Arnold Schwarzenegger
Governor

COMMERCE ENERGY BIOGAS/PV MINI-GRID RENEWABLE RESOURCES PROGRAM

FINAL PROGRAM REPORT

PIER FINAL PROJECT REPORT

Prepared For:
California Energy Commission
Public Interest Energy Research Program

Prepared By:
ITRON

March 2008
CEC 500-2007-049

Prepared By:
ITRON
Patrick Lilly, ***Program Director***
1104 Main Street, Suite 630
Vancouver, WA 98660
Contract No. 500-00-036

Prepared For:
Public Interest Energy Research (PIER) Program
California Energy Commission

Zhiqin Zhang
Contract Manager

Gerry Braun
Program Area Lead
PIER Renewables

Elaine Sison-Lebrilla
Office Manager
Energy Generation Research

Martha Krebs
Deputy Director
ENERGY RESEARCH & DEVELOPMENT DIVISION

Melissa Jones
Executive Director

DISCLAIMER

This report was prepared as the result of work sponsored by the California Energy Commission. It does not necessarily represent the views of the Energy Commission, its employees or the State of California. The Energy Commission, the State of California, its employees, contractors and subcontractors make no warrant, express or implied, and assume no legal liability for the information in this report; nor does any party represent that the uses of this information will not infringe upon privately owned rights. This report has not been approved or disapproved by the California Energy Commission nor has the California Energy Commission passed upon the accuracy or adequacy of the information in this report.

Table of Contents

Commerce PIER Renewable Mini-Grid Program Acknowledgements ACK-1

California Energy Commission Staff:..... ACK-1
Commerce Energy Team: ACK-1
Renewables Program Advisory Committee Members:..... ACK-1
Technical Advisory Committee Members:..... ACK-2
Host Facilities ACK-2

Preface P-1

Abstract Commerce Energy Program Final Report A-1

Program Goals A-1
Key Program Outcomes by Project A-1

Executive Summary ES-1

ES.1 Program Outcomes ES-1
Chino Basin Mini-Grid Market Potential Distribution System Assessment ES-1
Biogas to Energy Projects ES-5
Building Applied PV Projects ES-7
ES.2 Program Conclusions and Recommendations ES-9
Chino Basin Mini-Grid Distribution System Assessment ES-9
Biogas to Energy Projects ES-9
Building-Applied PV Projects ES-10

***1* Introduction to the Commerce Energy PIER Renewables Mini-Grid Program 1-1**

1.1 Background and Overview 1-1
Emphasis Area 1 1-1
Emphasis Area 2 1-2
Emphasis Area 3 1-2
Emphasis Area 4 1-2
1.2 Commerce Energy Program Goals and Objectives 1-2
1.3 Commerce Energy Program Projects 1-3
Program Planning and Analysis 1-3
Biogas to Energy Projects 1-4
Building-Applied PV Projects 1-7
1.4 Report Organization 1-8

***2* Commerce Energy Renewable Mini-Grid Program Approach 2-1**

2.1 Program Planning, Analysis and Prioritization of Resource Options 2-1
Initial Mini-Grid Study Area 2-1
Mini-Grid Renewable Resource Determination 2-3
Determination of Electric T&D Boundaries within the Mini-Grid Study Area 2-5
Renewable Resource Market Potential Assessment 2-6
Economic and Environmental Benefits of Mini-Grid Renewable Resources 2-8
Estimation of Future Mini-Grid Renewable Resource T&D Public Benefits 2-8

Identification and Prioritization of Candidate Renewable Generation Facilities *2-12*
2.2 Development and Implementation of Selected Projects 2-14
Biogas to Energy Projects *2-14*

***3* Program Outcomes 3-1**

3.1 Program Challenges and Market Issues 3-1
Chino Basin Mini-Grid Distribution System Assessment *3-1*
Biogas to Energy Projects *3-10*
Building-Applied PV Projects *3-12*
3.2 Program Results 3-14
Chino Basin Mini-Grid Distribution System Assessment *3-14*
3.3 Key Findings 3-19
Biogas to Energy Projects *3-20*
Building-Applied PV Projects *3-45*

***4* Conclusions and Recommendations 4-1**

4.1 Commerce Program Conclusions by Project Area 4-1
Chino Basin Mini-Grid Distribution System Assessment *4-1*
Biogas to Energy Projects: Project 2.1 through Project 3.1 ..... *4-2*
Building-Applied PV Projects: Project 3.2 and Project 3.3 ..... *4-21*
4.2 Recommendations by Project Area 4-24
Chino Basin Mini-Grid Distribution System Assessment *4-24*
Biogas to Energy Projects *4-25*
Building-Applied PV Projects *4-25*
4.3 Program Benefits to California 4-26
Existing and Future Benefits Derived from the Commerce Program *4-26*
Potential Future Program Benefits from Market Dissemination and Transformation *4-29*
4.4 Summary of Conclusions and Recommendations 4-29

Endnotes E-1

References R-1

List of Figures

Figure ES-1: Commerce Energy Chino Basin Mini-grid Map 2
Figure ES--2: Expected Market Potential by Resource Type 3
Figure ES-3: Commerce Project Prioritization Scoring Results 5
Figure 2-1 Mini-Grid Map 2-3
Figure 2-2: Landfill Bioreactor Conceptual Design 2-13
Figure 3-1: Expected Market Potential by Resource 3-3
Figure 3-2: Low Market Potential by Resource 3-4
Figure 3-3: High Market Potential by Resource 3-5
Figure 3-4: Commerce Energy Renewables Mini-grid Map 3-14
Figure 3-5: Overview of Local Chino Basin Mini-Grid 3-15
Figure 3-6: Moisture Treatment Performance: Average Moisture in Gas (g/L) 3-24
Figure 3-7: H_2S Scrubber Performance 3-26
Figure 3-8: Siloxane Treatment Performance: Average Siloxane Levels (ppbv) 3-27

Figure 3-9: Implemented Iron Sponge System Modifications 3-29
Figure 3-10: Manure and Food Waste Daily Flow into Digester 4 at IEUA RP-1. 3-30
Figure 3-11: Biogas Production from Digester 4 at IEUA RP-1. 3-30
Figure 3-12: Systems 1 and 2 Ratings Comparison 3-48
Figure 3-13: System 3 Subsystem Ratings Comparison 3-49
Figure 3-14: Probability that field -based STC dc ratings agree with two factory-based thresholds 3-50
Figure 3-15: Initial and One-Year PTC Ratings Comparison 3-52
Figure 3-16: Probability that field -based STC dc ratings agree with two factory-based thresholds 3-53
Figure 4-1: Manure Co-Digestion Biogas Generation at RP-1 Digestion Facility 4-9
Figure 4-2: Summary of Yields Referenced to Different Ratings 4-22

List of Tables

Table ES-1: Potential Distribution Facility Deferral Benefits 3
Table ES-2: Summary of Large System Performance Index and Energy Production 7
Table ES-3: Summary of Small System Efficiencies and Ratings 8
Table 1-1: Commerce Energy Projects by PIER Program Emphasis Area.....1-3
Table 2-1: Description of Low-, Expected-, and High-Potential Scenarios 2-7
Table 2-2: Illustration of Market Potential Model.....2-8
Table 2-3: Evaluation Criteria List.....2-10
Table 2-4: Top-Level Evaluation Criteria Priority Weighting 2-11
Table 2-5: Project 2.1 Preferred Landfill Bioreactor Sites.....2-12
Table 3-1: Expected Market Potential by Resource.....3-2
Table 3-2: Low Market Potential by Resource 3-3
Table 3-3: High Market Potential by Resource 3-4
Table 3-4: Expected Scenario Potential – Biogas and BI-PV Resources 3-6
Table 3-5: Benefit / Cost Ratio for Prioritized Biogas and BI-PV Projects 3-7
Table 3-6: Potential Distribution Facility Deferral Benefits.....3-16
Table 3-7: Potential Hourly Mini-Grid Distribution Loss Value 3-16
Table 3-8: Potential Hourly Transmission and Subtransmission Loss Value.....3-17
Table 3-9: Summary of Digester Operation and Cost During Each Test Phase 3-19
Table 3-10: Summary of the Ultrasounds' Affects on Dewaterability.....3-21
Table 3-11: Summary of Gas System Operation and Performance.....3-25
Table 3-12: RP-1 Manure Baseline and Co-Digestion Environmental Benefits.....3-32
Table 3-13: RP-1 Biosolids Baseline and Co-Digestion Environmental Benefits 3-34
Table 3-14: RP-1 Manure Baseline and Co-Digestion Project Economics 3-37
Table 3-15: RP-1 Biosolids Baseline and Co-Digestion Project Economics.....3-39
Table 3-16: System Descriptions 3-43
Table 3-17: Summary of Small System Efficiencies and Ratings 3-45

Table 3-18: Summary of Large System Performance Index and Energy Production 3-46
Table 3-19: Large System Descriptions 3-47
Table 3-20: Summary of Systems in Small PV System Comparison 3-50
Table 3-21: Summary of System Efficiencies and Ratings 3-51
Table 4-1: Technical, Environmental and Economic Performance of Ultrasound units as Tested at Full Scale at Riverside WWTP 4-4
Table 4-2: Summary of Gas System Operation and Performance 4-7
Table 4-3: Manure Baseline and Co-Digestion Environmental Benefits 4-12
Table 4-4: RP-1 Biosolids Baseline and Co-Digestion Environmental Benefits 4-13
Table 4-5: Manure Baseline and Co-Digestion Project Economics 4-15
Table 4-6: Biosolids Baseline and Co-Digestion Project Economics 4-18
Table 4-7: Technical and Market Potential for New Renewable Power (MW) in California from Co-Digestion of Food Waste withy Dairy Manure and Biosolids 4-20

Commerce PIER Renewable Mini-Grid Program

Acknowledgements

Commerce Energy, on behalf of the Commerce Energy PIER Mini-Grid Program would like to acknowledge and thank the following individuals and/or companies for their outstanding support and long-term continuous assistance with this important research development and demonstration Program.

California Energy Commission Staff:

- Ms. Zhiqin Zhang, Commission Project Manager
- Ms. Elaine Sison-Lebrilla
- Mr. Val Tiangco
- Mr. Hassan Mohammed
- Mr. Prab Sethi

Commerce Energy Team:

- Mr. Max Carpenter, Commerce Energy – Commerce Project Development Lead
- Mr. Patrick Lilly, Itron, Inc. – Commerce Program Director and Team Lead
- Mr. Dave Hanna, Itron, Inc. – Project 1.1 Manager
- Mr. William Kitto, CH2M Hill -- Biogas Team Lead
- Mr. Keith Rutledge, Renewable Energy Development Institute (REDI)
- Mr. Hank Zaininger, Zaininger Engineering Company (ZECO)

Renewables Program Advisory Committee Members:

- Mr. Paul Grabowski – U.S. DOE Headquarters Forrestal Biogas Program
- Mr. Dan Kammen – University of California, Berkeley
- Mr. Carl Weinberg – Weinberg & Associates
- Mr. Peter West – Energy Trust of Oregon
- Mr. Ed Wheless – LA Sanitation District
- Mr. V. John White – Center for Energy Efficiency & Renewable Technology (CEERT)
- Mr. Raju Yenamandra – Shell Solar Industries, LP
- Mr. Robert Yinger – Southern California Edison, T&D Business Unit

Technical Advisory Committee Members:

- Mr. Tom Card – Environmental Management Consulting
- Mr. Don Gabb – East Bay Municipal Utility District
- Mr. Sudhir Murthy – District of Columbia Water and Sewer Authority
- Mr. Stephen Schultz – City of Riverside
- Mr. Joe Barra - PGE
- Mr. Kurt Roos - AgStar
- Mr. George Tchobanoglous – UC-Davis

Host Facilities

- Inland Empire Utility Agency – Headquarters
- Riverside Wastewater Treatment Plant – RP-1 and RP-2

Preface

The Public Interest Energy Research (PIER) 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 individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following seven 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
- Transportation

What follows is the Final Program Report for the Commerce Energy PIER Mini-Grid Renewable Resource RD&D Program, Contract Number 500-00-036 conducted by the Commerce Energy Team, comprised of Commerce Energy (formerly Commonwealth Energy), Itron, (formerly RER, Inc.), CH_2MHill, Behnke, Erdman and Whitaker (BEW) Engineering (formerly Endecon Engineering), Renewable Energy Development Institute (REDI) and Zaininger Engineering, Inc (ZECO). The report is entitled ("*Commerce Energy Program Final Program Report*"). This project contributes to the PIER Renewable Energy program element.

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

Abstract

Commerce Energy Program Final Report

Program Goals

The specific goals of the Commerce Program included:

- Develop and implement an approach to tailor resource development to the specific needs and resources of local mini-grids,
- Increase landfill gas production, accelerating biodegradation and decreasing landfill generation lifecycle costs,
- Lower costs associated with digester gas energy production,
- Improve the economics of producing energy from animal waste,
- Develop and test an improved approach for rating of photovoltaic (PV) **system** performance by **independent** third-parties
- Demonstrate common ownership agreements for large PV systems.

Key Program Outcomes by Project

The *Enhanced Anaerobic Digestion and Gas Cleaning* research project found that the ultrasound systems were either unreliable or did not significantly increase biogas production in an unstressed system. The gas cleaning systems were found to be important to the economics of biogas projects, and the biological hydrogen sulfide removal system was the most cost-effective and reliable gas cleaning system that was tested.

The *Dairy Waste to Energy* project showed that co-digestion of manure and food-waste produces more biogas than manure alone in a complete-mix digester. Environmental benefits clearly contribute to the cost-effectiveness of manure digester gas projects, particularly for air quality attributes. Co-digestion-based biogas generation potential is significant within California and appears economically viable.

The *Building-Integrated Photovoltaics (BI-PV) Testing and Evaluation* project supported results from other PV component performance tests demonstrating that most modules produce less than their nameplate rating when field-measured performance data are normalized to nameplate environmental conditions. The results also showed that the PVUSA Test Conditions (PTC) and CEC ratings are significantly different from the standard test

conditions (STC) ratings for each tested system, with an average PTC/STC ratio for the larger systems of 0.78.

Executive Summary

In June 2001 the Energy Commission awarded one of the first PIER programmatic contracts with Commonwealth Energy (now Commerce Energy) to implement a Renewable Energy RD&D program with a regional focus in Southern California and a resource emphasis on solar photovoltaics and biogas from various resources formed through anaerobic digestion. The specific goals selected for the Commerce Energy PIER Program include:

- To develop and implement an approach to tailor resource development to the specific needs of and available renewable resources within localized "mini-grids",
- To increase landfill gas production, while accelerating biodegradation and decreasing landfill-biogas power generation life-cycle costs,
- To lower costs associated with digester gas energy production,
- To improve the economics of producing energy from dairy waste,
- To demonstrate the use of proper systems integration to enhance photovoltaic system performance,
- To create a new (or improve an existing) *rating system* for solar photovoltaic power system performance, and
- To demonstrate the potential to take advantage of cost economics by installing relatively large PV systems under common ownership agreements.

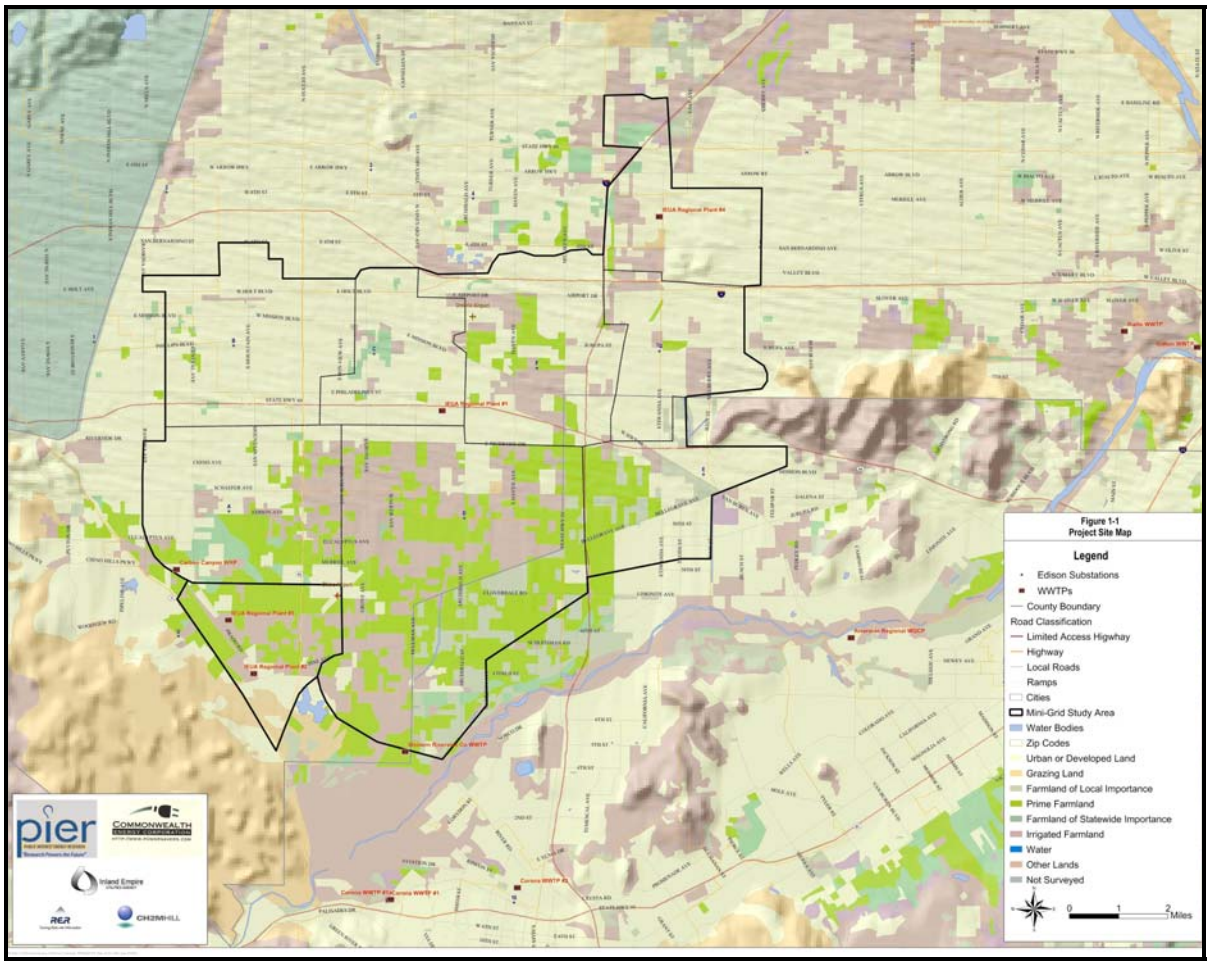
Given that the region is rich in both solar and various forms of biogas resources, and has experienced significant growth in the recent past, the Chino Valley Basin, located southeast of Los Angeles was selected as the *initial study area* for the Commerce PIER Renewables Mini-grid Program. The approach employed to design and implement the program necessarily involved a large amount of resource and electric system data to be collected and a detailed evaluation was performed of the renewable resources and electric system characteristics within the Chino Basin study area.

ES.1 Program Outcomes

Chino Basin Mini-Grid Market Potential Distribution System Assessment

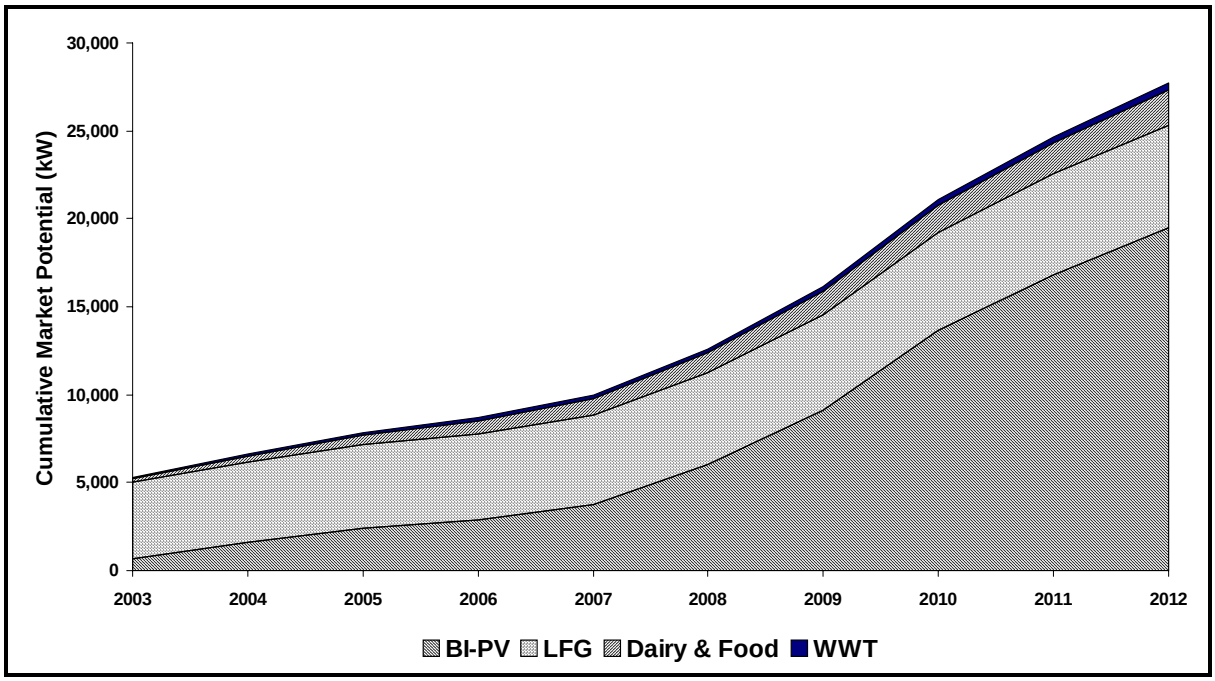
The Commerce Program planning activities began with assessments of local area energy needs, expected levels of biogas and solar PV resources to be developed within the next 1, 5 and 10 years, followed by the evaluation of regional grid conditions through power flow modeling based on the characteristics of the local subtransmission and distribution systems and finally involved prioritization of the potential site-specific renewable project options within the mini-grid area as outlined in Figure ES-1.

Figure ES-1: Commerce Energy Chino Basin Mini-grid Map



The combined *expected market potential* for the renewable resources evaluated within the Commerce mini-grid area is approximately 5 MW in 2003 and increases to nearly 28 MW by 2012 (see Figure ES--2). Under the *high case* renewable resource scenario, the market potential of the biogas and nonresidential PV resources is nearly doubled by 2012 -- to over 53 MW.

Figure ES--2: Expected Market Potential by Resource Type



Impacts on the transmission and distribution (T&D) system were evaluated for the three scenarios and benefits were evaluated in five areas: 1) Distribution Facility Deferral Benefits, 2) Distribution System Loss Reduction, 3) Distribution Voltage and Power Factor Correction Benefits, 4) Transmission and Subtransmission Facility Deferral Benefits, and 5) Transmission and Subtransmission Loss Reduction Benefits. The primary electric system benefits were found to be in deferral of distribution facilities. BI-PV and biogas projects can be strategically located throughout the heavily loaded distribution system to reduce peak feeder and distribution substation loads, deferring facility additions and resulting in a distribution facility deferral economic benefit. This potential economic benefit applies primarily to heavily loaded distribution facilities. These key T&D benefits are summarized in Table ES-1.

