optimal blends or "cocktails" for co-digestion projects.

Description of Activities Conducted during the Project: A model was prepared on this project for use on future projects. This model was developed to predict gas production and digester performance on future co-digestion projects.

Results of Project Activities: Drawing on the testing results, the model was refined so that it could be used to predict gas production and digester performance on future co-digestion projects.

Conclusions: The model was tested using the results of this project and can be used on future co-digestion projects.

Application of Findings to the State of California: The model is a key tool that is applicable to other projects throughout California.

4. **Environmental benefits from manure digester gas projects are important, particularly as related to air and water quality.**

Experience on the Commerce Energy Project shows that project revenues can be enhanced by monetizing and selling renewable energy credits, greenhouse gas (GHG) credits and particulate emissions reductions credits:

Renewable Energy Credits, also known as "green tags," which are based on California's Renewable Portfolio Standard (RPS), and are generated by renewable energy projects—these are sold at a price per kWh of new renewable energy generated, and have recently been traded by IEUA around $2.00 per MWh ($0.002 per kWh)

GHG Credits, which result from measurable and verified reductions in GHG emissions from a project—manure digestion projects capture GHG emissions by capturing emissions of methane (CH_4) and nitrous oxide (N_2O) from the manure, both of which are potent greenhouse gases. GHG credits are priced by the metric ton, of CO_2-equivalent, or "CO_2e." Carbon dioxide (CO_2) translates 1:1 to CO_2e. However, the more potent gases translate at higher ratios, making their capture more valuable. Methane translates to CO_2E at 21:1, and nitrous oxide translate at 310:1 (thus, 310 metric tons of CO_2E credited for each metric ton of N_2O captured). Prices have been low in the U.S., around $1.00 to $2.00 per metric ton CO_2e, however the forward price used in this report is $2.50/metric ton, based on upward pressure on pricing in general. In Europe there is a real market where EU-generated GHG credits can be traded, and those credits traded around $25.00 per metric ton ($CO_2e$) in early 2006. The $1.00 to $2.50 range is used in this report.

PM_{10} emissions credits, generated by reductions in emissions related to ammonia releases from dairy manure—trading is PM_{10} emissions credits is highly localized, but most valuable in the South Coast Air Quality Management District, where prices as high as $50,000 per pound per day have been reported for permanent reductions.[10]

These economic benefits can be significant and will be important in the economics of future dairy waste anaerobic digestion projects. Of particularly high potential economic value are emission reductions in PM_{10} from ammonia reductions. Because a method of translating ammonia to PM_{10} emissions has not yet been established or approved, the amount of ammonia reductions is reported in Table 4-2, but financial impact from corresponding PM_{10} emissions is not included in economic performance shown in Tables 4-3 and 4-4.

Relevant Project Goal: Quantify potential environmental benefits of dairy waste to energy projects in such a way that their values can be identified as the individual projects are being implemented

Description of Activities Conducted during the Project: In Task 3.1.6, the various emissions that could be eligible for credits were defined. Emissions before and after a dairy waste/food processing co-digestion project were developed as part of that task. The results of this work were used to certify emission reductions and sell them in order to generate additional project revenue streams.

Results of Project Activities: Using the model developed in Task 3.1.6, emission reductions for the pilot (as-tested) and full-scale projects for manure and biosolids co-digestion at RP-1 were determined and they are summarized in Table 4-2.

[10] Reference: Section 2.3.3 of the Task 3.1.6.C report – documented price in SCAQMD's Feb. 15, 2006 draft of Proposed Rule 1309.1 is $50,417 /lb/day of permanent PM10 reductions in the District.

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TABLE 4-2
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_2E/ year)	0	542.8	542.8	542.8
Nitrous Oxide (N_2O) reduction (tons/year)	0	8.6	8.6	8.6
CO_2 equivalent of N_2O reduction (tons CO_2E/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_2E/year)	0	0.0	Up to 1,190	Up to 3,000
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_2E/ 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_2E/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 and truck traffic less increases from combustion), (tons CO_2E/year)	0	3,200	3,100 - 4,300	3,100 - 6,100
NO_x 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 NO_x Emissions Increase (Reduction)	0	0.78	0.94	1.2
SO_x 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 SO_x 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 (tons/year)	0	5.2	5.2	5.2
Nitrate reduction in groundwater (tons/year)	0	0.22	0.22	0.22

TABLE 4-2
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)

In Table 4-2, for manure co-digestion, the base case is no manure digestion or co-digestion at the facility, i.e. the sewage treatment plant only digests biosolids sludge from its own primary and secondary clarifiers.