Table ES-1: Potential Distribution Facility Deferral Benefits

Year	Distribution Facility Deferral Benefit in Terms of PWRR* ($1000)					
	Expected Case		High Case		Low Case	
	Full Output	90% Output	Full Output	90% Output	Full Output	90% Output
2007	0	0	1,018	0	0	0
2012	2,027	1,709	4,357	3,835	0	0

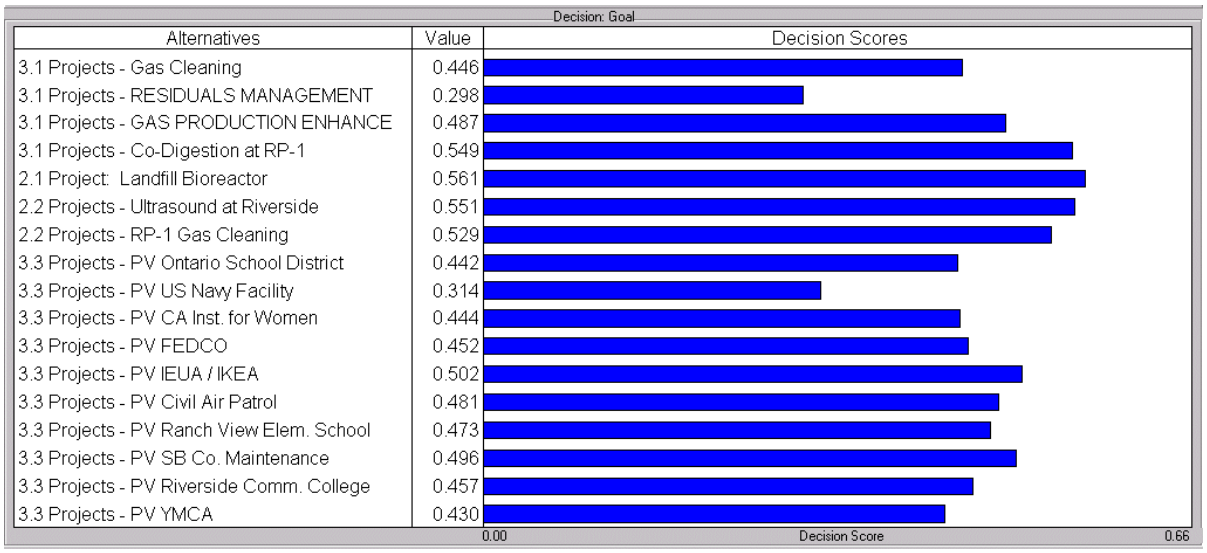
*Present worth of revenue requirements

The findings and observations resulting from the mini-grid power flow analysis are summarized below:

- Since the renewable penetration scenarios evaluated in this study are less than 10% of the mini-grid loads, the resulting mini-grid loss reductions are relatively small.
- No voltage regulation or power factor correction benefits or penalties were identified in this study.
- Distribution system voltage control problems may occur if large MW-scale distributed generators are added near the end of distribution feeders in the mini-grid.
- Flicker is not expected to be a problem for the expected, high and low renewable penetration scenarios assumed in this study.
- Distribution relaying schemes may need to be changed to properly accommodate reverse power flows resulting from large penetrations of distributed generation.
- BI-PV output and the biogas generation output will correlate nicely with the mini-grid annual early afternoon peak loads. Several new substation transformers and feeder additions will be required over the study period, and future mini-grid distribution facility additions can be deferred.
- No transmission and subtransmission facility deferral benefits were identified in this study.
- Potential transmission and subtransmission system loss reduction benefits calculated during peak loadings indicate that potential annual transmission system loss benefits will be smaller than the distribution loss benefits for the renewable penetration scenarios studied.

Following the T&D system assessment, the final step of the program planning incorporated the development of a weighted-objectives hierarchy model that was used as a decision tool for prioritizing over twenty potential biogas and PV projects along these criteria. The top-level set of criteria includes three categories:1) Commerce Business Plan, 2) Mini-Grid Benefits, and 3) RD&D Technical Criteria. The results of this prioritization process are shown in Figure ES-3: below.

Figure ES-3: Commerce Project Prioritization Scoring Results



Biogas to Energy Projects

The prioritization assessments lead to the selection of three major biogas to energy projects that were approved at the Critical Program Review meeting. These projects included Project 2.1: *Landfill Bioreactor at Mid-Valley*, Project 2.2: *Enhanced Digestion and Gas Cleaning*, and Project 3.1: *Co-digestion and Gas Cleaning at RP-1*.

Project 2.1 was not implemented due to the need for the selected landfill to accept waste in the area where the bioreactor would be implemented by early 2005 and the inability for the bioreactor to be installed under this timeline.

Enhanced Digestion and Gas Cleaning

The overall goal of Project 2.2 was to increase biogas power generation at wastewater treatment plants by testing gas cleaning systems for microturbines and testing processes that could optimize anaerobic digestion and therefore increase gas production. The key outcomes of the project are outlined below for ultrasound and biogas cleaning:

- Ultrasound Pilot Tests:
  - Test results did not meet performance expectations overall
  - Smaller sonic horns (<6kW) perform better and are more reliable
  - May experience more enhanced digestion on a system that is stressed (low HRTs)
- Gas Cleaning Pilot Tests:

- Biological hydrogen sulfide scrubber was effective and demonstrated several cost advantages

The siloxane treatment system was found to be effective. However, media capacity was not completely determined within the project test period. Media capacity and useful life of these media need to be fully determined for a thorough technology analysis.

Dairy Waste to Energy

The dairy waste to energy activities (Project 3.1) were designed to evaluate selected co-digestion with food processing waste options available within the Chino basin. Animal waste is becoming a larger issue due to the trend toward larger dairy operations, ground water and air emissions impacts and due to the encroachment of new urban areas into the basin nearer to the location of the major dairies.

Co-digesting food waste and manure has a synergistic effect. The key lessons learned from the co-digestion testing are that biogas production may be up to 12 percent higher than the expected levels 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 internal biogas distribution system, for both safety and regulatory 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. Food waste must be fed gradually (through an auto-feed system) in order to prevent spikes in biogas production.

The *Co-digestion Tactical Marketing Plan* quantified the technical potential and market potential for power generation from biogas sources including dairy waste and municipal biosolids sludge within California. The incremental market potential for co-digestion of food waste with dairy waste applications is about 73 MW and the incremental potential for co=digestion at wastewater treatment plants is 44 MW.

A model was developed to quantify and verify methane and other greenhouse gas (GHG) emission reductions, criteria air pollutant emission reductions, and water quality improvements attributed to this project. The GHG reductions and criteria air pollutant emission reductions along with renewable energy credits (RECs) can provide monetary incentives that help make dairy waste to energy projects cost-effective.

The rate of return for the full-scale biosolids-food waste co-digestion project is good – in excess of 20 percent. This indicates that given the expected conditions at full scale, it is a good investment to bring in food waste for co-digestion. The expected rates of return for manure food waste co-digestion at full scale are in the range of 12 – 13 percent. Environmental benefits in three areas are providing economic benefit to IEUA on this dairy

waste codigestion project, which should be obtained on future similar projects around the state:

- Greenhouse gas emission reductions credits
- RECs
- Ammonia reductions that affect PM_{10} emissions

Building Applied PV Projects

Two solar photovoltaics (PV) projects were planned under the Commerce program, but only one of the two projects was implemented.

Building Integrated Photovoltaics Testing and Evaluation

In this project, the team performed side-by-side *full system evaluations* of commercially available PV systems and their component technologies, and compiled objective, consumer-friendly information on the costs and performance parameters of each system. This type of information is not currently available from any independent source, and will be very useful for the PV-buying public. Both large (nominally 20 kW) and small (nominally 2 kW) systems were evaluated.

The large systems evaluation covered the selection, installation, operation, monitoring, and evaluation of three independent 20 kW PV systems installed on the roof of the IEUA Headquarters building in Chino, CA. The third large system was comprised of ten nominal 2 KW system in order to allow for a greater number of products to be included in this evaluation project.

Table ES-2 provides a summary of the 12 month large system performance.

Table ES-2: Summary of Large System Performance Index and Energy Production

Array	Manufacturer	Model	Tech	Mount	P_{STC} kW	P_{PTC} kW	PTC/STC rating ratio	P.I. %	Annual Energy* kWh
PL	Sanyo	HIP-190BA2	HIT	Sloped PG	22.80	17.97	0.79	92	31101
RWE	RWE/Schott	300-DGF/50	EFG	SunRf FS	24.00	18.52	0.77	92	31126
3A	UniSolar	US-116	3-a-Si	Quilt	2.32	1.86	0.80	96	3173
3B	UniSolar	PVL-128	3-a-Si	SIT	2.30	1.89	0.82	102	3384
3C	Shell Solar	ST40	CIS	Custom	2.40	2.13	0.89	94	3651
3D	First Solar	FS-45	CdTe	EZ Mount	2.70	2.10	0.78	101	3620
3E	AstroPower	APx-130	pc-Film	Quilt	2.73	1.63	0.60	97	3006
3F	Evergreen	EC-102	SR-pc	Custom	2.45	1.90	0.78	100	3182
3G	BP Solar	SX-140	pc-Si	Custom	2.52	1.95	0.77	97	3379
3H	RWE/Schott	SAPC-123	pc-Si	Custom	2.46	1.94	0.79	97	3361
3I	Shell Solar	SP140	mc-Si	Custom	2.52	2.02	0.80	101	3414
3J	AstroPower	AP-110	mc-Si	Custom	2.40	1.83	0.76	94	3081
Total					**71.6**	**55.7**	**0.78**	**94**	**95478**

This analysis suggests that it is common for consumers to receive PV modules that are on the lower end of published specifications. Although these data are limited, field experience over the past few decades support this conclusion. This situation is further complicated in a world market where module rating requirements differ. Both Germany and Japan have significantly more strict tolerance allowances on modules than does California.

The small system evaluation covered the selection, installation, operation, monitoring, and evaluation of three independent 2 kW PV systems installed on a mock roof at the Photovoltaics for Utility System Applications (PVUSA) facility in Davis, CA. This facility, currently managed by Renewable Ventures, has a long history of testing and evaluating PV systems from 2 kW to 400 kW in size. These three test systems were intended to be indicative of the kinds of residential-class BIPV hardware that are currently installed under the Energy Commission's Emerging Renewable Rebate Program as well as those to be installed under the Governor's Million Solar Roofs plan. Table ES-3 provides a summary of the small systems.

Table ES-3: Summary of Small System Efficiencies and Ratings

Array	Manufacturer	Model	Mount	Area	Eff_{SYS}	$Rating_{PTC}$	$Rating_{CEC}$	$Rating_{STC}$	PTC/STC
				sq. m.	%	kW	kW	kW	rating ratio
Sharp	Sharp	ND-123U1	SolarMount	33.8	6.80	2.30	2.38	2.95	0.78
Kyocera	Kyocera	KC167G	SolarMount	30.2	6.66	2.01	2.11	2.51	0.80
RWE/Schott	RWE/Schott	SAPC-165	SolarMount	29.2	8.22	2.40	2.45	2.97	0.81
TOT				93.2	7.20	6.7	6.9	8.4	0.80

The project team developed a website, www.pierminigrid.showdata.org, that was very successful at describing the systems under test, presenting the real time performance information, and documenting project results. Workshops were held in Sacramento and Chino, respectively. Key outcomes include the fact that 170 motivated and interested workshop participants were exposed to the PIER results. Key findings from the project were discussed in detail during the workshop sessions, and many participants were able to see the project testing facilities first hand. Tours were conducted at the PVUSA site for the Sacramento workshop attendees and at the IEUA site for the Chino attendees. Since neither of these facilities is open to the public for tours, this provided an important opportunity to display various aspects of the project.

ES.2 Program Conclusions and Recommendations

Chino Basin Mini-Grid Distribution System Assessment

It was necessary to conduct a power flow analysis study to determine where within a mini-grid the optimal benefits can be achieved and determine the magnitude of those benefits. The timing when certain distribution circuits and transformers become overloaded also assisted in the prioritization of renewable resource development and optimized the benefits. A detailed interconnection study, a follow-on to the work performed under Project 3.1, should be performed and should consider relaying requirements, integrated control of distribution system voltage, reactive power scheduling, communication requirements and short circuit duty impacts with high penetration levels of the distributed biogas and BI-PV generation installed.

Biogas to Energy Projects

A technology transfer program should be initiated to communicate the effectiveness of biological scrubbers and co-digestion to potential users. The technology transfer program could be complemented by additional testing.

Enhanced Digestion and Gas Cleaning

Future research should be conducted to optimize a combined system of chillers and media based systems to remove siloxane and hydrogen sulfide. Removing siloxane and hydrogen sulfide as part of the moisture removal system is an option because there are dual benefits

when using such moisture removal systems. Therefore, further testing of combined chiller/media systems, where the chiller is operating at less than 40°F and above -40°F, would determine the optimal temperature at which media life is balanced with electricity costs.

Systems that inject air into iron sponges prolong their life and are cost effective. The major drawback to such systems is maintaining pH at proper levels with chemicals that do not clog the feed nozzles. Chemicals other than lime should be tested to determine their effectiveness in maintaining the proper pH while avoiding nozzle clogging.

- Ultrasound
  - Smaller sonic horns (<6kW) work better
  - May see enhanced digestion on a system that is stressed
  - Test smaller ultrasound systems on a stressed WWT system
- Gas cleaning conclusions
  - Biological hydrogen sulfide scrubber advantages
  - Siloxane and moisture removal
  - Test optimal temperature for the chiller/media for siloxane removal

Dairy Waste to Energy

When considering and evaluating individual co-digestion projects, address revenue streams from both increased energy production and environmental benefits, including RECs 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. The co-digestion model produced under this project to estimate gas production rates for potential future projects should be used in planning new co-digestion projects. This model has safety factors built into it and they should be reviewed on a case-by-case basis for future projects.

- Co-digestion conclusions:
  - Co-digesting food waste and manure has a synergistic effect
  - Food waste must be fed gradually in order to prevent spikes in biogas production
  - Planning for future projects should use the model developed for predicting biogas production
- Co-digestion Potential in CA
  - Future of GHG and criteria air pollutants emissions reductions credits
  - Is there a future for water quality credits?
  - Proximity of dairies and industrial food manufacturers to wastewater treatment plants

Building-Applied PV Projects

Building Integrated Photovoltaics Testing and Evaluation

Requirements for system and component ratings need to be established and they need to be verified through third party comparative testing. We suggest that the Energy Commission adopt a requirement for PV modules specifying that the manufacturer's nameplate rating shall represent the minimum allowable output for that model. This rating should also include an allowance for initial Light Induced Degradation. This rating shall also represent the value from which the warranty power tolerance is calculated.

System and component characteristics need to be evaluated to ensure that performance benefits are understood. It is recommended that a future evaluation project contain the following: an enhanced eligible module listing procedure, extension to inverter performance characterization, system-level initial evaluation, and longer-term energy yield information.

Assessment of reliability requires continued long term monitoring of installed systems. With the newer, less proven technologies, it is especially important to provide the consumer with confidence that these products will continue to perform as expected.

The information from the project needs to be transferred by additional means to the different members of the PV community. The web presence should be enhanced to automate additional analyses and to report any new results through various documentation and presentation options. Further, continued training for installers is clearly important to the long-term success of PV industry.

1

Introduction to the Commerce Energy PIER Renewables Mini-Grid Program

1.1 Background and Overview

In 1996, Assembly Bill 1890 was enacted. AB1890 required that at least $62.5 million be collected annually from investor-owned utility ratepayers for public interest energy research, development, and demonstration (RD&D) efforts not adequately provided by competitive and regulated markets. The majority of these funds were to be transferred to the Energy Commission to administer specific energy RD&D projects, which could be linked to help diversify and improve affordability of California's electricity supply. Thus, the Public Interest Energy Research (PIER) Program was created to implement these types of projects.

In general, PIER Renewable Program element funds are allocated by four "*emphasis areas*":

- Emphasis Area 1: Assessing and Targeting Renewable Electricity Development,
- Emphasis Area 2: Increasing Affordability by Improving Existing Renewable Energy Facilities,
- Emphasis Area 3: Expanding Affordability & Diversity Using Renewable Distributed Generation, and
- Emphasis Area 4: Developing Renewable Technologies for Tomorrow's Electricity System.

The basic goals and objectives of each of the four emphasis areas mentioned above are described briefly in the paragraphs that follow.

Emphasis Area 1

To meet the objectives of Emphasis Area 1, the PIER Program seeks to support power flow modeling to identify existing or anticipated problems with electricity systems in targeted regions over the next five, ten, and fifteen years. Additionally, the PIER Program seeks to compile information on the availability and resource constraints associated with renewable and fossil resources in a target region. The PIER Program also seeks to establish cost and performance targets for specified renewable energy technologies, and to develop coordinated research and development efforts to achieve those targets.

Emphasis Area 2

To meet the objectives for Emphasis Area 2, the PIER program seeks to increase system operational efficiencies and lower operations and maintenance costs. Additionally, the Program seeks to establish new and diversified revenue streams, and to develop energy technologies to provide dispatchability, or peak generation capabilities.

Emphasis Area 3

For Emphasis Area 3, the PIER program seeks to develop low-emissions distributed generation technologies to match demand profiles in a targeted area, to defer investments in the local transmission and distribution system, and to provide power quality support. Through Emphasis Area 3, the PIER Program also seeks to integrate targeted technologies into mini-grids capable of providing affordable, reliable power with low environmental impacts. The performance of these technologies will be verified in the field to assess their potential for full-scale implementation.

Emphasis Area 4

Under Emphasis Area 4, the PIER Program supports the development of a renewable energy database to enhance customer awareness of available energy technologies. Additionally, through Emphasis Area 4, the PIER Program supports the development of small, modular renewable electricity products highly responsive to customer power demands that can be integrated into other appliances or electricity generation technologies. Finally, under Emphasis Area 4, the PIER program supports the development of super-efficient, super-clean renewable energy technologies for use in industrial or utility system settings.

1.2 Commerce Energy Program Goals and Objectives

The Commerce Energy Biogas/PV Mini-Grid Renewable Resource RD&D Program is just one of the renewable energy programs supported by PIER Program funds. The specific goals and objectives of the Commerce Energy Program are:

- To develop and implement an approach to tailor resource development to the specific needs and resources of local mini-grids,
- To increase landfill gas production, accelerating biodegradation and decreasing landfill generation lifecycle costs,
- To lower costs associated with digester gas energy production,
- To improve the economics of producing energy from dairy waste,
- To demonstrate the use of proper systems integration to enhance photovoltaic system performance,

- To create or modify a basic rating system for photovoltaic system performance, and
- To demonstrate the potential to take advantage of cost economics by installing relatively large PV systems under common ownership agreements.

In a broader sense, the Commerce Energy Program was designed to achieve certain specific objectives outlined in three of the four Pier Program Emphasis Areas, as outlined in Table 1-1.

Table 1-1: Commerce Energy Projects by PIER Program Emphasis Area

PIER Program Emphasis Area	Commerce Energy Program Project
	Project 0: Program Administration
Emphasis Area 1: Assessing and Targeting Renewable Electricity Development	**Project 1.1:** Program Planning and Analysis Project
Emphasis Area 2: Increasing Affordability by Improving Existing Renewables Investments	**Project 2.1:** Enhanced Landfill Gas Production Using Bioreactor Project
	Project 2.2: Enhanced Energy Recovery through Optimization of Anaerobic Digestion and Microturbines Project
Emphasis Area 3: Expanding Affordability and Diversity Using Renewable Distributed Generation	**Project 3.1:** Dairy Waste and Biosolids to Energy Project
	Project 3.2: Building Integrated PV Testing and Evaluation Project
	Project 3.3: Building Integrated PV on Public Facilities Project
Emphasis Area 4: Developing Renewable Technologies for Tomorrow's Electricity System	**None**

1.3 Commerce Energy Program Projects

Program Planning and Analysis

Program Planning and Analysis effort was directed by Itron. The overall goal of Project 1.1 was to develop a formal means to assess the potential for meeting sub-regional electricity needs with local renewable resources for one or two targeted areas within California, and to apply this approach to the development of biogas and solar photovoltaic generation facilities for at least one of those areas. The Project 1.1 activities included assessments of regional energy needs, assessments of biogas and solar PV resources, and the evaluation of regional grid conditions through power flow modeling on representations of the local subtransmission

and distribution systems. The objectives of the Program Planning and Analysis Project were to:

- Determine the most appropriate renewable resources in the region of interest to fully serve the electric distribution grid,
- Determine the most appropriate geographic and electric system boundaries of the electric distribution mini-grid system,
- Assess the technical and market electric generation potential of these identified resources within the specified markets in the mini-grid,
- Estimate the electric system public benefits of the full development of these renewable resources within the region of interest over the next 5 and 10 years, and
- Identify candidate sites to participate in the Commerce Energy Team's RD&D pilot program activities.

The primary deliverables of Project 1.1 included: (1) an assessment of the potential for meeting subregional needs with integrated local renewable resources for up to two areas within California, (2) a preliminary evaluation of the benefits of tailored development in those areas and in the state, (3) estimates of economic and environmental benefits, and (4) a detailed plan for developing specific biogas and solar photovoltaic generation facilities in at least one of the targeted areas.

Biogas to Energy Projects

Under this program, there were three proposed biogas to energy projects. The first involved developing a landfill bioreactor and increasing landfill gas production, the second involved enhancing anaerobic digestion of wastewater to produce more biogas and to clean the biogas for use in ultra-clean prime movers such as microturbines, the third involved converting dairy waste to energy using anaerobic digestion and the co-digestion of manure with food processing wastes.

Project 2.1: Enhanced Landfill Gas Production

The Enhanced Landfill Gas Production Project was managed by CH2M Hill. The overall goals of Project 2.1 were to:

- Advance the state of knowledge using bioreactors at landfills to increase landfill gas production and accelerate reclamation,
- Work with environmental and industry regulators to develop and implement a strategy for developing bioreactors while meeting applicable groundwater and other environmental standards, and
- Establish the economic and environmental benefits of landfill bioreactors.

To achieve these goals, Project 2.1 was designed to develop two types of landfill bioreactors (one fueled by municipal solid waste or source-separated organic waste materials, and one fueled by municipal solid waste or source-separated organic waste materials and supplemented by food or animal waste). Under Project 2.1, environmental benefits of these bioreactors were also to be documented.

Performance metrics for Project 2.1 were to include changes in methane production, reductions in CH_4 emissions and indirect reductions in other criteria air pollutants associated with displaced conventional generation, and changes in lifecycle costs of landfill gas generation. Two reports were to be developed to summarize the results of Project 2.1. One report was to summarize the regulatory issues addressed in the course of developing Project 2.1. This report was to include guidelines for future projects and a methodology for calculating the economic value of environmental benefits of the project. The second report was to summarize design and installation engineering work performed in support of Project 2.1, and to document installation, operation, and maintenance costs incurred. Project lifecycle costs were to incorporate engineering issues as well as the value of environmental benefits presented in the first report.

Unfortunately, the work on Project 2.1 was stopped in July 2004 due to the need for the selected landfill site to meet a timeline with a liner-extension project by early 2005. The bioreactor could not be implemented on the required local agency developer timeline and could not proceed without a firm commitment of Energy Commission PIER funding.

Project 2.2: Enhanced Energy Recovery through Optimization of Anaerobic Digestion and Microturbines

The Enhanced Recovery through Optimization of Anaerobic Digestion and Microturbines Project was managed by CH2M Hill. The overall goals of Project 2.2 were to:

- Optimize digester gas production through new research and demonstration of thermal hydrolysis and/or ultrasound processes,
- Develop, test and optimize cost-effective options for biogas cleanup systems,
- Evaluate and quantify environmental benefits from microturbines installed at sewage treatment plants, and
- Document operational performance and cost characteristics to further the state of knowledge regarding microturbine cost and reliability.

Under Project 2.2, the impacts of thermal hydrolysis and/or ultrasound processes upon gas production were to be analyzed and documented. Additionally, digester gas production and quality, biosolids reduction rate, and dewatering characteristics of these processes were to be examined. Furthermore, the cost-effectiveness of these technology applications was to be

analyzed. The cost-effectiveness analysis was to include a detailed evaluation and quantification of environmental benefits for each of the systems.

Additionally, under Project 2.2, at least three gas cleaning systems were to be defined and optimized. One of these systems was expected to involve hydrogen sulfide (H_2S) removal, biogas drying, and siloxane removal. A second system was expected to involve gas drying and siloxane removal. Finally, a third system, with parameters not yet defined, was expected to be formulated. The installed and operating cost for each of these systems was to be determined for the full project lifecycle. Additionally, the environmental benefits associated with each of these systems were to be identified and quantified relative to the Capstone microturbine.

Finally, under Project 2.2, a report was prepared to document the cost-effectiveness analysis results for the various microturbine gas cleanup systems evaluated. The cost-effectiveness of these systems was to be evaluated based on the value of electricity produced and waste heat recovered and used at the sewage treatment plant. Various alternatives were to be compared through an examination of the net present value of different systems and the rate of return based on funds utilized.

Project 3.1: Dairy Waste to Energy

The Dairy Waste to Energy Project was managed by CH2M Hill. The overall goals of Project 3.1 were to:

- Develop technologies to maximize recovery of energy from dairy animal waste,
- Develop and evaluate pilot projects at existing treatment plants and/or individual and clusters of dairies, and
- Evaluate and test the effectiveness of technologies developed in North America and Europe for the collection, processing, and recovery of energy from animal waste.

Under Project 3.1, CH2M Hill was to manage the technology selection, design, construction, and operation of animal waste to energy pilot plants. CH2M Hill was also to summarize and evaluate the economic and environmental costs and benefits associated with developing such facilities.

The deliverables for Project 3.1 included process flow diagrams and preliminary location plans depicting conceptual layouts of the pilot plants. Additionally, Project 3.1 deliverables included pilot plant test plan protocols, performance specifications, site drawings, and operating reports documenting plant performance and required modifications.

Building-Applied PV Projects

This PIER Programmatic effort had offered two building-integrated photovoltaic (BI-PV) projects. The first project involved testing and comparing different large and small photovoltaic (PV) systems. The second project involved installing BI-PV on public facilities to address infrastructure, affordability and related commercialization barriers.

Project 3.2: Building-Integrated Photovoltaic (BI-PV) Testing and Evaluation

The BI-PV Testing and Evaluation Project was managed by BEW Engineering. The overall goals of Project 3.2 were to:

- Address the gap between future third-party certified PV component and system performance evaluation and currently available information from manufacturers,
- Provide an independent comparative evaluation of PV systems applicable to the Commerce Energy's Project 3.3 and to the Energy Commission's Emerging Renewables Buydown Program (ERBP),
- Provide useful consumer decision-making information on those PV systems, and
- Improve the quality of systems installed in Project 3.3 and the California market through directed training efforts.

To achieve these objectives, BEW Engineering was to select, procure, install, and evaluate three candidate systems for implementation in Project 3.3. Flaws and weaknesses in design features were to be evaluated, and suggestions for improvement were to be provided. Additionally, BEW Engineering was to identify issues affecting life-cycle costs including ease of installation and comparative system performance. After installation and initial characterization, the PV systems were to be monitored for 12 months. Results from the monitored data would be used to develop recommendations for selection of future nonresidential systems in other similar public and/or private host facility applications by the Commerce Energy Team.

Ultimately, Project 3.2 was designed to yield a prototype for a *Consumer Reports-type* PV system rating manual that could be used by incentive program administrators, manufacturers, system integrators, third party-developers, and customers to guide the selection and design of commercial and residential photovoltaic systems. This manual would demonstrate the use of proper *systems integration* to enhance the overall performance of photovoltaic systems, and to demonstrate the use of a basic PV system performance rating approach to improve the flow of information on expected photovoltaic system performance.

Project 3.3: Building-Integrated Photovoltaic on Public Facilities

The Building-Integrated PV on Public Facilities Project was managed by REDI. Under Project 3.3, a number of BI-PV pilot projects were to be identified, evaluated, selected, designed and installed on public facilities. The primary purpose of these pilot demonstrations was to validate design development and installation mechanisms for energy service providers (ESPs), host public entities, and/or other building owners. These mechanisms to be demonstrated were expected to: 1) improve consumer affordability for these higher cost systems, 2) reduce installed PV system costs per peak watt (and per life cycle kWh), and, 3) identify and demonstrate methods to add value to the PV system installation over its life (i.e., through common ownership arrangements and/or dual- or tri-use applications of the PV system).

Project 3.3 was expected to yield a set of specific photovoltaic facilities ranging in size from 10 kW to 150 kW. Each facility application was to address an infrastructure or commercialization barrier. At least one relatively large PV system was expected to be installed under a common ownership agreement. The cumulative capacity of BI-PV systems expected to be procured and installed under this program element ranged from 120 kW to 300 kW.

The Project 3.3 Team received a request to stop-work on the Project in November 2004. Although the Commerce Energy Project Team was willing to move ahead with the final design and installation of the PV projects, earlier task deliverables were held up in the review process, thus causing significant project delays, coupled with Self-Generation Incentive Program (SGIP) Level 1 over-subscription during the same timeframe, all of which would have prevented the project from being completed within the RD&D Program's timeframe.

1.4 Report Organization

The remainder of this Commerce Energy PIER Final Program Report is organized as follows:

- **Section 2** addresses the PIER Renewables Mini-Grid Program approach.
- **Section 3** discusses the results yielded from the Commerce Energy PIER Program.
- **Section 4** presents the conclusions and recommendations from the Program.

2

Commerce Energy Renewable Mini-Grid Program Approach

The Commerce Energy Renewable Mini-Grid Program began with an assessment of renewable resources available in the Chino Basin study area, local transmission and distribution system planning assessment options, and finally, prioritization of the potential site-specific resource options. Section 2.1 summarizes the approach taken to perform this assessment. The second major part of the Programmatic effort included development and implementation of a selected number of biogas and solar photovoltaic projects. The approach taken to develop and implement these research and demonstration projects is provided in Section 2.2.

2.1 Program Planning, Analysis and Prioritization of Resource Options

This sub-section summarizes tasks completed under Project 1.1: Program Planning and Analysis. Under Project 1.1, the initial mini-grid study area and the final electric transmission and distribution (T&D) system influence boundaries were defined, the renewable resource potential was evaluated, the economic potential of the selected mini-grid renewable resources were quantified, the public benefits were estimated, and a number of candidate demonstration renewable generation facilities were identified and prioritized. Each of these task elements is described in more detail below.

Initial Mini-Grid Study Area

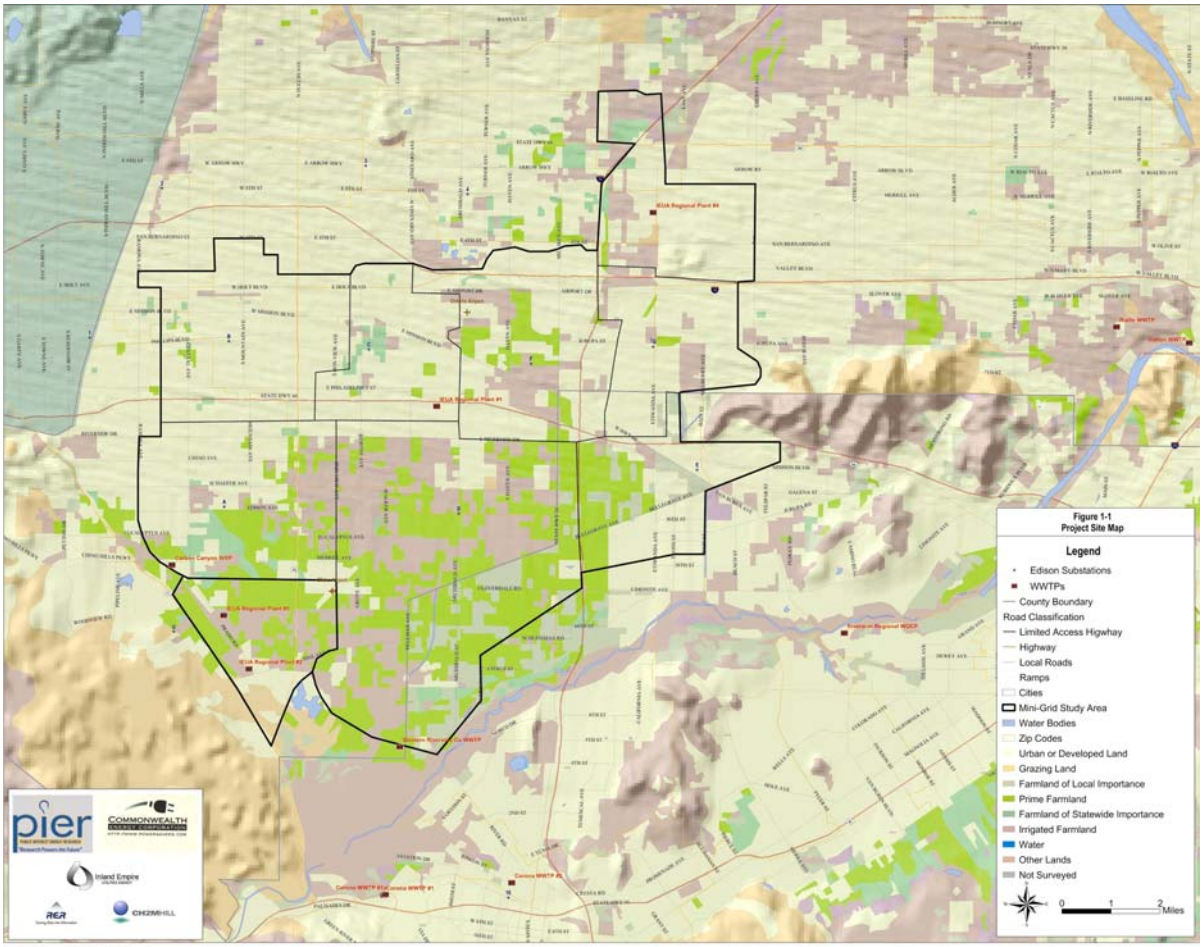
The Commerce PIER Renewables Program *Planning and Analysis Project* work scope called for the establishment of an electric T&D system mini-grid in Southern California within which a technical and market potential and electric-grid impacts study, and a number of pilot renewable generation projects would be implemented by the Commerce Energy Team. Two of the Program's early objectives were to assess: a) the potential for select advanced biogas and nonresidential Building Integrated Photovoltaic (BI-PV) electric generation within a small region, and b) the impacts of the future development of these selected generation resources on the local electric utility distribution and subtransmission systems. In order to allow work on these objectives to progress in the early stages of the program, an initial determination of the *mini-grid study area* was required. In addition to being located in a

relatively local geographical region with respect to the electric system, the selected Southern California mini-grid had to satisfy several additional criteria, including:

- A significant recoverable livestock waste resource,
- A building infrastructure undergoing growth,
- A growing wastewater treatment and solid waste disposal infrastructure,
- A significant number of publicly-owned facilities, and
- An electric distribution system with significant intertie(s) to the transmission infrastructure

Initial investigations by the Commerce Team identified and selected one prime location within Southern California that satisfied these initial requirements. This local area is generally referred to as the Chino Valley Basin, and includes, but is not limited to, the communities of Chino and Ontario. The map in Figure 2-1 identifies the selected initial mini-grid in a bold black area and the black lines within the mini-grid represent the electric distribution substation service zones within the mini-grid. The Commerce Program describes this area as the *Chino Basin Mini-Grid Area*.

Figure 2-1 Mini-Grid Map



Mini-Grid Renewable Resource Determination

Two general types of renewable resources are assessed and utilized under the Commerce Program: biogas and nonresidential solar photovoltaic power. Each resource potential was inventoried and the results are discussed in the following sections.

Biogas Resource Inventories

Under the biogas portion of the Commerce Program, resource inventories were initially developed in three areas. These include landfills, sewage treatment plants, and agricultural livestock waste. In each case, the goal was to identify potential locations for demonstration projects using biogas from the three sources listed above. The highlights of the approach to conduct these inventories in each of these three areas are summarized below.

Landfills:

The process to identify suitable locations for a landfill bioreactor involved looking first at landfills in four southern California counties. This initial approach was intended to screen

out landfills that would not be suitable for developing a bioreactor. For example, landfills that were closed were eliminated as it was recognized that they could not be reopened and permitted as a bioreactor. Similarly, landfills that did not accept organic material were eliminated. The approach then applied more site-specific considerations to identify the top four sites that were to be analyzed in the prioritization task. A key consideration in this task was to identify a means to model a potential bioreactor within the Mini-Grid. As part of the landfill inventory work, the Milliken landfill was used to model potential transmission and distribution system benefits.

Sewage Treatment Plants:

Sewage treatment plant process and energy production/use data were collected in order to identify suitable locations within the Mini-Grid for demonstration projects in two areas: enhanced anaerobic digestion and gas cleaning for microturbines. In the case of the enhanced anaerobic digestion activities, treatment processes employed at each plant were evaluated to identify those that would benefit from the deployment of thermal hydrolysis or ultrasound technologies. Special consideration was given to plants that were representative of those found elsewhere in the Mini-Grid and in California. In the case of the gas cleaning for microturbine projects, quantities of digester gas produced and current utilization practices were reviewed.

Agricultural Waste Inventory:

Large numbers of dairy cows are located in the Chino Basin. Biogas production rates were modeled for various size herds of dairy cows and the location of individual dairy operations was identified. These two sets of data were then merged using a geographic information system to inventory the quantity of manure produced that could be used for energy production. Food processing facilities within the Mini-Grid were located and contacted to gauge their interest in participating in the Commerce PIER Program.

PV Resource Inventories

The development of the non-residential PV resource inventory within the mini-grid started with the determination of available area and ended with the assessment of the technical potential for BI-PV generation. Technical potential is defined in this context as the total system capacity, in kW, if all technically feasible BI-PV opportunities were utilized and no economic barriers exist. The steps in estimating BI-PV technical potential were as follows:

- The number of non-residential public facilities and private sector establishments was estimated.
- Building energy usage and availability of area for BI-PV were explored at the building-specific level and used to estimate BI-PV system sizes necessary to offset 100% of building energy consumption.

- The BI-PV technical potential was derived on a building type basis through the evaluation of the total floor area and the energy consumption per facility. Quantities of public facilities and private sector establishments were then combined with estimates of average area available per building and with BI-PV system sizing factors to yield estimates of BI-PV technical potential for the mini-grid area.

Each of these steps is described in more detail below.

Estimating the Number of Establishments:

The first step in creating an inventory of photovoltaic technical potential was to determine the amount of public and commercial facilities within the target area of the study. A list of public agencies and facilities was created through a compilation of databases and the number of public facility buildings that exist at each public facility was determined, since many public entity's facilities contain more than one building.

Estimating Energy Usage:

Estimates of building Energy Use Intensities (EUIs) were combined with the floor space results to calculate estimates of total annual electric energy consumption.

Estimating Technical Potential:

Two types of photovoltaic technologies were addressed in estimating the PV technical potential; crystalline photovoltaic cells and amorphous photovoltaic cells. To estimate technical potential it was necessary to estimate PV *system* capacity corresponding to the available installation area. This methodology resulted in producing the average size of a photovoltaic power generation system needed to offset 100% of electric energy consumption that each building type could possibly house if all of the available area was utilized for photovoltaic arrays. To estimate the total BI-PV potential within the targeted area for public facilities, parking lot shade structures and awnings on the south side of the facilities were considered as available area for photovoltaic arrays. Also included as additional area were potential BI-PV shade structures, entry canopies, and direct-current (DC) PV applications. The type of roof a potential BI-PV facility contained was taken into consideration as a solar siting concern as well.

Determination of Electric T&D Boundaries within the Mini-Grid Study Area

In order that boundaries of the electric transmission and distribution (T&D) system could be determined, a database of the components of the T&D system within the Chino Basin needed to be developed with the help of Southern California Edison (SCE). The components necessary to determine the boundaries included the following:

- The general locations of the distribution level substations (66 kV stepping down to 12 kV).
- The geographic layout of the 12 kV feeders radiating out from each of the substations.
- Shunt, switch and fuse locations, and
- Maps of the locations and layout of each of the components, which were provided by SCE.

Once the substation and feeder database was developed, the locations of the BI-PV and biogas resources were laid out relative to the T&D components. The boundaries needed to contain entire feeder circuits and associated components at a minimum. Whenever possible, entire distribution substations were included.

Renewable Resource Market Potential Assessment

The market potential was estimated, defined as the quantity of non-residential renewable energy capacity that can be expected to influence future electrical distribution infrastructure operations, and potential expansion requirements within the mini-grid area over a ten year study period beginning in 2003 and ending in 2012 was estimated. Market potential represents a subset of economic potential, which in turn represents a subset of the identified technical potential. The following discussion addresses the development of economic potential and the further assessment of market potential, which takes into account other possible institutional and market barriers to adoption of the selected renewable technology.

Economic Potential Analysis

Analysis of the financial viability of renewable energy system deployment constitutes a critical step in the assessment of market potential corresponding to a given quantity of technical potential. This analysis consisted of the following steps.

- The financial performance of specific project prototypes is estimated in terms of internal rates of return (IRR).
- The minimum acceptable project financial performance is expressed in terms of a distribution of hurdle rates.
- The project financial performance estimates and investor financial performance requirements are combined in a calculation of acceptance rates representing the portion of technical potential meeting or exceeding the minimum requirements of prospective investors in these renewable energy systems.

Each of these is discussed in more detail below:

Prototypical Project Financial Performance

For this analysis, expected economic and market potential results were augmented with results for *low-potential*, *expected potential*, and *high-potential* scenarios. The bases of the three scenarios are summarized in Table 2-1.

Table 2-1: Description of Low-, Expected-, and High-Potential Scenarios

Scenario	Description
Low Potential	Estimated potential based on conservative estimates of the values of financial and market parameters that yield estimates on the lower side of possible outcomes.
Expected Potential	Estimated potential based on best guesses of the values of financial and market parameters.
High Potential	Estimated potential based on more aggressive estimates of the values of financial and market parameters that yield estimates on the upper end of possible outcomes.

Required Project Financial Performance

The conversion of technical potential into economic potential was accomplished using information from a previous study on required rates of return (i.e., hurdle rates) conducted by Regional Economic Research (RER) for the Energy Commission.[1] The hurdle rate distributions developed in that study for site owners, developers, and lenders were adjusted to reflect current market conditions using the approach recommended in the study. The mean required rate of return used in this analysis was just under 14% in nominal term and was used for all prototype analyses.

Calculation of Economic Potential

The calculation of economic potential for each prototype in this analysis entailed two steps. First, the prototype IRR was used in combination with the hurdle rate distribution to estimate an acceptance rate. Second, the economic potential was calculated as the product of the net technical potential corresponding to the specific prototype application and the acceptance rate for the prototype.

Market Potential Model Overview

Results of the financial analysis were combined with technical potential results in the calculations of the economic and market potential. The general form of the market potential model is illustrated in Table 2-2.

[1] Regional Economic Research, Inc., "Estimation of Hurdle Rates Applicable to Energy-Related Investments," June 25, 1989.

Table 2-2: Illustration of Market Potential Model

Year	Gross Tech Potential Start of Year (Tg, kW)	Net Tech Potential Start of Year (Tn, kW)	Acceptance Rate (%)	Economic Potential During Year (E, kW)	Incremental Market Potential During Year (Mi, kW)	Cumulative Market Potential End of Year (Mc, kW)
1	Tg_1	Tn_1	A_1	E_1	Mi_1	Mc_1
2	Tg_2	Tn_2	A_2	E_2	Mi_2	Mc_2
3	Tg_3	Tn_3	A_3	E_3	Mi_3	Mc_3

The Commerce PIER Program will directly influence the quantity of non-residential renewable energy system capacity deployed within the Chino Basin mini-grid and will contribute directly to incremental market potential. Additional market potential is calculated as the product of market penetration rate and remaining economic potential.

Economic and Environmental Benefits of Mini-Grid Renewable Resources

Though not explicitly targeted to be quantified, the economic and environmental benefits of renewable resources within the mini-grid were taken into consideration.

Economic Benefits

In the market potential assessment, an evaluation of the economic potential for the various resources was performed from the facility developer's perspective. The direct economic benefits associated with the development and use of biogas and PV resources were assessed and the prioritization process considered a benefit cost ratio from the developers' perspective. The economic benefits to the electric grid were also taken into consideration through the prioritization of candidate renewable generation facilities.

Environmental Benefits

The environmental benefits associated with the biogas and PV resources within the mini-grid area were identified in the market potential assessment and where they had a direct impact on the facility developer they were quantified in an economic sense. These benefits took the form of avoided cleanup and abatement costs primarily associated with groundwater contamination and green tags or renewable energy credits for the air quality benefits and renewable energy generation.

Estimation of Future Mini-Grid Renewable Resource T&D Public Benefits

The electric T&D system public benefits that could be accrued by the realization of the mini-grid renewable resource market potential were estimated as part of this project. The methodology involved first identifying the T&D system components in and around the

initially identified *mini-grid study area*. Next, a base case power flow model was developed from which the impacts of the renewable resources could be evaluated under differing penetration scenarios and the modeled T&D impacts resulting from the market potential expected to be implemented over time were quantified. Then, interconnection requirements and issues were identified and a dynamic study of three BI-PV and biogas high-penetration scenarios was performed.

T&D System for Mini-Grid

A local mini-grid electrical T&D system database was developed using reasonable assumptions and peak load projects for 2003. The database provided representative electrical characteristics of the SCE substations and distribution feeders serving the mini-grid area. The combination of substations and feeders provided a resource mix that made it possible to study a combination of renewable distributed generation in the mini-grid market assessment and the power flow modeling.

Base Case Development

The base case load flow model of the T&D system showed that the major impacts of installing renewable generation within the mini-grid were expected to be on the local mini-grid T&D facilities - first at the feeder level and then as penetration increases at the distribution substation level. Large penetrations of distributed renewable generation were expected to have some measurable impact on power flows in the "local" bulk 500/230 kV transmission system that serves southern California. Therefore, the plan was to model the transmission system as well as the local mini-grid system.

Estimation of Public Benefits

The renewable distributed generation under expected, high, and low penetration scenarios as well as peak and light load conditions were modeled and mini-grid power flow results for 2007 and 2012 were developed. Impacts on mini-grid power flow, losses, voltage regulation, reliability, reverse power flow, and flicker within the mini-grid due to the installation of renewables were developed and potential economic T&D public benefits were calculated.

Identification of Pertinent Interconnection Requirements and Issues

Several pertinent interconnection practices and standards documents were reviewed. Current California distributed generation interconnection requirements are described in Rule 21 documents for SCE, PG&E and SDG&E. Rule 21 interconnection requirements for each of these utilities will be reviewed, along with supplemental guidelines currently under development in California. Interconnection requirements developed in IEEE P1547 and Texas (and other pertinent interconnection requirements discovered while performing this task) were also reviewed for comparison purposes. In addition, progress on P1547 tasks –

P1547.1 Testing, P1547.2 Application Guide, P1547.3 Monitoring and Control, and newly formed P1547.4 Isolated Operation - were reviewed and appropriate results to date will be summarized. Other IEEE and ANSI standards were reviewed where appropriate.

Interconnection requirements are expected to vary as a function of generation type, generation size, location, and cumulative penetration level on the distribution system feeders. Appropriate PV and biogas generation characteristics were identified for potential renewable additions. BI-PV and biogas technologies using microturbines will interface with the utility through static power converters. Some biogas technologies will use rotating power converters. These rotating power converters will likely be synchronous generators.

Three potential high-penetration renewable scenarios for two selected feeders were developed to examine the expected range of potential interconnection requirements and issues. The scenarios to be developed during the course of the project were expected to be compatible with the previous task DG feeder penetration scenarios where possible. These three high-penetration renewable scenarios were employed on two distribution feeders with different characteristics. One feeder with primarily underground construction and one feeder with primarily overhead construction were selected to examine potential interconnection requirements.

The high-penetration BI-PV and biogas feeders were integrated into a simplified distribution system model with characteristics similar to one of the distribution systems used in the previous Chino area mini-grid study. The local distribution feeders, loads and distribution substation facilities will be modeled as appropriate and connected to a representative local subtransmission and transmission system model, which were connected to an infinite bus. The GE PSLF (positive sequence load flow) program were used as appropriate for the interconnection study.

The base case interconnection study considered relaying requirements, integrated control of distribution system voltage, reactive power scheduling, communication requirements, and short circuit duty impacts for the three high-penetration biogas and BI-PV penetration scenarios on each of the two feeder types using Rule 21 requirements. Other pertinent interconnection requirements and issues identified during the course of this task were studied where appropriate.

Some relaying issues addressed in the interconnection study include detecting faults and coordination of the distributed generation relaying with utility distribution system breakers, reclosers, fuses, and sectionalizers. Important considerations include coordinating fault clearing, utility reclosing, islanding, behavior of BI-PV and biogas generation containing rotating generators and static power converters, and different transformer connections between BI-PV and biogas generation and the distribution feeders. Some power quality

voltage and var control issues include voltage deviations after the renewable generation trips off-line, and coordination with transformer LTC and capacitor switching. Other important issues studied include evaluating potential positive (or negative) reliability impacts to the distribution system associated with large penetrations, and determining limitations and requirements to correct any adverse reliability impacts discovered. Harmonics issues associated with static power converters were not included in the interconnection study, as harmonics levels are now controlled by using pulse-width modulated (PWM) inverter technology.

Dynamic Study of Three BI-PV and Biogas High-Penetration Scenarios

The GE PSLF/PSDS (positive sequence load flow/positive sequence dynamic simulation) program was used for the dynamic study. PV and biogas technologies using microturbines will interface with the utility through static power converters. Some biogas technologies will use rotating power converters. These rotating power converters will likely be synchronous generators. Suitable distribution system characteristics for the local distribution feeders, loads and distribution substation facilities developed in the interconnection study will be modeled for the dynamic calculations. Appropriate BI-PV and biogas generator models, exciter models and static power converter models will be developed for the three potential BI-PV and biogas scenarios.

A dynamic study of the transient response of the three high-penetration scenarios of distributed biogas and BI-PV generation to disturbances on the feeder, or on nearby feeders and substations were performed to determine the stability of the DG. A series of three-phase faults will be examined at up to five selected locations on or near the feeders containing the DG in order to examine the system performance with the DG in operation. Dynamic runs were performed during peak load and light load conditions used in the steady-state power flow studies. Transient stability were tested with dynamic runs made for ten seconds. Both voltage and swing angle at the DG locations were plotted for each of the disturbances. An important issue studied is stability analysis of faults that the high-penetration distributed biogas and BI-PV generation scenarios need to ride-through to provide expected distribution system reliability. Static power converters have no inertia and are typically assumed to switch off shortly after a disturbance. This study investigated whether the static power converter output can be controlled to ride-through disturbances where needed. Other important issues to be considered are potential feeder islanding, and inadvertent breaker operation.