The first analysis is done for digesting manure with no food waste added at the facility. The second analysis is for co-digestion of manure with food waste as tested at RP-1's digester 4, meaning that the gas and energy production are based on data from the testing period. However, the amount of food waste fed during the test period was substantially lower than originally planned for a full-scale test, so a third analysis is shown for "full scale" manure co-digestion at RP-1's digester 4, with about four times the food waste volume.

Environmental benefits in Table 4-3 are grouped into the following categories:

GHG emission reductions: Most of these are generated by capturing methane and nitrous oxide that would have been emitted by the manure that is collected. There are some potential reductions due to additional methane capture from food waste, although it is not yet defined how those reductions could be monetized. Those reductions are therefore presented to show the maximum amount that might be captured, which is all of the incremental methane that the food waste is expected to generate in the digester. Changes in truck traffic also affect GHG emissions; in the case of RP-1, there was a reduction for changing manure transport, but an increase from transport of food waste. Finally, combustion of extra methane creates emissions. Some methane is expected from incomplete combustion, however the CO_2 that is generated is not counted, because it is *biogenic*, meaning that it originates from *recent* biological activity (not fossil fuels), so that its combustion is not expected to alter the overall carbon balance in the atmosphere. GHG emissions reductions are expected to have economic benefits, as shown in the financial analyses in Tables 4-3 and 4-4.

NO_x emissions: NO_x emissions are expected to increase from combustion of additional biogas generated by these projects. Truck traffic changes could reduce or further increase them. NO_x emissions limitations, especially in SCAQMD, can be quite restrictive, so expected additions must be analyzed carefully when planning these projects. This also shifts equipment selection in favor of low NO_x-producing technologies, such as microturbines or lean-burn, low NO_x-emitting reciprocating engines.

SO_x emissions: Similar to NO_x, SO_x emissions are expected to increase slightly from combustion of extra biogas. Truck traffic is not expected to affect these emissions.

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Ammonia/PM_{10} emission reductions: These reductions are generated by removing manure from stockpiles and thereby preventing ammonia emissions. The generation of particulate (PM_{10}) from ammonia in the atmosphere is a known phenomenon. However, a quantitative translation from ammonia to PM_{10} has not yet been defined and approved. Table 4-2 shows expected reductions of ammonia. Financial benefits are not determined, as shown in Tables 4-3 and 4-4. However, as mentioned above, these have the potential of being highly valuable in certain locations such as the SCAQMD.

TDS/Nitrate reductions in groundwater: It is known that both TDS and nitrates migrate from manure on the ground into the soil and groundwater. The numbers in the table are based on an analysis in the Task 3.1.6.4 document using an 18-acre model farm, and scaling the numbers for the amount of manure that is fed to RP-1. There is currently no mechanism to translate these into monetary benefits.

For biosolids co-digestion environmental benefits in Table 4-3, the base case is digesting biosolids with no food waste addition, and using the biogas for heat and/or power generation, which is the case at many sewage treatment plants. The first analysis is for biosolids co-digestion with food waste as tested at RP-1, using the train of digesters 1, 2, 3, 6, and 7. The second analysis is for using this same setup at "full scale." As with the manure co-digestion testing, the amount of food waste fed during the test period was substantially lower than originally planned for a full-scale test.

TABLE 4-3
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_2E/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_2E/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 (tons CO_2E/year)	0	**99.1**	115.5
CO_2 (tons/year)	0	**0.0**	0.0
Net GHG Emissions Reductions (Reductions from manure management and truck traffic less increases from combustion), (tons CO_2E/year)	0	**Up to 10,790**	Up to 22,540
NOx Emissions (tons/year)			
Increases from Combustion (Energy Recovery)	0	1.7	2.0

TABLE 4-3
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
Less: Reductions (Increase) From truck traffic	0	0.1	0.9
Net NO_x Emissions Increase (Reduction)	0	**1.8**	2.9
SO_2 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 SO_x 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

Environmental benefits in Table 4-3 are grouped the same way as for Table 4-2. For biosolids, some environmental benefits are affected differently than for manure co-digestion:

GHG emission reductions: No manure management GHG reductions apply. There are potential reductions from the food waste capture; as with manure these are not monetized, and the maximum amount possible (all of the incremental methane that the food waste is expected to generate in the digester) is shown. Changes in truck traffic and combustion of extra methane do apply.

NO_x emissions: Similar to the case with manure co-digestion, NO_x emissions are expected to increase from combustion of additional biogas generated and increase or decrease with truck traffic changes.

SO_x emissions: Similar to NO_x, SO_x emissions are expected to increase slightly from combustion of extra biogas. Truck traffic is not expected to affect these emissions.

Ammonia/PM_{10} emission reductions: Since these are generated by manure capture, they are not applicable to biosolids/food waste co-digestion.

TDS/Nitrate reductions in groundwater: Since these are generated by manure capture, they are not applicable to biosolids/food waste co-digestion.

Greenhouse gas credits have been sold along with renewable energy credits in the past by IEUA and can be expected to increase in value in future years as their markets expand. In 2005 revenues of approximately $15,000 were received for these credits and it is expected that they will increase to about $20,000 per year in 2006. In addition, buyers have expressed interest in purchasing ammonia reductions for possible use in future PM_{10} transactions. Data from this project are being used to document the relationship between ammonia and PM_{10}. The price for PM_{10} reductions from ammonia is yet to be finalized, but as discussed above, it is expected to be significantly higher in certain areas such as the South Coast and the San Joaquin Valley than that obtained for the greenhouse gas and renewable energy credits.

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Conclusions: Environmental benefits in three areas are providing economic benefit to IEUA on this project and can be obtained on future similar projects around the state:

Greenhouse gas emission reductions credits
Renewable energy credits
Ammonia reductions that affect PM_{10} emissions

In addition, there are water quality benefits that can't be monetized at this time because there are not existing markets where emission reductions can be traded; however, these benefits are important from a water quality standpoint in the areas where the dairies are located.

Application of Findings to the State of California: The benefits described in the Conclusions section above are applicable to future projects in California. The greenhouse gas and renewable energy credits will be important to the economic viability of all future projects in the State. The ammonia reduction credits will also provide economic benefit to future projects, but their use is not yet accepted and may not be applicable in all regions in the State. However, they are expected to be applicable in the San Joaquin Valley, which also has heavy agricultural activity, a large number of dairies, and tight PM_{10} emissions restrictions.

5. **Co-digestion potential is significant in California and projects are actively being planned in Southern California and Central Valley.**

As shown in Table 4-1, the technical potential for new generation from biosolids co-digestion is estimated at 59 MW in the mid term and up to 129 MW in the long term. The technical potential for new generation from manure co-digestion is estimated at 98 MW in the mid-term and up to 298 MW in the long-term. Because not all projects are expected to be economic, the market potential is estimated at 44 MW (mid term) and 97 MW (long-term) for biosolids co-digestion and 73 MW (mid-term) and 223 MW (long-term) for dairy waste co-digestion. The first key finding discussed above indicates that the technical potential for manure co-digestion may be increased by 12 percent to 110 MW in the mid-term and up to **334** MW in the long-term, and the market potential estimate may be increased accordingly to **82** MW in the mid-term and up to 250 MW in the long-term.

Relevant Project Goals: Develop technologies that will address the lack of knowledge of the relationship between various co-digestion feedstocks and gas production. Pilot (demonstration) scale systems will be developed to yield information on the direct relationship between the physical and chemical characteristics of the feedstocks and the operating parameters of the co-digestion system and the increase in gas production associated with their co-digestion.

Report the results of studies conducted that led to the establishment of the goals listed above.

Description of Activities Conducted during the Project: Economic and technical analyses of co-digestion projects were performed to demonstrate their economic viability. The

results include economic analysis that demonstrates the applicability to other locations in California.

Results of Project Activities: The economic performance of the co-digestion project at IEUA's RP-1 facility is shown in Table 4-4. This is being used to demonstrate the economic viability of these projects to potential developers and thereby expand the market.