Identification and Prioritization of Candidate Renewable Generation Facilities

One of the major objectives of the Planning and Analysis Project is the prioritization of candidate sites to participate in the Commerce Energy's RD&D pilot program activities. The prioritized site selection methodology is based on a set of criteria used to evaluate potential

RD&D pilot projects. The full list of criteria for evaluation of identified projects has three major groups of criteria:

- Criteria from the Commerce Energy Business Plan
- Mini-Grid System Benefits
- Technical (RD&D) Attributes

There are several levels of criteria sub-groups. Table 2-3 lists these criteria by major groups.

Table 2-3: Evaluation Criteria List

Commerce Business Plan		
Non Financial		
Community Aggregation		
Near Term Targets		Areas that Commerce wishes to target with projects
	Santa Monica	
	No. California Community	
	Chino	
	Ontario	
	Central Valley Community	
Long Term Positioning		Market areas for strategic growth and positioning
	Applicability to Others in Municipal Sector	
	Applicability to Others in Agricultural Sector	
	Contributes to Renewable Resource Affordability (size, reliability, cost and dispatchability)	Stated strategic goal of the PIER program
Greenfield Development		
Green Tags		Based on the State's Renewable Portfolio Standard
Other Benefits		
Environmental		
Power Diversity		
Power Reliability		
Credibility / Branding		Extension of Commerce's name into new markets due to project
Financial		
Expected Revenue ($1,000s)		
	Direct Revenue	Directly due to the project
	Indirect Revenue	Potential from spin-off projects in the same area
Benefit/Cost Ratio		Defined as the present worth of the 15-year direct revenue stream discounted at 9% divided by a rough-order-of magnitude (ROM) cost for the project(s)
Mini Grid Benefits –From the Perspective of the Mini-Grid		
Non Financial		

New System Capacity (kW)	Amount of new system capacity in kW represented by the project(s)
Distribution System Deferral Benefit	Potential to defer building a new sub-station due to new renewable energy from project
Distribution System Cost Savings Benefit	Potential to reduce distribution maintenance costs due to reduced distribution system load
Voltage Regulation Benefits	Contribution of project to better voltage regulation in the distribution system
Line Loss Reductions Benefits	Reduced line losses from project due to on-site generation of renewable energy
Financial	
Quantifiable Benefit / Total Cost Ratio	This is benefits from sub-station deferral divided by costs to the mini-grid, such as self generation incentives
NPV of Net Benefits to Mini-Grid	This is present value of future benefits from sub-station deferral, less the self-generation incentive
Total Deferred Capital Cost	This is the total cost deferral from sub-station deferral from the project.
Technical Criteria	
Suitability for Demonstrating Technology	Goal of PIER program - demonstrate new technologies
Permitting Capability	Critical issue for those projects requiring permits
Statewide Applicability	Goal of PIER program - develop technologies that can be applied elsewhere in the state
Technology Risk	
Lead Time	Time horizon of project versus time horizon of PIER program funding
Match Fund Ratio	Defined as (Match Funds)/(PIER + Match funds)
Host / Developer Economics and Financing	
Program Linkage	

A weighted-objectives hierarchy model was used as a decision tool for prioritizing projects along these criteria. The top-level set of priorities for this project is the three main categories of criteria: Commerce Business Plan, Mini-Grid Benefits, and Technical Criteria. They were weighted as shown in Table 2-4.

Table 2-4: Top-Level Evaluation Criteria Priority Weighting

Top Level		
	Weightings	
Evaluation Criteria	Score 1-5	Absolute
Commerce Business Plan	5	0.421
Mini-Grid Benefits	3	0.211
Technical	4.5	0.368
TOTAL		1.000

Finally, the scoring results were such that natural dividing points between groups ("tiers") of projects were evident for both the range of potential biogas and BI-PV projects. For both sets, projects were divided into a Tier 1, a Tier 2, and a Tier 3. Tier 1 projects are those that warrant further funding and implementation at this time. Tier 2 projects include those that may be implemented after requirements for Tier 1 projects are met. Tier 3 projects include those that do not sufficiently meet the combined goals of Commerce business objectives and the PIER RD&D program to be implemented at this time. This allows for the most appropriate allocations of available public and private resources on the highest priority projects in order to assure optimal program results.

2.2 Development and Implementation of Selected Projects

Biogas to Energy Projects

Three biogas to energy projects were planned, but only two were implemented. The three projects were: Project 2.1 *Enhanced Landfill Gas Production*, Project 2.2 *Enhanced Digestion and Gas Cleaning*, and Project 3.1 *Dairy Waste to Energy*. Project 2.1 was not implemented due to the need for the selected landfill to accept waste in the area where the bioreactor would be implemented by early 2005 and the inability of the bioreactor to be installed under this timeline.

Project 2.1 Enhanced Landfill Gas Production

The overall goal of Project 2.1 was to enhance landfill gas production and advance the state-of-the-art technology for landfill bioreactors. Project 1.1 work had narrowed down the list of potential sites to the four landfills shown in Table 2-5. Following a lengthy data collection and multi-site evaluation process, it was decided that the bioreactor would best be installed at Mid-Valley landfill in San Bernardino County. If the project had proceeded the bioreactor would have been built within the Unit 3 cell during the cell's expansion.

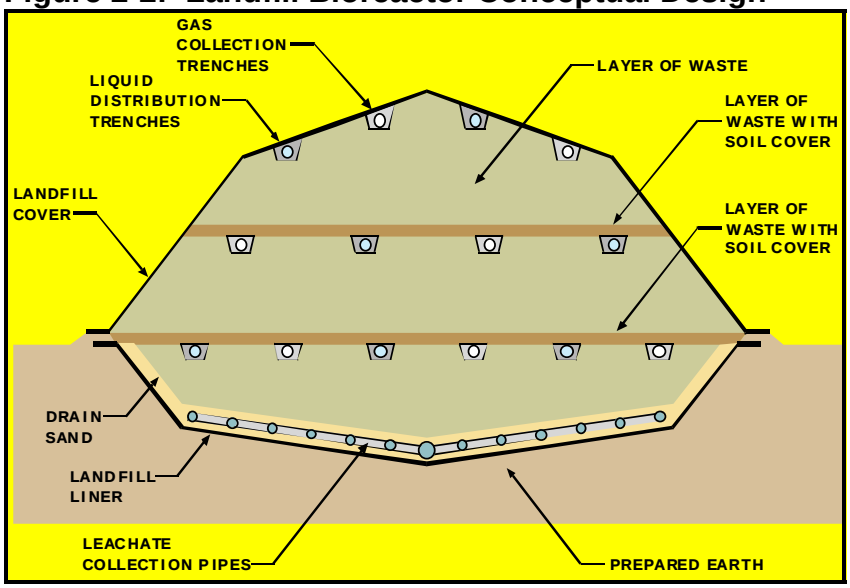
Table 2-5: Project 2.1 Preferred Landfill Bioreactor Sites

Landfill Name	Location	Owner	Waste In Place (tons)	Waste Acceptance Rate (tons/day)	Potential Power (MW)
Badlands Disposal Site	Moreno Valley	Riverside County	5,168,932	1,500	
El Sobrante	Corona	Western Waste Industries	8,000,000	4,900	
Fontana (Mid-Valley)	Fontana	San Bernardino County	2,800,000	3,000	8
San Timoteo	Redlands	San Bernardino County	880,000	500	2

After the site was chosen, an evaluation of the type of waste entering the landfill was performed in order to predict how much gas could potentially be produced. Also, environmental benefits and/or concerns associated with the bioreactor were assessed.

A conceptual design for the bioreactor was constructed that would link the bioreactor to the expansion of the Unit 3 cell, as shown in Figure 2-2 After the landfill bioreactor was designed, plans could begin for the construction and testing of the bioreactor, and environmental permits would be obtained following the necessary regulatory approvals.

Figure 2-2: Landfill Bioreactor Conceptual Design



This project did not continue past the planning stage due to the need for the selected landfill to accept waste in Unit 3 expansion by early 2005 and the inability of the bioreactor to be installed under this timeline.

Project 2.2 Enhanced Digestion and Gas Cleaning

The overall goal of Project 2.2 was to increase biogas power generation at wastewater treatment plants by testing gas cleaning systems for microturbines and testing processes that could optimize anaerobic digestion and therefore increase gas production. The first step for this project was to evaluate and select two sets of processes that could be potentially employed at the sites identified in Project 1.1. These two sets of processes were then evaluated.

Gas Cleaning for Power Generation with Microturbines

In California, there is a move toward microturbines for power generation from biogas, due to their reduced air emissions compared with internal combustion engines. However, field experience indicates that microturbines are more sensitive to contaminants and moisture than internal combustion engines. Close attention to cleaning and treatment of the biogas prior to use as a fuel has been shown to be necessary for a successful project. Inland Empire Utility Agency's (IEUA) existing Capstone 31-kW microturbines provide a convenient and low-cost venue for testing and piloting new biogas treatment technologies. Operations experience already exists on these units, and the units may potentially be retrofitted with gas treatment equipment for testing. They also provide a good opportunity to solve specific gas treatment problems while developing experience for packaged system designs that can be used state-wide at other biogas generation facilities.

The following are measures for biogas treatment that were considered:

- Drying (moisture removal)
- Hydrogen sulfide removal
- Siloxane removal
- Measures to achieve consistent heating value (fuel blending)

Ultimately it was decided that a custom system capable of removing moisture, hydrogen sulfide, and siloxanes would be most applicable and beneficial for this project. The *Microturbine and Gas Cleaning System Design and Construction Drawings* were prepared that integrated the microturbine, gas cleaning, and related equipment including heat recovery into the requirements of IEUA Regional Plant 1. Mechanical, electrical, instrumentation/controls, and site/civil drawings, suitable for construction were prepared.

A test plan was then developed that listed specific data that should be collected as part of the test, facilities, equipment, and instrumentation that were needed for the test, test parameters and procedures, data analysis procedures, quality assurance procedures, and contingency

measures. Data would be collected to determine the removal efficiency and the cost-effectiveness of operating each of the technologies.

Enhanced Gas Production

Hydrolysis of the secondary solids is generally held to be the rate limiting step in anaerobic digestion. Therefore, for optimization of gas production, the focus has been on technologies that enhance hydrolysis. There are three primary methods by which hydrolysis can be accomplished:

- Physical – breakdown by mechanical means, such as pressure, temperature and attrition.
- Chemical – breakdown by changing the pH, with acid or alkali addition.
- Biological – biological decomposition, by microbial action.

Physical hydrolysis processes include thermal hydrolysis, which uses high temperature and pressure, ultrasound, which uses cavitation effects of sound waves, and mechanical grinding technologies such as ball mills. Chemical hydrolysis is a highly effective method of hydrolysis, however, it is not considered appropriate for digestion of municipal solids. Biological hydrolysis processes include addition of enzymes and microbes, usually in a powder form. Thermal hydrolysis and ultrasound are technologies that have been gaining increasing interest in the application of improving gas production from digestion of municipal solids and were therefore recommended for this project. The City of Riverside was the recommended location for the ultrasound pilot testing program because the processes at this sewage treatment plant are representative of other plants; therefore, the results are applicable to treatment plants across California.

Two manufacturers, Dirk IWE Tec and Sonico, were selected to provide ultrasound systems for pilot testing. *Ultrasound System Design and Construction Drawings* were prepared to facilitate installation of the ultrasound optimization equipment in the host facility.

A test plan was developed to assist in the implementation of a demonstration trial which was conducted to investigate the economic, practical and technical benefits of using ultrasound to increase gas production on existing anaerobic digesters at the City of Riverside Sewage Treatment Plant. The test plan lists specific data that should be collected as part of the test, facilities, equipment, and instrumentation that are needed for the test, test parameters and procedures, data analysis procedures, quality assurance procedures, and contingency measures. Data were collected to establish baseline performance data for the test digesters, evaluate performance of two digesters, each with a different ultrasound system, and evaluate operability of the two ultrasound systems.

Project 3.1 Dairy Waste to Energy and Co-Digestion

Project 3.1 was designed to evaluate selected technologies available for the conversion of animal waste to energy. Animal waste is becoming a larger problem due to the trend toward larger dairy operations and due to the number of dairies that are located near urban areas.

Compare Plug Flow and Complete Mix Digesters in the U.S. 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 U.S. and in Denmark.

An economic analysis of the Regional Plant (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, including air quality improvement, water quality improvement, greenhouse gas reduction, and solid waste management.

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. 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)

Of the above, anaerobic digestion was chosen as the best opportunity for applying technologies to improve performance and economics. 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
- Thermophilic/temperature-phased anaerobic digestion (TPAD)
- Dewatering improvement (residuals management)

- Recycle stream management
- Biological gas treatment to remove hydrogen sulfide

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

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

The top three technologies were 1) co-digestion, 2) biological gas treatment to remove hydrogen sulfide, and 3) cellulose destruction using ultrasound. Co-digestion and biological gas treatment to remove hydrogen sulfide were the chosen technologies for the test.

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

The top three sites were:

- IEUA RP-1
- IEUA RP-5
- Burrtec

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 of California, it was decided to investigate and quantify this market opportunity.

Design the Pilot Plant(s) and Prepare Test Plans on Co-Digestion

Co-digestion refers to the addition of other organic waste streams into the manure slurry feeding an animal waste digester. To exploit co-digestion, it is necessary to identify other waste streams suitable for co-digestion with manure based on quality, quantity, availability, delivery and holding requirements. Once identified, the system modifications necessary to receive and blend these waste streams with manure need to be established and implemented. Based on the result of the phased-digestion/thermophilic digestion testing, the co-digestion operating mode was selected and implemented. System performance improvements were determined by proportionally feeding the co-digestion waste streams with manure. The various manure-to-other waste ratios and different waste streams for co-digestion were tested. Modifications were made at RP-5 to allow the introduction of high-energy food processor wastes into the manure digester. A test plan was developed to evaluate the performance and cost-effectiveness of co-digestion.

In a biological gas treatment system, the digester biogas was transferred to a separate hydrogen sulfide (H_2S) removal unit, having a tank which was filled with a bed of plastic or ceramic filter chips that act as a bacteria growing media. A mixture of water and nutrient solution (nitrogen, phosphorus, potassium [N, P, K]) with micronutrients was added to the tank and sprayed out over the chips. The nutrient spray cools the biogas, and water is removed by condensation, which in turn removes most of the ammonia (NH_3) and about 15 to 25 percent of the H_2S. Existing biogas cleaning units show that biological H_2S removal easily reduces the H_2S content by 90 to 99 percent, so that typical H_2S concentrations in the 2,000 ppm range before treatment can be reduced to as low as 20 ppm after treatment. A test plan was developed in order to estimate the performance and costs of the biological hydrogen sulfide removal system.

Pilot Plant Design and Test Plans

The food waste mixtures to be tested were selected based on the bench-scale test results and the availability of different food waste types. Lactose waste (Cacique) and cheese residual (Golden Cheese) were planned to be used in manure co-digestion. All three feed streams were to be fed to the Acid Manure Digester (AMD). Lactose waste (Cacique), cheese residual (Golden Cheese), salad dressing (GFF), tomato waste (UBF), and vinegar waste (Mizkan) were used in biosolids co-digestion at different feed ratios. Ice cream waste (Alta Dena) was also considered as a supplement for biosolids co-digestion.

Environmental Benefits of Anaerobic Digesters

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 and is useful in identifying issues that should be considered by various stakeholders when determining economic value of environmental benefits from these projects.

Building-Applied Photovoltaic (PV) Projects

Two separate types of PV projects were planned, but only one was fully implemented. The two projects were: Project 3.2 *Building Integrated Photovoltaics Testing and Evaluation* and Project 3.3 *Building Integrated Photovoltaics on Public Facilities*. Project 3.3 did not progress past the planning and initial site selection stage due to the receipt of a stop-work notification in November 2004 .

Project 3.2 Building Integrated Photovoltaics (BI-PV) Testing and Evaluation

The objective of this project was to perform side-by-side evaluations of commercially available PV systems and component technologies, and to compile objective, consumer-friendly information on the costs and performance parameters of those systems. This type of information was not currently available from any one source, and is needed by the PV-buying public.

The systems were evaluated in order to develop a rating system for use by consumers and compiled into a *Consumer Confidence Guidelines* document. Manufacturers and system integrators will also find this information valuable in selecting, designing, and installing PV systems. Real-time performance data as well as various reports on performance comparisons between the installed commercial-and residential-oriented systems continue to be available online at www.pierminigrid.showdata.org.

While the PV systems under evaluation were selected for their application to the California market, results are clearly relevant and useful for all national markets. The procedures developed in this program will provide the basis for the development of standardized tests to be adopted nationwide. This project is linked with efforts to produce a national PV system testing procedure underway for the U.S. Department of Energy at Sandia National Laboratories. The results of this project will be used to help establish standards to be published by organizations like the Institute of Electrical and Electronic Engineers (IEEE) or the American Society for Testing and Materials (ASTM).

Building Integrated PV Testing and Evaluation Project

This work was divided into two categories of systems intended for building integration:

- Large Systems – three nominal 20 kW systems representing large commercial rooftop systems each configured as a single or multiple building blocks.
- Small Systems – three nominal 2 kW residential/small commercial rooftop systems.

Large and Small System Selection

Systems were bought from dealers, distributors, or otherwise in such a way as to ensure that the components were not specially selected by the supplier. The small systems were nominally 2.0 kW (ac, PTC rating). Equipment selection criteria included the following:

- Price
- Supplier experience
- Degree to which proposed system met program objectives
- Degree to which proposed system added variety to project
- Degree to which proposed system is representative of potential PV products in the California market

The Commerce Energy team were able to obtain five pre-engineered large system arrays (both of the 20kW single inverter systems and three of the multi-string arrays) while the remaining seven multi-string arrays were designed by project personnel. A preference for pre-engineered solutions was given over variety of components for the small systems, given the wide variety that had been obtained in the large systems selection.

Not all of the systems fit the strict definition of “Building Integrated”, which usually implies that the PV array takes on some function of a traditional building material (cladding, glazing, insulation, etc.). Several of the systems—PowerLight Sloped PowerGuard, SIT, IES Solar Quilt—are intended to act as roofing material replacements or augmentation, so do meet the purist definition. However, the number of suitable building material-type PV modules was

very limited in 2003 when we were selecting systems, and even though the IEUA Headquarters was under construction, it would have been exceedingly difficult to try to architecturally integrate anything into the building, particularly since construction had already begun. Finally, by taking the roof mounted approach, we were able to test a much wider variety of the most commonly available products.

Large System Site Selection

The Large PV systems were co-located (at a single common site) for fair and impartial comparison of the selected technologies. As the cost of these systems was borne by the project participant, it was ideal that this location allowed the participant to take advantage of both the energy generated and the public relations value of using a renewable energy source. The co-location of the compared systems allowed the project participant to access CPUC Self-Gen Incentive program rebate funds that were available for systems over 30kW.

Small System Site Selection

The Small PV systems were co-located (at a single site) for fair and impartial comparison of the selected technologies. The selected site for this activity was the EMT/SST area of the PVUSA site in Davis, CA. The Commerce Energy team were able to reach a cooperative agreement with Renewable Ventures to use the site and its facilities in exchange for engineering and operations assistance. The site is well characterized, has excellent solar resource, and was originally designed and built to test PV systems and components.

Comprehensive Large PV System Comparison

The Large system evaluation covered the selection, installation, operation, monitoring, and evaluation of three independent 20 kW PV systems. These systems were intended to be indicative of the kinds of nonresidential PV hardware that was expected to be installed under Project 3.3 of the Commerce PIER program.

Comprehensive Small PV System Comparison

The small system evaluation covered the selection, installation, operation, monitoring, and evaluation of three independent nominally sized at 2kW PV systems. These systems were intended to be indicative of the kinds of PV hardware that an energy service provider would market to its residential and small commercial customers and was also indicative of hardware installed under the California Emerging Renewables Buydown Program. Pre-engineered systems (i.e. Sharp *2500*, Kyocera *MYGEN*, and Schott Solar *SunRoof*) were selected for this evaluation.

System Testing and Monitoring

PV systems were installed and monitored for 12 months to provide "real-world" performance data relevant to building-integrated PV applications. Information on design features, flaws, weak points, etc. were evaluated to develop suggested fixes. Factors affecting overall system value, including ease of installation, component selection, component failures, and performance factors, were assessed and reported.

Documentation and Design Review

A complete system documentation package is essential to reproducible success in system installations. The detailed description of which elements were included in the documentation and design review are covered in detail in the Consumer Confidence Guidelines report. These elements included issues such as the following:

- System description and specifications
- Parts and source lists for equipment supplied and not supplied with package
- Electrical diagrams and schematics
- Array installation guidelines and mechanical drawings
- Installation and checkout procedures
- Operation, maintenance and troubleshooting instructions
- Owners manuals for individual major components
- Information on how system performance monitoring is accomplished
- Warranty information on components and complete system

Project 3.3 Building Integrated Photovoltaics (BI-PV) on Public Facilities

Project 3.3 was designed to yield up to four public sector BI-PV projects ranging in size from 10 kW to 150 kW. Each project would address an infrastructure or commercialization barrier.

The first step in implementing Project 3.3 was to develop a database of public sector clients in order to select the test sites for the BI-PV. The second step was to develop a database that listed PV equipment vendors and service providers. A BI-PV *Evaluation Tools Package* (*ETP*) was designed in order to analyze the proposed Public Sector BI-PV demonstration systems. The *ETP* estimates system performance, performs financial analyses, and quantifies environmental benefits for the proposed BI-PV system demonstration sites, and was intended to be used by the Project 3.3 Team and other consultants involved in developing the projects, such as architects, energy engineers, and other PV professionals. The *ETP* along with information obtained in Project 1.1 would provide valuable information in selecting the top four sites for the project. Recommendations for the PV systems to be used in Project 3.3 were originally designed to come out of the initial results of Project 3.2.

A BI-PV Public Loan Program was to be organized in order to finance BI-PV systems at new and existing facilities. Financing would be provided for four sites as needed, and a variety of financing options would be pursued. The BI-PV systems would then be installed and monitored according to the project's defined test plan throughout the duration of the PIER Program.

Project 3.3 did not progress past the planning and initial site selection and system configuration due to receipt of a stop-work notification in November 2004.

3

Program Outcomes

3.1 Program Challenges and Market Issues

This Commerce Energy Program included a total of six projects on three project areas. The first project area was the Chino Basin Mini-Grid distribution assessment and this work was completed as part of the *Program Planning and Analysis* project. The second project area was biogas to energy projects, and there were three projects under this category: *Enhanced Landfill Gas Production*, *Enhanced Anaerobic Digestion and Gas Cleaning*, and *Dairy Waste to Energy*. The third project area was building-integrated photovoltaics projects, and there were two projects under this category: *Building-Integrated Photovoltaics Testing and Evaluation* and *Building- Integrated Photovoltaics on Public Facilities*. The following sections discuss the challenges and market issues associated with each project.

Chino Basin Mini-Grid Distribution System Assessment

Challenges

The Project 1.1 team experienced delays in development of the local electrical T&D database and load flow model. The mini-grid area was found to contain seven separate distribution systems serving a total peak load of approximately 535 MW. Due to the size of the mini-grid area, each of the distribution subsystems could be considered a mini-grid. Furthermore, the complexity of the local electric T&D system required the development of 12 kV feeder electrical data for 67 feeders to develop the load flow T&D model. Thus, characterization of the mini-grid's electric T&D system posed significant challenges to the project team.

Additionally, in 2002, data for a distribution substation outside the local area was added, which contained information on 12 kV feeders serving loads in the area north of Pine Street and east of Route 71. These loads were not served by the seven local distribution systems, which contained RP-5 and RP-2 loads. Data for an additional distribution substation outside the local area were also added to the T&D database and load flow model. This substation contained 12 kV feeders serving loads in the northeast region of the mini-grid north of Route 10 and east of Route 15 to Etiwanda Avenue. This area contained RP-4 and an Ikea warehouse. The additional work to identify pertinent interconnection requirements and issues as well as conduct a dynamic load simulation study for high penetration BI-PV and biogas to energy senarios was not approved until the second half of 2005. It was a challenge

to complete the study with the limited time remaining in the PIER Commerce contract, but it did not prove to be a hindrance.

Market Potential Assessment of Mini-Grid Renewable Resources

This assessment addressed the market potential of nonresidential BI-PV, agricultural and food processing waste biogas, incrementally developed generation capacity from enhanced wastewater treatment biogas, and landfill bioreactor gas (LFG) resources over the period of 2003 through 2012.

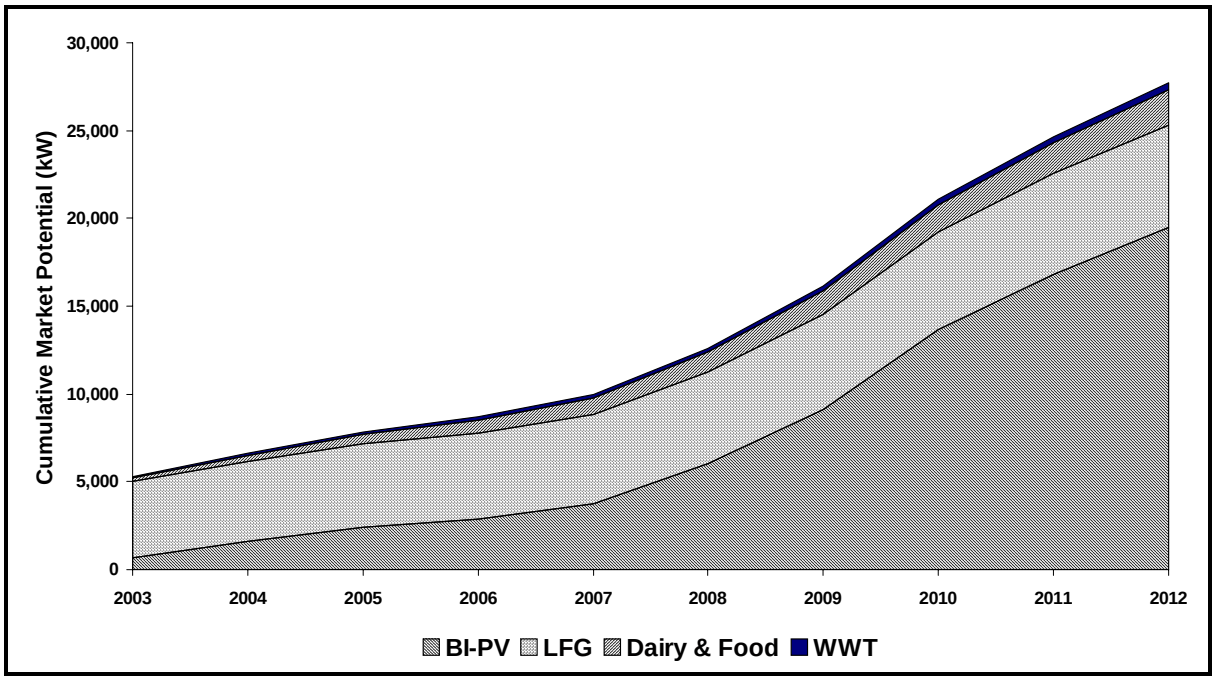
Summary of Combined Market Potential by Resource

The combined expected market potential for these four nonresidential renewable resources within the Commerce Energy Program mini-grid is approximately 5 MW in 2003 and increases to nearly 28 MW by 2012. In the early years, the combined potential is dominated by LFG. By the end of the planning horizon, the BI-PV potential dominates the combined potential. Table 3-1 and Figure 3-1 present the results.

Table 3-1: Expected Market Potential by Resource

Year	Total (kW)	BI-PV (kW)	LFG (kW)	Dairy & Food Waste (kW)	Incremental WWT (kW)
2003	5,263	685	4,344	167	67
2004	6,639	1,593	4,540	395	111
2005	7,859	2,442	4,733	541	143
2006	8,694	2,885	4,916	726	167
2007	9,960	3,765	5,090	919	186
2008	12,588	6,004	5,256	1,124	204
2009	16,108	9,118	5,413	1,356	221
2010	21,061	13,631	5,563	1,570	298
2011	24,663	16,831	5,704	1,777	351
2012	27,721	19,460	5,839	2,033	389

Figure 3-1: Expected Market Potential by Resource

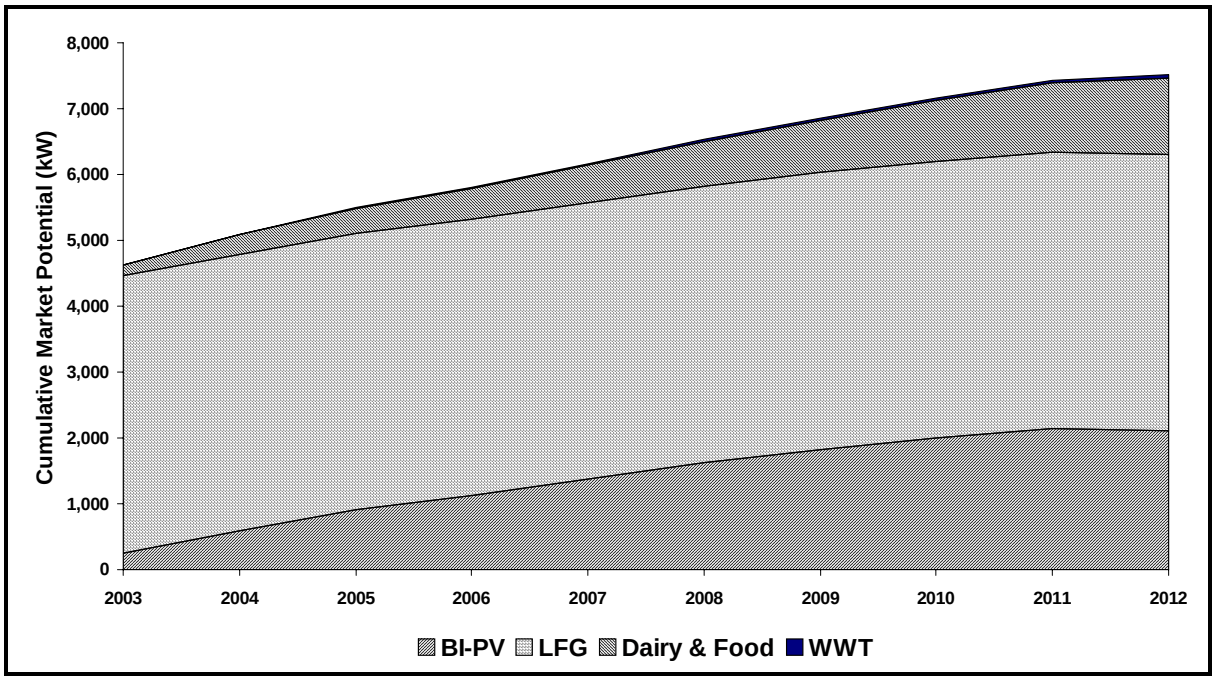


In the combined low market scenario, market potential reaches 7.5 MW, and the LFG resource dominates throughout the entire planning horizon. By 2012, BI-PV begins to make a major contribution to the total. The results are shown in Table 3-2 and Figure 3-2.

Table 3-2: Low Market Potential by Resource

Year	Total (kW)	BI-PV (kW)	LFG (kW)	Dairy & Food Waste (kW)	Incremental WWT (kW)
2003	4,630	258	4,200	167	4
2004	5,098	585	4,200	305	8
2005	5,501	906	4,200	383	12
2006	5,806	1,124	4,200	467	16
2007	6,161	1,368	4,200	573	20
2008	6,531	1,619	4,200	689	24
2009	6,855	1,830	4,200	797	27
2010	7,168	2,004	4,200	929	35
2011	7,427	2,135	4,200	1,050	42
2012	7,521	2,103	4,200	1,169	49

Figure 3-2: Low Market Potential by Resource

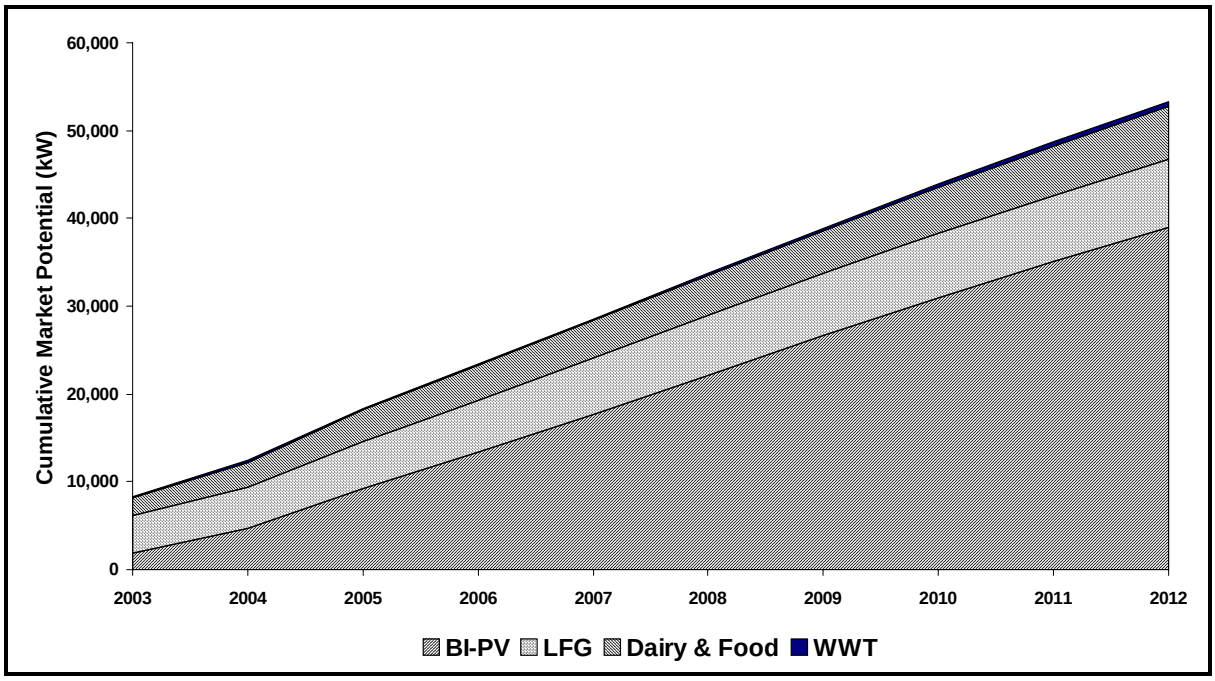


In the combined high scenario, market potential for the renewable resources within the mini-grid is approximately 8 MW in 2003 and increases to 53 MW by 2012. In the first year, the combined potential is dominated by the LFG. By the end of the planning horizon the BI-PV potential dominates the combined potential by a large margin. The results are shown in Table 3-3 and Figure 3-3.

Table 3-3: High Market Potential by Resource

Year	Total (kW)	BI-PV (kW)	LFG (kW)	Dairy & Food Waste (kW)	Incremental WWT (kW)
2003	8,362	1,851	4,344	2,017	150
2004	12,415	4,671	4,736	2,833	176
2005	18,348	9,293	5,285	3,580	189
2006	23,472	13,358	5,908	4,005	201
2007	28,545	17,674	6,407	4,252	213
2008	33,745	22,163	6,805	4,547	229
2009	38,852	26,604	7,124	4,879	245
2010	43,968	30,893	7,379	5,255	442
2011	48,711	35,024	7,584	5,627	476
2012	53,292	39,005	7,747	6,046	494

Figure 3-3: High Market Potential by Resource



There is a very large technical and economic potential for biogas and non-residential BI-PV distributed generation within the Commerce Energy mini-grid. In fact, the total gross technical potential of 599 MW is actually slightly greater than the entire peak electric load on the distribution system within the mini-grid itself. In the expected case, incremental renewable generation that will impact the electric grid is estimated to be less than 4% of the gross technical potential by 2012.

In order for more of this potential to be adopted within the mini-grid, many market barriers will need to be overcome. New ownership models may be necessary to help overcome some of the market entry barriers. Publicly supported incentives and educational programs can have an impact on market adoption if they are persistent and are perceived as reliable and part of a longer-term strategy. The development of environmental emissions credit markets has the potential to monetize the environmental benefits that can be accrued. These various regulatory driven credit markets would make an already economical renewable generation market even more competitive to third party project developers.

Economic and Environmental Benefits of Mini-Grid Renewable Resources

Economic Benefits

The economic benefits of the renewable resources examined under this project are captured in the economic potential assessment and the T&D public benefits results.

The economic potential assessment involved cash flow modeling of technology prototypes developed to represent those that are likely to be implemented in the Chino Basin as well as those explored in other PIER Commerce Energy Projects under the broader PIER Commerce Energy research, development and demonstration program. The selected financial measure of performance used in this analysis was the internal rate of return (IRR). The IRR was computed for these prototypes under a number of financial conditions consistent with the three economic and market scenarios. These cash flow analyses results were subsequently fed into the economic hurdle rate model developed for this project to determine the relative portion of the technical potential that is considered economically viable.

The results of these assessments present a comprehensive picture of the prospects for biogas and BI-PV distributed generation within the defined mini-grid. The results for the expected scenario are summarized in Table 3-4.

Table 3-4: Expected Scenario Potential – Biogas and BI-PV Resources

Year	Gross Technical Potential	Net Technical Potential	Incremental Known Projects (kW)	Remaining Economic Potential (kW)
2003	598,842	598,771	4,200	195,426
2004	619,895	614,632	150	141,828
2005	639,962	633,472	0	72,634
2006	654,521	646,812	0	69,144
2007	665,732	657,188	0	119,977
2008	677,422	667,612	0	275,713
2009	688,401	675,963	0	385,754
2010	700,287	684,329	0	558,473
2011	710,544	689,632	0	437,444
2012	720,958	696,445	0	392,405

In this base scenario, the cumulative economic potential for all four of the identified Program renewable resources are 32.6% of the gross technical potential in 2003. This share of economic potential to technical potential grows to 54.4% by 2012.

Project specific economic benefits were examined in the prioritization of potential pilot projects as well. The ratio of the expected lifetime revenue over the expected project cost from the project owner's perspective was developed for each project. This benefit/cost ratio is defined as the present worth of the 15-year direct electric revenue stream (numerator of the ratio) discounted at 9% divided by a rough-order-of magnitude (ROM) cost for the project(s). The value of the electricity for the biogas projects was based on an average rate of

$0.09/kWh applied to all the electricity produced. For the BI-PV projects, the value of electricity took into consideration the time value of electricity, which is typically greater at peak hours as opposed to off peak hours. Since BI-PV electric production typically occurs at peak hours, the value of electricity used to estimate the revenue stream for these projects varied between approximately $0.12/kWh and $0.17/kWh, depending on each site's electric rate. The ROM costs are the estimated capital costs for the projects. The expected lifetime revenue (numerator of the ratio) was discounted back to present value using a discount rate of 9 percent. A lifetime of 15 years was assumed. Results are shown in Table 3-5.

Table 3-5: Benefit / Cost Ratio for Prioritized Biogas and BI-PV Projects

Project	B/C Ratio
Biogas Projects	
2.1 Project - Landfill Bioreactor	3.40
2.2 Projects - Ultrasound at Riverside	2.38
2.2 Projects - Gas Treatment (Sewage Treatment Plants)	N/A[1]
3.1 Projects - Gas Cleaning (Dairy Operations)	N/A[1]
3.1 Projects - RESIDUALS MANAGEMENT	N/A[1]
3.1 Projects - GAS PRODUCTION ENHANCEMENT	4.75
3.1 Projects - Co-Digestion at RP-1	1.72
3.3 Projects - Ontario School District facility	0.30
3.3 Projects - U.S. Navy Facility	0.31
3.3 Projects - CA Institute for Women	0.23
3.3 Projects - FEDCO facility	0.17
3.3 Projects - IEUA / IKEA facility	0.21
3.3 Projects - Civil Air Patrol facility	0.29
3.3 Projects - Ranch View Elem. School facility	0.30
3.3 Projects - San Bernardino Co. Maintenance facility	0.29
3.3 Projects - Riverside Comm. College facility	0.18
3.3 Projects - YMCA facility	0.29
Notes: 1. N/A – Benefit/Cost ratio not analyzed.	

Environmental Benefits

There are several environmentally related non-energy benefits associated with dairy waste to energy facilities. The first major benefit is groundwater decontamination. This is very significant to the Chino basin mini-grid area due to the nitrates (salts) that leach into the groundwater as a result of current manure management practices. It is expected that as

improvements in manure management are made to facilitate the collection and transportation of dairy waste to centralized anaerobic digester (CAD) facilities, fewer salts and related contaminates will be required to be removed from the groundwater, thereby reducing the future cost of groundwater cleanup efforts in the basin.

The second environmentally related non-energy benefit associated with dairy waste biogas, and to a lesser degree for landfill biogas and wastewater treatment biogas, is the reduction in greenhouse gas emissions, including methane and nitrous oxide, and reductions in criteria air pollutants such as particulate matter 10 μm in diameter and smaller (PM_{10}). It is conceivable that markets for methane emission reduction credits will be created by regulatory actions in the future. Niche markets may well exist for this within 10 years. The development of an ammonia credits market is much more uncertain (ammonia is a precursor for PM_{10}). The drawbacks of ammonia emissions are more limited to odor problems and to a lesser degree the impact on local vegetation as a result of re-deposition. More importantly, ammonia credits may in the near future be valued far greater than GHG credits. However, it is not clear that a market for ammonia credits is as likely to develop as for methane credits.

A key valuation aspect from the economic potential perspective is whether the benefits are accrued by the owner of the CAD facilities. In the case of groundwater contamination, owners of CAD facilities would not necessarily be expected to be responsible for ground water cleanup. One of the prototypes used in the market assessment includes a public agency to own and operate CAD facilities. IEUA has been contracted to initiate a pilot plant to test groundwater contamination cleanup in the mini-grid area and operate a CAD facility. In this case it is certainly conceivable that IEUA will realize future groundwater cleanup cost savings from their dairy CAD operations. The real question is: what is the estimated magnitude of this financial benefit?

To incorporate the impact of a future GHG credits market into the market potential assessment, the issues of GHG quantification and credit valuation need to be addressed. The valuation of the GHGs has been done on a carbon dioxide equivalent (CO_2e) basis. Methane is assumed to have a CO_2e of 21:1. In other words, every ton of methane is assumed to be equivalent to 21 tons of CO_2. In the case of nitrous oxide (N_2O), the assumed CO_2e conversion is 310:1. The value of the GHG credits was computed on an animal unit (AU) basis. The final value for methane used in the market assessment was $1.06 per AU per year and the value of N_2O was $0.91 per AU per year for a total GHG credit of $1.97 per AU per year.

The avoided cost of salt contamination removal was developed based solely on the variable O&M costs for a reverse osmosis system. The avoided cost value derived was $688 per AU. The avoided cost impact of the CAD on ground water contamination was assumed to take

five years from the time the CAD began operation. The derivation of a value for this environmental benefit was addressed in Project 3.1 of the PIER Commerce Energy Program.

Some portion of consumers ascribe value to the environmental and other distinctive attributes corresponding to PV-based electrical energy production, and are willing to pay for some quantity of these attributes. This willingness to provide economic contribution can be viewed in at least two different lights. First, a consumer may choose to install a PV system on his or her own building. For a consumer making this decision, if the total levelized cost of PV-based electrical energy production and power output exceeds the cost of electrical energy and power from conventional sources then the difference represents the incremental willingness to pay more for PV. Second, a consumer may choose to purchase the non-electric attributes corresponding to the production of a PV system owned by someone else. In this case the non-electric attributes may be represented by the value of the "green tags", or Renewable Energy Certificates (RECs).

The total incremental value ascribed by society to non-electric attributes of PV-based electrical energy production and power output could be accounted for in the market potential assessment by using the "own building" model, the "green tags" model, or both. The "green tags" model was used the market potential assessment of BI-PV. Although far from mature, markets for green tags do exist today. A consumer with a credit card and an Internet connection can purchase green tags in a matter of minutes. While markets for green tags exist, they are in their infancy. It may not yet be possible to purchase green tags corresponding solely to PV system operational attributes. To date, because of their market volume and relative cost of electric generation, most green tags transactions have involved wind power. However in the future, as RPS standards are implemented and generation volumes increase, more robust markets for PV-based green tags are likely to develop.

It is not possible to know precisely what PV-based green tags prices will be in the future. In the case of one program involving 80 kW of PV, owners of some small PV systems in Oregon and Washington are selling the non-electric attributes corresponding to operation of their PV systems for 10 cents/kWh under 5-year contracts. Conversations with others familiar with green tags markets and renewable energy project development suggest that larger-scale markets might price PV-based green tags somewhere in the neighborhood of 4 to 6 cents/kWh. For this market potential assessment a range of green tags values was defined. For the *expected-potential* scenario a PV green tag value of 2 cents/kWh was assumed. Conversations with others familiar with green tag markets and renewable energy project development suggest that larger-scale markets might price biogas-based green tags somewhere in the neighborhood of 0.5 cent/kWh. Since better market information is not currently available, the biogas green tag value has been assumed to be fixed over time.

Biogas to Energy Projects

Three biogas to energy projects were planned, but only two were implemented. The three projects were: Project 2.1 *Enhanced Landfill Gas Production*, Project 2.2 *Enhanced Digestion and Gas Cleaning*, and Project 3.1 *Dairy Waste to Energy*. Project 2.1 was not implemented due to the need for the selected landfill to accept waste in the area where the bioreactor would be implemented by early 2005 and the inability of the bioreactor to be installed under this timeline.

Project 2.1 Enhanced Landfill Gas Production

Challenges

The first challenge involved obtaining regulatory acceptance of bioreactor landfill project. In order to facilitate this process, the Project 1.1 team met with the CEC, the State Water Resources Board, the Integrated Waste Management Board, the Regional Water Quality Control Board, and others potentially or actually involved in the permitting process. During this process, the Project 1.1 team learned of a R&D exemption that would potentially affect permitting of the bioreactor pilot research project, and according to the EPA, this exemption would be issued in spring 2003. The Project 1.1 team stayed abreast of regulatory developments in bioreactor permitting.

The second challenge faced by the project team was the additional planning and design activity associated with preparing the bioreactor project for public bidding. During this process, the Commerce Energy team worked closely with the San Bernardino County design engineer to develop a plan to jointly implement the proposed expansion/bioreactor project. This plan included a permitting component and design efforts for the integrated public bidding effort.

In July 2004, San Bernardino County chose to proceed with the construction of the Unit 3 liner project in order to ensure that the liner extension construction would occur this summer. As the County could not delay their decision, the PIER CE bioreactor project was stopped without including the bioreactor elements.

Market Drivers and Issues

The potential for landfill bioreactors is heavily driven by the regulatory approval processes and requirements within the local mini-grid region.

Project 2.2 Enhanced Digestion and Gas Cleaning

Challenges

The Sonico and IWE Tech ultrasound units, which were installed to enhance anaerobic digestion at Riverside, did not operate reliably. The IWE Tech unit was down 69 percent of the time and therefore plans were made to remove the IWE unit before testing was complete.

The Sonico unit was more reliable than the IWE Tech unit. Another advantage for the Sonico system was that a company representative was more accessible. IWE Tech is located in Germany and this made it more difficult to solve operational problems.

Difficulties were also encountered with the gas cleaning system, including an unforeseen increase in the siloxane levels during the baseline period and problems installing the H_2S biological scrubbing system. The baseline period was extended in order to establish a reliable baseline concentration for siloxane. The start-up of the biological gas scrubber system was delayed and vendor installation costs of the biological scrubber increased because of difficulties associated with interconnection into the gas cleaning system and the associated system requirements necessitated a more expensive system than planned. This caused the overall budget for this task to be exceeded.

Market Drivers and Issues

The potential for enhanced WWT processes to produce additional biogas to energy is driven by the willingness of the WWT agency to take advantage of new advancements in anaerobic digestion, energy recovery, and gas cleaning technologies that are being developed. The economics appear to be very favorable given the potential outcomes. The primary risk is in demonstrating the true performance and reliability of these technologies. Most WWT facilities are not willing to take on new projects or try new technologies.

Project 3.1 Dairy Waste to Energy

Challenges

The initial co-digestion test involved slug-feeding the food waste into the digester and this produced large spikes in biogas production because the operators slug-fed all of the food waste at once instead of gradually. This burdened the gas system, affected engine operation, and created problems associated with air emissions. The problem was solved by installing an automated feeder, however, air emission and safety concerns prevented the full-scale test from proceeding.

Market Drivers and Issues

For dairy waste resources, the key economic driver is not so much the capital costs, but rather the environmental benefits accrued from the reduction in reactive organic gases and the reduction in nitrates leaching into the groundwater. Currently there is an infrastructure in place for trading greenhouse gas emissions (includes carbon dioxide, methane, and nitrous oxide), renewable energy credits, and particulate matter 10 μm in diameter and smaller (PM_{10}). In the future, a reduction in ammonia emissions will be sold as PM_{10} reductions. The conversion of ammonia to PM_{10} requires more research, but the price for permanent PM_{10} reductions in the California South Coast and Central Valley areas are high. It is also

expected that in the future water quality improvements will be better quantified, allowing reductions in total dissolved solids and nitrates to be traded.

The key driver for the food waste resource is the relative economics for the food processing companies in the area. Disposal of the food processing wastes is not the only option available to these firms, and some of the firms have already developed economic alternative uses for the substances within their process waste streams. The most viable option to take advantage of biogas production from these wastes may be to integrate food waste into the wastewater treatment AD systems that already exist.

Building-Applied PV Projects

Two PV projects were planned, but only one was implemented. The two projects were: Project 3.2 *Building Integrated Photovoltaics Testing and Evaluation* and Project 3.3 *Building Integrated Photovoltaics on Public Facilities*. Project 3.3 did not progress past the planning stage due to the receipt of a stop-work order in May 2005. Although the Project 3.3 Team was ready to move ahead with the project, many deliverables were held up in the review process, causing significant project delays, which would have prevented the project from being completed within the Program time-frame.