TABLE 4-4
RP-1 Manure Baseline and Co-Digestion Project Economics

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 (MW)	0	0.200	0.223	0.269
		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
Total Annual Revenue from biogas power output ($0.11/kWh)	0	$173,448	$193,395	$233,288
Capital Cost ($)				
Gas System Improvements	0	$ -	$72,956	$72,956
Digester Improvements	0	$800,000	$960,403	$960,403
Power Generation and related equipment	0	$300,000	$334,500	$403,500
Total Investment ($)	0	$1,100,000	$1,367,860	$1,436,860
Annual O&M Costs ($/year)				
Waste Collection and transportation costs	0	$ -	$ -	$ -
Less, tipping fees collected	0	$(2,916)	$(2,916)	$(2,916)
Digester and gas system O&M	0	$7,006	$14,012	$14,012
Power system O&M ($0.010/kWh)	0	$15,768	$17,581	$21,208
Total O&M cost	0	$19,858	$28,678	$32,304
Environmental Benefits ($)				
Renewable Energy Credits (RECs)				

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TABLE 4-4
RP-1 Manure Baseline and Co-Digestion Project Economics

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
Value based on # of kWh produced	0	1,576,800	1,758,132	2,120,796
Total Value at $0.005 per kWh	0	$7,884	$8,791	$10,604
GHG Emissions Reductions Credits				
Value based on tons/yr of GHG reduced	0	3,200	3,100 - 4,300	3,100 - 6,100
Price per ton (actual for as tested, expected for full scale)		$1.00	$1.00	$2.50
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 (=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%
Levelized annual cost (over 15 years)	N/A	$93,191	$119,869	$128,095
Levelized cost per kWh	N/A	$0.0591/kWh	$0.0682/kWh	$0.060/kWh
Levelized cost per MMBTU	N/A	$3.77/MMBTU	$4.33/MMBTU	$3.98/MMBTU

For manure co-digestion, the base case is no manure digestion or co-digestion at the facility, i.e. the sewage treatment plant only digests biosolids sludge from its own primary and secondary clarifiers.

The first analysis is done for digesting manure with no food waste added at the facility. The second analysis is for co-digestion of manure with food waste as tested at RP-1's digester 4, meaning that the gas and energy production are based on data from the testing period. However, the amount of food waste fed during the test period was substantially lower than originally planned for a full-scale test, so a third analysis is shown for "full scale" manure co-digestion at RP-1's digester 4, with about four times the food waste volume.

Economic performance is shown by net present value (NPV), simple payback, and rate of return of each scenario over the base case. As indicated, rates of return for manure only and manure co-digestion at full scale are in the range of 12 to 13 percent. Also shown is the incremental rate of return on the investment to go from existing manure digestion to full-scale manure co-digestion. This project's return is 16 to 17 percent, indicating that going to co-digestion in an existing manure digester provides higher economic return.

Table 4-4 also shows costs for each case in terms of levelized cost. As was the case for the NPV analysis, all of these cases have a favorable levelized cost and merit consideration in developing plans for such projects at other facilities.

For biosolids co-digestion, the base case is digesting biosolids with no food waste addition, and using the biogas for heat and/or power generation, which is the case at many sewage treatment plants. The first analysis is for biosolids co-digestion with food waste as tested at RP-1, using the train of digesters 1, 2, 3, 6, and 7. The second analysis is for using this same setup at "full scale." As with the manure co-digestion testing, the amount of food waste fed during the test period was substantially lower than originally planned for a full-scale test.

Table 4-5 shows project economics for biosolids co-digestion projects:

TABLE 4-5
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)
Electricity Production			
Total capacity (MW)	1.168	1.434	1.739
Average Annual Output ($)			
Gas Production (cfd as biogas (60% CH_4))	690,869	814,696	949,030
Gas Production (MMBtu/year)	151,300	178,418	207,838
Power Generation (kWh/year) (90% availability)	9,208,512	11,305,656	13,710,276
Total Annual Revenue from biogas power output ($0.11/kWh)	$1,012,936	$1,243,622	$1,508,130
Capital Cost ($)			
Gas System Improvements	0	$360,044	$360,044