Project 3.2 Building Integrated Photovoltaics (BI-PV) Testing and Evaluation

Challenges

The final contract between Commerce Energy and IEUA was presented to the IEUA Board in April 2003, a month later than originally anticipated. The delay in Board approval, in turn, resulted in a day-for-day delay in project development since equipment could not be ordered until the contract was executed. Equipment purchases were further delayed by information requests from the Commerce Energy legal department, who raised numerous questions regarding subcontracts for the installation of the 60 kW PV system. Delays in Commerce Energy approval, in turn, held up signatures for many of the purchase orders for some components of the large systems. Then, shipping delays for equipment ordered from abroad delayed the progress of Project 3.2 by approximately one month.

Also, equipment problems led to delays in project development in late 2003. Specifically, in November 2003, a problem with the PowerLight array was identified. Intensive troubleshooting was required to pinpoint the source of the problem. Xantrex (the inverter manufacturer), PowerLight (the array supplier), and Sanyo (the module manufacturer) worked with the project team to identify the source of the problem. Ultimately, the problem was traced to the incompatibility of the PV array with the inverter, rather than the field wiring. The array was determined to possess a capacitive nature that did not allow the inverter to function properly. In December 2003, Xantrex worked with the project team to

develop a software solution to the problem. However, ultimately, the troubleshooting process for the PowerLight array interrupted the acceptance testing of the other PV systems.

Market Drivers and Issues

For BI-PV, the key economic driver is availability of financial support through utility ratepayer funded public purpose rebate/buydown programs and tax-related government incentives.[1] In addition, consumer level of familiarity with the technology is a key market driver, as currently many consumers are unfamiliar with solar electric distributed generation technology, and may even confuse it with solar thermal technology.

Project 3.3 Building Integrated Photovoltaics (BI-PV) on Public Facilities

Challenges

The major challenges encountered in this project were due to lengthy wait times and multiple outside technical reviews and revisions of the BI-PV *Evaluation Tools Package*, response to comments by Commission staff, and the independent peer review process. Also, in May through October 2004, a key personnel redirection at REDI limited task work while an appropriate replacement was determined.

Project 3.3 did not progress past the planning stage due to the receipt of a stop-work order in May 2005. Although the Project 3.3 Team was ready to move ahead with the project, many deliverables were held up in the review process, causing significant project delays, which would have prevented the project from being completed within the Program time-frame.

Market Drivers and Issues

Project 3.3 has the same market issues as Project 3.2. For BI-PV, the key economic driver is availability of financial support through utility ratepayer funded public purpose rebate/buydown programs and tax-related government incentives.[2] In addition, consumer level of familiarity with the technology is a key market driver, as currently many consumers are unfamiliar with solar electric distributed generation technology, and may even confuse it with solar thermal technology.

---

[1] Over $100 million dollars of ratepayer funded incentives are currently available for BI-PV systems statewide. Continued availability of such financial support depends on political, regulatory and other circumstances and therefore is uncertain.

[2] Over $100 million dollars of ratepayer funded incentives are currently available for BI-PV systems statewide. Continued availability of such financial support depends on political, regulatory and other circumstances and therefore is uncertain.

3.2 Program Results

Program results from each of the six Commerce Energy Pier Program projects are discussed in the sections that follow.

Chino Basin Mini-Grid Distribution System Assessment

An electric T&D system "mini-grid" was established in Southern California, as shown in Figure 3-4, for use in a market potential and grid impacts study. The Chino Basin mini-grid area is served by nine (66 kV stepping down to 12 kV) substations and 72-twelve kV feeders. An outline of the mini-grid map, shown in Figure 3-5 provides an overview of the influence zones served by the nine 66/12 kv substations. Both transmission and distribution system information have been developed for the local Chino Basin mini-grid area.

Figure 3-4: Commerce Energy Renewables Mini-grid Map

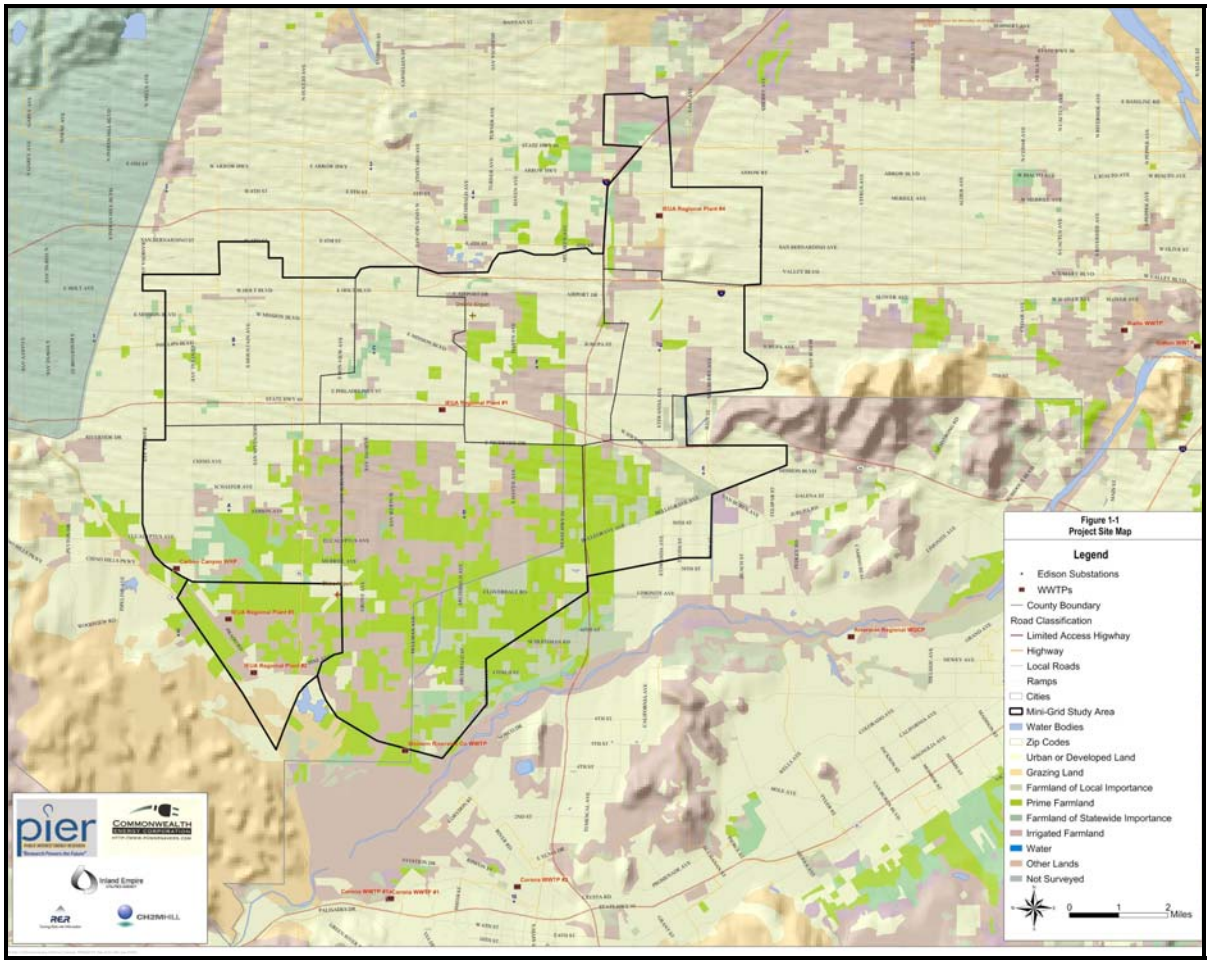
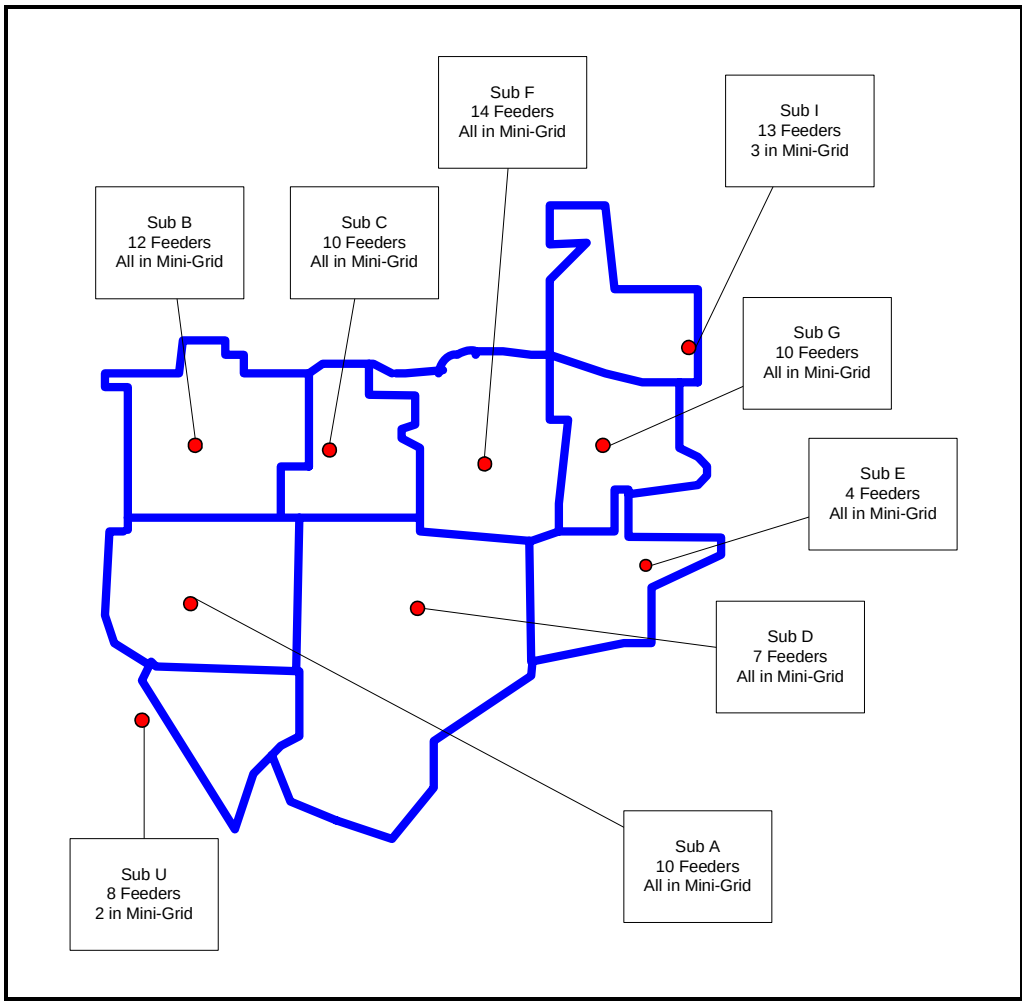


Figure 3-5: Overview of Local Chino Basin Mini-Grid



Estimation of Future Mini-Grid Renewable Resource T&D Public Benefits

Impacts on the T&D system were evaluated for three scenarios (an expected case, a high case and a low case) and benefits were found for five areas. The expected renewable resource in each of these scenarios is expected to less than 10% of the current Chino mini-grid peak load of 535 MW. Each of the five areas of benefits are discussed briefly below.

- ***Distribution Facility Deferral Benefits***. BI-PV and biogas projects can be strategically located throughout the heavily loaded distribution system to reduce peak feeder and distribution substation loads, deferring facility additions and resulting in a distribution facility deferral economic benefit. This potential economic benefit applies primarily to heavily loaded distribution facilities. If BI-PV and biogas projects are installed on lightly loaded distribution feeders, there will not be an economic benefit, even if the (lightly loaded) distribution system peak loads are reduced. The potential benefits are summarized in Table 3-6.

Table 3-6: Potential Distribution Facility Deferral Benefits

Year	Distribution Facility Deferral Benefit in Terms of PWRR* ($1000)					
	Expected Case		High Case		Low Case	
	Full Output	90% Output	Full Output	90% Output	Full Output	90% Output
2007	0	0	1,018	0	0	0
2012	2,027	1,709	4,357	3,835	0	0

*Present worth of revenue requirements

- ***Distribution System Loss Reduction Benefits.*** Generally, annual distribution system resistive (I^2R) losses will tend to reduce as distributed generation increases up to a point when the distributed generation output equals the distribution loads. After this, distribution losses may tend to increase as the distributed generation increases. The magnitude of the values of the hourly losses in Table 3-7 indicate that potential distribution system loss benefits will be small for the renewable penetration scenarios considered in this study.

Table 3-7: Potential Hourly Mini-Grid Distribution Loss Value

Year/Load	Wholesale Rate	Hourly Loss Value ($)					
		Expected Case		High Case		Low Case	
	$/MWh	Full Output	90% Output	Full Output	90% Output	Full Output	90% Output
2007 Peak	34.60	14	11	43	34	8	7
2007 Light	34.60	6	4	16	13	3	3
2012 Peak	49.70	69	56	126	102	18	14
2012 Light	49.70	26	21	46	37	7	6

- ***Distribution Voltage and Power Factor Correction Benefits.*** Installing distributed BI-PV and biogas projects can improve distribution system voltage regulation by supplying real power (kW) during peak loading and by improving voltage regulation or provide power factor correction. In this study, the renewable generation was operated at unity power factor. Potential voltage spread problems were identified with the distributed generation operating in this manner. However, since these generators are expected to supply or absorb vars as scheduled to maintain proper voltage regulation in the distribution system when the generation is operating, there is no voltage spread penalty. These distributed generators also would not be allowed to operate in a voltage regulation mode, so there is no voltage regulation benefit either.
- ***Transmission and Subtransmission Facility Deferral Benefits.*** Transmission and subtransmission facility deferral benefits are difficult to identify and quantify for the small, distributed generation penetration scenarios considered in this study, due to the order of magnitude difference between transmission and subtransmission facility ratings and distributed generation size (up to 54 MW). However, general transmission system capital investment requirements as a function of load increase in the vicinity of the mini-grid may be available from

transmission studies to assign transmission system deferral benefits to distributed resources or other demand side resources.

- ***Transmission and Subtransmission Loss Reduction Benefits.*** Transmission and subtransmission loss benefits are difficult to identify and quantify for the small, distributed generation penetration scenarios considered in this study, due to the order of magnitude difference between transmission and subtransmission losses and transmission loss impacts of the distributed generation size (up to 54 MW). As an alternative, general transmission system loss impacts as a function of load or energy may also be available from transmission studies to assign transmission system loss benefits to distributed resources or other demand side resources. Potential transmission and subtransmission system loss reductions for the expected, high and low mini-grid renewable penetration scenarios during 2007 and 2012 peak load conditions are shown in Table 3-8.

Table 3-8: Potential Hourly Transmission and Subtransmission Loss Value

Year	Wholesale Rate	Hourly Loss Value ($)					
		Expected		High		Low	
	$/MWh	Full Output	90% Output	Full Output	90% Output	Full Output	90% Output
2007 Peak	34.60	9	7	22	18	6	5
2012 Peak	49.70	32	26	59	48	9	8

Identification of Interconnection Requirements and Issues

Several pertinent interconnection practices and standards documents were reviewed. These included California Rule 21 and IEEE standard 1547. The requirements and issues identified are discussed briefly below.

- Simplified Interconnection. The distributed resources (DR) in the high penetration scenario do not qualify for a "simplified interconnection" as defined in the SCE Rule 21 document.
- Radial Distribution Circuit Protection. There are several important issues that need to be considered when there is a high penetration of DR.
  - Area electric power system (EPS) faults[3] and reclosure coordination - Rule 21 identifies several requirements concerning disconnecting under fault conditions and reclosure.
  - Islanding - Rule 21 states that the DR interconnection system must detect an islanding condition and cease to energize the area EPS within two seconds of the formation of an island.
  - Abnormal voltage – Rule 21 specifies that the DR interconnection system shall detect voltage levels and identifies the range of normal voltages outside

[3] A fault is defined as the condition when one or more electrical conductors contact ground and/or each other. A fault current is many times larger in magnitude than the current that normally flows through a circuit.

which the system must cease to energize the EPS and the time in which it must clear. Clearing time is the time between the start of the abnormal condition and the DR ceasing to energize the EPS.

- Abnormal frequency – Rule 21 defines the range of normal frequencies outside which the DR cease to energize the EPS and the associated clearing times.
- Voltage regulation – Rule 21 states that the DR shall not cause the service voltage on the EPS to go outside its normal voltage range. The DR is not permitted to actively regulate voltage because it can interfere with SCE's voltage regulation scheme.
- Paralleling and flicker – The DR must operate in parallel with the area EPS such that it does not cause voltage fluctuations at the point of connection to the EPS greater than plus or minus 5% of the prevailing voltage level. It also states that the DR shall not create objectionable flicker for other customers on the area EPS.
- Monitoring, control and communication – The SCE rule 21 does not specifically address this (yet) but it is covered by IEEE 1547. IEEE 1547 states that each DR (unit or aggregate) of 250 kVA or more shall monitor connection status, real power output, reactive power output, and voltage at the point of DR connection.

Dynamic Study of BI-PV and Biogas High-Penetration Scenarios

A dynamic load modeling study was performed to test the transient response of three BI-PV and biogas renewable generation scenarios on two distribution circuits to disturbances on adjacent distribution feeders or other nearby substations. The hypothetical DRs included BI-PV delivering power to the EPS through static power inverters and biogas generation delivering power to the EPS through synchronous generators.

The high penetration scenarios are designed to evaluate the DR clearing and ride-through performance during potential "worst-case" voltage dip and duration and frequency swings at three DR locations for a number of nearby fault condtions. The three DR location scenarios are a) close to the substation, b) in the middle of the distribution circuit, and c) near the end of the distribution circuit.

The results of the dynamic study show that:

- Both the BI-PV and biogas generation will trip for three-phase faults in adjacent feeders cleared in 10 cycles[4],

[4] Fault clearing time is defined as the number of alternating current cycles it takes for a protective relay to respond to a fault condition. The normal frequency for alternating current on an EPS is 60 cycles per second. Therefore, if it takes six cycles to clear a fault that means it takes one tenth of a second to clear.

- BI-PV will trip and biogas generation will ride through three-phase faults in adjacent feeders cleared in 6 cycles,
- Both the BI-PV and biogas generation will ride-through three-phase faults in feeders served by other substations cleared in 6 or 10 cycles,
- BI-PV will trip for three-phase faults in local 66 kV subtransmission lines cleared in 6 or 8 cycles,
- Biogas generation will ride through three-phase faults in local 66 kV subtransmission lines cleared in 6 cycles,
- Biogas may trip for three-phase faults in local 66 kV subtransmission lines cleared in 8 cycles.

Adding high penetration levels of biogas DR with synchronous generators significantly increases fault or short circuit current on the circuits modeled. This will likely require that existing circuit breakers be replaced with more expensive breakers with higher short circuit duty at distribution substations. Adding high penetration levels of BI-PV with inverters does not have much impact on short circuit current levels on the circuits modeled.

3.3 Key Findings

Key findings and observations resulting from the mini-grid power flow study are as follows:

- Since the renewable penetration scenarios evaluated in this study are less than 10% of the mini-grid loads, the resulting mini-grid loss reductions are relatively small.
- No voltage regulation or power factor correction benefits or penalties were identified in this study.
- Distribution system voltage control problems may occur if large MW-scale distributed generators are added near the end of distribution feeders in the mini-grid.
- Flicker is not expected to be a problem for the expected, high and low renewable penetration scenarios assumed in this study.
- Distribution relaying schemes may need to be changed to properly accommodate reverse power flows resulting from large penetrations of distributed generation.
- BI-PV output and the biogas generation output will correlate nicely with the mini-grid annual early afternoon peak loads. Several new substation transformers and feeder additions will be required over the study period, and future mini-grid distribution facility additions can be deferred.
- No transmission and subtransmission facility deferral benefits were identified in this study.

- Potential transmission and subtransmission system loss reduction benefits calculated during peak loadings indicate that potential annual transmission system loss benefits will be smaller than the distribution loss benefits for the renewable penetration scenarios studied.
- A number of interconnection issues exist. All appear solvable for high penetrations of biogas and BI-PV installed on the urban distribution circuits studied.
- Interconnection requirements are location specific.
- System impacts are more severe for biogas with synchronous generators.
- Transfer trip is required. This entails the use of protective relays capable of detecting abnormal conditions.
- A SCADA system is recommended to provide monitoring and control functions on circuits with high penetrations of renewable distributed generation.

Biogas to Energy Projects

Three biogas to energy projects were planned, but only two were implemented. The three projects were: Project 2.1 *Enhanced Landfill Gas Production*, Project 2.2 *Enhanced Digestion and Gas Cleaning*, and Project 3.1 *Dairy Waste to Energy*. Project 2.1 was not implemented due to the need for the selected landfill to accept waste in the area where the bioreactor would be implemented by early 2005 and the inability for the bioreactor to be installed under this timeline.

Project 2.1 Enhanced Landfill Gas Production

The overall goal of Project 2.1 was to enhance landfill gas production and advance the state-of-the-art technology for landfill bioreactors. This project did not continue past the planning stage due to the need for the selected landfill to accept waste in the Unit 3 expansion by early 2005 and the inability for the bioreactor to be installed under this timeline.

Project 2.2 Enhanced Digestion and Gas Cleaning

The overall goal of Project 2.2 was to increase biogas power generation at wastewater treatment plants by testing gas cleaning systems for microturbines and testing processes that could optimize anaerobic digestion and therefore increase gas production. Results obtained for the ultrasound systems and biogas cleaning are described in the sections below.

Enhanced Anaerobic Digestion - Ultrasound

During the baseline and ultrasound test periods, the digesters were monitored for a number of key performance parameters, such as gas production and volatile solids reduction (VSR). The two test digesters, digesters 1 and 2, were the main focus. Digester 3, which is a smaller digester, was operated slightly differently. However, monitoring of this digester was used to

verify trends seen in the other two digesters. Table 3-9 and Table 3-10 summarize the baseline and ultrasound test results.

Table 3-9: Summary of Digester Operation and Cost During Each Test Phase

		Digester 1				Digester 2				Digester 3			
		Baseline Phase	Test Phase (With Sonico Ultrasound System)		Continuation Phase (No Ultrasound)	Baseline Phase	Test Phase (With IWE Tec/Hielscher Ultrasound System[1])		Continuation Phase (No Ultrasound)	Baseline Phase	Test Phase (no ultrasound system installation)		Continuation Phase (No Ultrasound)
Digester Data	**Units**	**(6/1/04 - 8/31/04)**	**(9/1/04 - 11/30/04)[3]**	**(12/1/04 - 2/28/05)**	**3/1/05 – 5/31/05**	**(6/1/04 - 8/31/04)**	**(9/1/04 - 11/30/04)[3]**	**(12/1/04 - 2/28/05)**	**3/1/05 – 5/31/05**	**(6/1/04 - 8/31/04)**	**(9/1/04 - 11/30/04)**	**(12/1/04 - 2/28/05)**	**3/1/05 – 5/31/05**
Operational Parameters													
Volatile Solids Reduction (VSR)	%	57	52	58	59	54	54	58	59	54	54	57	59
Biogas Production[2]	cfd	181,460	175,430	171,650	180,960	153,910	144,950	174,880	196,590	117,380 [4]	112,130 [4]	121,280 [4]	127,231
Biogas Production Yield	cfd/lb VSR	15.6	15	13.3	14.7	13.9	13.6	14.4	14.9	17	15	14.8	15.2
Cost As Tested													
Installation Cost	$	NA	$231,500		NA	NA	$205,500		NA	NA	NA	NA	NA
Additional Electricity Cost	$	NA	$2,834	$1,244	NA	NA	$1,344	$432	NA	NA	NA	NA	NA
Ultrasound Maintenance Cost	$	NA	$14,000	$14,000	NA	NA	$40,000	$40,000	NA	NA	NA	NA	NA
Polymer Cost	$	$23,871	$23,871	$17,938	$23,871	$23,871	$23,871	$23,871	$23,871	$23,871	NA	NA	$23,871
Biosolids Management Cost	$	$146,264	$146,264	$109,261	$146,264	$146,264	$146,264	$146,264	$146,264	$146,264	NA	NA	$146,264
Labor Cost	$	NA	$3,640	$3,640	NA	NA	$5,460	$840	NA	NA	NA	NA	NA
Actual Total Operating Cost For Quarter	$	$170,135	$190,609	$146,082	$170,135	$170,135	$216,939	$211,407	$170,135	$170,135	NA	NA	$170,135
Natural Gas Offset Value	$	($92,096)	($92,096)	($94,490)	($92,096)	($92,096)	($92,096)	($92,096)	($92,096)	($92,096)	NA	NA	($92,096)
Actual Net O & M	$	$78,039	$98,513	$51,592	$78,039	$78,039	$124,843	$119,311	$78,039	$78,039	NA	NA	$78,039
Average Annual Net O & M	$	$312,157	$300,211		$312,157	$312,157	$488,309		$312,157	$312,157	NA	NA	$312,157

		Digester 1				Digester 2				Digester 3			
Digester Data	**Units**	**Baseline Phase (6/1/04 - 8/31/04)**	**Test Phase (With Sonico Ultrasound System) (9/1/04 - 11/30/04)[3]**	**(12/1/04 - 2/28/05)**	**Continuation Phase (No Ultrasound) 3/1/05 – 5/31/05**	**Baseline Phase (6/1/04 - 8/31/04)**	**Test Phase (With IWE Tec/Hielscher Ultrasound System[1]) (9/1/04 - 11/30/04)[3]**	**(12/1/04 - 2/28/05)**	**Continuation Phase (No Ultrasound) 3/1/05 – 5/31/05**	**Baseline Phase (6/1/04 - 8/31/04)**	**Test Phase (no ultrasound system installation) (9/1/04 - 11/30/04)**	**(12/1/04 - 2/28/05)**	**Continuation Phase (No Ultrasound) 3/1/05 – 5/31/05**
Reliability													
Percentage of Days Operated	%	NA	90%	41%	NA	NA	31%	NA[5]	NA	NA	NA	NA	NA

1. IWE Tec Ultrasound System was decommissioned in December 2004 due to problems encountered with the ultrasound equipment provided by Hielscher.
2. Numbers were rounded to the nearest 10.
3. Averages included November 2004 data, so were impacted by the unequal TWAS flow to digesters 1 and 2.
4. Biogas flow from Digester #3 was not available. A new gas meter was installed in July 2004, but it was not calibrated and was not connected to the SCADA system. Gas is calculated from the difference between the total gas flow meter and Digesters 1 & 2 and includes a small amount of gas from Digester 4.
5. IWE Tec equipment only ran 9 days in the third quarter and was decommissioned in mid-December.

Table 3-10: Summary of the Ultrasounds' Affects on Dewaterability

Parameter	Units	Baseline Phase	Ultrasound Phase		Continuation Phase
		(6/1/04 – 8/31/04)	(9/1/04 – 11/30/04)	(12/1/04 – 2/28/05)	(3/1/05 – 5/31/05)
BFP Dewatered Cake					
Quantity	wtpd	165	133	39	48
TS%	%	13%	14%	17%	14.70%
BFP Operation					
Polymer	lb/ton	26	27	20	27

Similar digester feed sludge characteristics and digester operating conditions were maintained until April 27, 2005 (continuation phase), at which time another project conducted by Riverside was started, to pilot test addition of fat oil and grease (FOG) from restaurants. The VSR in the digesters appeared to be increasing through May 2005, following the commencement of FOG addition to the digester. Given the accuracy of solids sampling and flow measurement through a digester, minor differences of VSR between digesters and the different testing phases are within the margin of error.

Examination of the total metered gas sent to the plant's co-generation system shows a slight increase of 4 percent in gas production between the baseline and ultrasound phase (from an average 452,400 cfd to 472,680 cfd). This slight variation might be due to an increase in the solids load to the digesters, which showed a 4.5 percent increase. This indicates that the installation of the two ultrasound systems did not significantly increase the total gas production from the overall digestion system.

Digester 1 showed higher biogas yield, defined as the amount of gas generated per unit mass of solids destroyed, than Digester 2 from the baseline period to the end to November 2004, after which biogas yields were similar for the two digesters. For the second half of the six month ultrasound test period, the average biogas yield was 13.3 and 14.4 cf/lb VSR for digesters 1 and 2, respectively. The biogas production from digester 3 was not directly measured, so the calculated biogas yield can only be used as a reference. A biogas yield of 16 cf/lb VSR is normally taken as the theoretical value. Chemical data for alkalinity, pH, volatile acids, ammonia, and total Kjeldahl nitrogen (TKN) in digesters 1, 2, and 3 were similar.

The Sonico system was more reliable than the IWE Tec system and the use of multiple lower-power stacks provided better redundancy, allowing for 65 percent uptime over the six-month ultrasound testing period. For the IWE Tec system, there were two main sources of problems with operation of the unit. The first was with the ultrasound stacks themselves. For much of the time, the power draw was below the target range, and the transducers repeatedly failed,

being unable to maintain frequency. In addition, the oil and water cooling system did not appear to be appropriate for this application. The periods of nonoperation were also increased as replacement parts and a Hielscher technician had to be sent from Germany, and there were often delays with the equipment at U.S. customs. By the end of this test period, it was clear that the high-power ultrasound units were not suitable for application on TWAS, nor was the cooling system suitable for the high loads on the transducers and the high temperatures in southern California.

Installation, operation, and maintenance costs are summarized in Table 3-9. As shown in the table, the Sonico system was slightly more expensive to install than the IWE Tec system. However, Sonico was much less expensive to operate.

The dewaterability of digested solids is a key cost component for digester operation and the cost-benefit analysis of using ultrasound. With the use of ultrasound, there is the potential to improve dewaterability through less use of polymer and production of a drier cake.
Data from the second half of the ultrasound period showed that the two belt filter presses (BFPs) achieved a cake solids concentration of approximately 17 percent, significantly higher compared with 14 percent and 13 percent for the first half of the ultrasound testing period and baseline phase. This value is within the range of what would be expected from BFP dewatering of digested sludge, where solids concentrations of 14 to 18 percent are more typical. During the continuation phase the performance dropped to an average of 14.7 percent. Polymer use during the second half ultrasound period averaged 20 lb/ton of solids processed, which is significantly lower than 26 and 27 lb/ton during the other phases. Considering the balance of BFP flow rates and polymer dose against TS concentration, it appears that dewaterability was better between October 2004 and March 2005, compared with the baseline period and the end of the continuation period. It is possible that some of this improvement may have been due to installation of the ultrasound system. Due to the HRT in the digester, a time lag would be expected between installation of the ultrasound system and changes in dewaterability. Seasonal variations may also have impacted dewaterability.

Microturbine Gas Cleaning

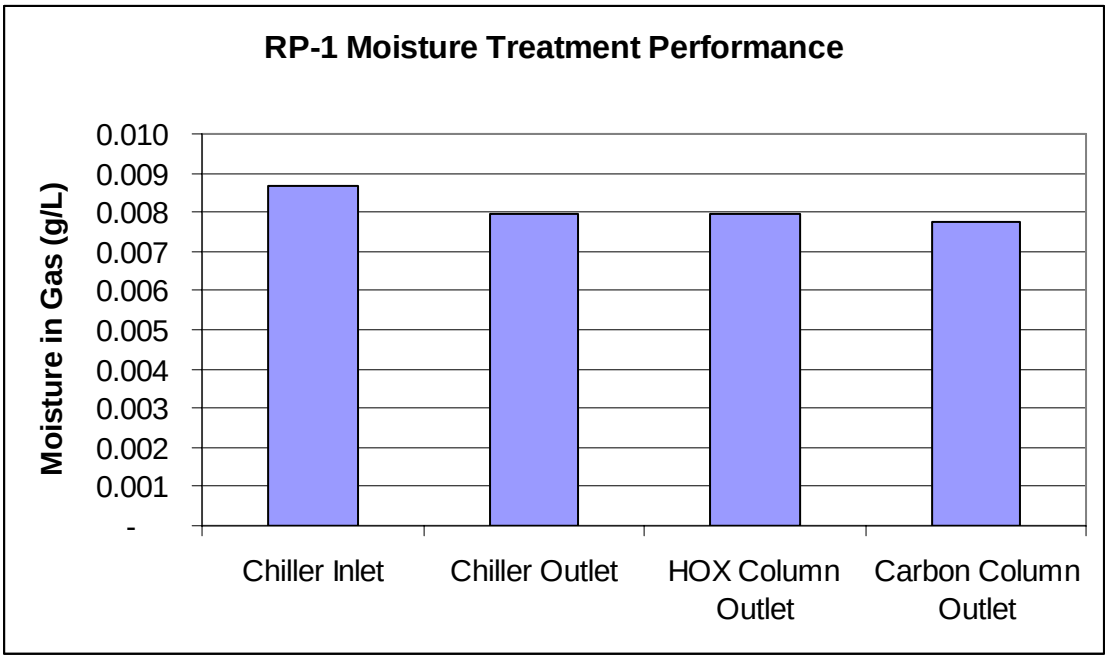
Three gas cleaning systems were installed and tested at IEUA's Regional Plant No. 1 during this project. The first system included a chiller that had two purposes: moisture removal and siloxane removal. The second system tested was a biological scrubber system that was installed to remove H_2S from the gas stream. The third system tested involved using different absorption media for siloxane removal, a graphite based media and a polymer based media.

During the baseline and gas cleaning test periods, the digesters and gas treatment systems were monitored for a number of key operational and performance parameters, such as ferric chloride addition, volatile solids (VS) fed to the digesters, VS reduction, digester gas production, H_2S concentration in the digester gas, and H_2S in the combined gas before and after the iron sponge system. Table 3-11 summarizes the gas cleaning system operation results.

Gas Drying (Chiller)

The chiller was operated and tested between July 2005 and December 2005. Figure 3-6 and Table 3-11 summarize the chiller's performance in removing moisture.

Figure 3-6: Moisture Treatment Performance: Average Moisture in Gas (g/L)



The chiller performed relatively well during the test period, however the unit only functioned 47% of the operating time. This unit was cost effective because it served two functions: moisture removal and siloxane removal.

Table 3-11: Summary of Gas System Operation and Performance

					With Project SagPak HOX-Based		With Project SagPak C-Based		With Project Chiller		With Project H_2S Scrubber		
	Units	Baseline (July/04 - May/05)	Baseline 12-Oct-04	Baseline 16-Nov-04	Inlet (July/05 - Dec/05)	Outlet	Inlet (July/05 - Dec/05)	Outlet	Inlet (July/05 - Dec/05)	Outlet	Inlet (July/05 - Dec/05)	Outlet	With Project Iron Sponge (July/05 - Dec/05)
Operational Parameters													
Biogas Production Total	cfd	707,000	230,000	640,000									
Biogas Production Unit 4	cfd	107,000	97,000	116,000									
H_2S [1]	ppmv	-	77	26	-	-	-	-	-	-	1,263	14	19 [6]
Moisture	mg/mL	-	0.016		0.008	0.008	0.008	0.008	0.009	0.008	-	-	-
Siloxane	ppbv	518	36,000[2]	5,000[3]	-	-	-	-	2,885	1,223	-	-	-
Siloxane	ppbv	518	36,000[2]	5,000[3]	2,470	613	1,470	181	3,660	2,470	-	-	-
Cost As Tested													
Installation Cost	$	-	-	-	53,815 [4]		53,815 [4]		151,570		417,860		157,500 [7]
Annual Operating Cost	$	-	-	-	8,750		8,750		8,750		8,750		8,750
Reliability													
Percent of Days Operated	%	NA	NA	NA	47%		47%		47%		100%		

NA: Not applicable

[1] Digester 4 data; with $FeCl_3$ addition for H_2S control during baseline, and without $FeCl_3$ addition after project implementation.

[2] Combined gas at the flare.

[3] Combined gas after the compressors.

[4] Price of media replacement.

[5] Price of one complete unit.

[6] No change from baseline gas loop measurements. Field test period was insufficient to determine useful life of test unit.

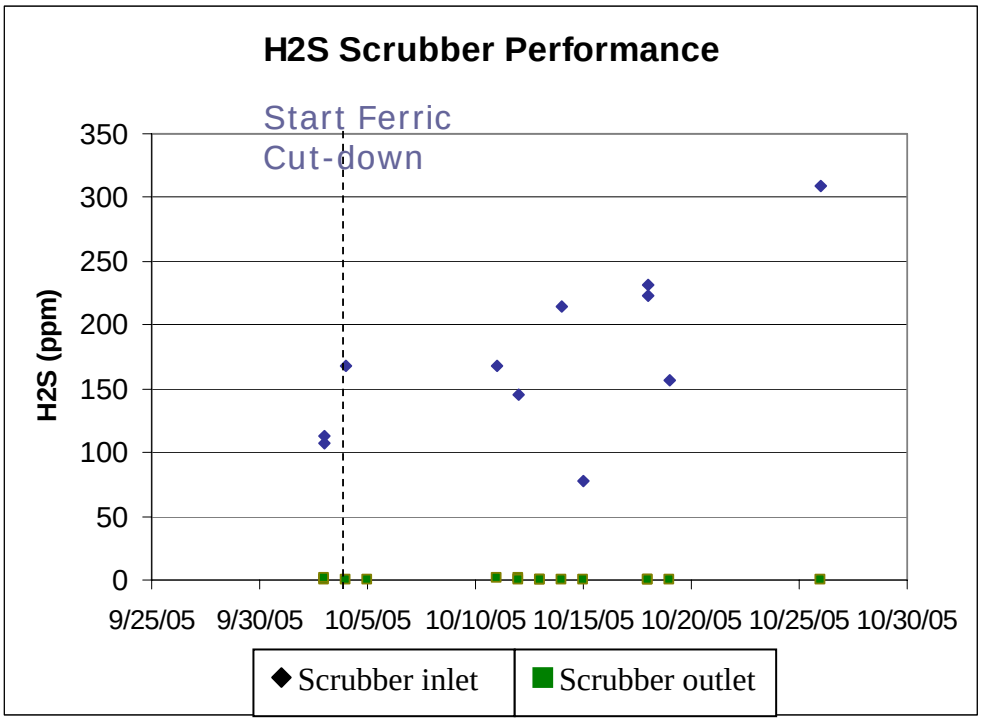
[7] Price of modifications to existing system and media addition.

[8] Assumes chiller saves 1 change-out per year of SagPak media.

H_2S Removal

The H_2S scrubber installed and tested under this project was a biological treatment unit. This unit was operated and tested between July 2005 and December 2005. Figure 3-7 and Table 3-11 summarize the scrubber's performance in removing H_2S.

Figure 3-7: H_2S Scrubber Performance



As shown in Figure 3-7, this unit was very effective. With the shutdown of H_2S control with $FeCl_3$ addition, the H_2S level increased beyond the detection level of the H_2S meter, yet the H_2S level at the scrubber outlet was below 15 ppm.

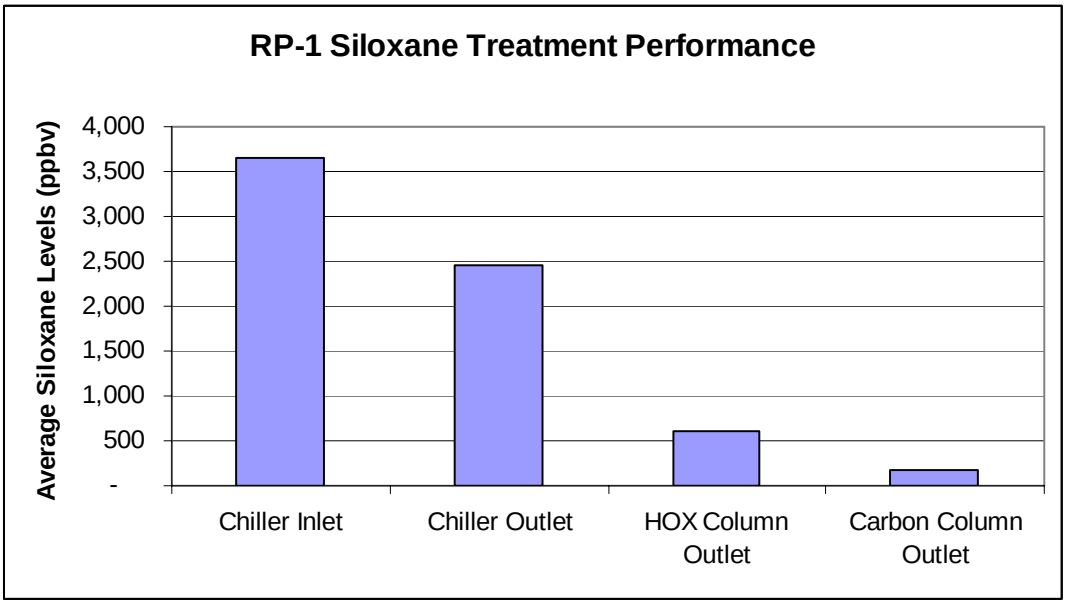
Because this unit is based on biological treatment, this technology reduces or eliminates chemical usage (e.g. ferric chloride addition for H2S control) at the facility. Another advantage of the unit was the easy and automated operation, and minimal operator attention and labor requirements. This system was the most reliable of the three systems tested and operated 100% of the operating time. Out of all the systems tested, the biological scrubber offered the most significant advantages from operational and economic standpoints.

Siloxane Treatment

The package siloxane treatment system (SagPack columns) installed and tested under this project was operated and tested between July 2005 and December 2005. Two siloxane removal

media were tested during this project. The SagPack columns were packed with either graphite based or polymer based media treatment. Figure 3-8 and Table 3-11 summarize the system's performance in removing siloxanes.

Figure 3-8: Siloxane Treatment Performance: Average Siloxane Levels (ppbv)



As shown in the above figures and Table 3-11, the siloxane treatment system was effective at removing siloxane. However, media capacity was not completely determined within the project test period. Media capacity and useful life of these media need to be determined for a thorough technology analysis. This equipment was not as reliable as the H_2S scrubber. However, it operated at the same percentage of time, 47 percent, as the moisture removal equipment.

Project 3.1 Dairy Waste to Energy

Project 3.1 was designed to evaluate selected technologies available for the conversion of animal waste to energy. Animal waste is becoming a larger problem due to the trend toward larger dairy operations and due to the number of dairies that are located near urban areas.

Tactical Marketing Plan Outcomes

The *Tactical Marketing Plan* quantified the technical potential and market potential for power generation from biogas sources including dairy waste and municipal biosolids sludge within California.

Dairy Waste Technical Potential

It was estimated that capturing 34 percent of the manure from the 1.62 million dairy cows located within the state of California would provide a waste stream capable of generating approximately 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 generated.

Biosolids Sludge Technical Potential

At least 114 wastewater treatment plants that have anaerobic digestion facilities installed, totally about 2,505 million gallons per day (MGD) average dry weather flow rate. If all of these sites used the biogas from their digesters for power generation, they could generate approximately 102 MW of power as a baseline. Implementing co-digestion with food waste would increase the estimate by 59 MW.

Market Potential

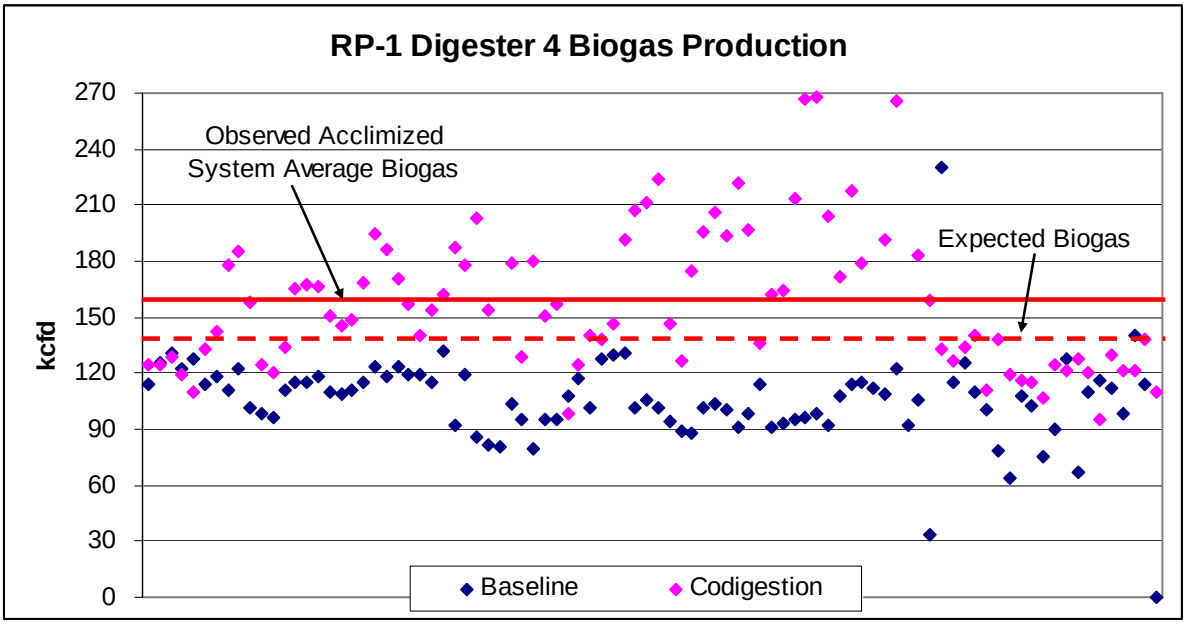
The market potential analysis yielded a 75 percent market acceptance rate, (i.e. 75 percent of these projects would provide an acceptable rate of return based on the range of input assumptions used). This results in a market potential for dairy waste applications of 73 MW and for wastewater treatment plants of 44 MW.

Operate and Test Pilot (Demonstration) Plant(s)

Co-digestion of manure and food waste and biosolids and food waste was done at Inland Empire Utilities Agency (IEUA) Regional Plant 1 (RP-1). Manure and food waste co-digestion was performed at Digester 4 and biosolids and food waste co-digestion was performed on a digester train which included Digesters 1, 2, 3, 6, and 7. Biogas production increased at both Digester 4 and the biosolids digester train 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.

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 3-9.

Figure 3-9: Implemented Iron Sponge System Modifications



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 limiting nutrient(s) was available in a higher concentration and this facilitated the improved volatile solids reduction and higher biogas production. This phenomenon was not observed in a measurable way for co-digestion with biosolids, which have a higher nutrient content than dairy manure.

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. Figure 3-10 and Figure 3-11 illustrate what happened.

Figure 3-10: Manure and Food Waste Daily Flow into Digester 4 at IEUA RP-1.

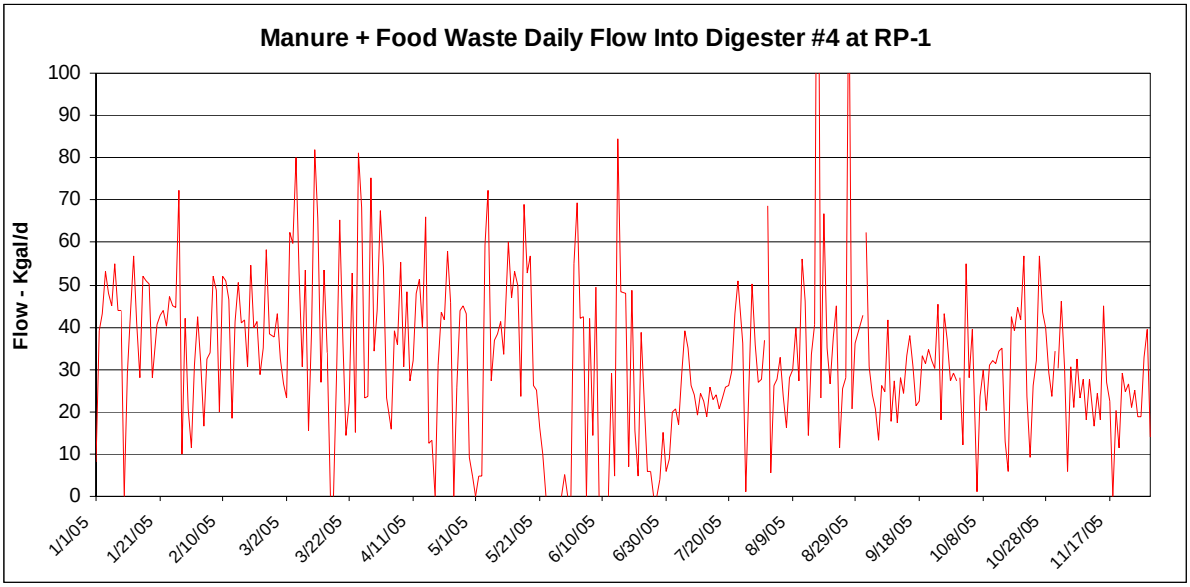
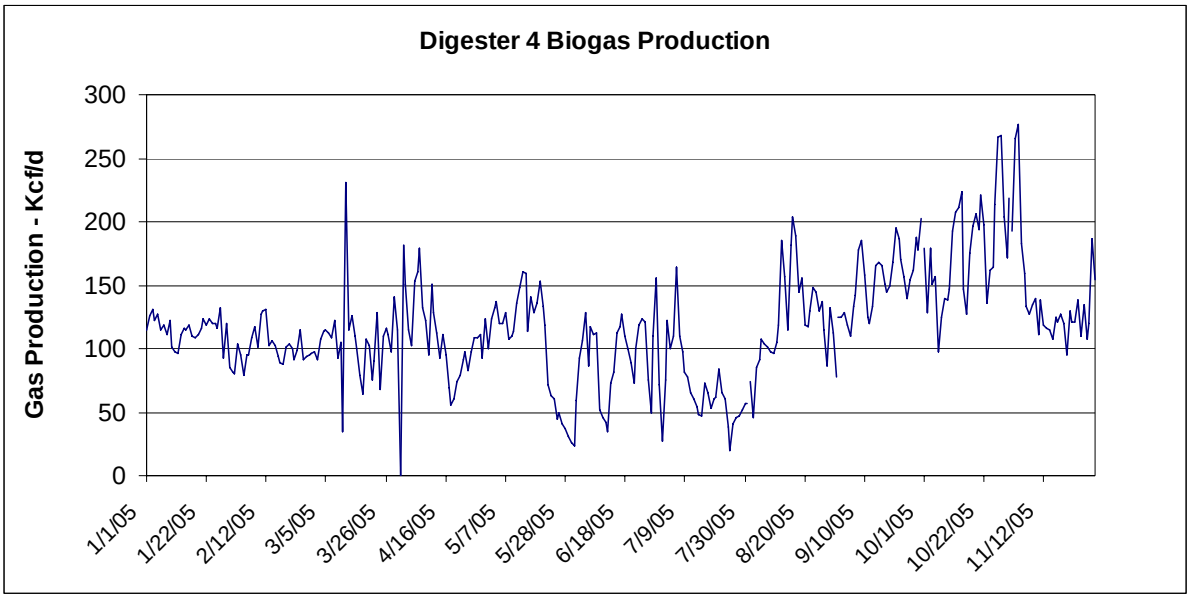


Figure 3-11: Biogas Production from Digester 4 at IEUA RP-1.