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TABLE 4-5
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)
Digester Improvements	0	$791,597	$791,597
Power Generation and related equipment	0	$399,000	$ 856,500
Total Investment ($)	0	$1,550,640	$2,008,140
Annual O&M ($/year)			
Waste Collection and transportation costs	0	$ -	0
Less, tipping fees collected	0	$ -	$0
Digester and gas system O&M	$34,576	$69,152	$69,152
Power system O&M ($0.010/kWh)	$92,085	$113,057	$137,103
Total O&M	$126,661	$182,208	$206,254
Environmental Benefits ($)			
Renewable Energy Credits (RECs)			
Value based on # of kWh produced	9,208,512	11,305,656	13,710,276
Total Value at $0.005 per kWh	$46,000	$56,500	$68,600
GHG Emissions Reductions Credits			
Value based on tons/yr of GHG reduced (food waste only)	0	Up to 10,790	Up to 22,540
Price per ton (actual for as tested, expected for full scale)	N/A	$ 1.00	$ 2.50
Total Value of GHG emissions reductions	0	Up to $10,800	Up to $56,300
PM_{10} emissions reductions	N/A	N/A	N/A
Total Monetized Environmental Benefits ($/yr)	$46,000	$56,500 - $67,300	$68,600 - $124,900
TOTAL ANNUAL CASH FLOWS (=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%
Levelized annual cost (over 15 years)	N/A	$285,584	$340,130
Levelized cost per kWh	N/A	$0.025/kWh	$0.025/kWh

TABLE 4-5
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)
Levelized cost per MMBTU	N/A	$1.60/MMBTU	$1.64/MMBTU

The rate of return for the full-scale co-digestion project is good—in excess of 20 percent. This indicates that given the conditions shown in the table, the investment to bring in food waste for co-digestion. The 8 to 9 percent returns for the project as tested show performance for the same amount of investment as full-scale, but less food waste due to air emissions limitations that were experienced at times during the testing period.

It should be noted that both manure and food waste treatment will produce filtrate, which must be disposed of in a proper facility. At IEUA's RP-1 facility, the filtrate is sent to the ocean through a pipeline called the "NRW Line." There is a cost for using this line, and additional filtrate from co-digestion will increase this cost. At RP-1, the cost is based on a volumetric charge of around $1,300 per million gallons discharged in the NRW line, plus surcharges for TSS and COD in excess of certain limits. A preliminary evaluation indicated adding these NRW costs to the projects in Tables 4-5 and 4-6 would lower project rates of return by about 1 to 3 percent. Filtrate disposal practices will vary between different facilities, however all facilities will face this issue, and filtrate handling costs should be considered in project-specific analyses.

Table 4-5 also shows costs for each case in terms of levelized cost. As was the case for the NPV analysis, all of these cases have a favorable levelized cost and merit consideration in developing plans for such projects at other facilities.

Conclusions: The economics of both manure/food processing waste and biosolids/food processing waste co-digestion projects were demonstrated to be favorable at the demonstration scale project at IEUA and activities are underway to implement the project at full scale at RP-1 and at other IEUA facilities.

Application of Findings to the State of California: The Project's results are applicable in multiple regions of the state and this effect is anticipated to increase the overall technical potential over what was originally estimated in the Tactical Marketing Plan by the amount shown Table 4-6.

TABLE 4-6
Technical and Market Potential for New Renewable Power (MW) in California from Co-Digestion of Food Waste with Dairy Manure and Biosolids

	Technical Potential (MW)		Market Potential (MW)[1]	
	Long-Term	Mid-Term	Long-Term	Mid-Term
Dairy Manure Co-Digestion[2]	**334**	**110**	**250**	**82**
Biosolids Co-Digestion	129	59	97	44

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TABLE 4-6
Technical and Market Potential for New Renewable Power (MW) in California from Co-Digestion of Food Waste with Dairy Manure and Biosolids

	Technical Potential (MW)		Market Potential (MW)[1]	
	Long-Term	Mid-Term	Long-Term	Mid-Term
Dairy Manure Co-Digestion[2]	334	110	250	82

[1] A market potential analysis performed by RER/Itron for the Tactical Marketing Plan resulted in a market acceptance rate of 75%, meaning that 75% of the projects within the technical potential are expected to show strong enough economic performance to be accepted by potential developers. Thus the market potential estimates are each 75% of their corresponding technical potential estimates.

[2] Dairy Manure co-digestion potential increased by 12% due to observed data from testing showing synergistic increase beyond what was expected. Biosolids manure was not affected by this.

6. **The wastewater treatment community is increasingly interested in co-digestion and the PIER Program is contributing to increased knowledge and interest in co-digestion.**

   Numerous presentations have been given at various professional meetings and activities are planned at upcoming CASA and SCAP meetings.

   Relevant Project Goal: Report the results of studies conducted that led to the establishment of the goals listed above.

   Description of Activities Conducted during the Project: The activities of the Project were presented at technical and professional meetings at locations in California and other cities in the U.S. In addition, project team members have been giving presentations to entities interested in such projects.

   Results of Project Activities: This project has increased interest by wastewater treatment plant entities in co-digestion as a means to increase biogas production, reduce energy expenditures and improve waste management practices. The results of the project, which have been presented to other prospective hosts of such facilities, have demonstrated the economic feasibility of co-digestion projects.

   Conclusions: The results of the co-digestion projects demonstrated on this project can be applied elsewhere. Other entities are interested in obtaining the benefits of such projects and also recognize the importance of taking advantage of the lessons learned.

   Application of Findings to the State of California: The results of the testing are applicable throughout California. In applying the results it is important to consider both the benefits and lessons learned.

4.3 Recommendations

The following are recommendations from Project 3.1:

1. Establish a technology transfer program to disseminate information about the benefits of co-digestion so that proponents can initiate co-digestion at facilities around the State of

California. This includes co-digestion projects involving manure and food processing waste and biosolids and food processing waste. It also includes describing the opportunity to use available digester capacity at existing wastewater treatment plants.

2. In conjunction with the technology transfer program described above, use the co-digestion model produced under this project to estimate gas production rates for potential future projects. This model has safety factors built into it and they should be reviewed on a case-by-case basis on future projects.
3. When considering and evaluating individual co-digestion projects, address revenue streams from both increased energy production and environmental benefits, including renewable energy credits when evaluating the economics of individual co-digestion projects.
4. Carefully review food waste addition practices and gas system capacities for each project, to make sure they are compatible with the anticipated gas production increases.

SECTION 5

References

CH2M HILL. 2003. *Task 2.2.1 Process Selection Report for Wastewater Treatment Plants*. August 2003.

CH2M HILL. 2004. *Task 2.2.2 Site Selection and Test Plan Report*. January 2004.

CH2M HILL. 2005. *Task 3.1.1.b, Final Report: Assessment, Evaluation, and Selection of Dairy Waste to Energy Technology.*

CH2M HILL. 2005. *Task 3.1.3(c), Final Report: RP-1 Modifications and Pilot Plant Design Memorandum, and Final Co-Digestion Pilot Plant Test Plan*. July 2005.

CH2M HILL. 2005. *Task 3.1.2 Tactical Marketing Plan: Bringing Co-Digestion and New Biogas Electric Power to Market* in California. Appendix A to *Site Selection Report*. October 2005.

SECTION 6

Glossary

BIPV	Building Integrated Photovoltaic
CCX	Chicago Climate Exchange
Energy Commission	California Energy Commission
EPA	U.S. Environmental Protection Agency
ERC	emission reduction credit
ERG	Eastern Research Group
ERT	Environmental Resources Trust
GHG	greenhouse gas
H_2S	hydrogen sulfide
IEUA	Inland Empire Utilities Agency
kW	kilowatt
MPI	market price index
MW	megawatt
MWh	megawatt per hour
OCSD	Orange County Sanitation District
PIER	Public Interest Energy Research
ppm	part(s) per million
PV	photovoltaic
RD&D	Research, Development, and Demonstration
REDI	Renewable Energy Development Institute
RP	Regional Plant
SCAQMD	South Coast Air Quality Management District
SJVAPCD	San Joaquin Valley Air Pollution Control District
STP	sewage treatment plant
TOC	total organic compound
TPAD	temperature-phased anaerobic digestion
TS	total solid
TSS	total suspended solid

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VS	volatile solid	
ZECO	Zaininger Engineering, Inc.	

APPENDIX A
Co-Digestion Model