These spikes would at times overload the gas handling and storage system, causing unplanned releases of biogas. When this happened, most of the gas had to be sent to the flares, and even these were occasionally overloaded. It was sometimes necessary to shut down the biogas-to-energy operations temporarily in order to prevent exceeding the air emissions limits. These episodes made it hard to maintain biogas production at consistent levels.

Partially because of the spikes in gas production, the food waste feed rate was reduced, therefore performance summary tables 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 into the digesters. Gas storage should also be carefully considered and sized for these systems, so that there is enough storage to absorb temporary increases and fluctuations in gas supply without releasing biogas or affecting power system operations.

Economic and Environmental Assessment

A model was developed to quantify and verify methane and other greenhouse gas (GHG) emission reductions, criteria air pollutant emission reductions, and water quality improvements attributed to this project. The GHG reductions and criteria air pollutant emission reductions along with renewable energy credits (RECs) can provide monetary incentives that help make dairy waste to energy projects cost-effective.

Environmental Benefits

Table 3-12 and Table 3-13 shows the reductions in GHG emissions, criteria air pollutant emissions (NOx, Sox, and ammonia), and total dissolved solids (TDS) and nitrate reductions in groundwater. Table 3-12 shows the environmental benefits for manure and food waste co-digestion, while Table 3-13 shows the environmental benefits for biosolids and food waste co-digestion.

Table 3-12: 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 (tonsCO_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 & truck traffic less increases from combustion), (tons CO_2E/year)	0	3,200	3,100 - 4,300	3,100 - 6,100

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)
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

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.

Table 3-13: 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 (tonsCO_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
NO_x emissions (tons/year)			
Increases from Combustion (Energy Recovery)	0	1.7	2.0
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

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			
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 are grouped into the following five 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 Table 3-14 and Table 3-15.

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.

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 3-13 shows expected reductions of ammonia. Financial benefits are not determined, as shown in Table

3-14 and Table 3-15. 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 values provided in Table 3-12 and Table 3-13 are based on an analysis 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 3-13, 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. Environmental benefits in Table 3-13 are grouped the same way as for Table 3-12. 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.

Economic Assessment

The economic performance of the co-digestion project at IEUA's RP-1 facility is shown in Table 3-14.

Table 3-14: 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% CH4))	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	$32,304
Environmental benefits ($)				

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 -
Renewable Energy Credits (RECs)				
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%

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 – 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 – 17 percent, indicating that going to co-digestion in an existing manure digester provides higher economic return.

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 3-15 shows project economics for biosolids co-digestion projects.

Table 3-15: 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% CH4))	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	$1,012,936	$1,243,622	$1,508,130

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)
power output ($0.11/kWh)			
Capital cost ($)			
Gas System Improvements	0	$360,044	$360,044
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 & 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

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)
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%

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, it is a good 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 Table 3-14 and Table 3-15 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.

Additional Monetary Benefits

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. The price for PM_{10} reductions from ammonia is yet to be finalized, but 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.

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.

Building-Applied PV Projects

Two PV projects were planned, but only one was implemented. The two projects were: Project 3.2 *Building Integrated Photovoltaics Testing and Evaluation* and Project 3.3 *Building Integrated Photovoltaics on Public Facilities*. Project 3.3 did not progress past the planning stage due to the receipt of a stop-work order in May 2005. Although the Project 3.3 Team was ready to move ahead with the project, many deliverables were held up in the review process, causing significant project delays, which would have prevented the project from being completed within the Program time-frame.

Project 3.2 Building Integrated Photovoltaic Testing and Evaluation

The objective of this project was to perform side-by-side evaluations of commercially available PV systems and component technologies, and to compile objective, consumer-friendly information on the costs and performance parameters of those systems. This type of information is not currently available from any one source, and would be useful for the PV-buying public. Both large (20 kW) and small (2 kW) systems were evaluated.

System Descriptions

Three 20 kW commercial-scale (large) systems were installed at the IEUA Headquarters building in Chino CA. One of the large systems comprises a 10-segment array, giving data for 10 different module types and providing an opportunity to evaluate a system implemented with multiple identical inverters. In reality, each of the 10 segments was evaluated as a separate system, providing four times more information than originally projected for the large Segment. The cost of these systems was covered by Commerce Energy, and will be recovered through a Power Purchase Agreement with IEUA. In addition, 3 residential-scale (small) systems were installed at the Photovoltaics for Utility Scale Applications (PVUSA) site in Davis, CA. These

systems were offered on-loan from the manufacturers for the duration of the testing period. Table 3-16 provides descriptions of these systems.

Table 3-16: System Descriptions

Site	Integrator	Module	Tech	Inverter	Mount	Ratings			
						PTC (kW)	CEC (kW)	STC (kW)	PTC/ STC
IEUA, Chino, CA	PowerLight	Sanyo HIP-190BA2	HIT	Xantrex PV20-208	Sloped PG	17.97	20.59	22.80	0.81
	Schott Solar	Schott 300-DGF/50	EFG		SunRf FS	18.52	20.67	24.00	0.77
	IES	UniSolar US-116	a-Si	SMA SWR 2500U	Quilt	1.86	2.07	2.32	0.80
	SIT	UniSolar PVL-128	a-Si		SIT	1.89	2.05	2.30	0.82
	N/A	Shell Solar ST40	CIS		Custom	2.13	1.99	2.40	0.89
	First Solar	First Solar FS-45	CdTe		EZ Mount	2.10	2.41	2.70	0.78
	IES	AstroPower APx-130	pc-Film		Quilt	1.63	2.11	2.73	0.60
	N/A	Evergreen EC-102	SR-pc		Custom	1.90	2.06	2.45	0.78
	N/A	BP Solar SX-140	pc-Si		Custom	1.95	2.09	2.52	0.81
	N/A	Schott SAPC-123	pc-Si		Custom	1.94	2.03	2.46	0.79
	N/A	Shell Solar SP140	mc-Si		Custom	2.02	2.13	2.52	0.80
	N/A	AstroPower AP-110	mc-Si		Custom	1.95	2.09	2.40	0.81
PVUSA, Davis, CA	Sharp	Sharp ND-123U1	pc-Si	Sharp JH-3500U	SolarMount	2.30	2.38	2.95	0.78
	Kyocera	Kyocera KC167G	pc-Si	SMA SWR 2500U	SolarMount	2.01	2.11	2.51	0.80
	Schott Solar	Sharp SAPC-165	pc-Si		SolarMount	2.40	2.45	2.97	0.81
	TOTAL					62.6	69.2	80.0	0.79

Technology:
HIT: Mono-Crystalline Silicon surrounded by thin Amorphous Silicon layer
EFG: Edge-defined Film-fed Growth Poly-Crystalline Silicon
a-Si: Triple-Junction Amorphous Silicon
CIS: Copper Indium Diselenide
CdTe: Cadmium Sulfide/Cadmium Telluride
pc-Film: Poly-Crystalline Silicon Film
SR-pc: String Ribbon Poly-Crystalline Silicon
pc-Si: Poly-Crystalline Silicon
mc-Si: Mono-Crystalline Silicon

The small system evaluation covered the selection, installation, operation, monitoring, and evaluation of three independent 2 kW PV systems installed on a mock roof at the PVUSA facility in Davis, CA. This facility, currently managed by Renewable Ventures, has a long history of testing and evaluating PV systems from 2 kW to 400 kW in size. These three test systems were intended to be indicative of the kinds of residential-class Building Integrated PV hardware that are currently installed under the Energy Commission Emerging Renewable Rebate Program as well as those to be installed under the Governor's Million Solar Roofs plan.

These systems represent currently available electrical technologies (PV cells/modules, structures, inverters, wiring, etc.) that are used by the thousands in the California market.

Determine flaws, weak points, poor design features, etc. and offer suggested fixes

The design and installation of each system installed was described in the system characterization reports, and ongoing issues with operation were described in the *Interim*, *Six-Month*, and *Twelve-Month* reports, which can be found online at http://www.pierminigrid.org/pubproject32.html. Some specific flaws are discussed below.

Xantrex MPPT

As originally received, the control software in the Xantrex PV20-208 was not optimized to work with Sanyo HIT technology, which exhibits a higher than typical array capacitance and a high fill factor causing the array to routinely provide a higher voltage than the inverter was designed to track. The effective capacitance of the array impacts how the array responds to step changes in operating voltage and must be accounted for when the inverter is maximum power point tracking. In addition, the inverter had trouble finding MPPT whenever the array maximum power voltage exceeded 400V (a condition that occurs most of the year), characterized by wide swings in array voltage. These problems had not been noticed in other systems in part because of the transient nature of the event, and in part because, apparently, those systems were not monitoring array voltage, relying only on ac energy meters to provide system performance. Over the course of several site visits, Xantrex personnel were able to diagnose and correct the problem as of May-2004.

Xantrex Voltage trip window

Utility connected distributed resources must “cease to energize” the utility when any line to neutral voltage goes outside of a ±10% window around the nominal voltage. With its delta transformer connection, the PV20-208 measures line to line voltage and therefore must trip within a narrower ±6% window to account for a possible single phase voltage reduction or increase. Under the more common 3 phase voltage drop or rise, the inverter will operate much more conservatively than a unit measuring the line to neutral voltages. Tied to a service panel well inside the IEUA headquarters building, the large systems are subject to the normal utility variations in voltage as well as well as building load induced changes. The result was that the unit experienced more frequent under and over voltage trips. This was eventually corrected by asking the utility to allow wider than normal trip settings, which they did. Following many of these voltage trips, the unit locked itself out and would not automatically restart when the voltage came back into spec. This was also corrected with a software fix.

APex high temperature/low voltage

So as not to exceed the inverter maximum power limit at low temperatures, the AstroPower APex array was designed by the project team as a single string of 20 modules in series, which created a potential low voltage concern at high temperatures. The system was mounted using the IES Solar Quilt mounting system that had an untested impact on module operating temperature. The operating temperature turned out to be substantially higher than expected. This graph shows that the APex system approaches a 55 °C temperature rise above ambient at 1000 W/m^2 compared with the 30°C or so rise of the PowerLight array (thus at 20°C ambient and 1000 W/m^2, the arrays would be at 75°C and 50°C respectively). As temperature rises, the array max power voltage drops and at peak irradiance conditions (i.e., > 800 W/m^2), the APex array maximum power voltage would drop below the inverter's minimum operating voltage, causing an even steeper decline in output vs. temperature. The situation was probably exacerbated by the fact that, like all the other systems, the modules were delivered with power and voltage characteristics below specification. The result is an inappropriate system rating because at peak irradiance, the array was not at maximum power.

Monitor and report on system performance for 12 months

System operation and monitoring began on March 1, 2004. Installation of the small systems was completed and the systems energized in May of 2004. The starting date for operation and monitoring was June 1, 2004. Table 3-17 provides a summary of the small systems.

Table 3-17: Summary of Small System Efficiencies and Ratings

Array	Manufacturer	Model	Mount	Area	Eff_{SYS}	$Rating_{PTC}$	$Rating_{CEC}$	$Rating_{STC}$	PTC/STC
				sq. m.	%	kW	kW	kW	rating ratio
Sharp	Sharp	ND-123U1	SolarMount	33.8	6.80	2.30	2.38	2.95	0.78
Kyocera	Kyocera	KC167G	SolarMount	30.2	6.66	2.01	2.11	2.51	0.80
RWE/Schott	RWE/Schott	SAPC-165	SolarMount	29.2	8.22	2.40	2.45	2.97	0.81
TOT				93.2	7.20	6.7	6.9	8.4	0.80

Most presentations of simple PV economics and performance normalize the installed cost to $/kW and the annual energy production to kWh/kW often using a system rating based on the aggregate module dc rating at Standard Test Conditions (STC). The Emerging Renewables Program (ERP) has already taken the first step towards the use of more realistic ratings by converting the traditional STC module rating to the PVUSA Test Condition (PTC) rating, which better represents peak conditions in the field. While for some, this seems a step in the wrong direction—since the PTC rating for a given system is lower than the STC rating, the $/kW frustratingly increase—it does provide a rating that more closely resembles actual system performance. However while the ERP rating ("CEC" in this project) addresses the module temperature issue and also includes a measure of inverter efficiency, it does not address a number of other system losses including wiring, mismatch, and module rating.

Large Systems 12 Month Performance Summary

The large system evaluation covered the selection, installation, operation, monitoring, and evaluation of three independent 20 kW PV systems installed on the roof of the IEUA Headquarters building in Chino, CA. Table 3-18 provides a summary of the large system performance.

Table 3-18: Summary of Large System Performance Index and Energy Production

Array	Manufacturer	Model	Tech	Mount	P_{STC} kW	P_{PTC} kW	PTC/STC rating ratio	P.I. %	Energy* kWh
PL	Sanyo	HIP-190BA2	HIT	Sloped PG	22.80	17.97	0.79	92	31101
RWE	RWE/Schott	300-DGF/50	EFG	SunRf FS	24.00	18.52	0.77	92	31126
3A	UniSolar	US-116	3-a-Si	Quilt	2.32	1.86	0.80	96	3173
3B	UniSolar	PVL-128	3-a-Si	SIT	2.30	1.89	0.82	102	3384
3C	Shell Solar	ST40	CIS	Custom	2.40	2.13	0.89	94	3651
3D	First Solar	FS-45	CdTe	EZ Mount	2.70	2.10	0.78	101	3620
3E	AstroPower	APx-130	pc-Film	Quilt	2.73	1.63	0.60	97	3006
3F	Evergreen	EC-102	SR-pc	Custom	2.45	1.90	0.78	100	3182
3G	BP Solar	SX-140	pc-Si	Custom	2.52	1.95	0.77	97	3379
3H	RWE/Schott	SAPC-123	pc-Si	Custom	2.46	1.94	0.79	97	3361
3I	Shell Solar	SP140	mc-Si	Custom	2.52	2.02	0.80	101	3414
3J	AstroPower	AP-110	mc-Si	Custom	2.40	1.83	0.76	94	3081
Total					**71.6**	**55.7**	**0.78**	**94**	**95478**

The average annual air temperature in Chino is about 16 °C (61 °F), with a typical range of -2 to 40 °C (29-103 °F). Average wind speed is 1.5 m/s (3.4 mph), with a sustained peak of 6.7 m/s (15 mph)[5]. Annual average daily peak hours of sunlight on a horizontal surface is 5.4 hrs, with monthly average range about 2.7 hrs in December to 7.6 hrs in June.[6] The Chino area has an extensive dairy and other livestock industry producing more airborne soil contaminants than most urban and suburban sites. This airborne soil collects on PV modules and reduces photovoltaic output.

These systems were intended to be indicative of the kinds of BI-PV hardware that were common to commercial installations in California. While these sample systems may not all represent actual building integrated products (i.e., those designed to replace traditional building roofing, glazing, or cladding materials), they were representative of currently available

[5] Basic weather data derived from four years of Pomona weather data commencing in January 2000, obtained from http://www.cimis.water.ca.gov.

[6] Solar resource data provided by the NASA (National Atmospheric and Space Administration) Surface meteorology data site on the web at http://eosweb.larc.nasa.gov/sse/ .

electrical technologies (PV cells/modules, structures, inverters, wiring, etc.) that have been or could be used to make BI-PV products.

The starting date for operation was March 1, 2004 and the period of performance covered in this report is from that date through February 28, 2005, with some use of additional data acquired through April 2005. Table 3-19 summarizes the systems evaluated in this project. As the table shows, for our large systems category there are six different mounting systems, nine module manufacturers, 12 different modules, and nine different PV module technologies.

Table 3-19: Large System Descriptions

Site	Integrator	Module	Tech	Inverter	Mount	Ratings			
						PTC kW	CEC kW	STC kW	PTC/ STC
IEUA, Chino, CA	PowerLight	Sanyo HIP-190BA2	HIT	Xantrex PV20-208	Sloped PG	17.97	20.59	22.80	0.81
	Schott Solar	Schott 300-DGF/50	EFG		SunRf FS	18.52	20.67	24.00	0.77
	IES	UniSolar US-116	a-Si	SMA SWR 2500U	Quilt	1.86	2.07	2.32	0.80
	SIT	UniSolar PVL-128	a-Si		SIT	1.89	2.05	2.30	0.82
	N/A	Shell Solar ST40	CIS		Custom	2.13	1.99	2.40	0.89
	First Solar	First Solar FS-45	CdTe		EZ Mount	2.10	2.41	2.70	0.78
	IES	AstroPower APx-130	pc-Film		Quilt	1.63	2.11	2.73	0.60
	N/A	Evergreen EC-102	SR-pc		Custom	1.90	2.06	2.45	0.78
	N/A	BP Solar SX-140	pc-Si		Custom	1.95	2.09	2.52	0.81
	N/A	Schott SAPC-123	pc-Si		Custom	1.94	2.03	2.46	0.79
	N/A	Shell Solar SP140	mc-Si		Custom	2.02	2.13	2.52	0.80
	N/A	AstroPower AP-110	mc-Si		Custom	1.95	2.09	2.40	0.81
	TOTAL					55.7	62.2	71.6	0.78

Technology:
HIT: Mono-Crystalline Silicon surrounded by thin Amorphous Silicon layer
EFG: Edge-defined Film-fed Growth Poly-Crystalline Silicon
a-Si: Triple-Junction Amorphous Silicon
CIS: Copper Indium Diselenide
CdTe: Cadmium Sulfide/Cadmium Telluride
pc-Film: Poly-Crystalline Silicon Film
SR-pc: String Ribbon Poly-Crystalline Silicon
pc-Si: Poly-Crystalline Silicon
mc-Si: Mono-Crystalline Silicon

Figure 3-13 show the initial and final PTC ratings for the large systems after one year of operation. Ideally such rating estimates would be recomputed periodically over several years to identify degradation rates, but the duration of this project only allows for a one-year re-evaluation. The most obvious feature is the apparent improvement in ratings after one year of operation for seven of the systems, but the confidence intervals overlap in all but one instance. Therefore, we cannot conclude that this is a significant statistical variation. The SP-140 rating jump does appear to be statistically significant, and is probably due to soiling that was not observed during the initial rating period for that subsystem (5/30/2004 through 6/1/2004). The higher of these ratings has been used as the PTC rating throughout this report.

Figure 3-12: Systems 1 and 2 Ratings Comparison

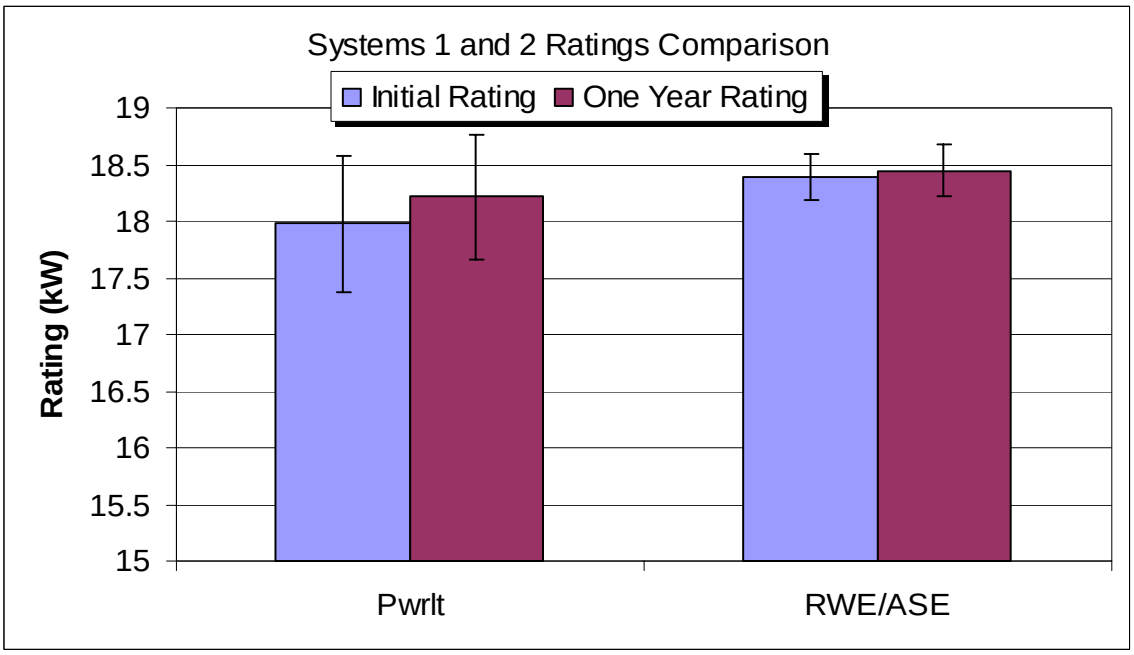


Figure 3-13: System 3 Subsystem Ratings Comparison

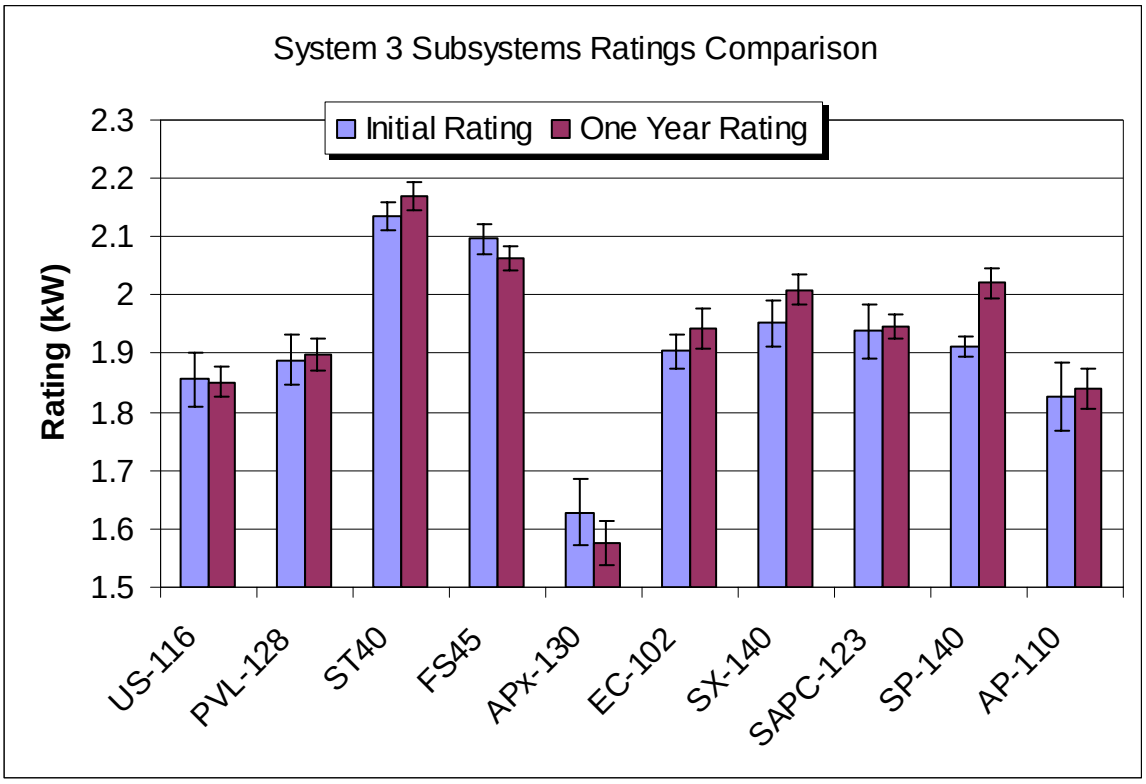
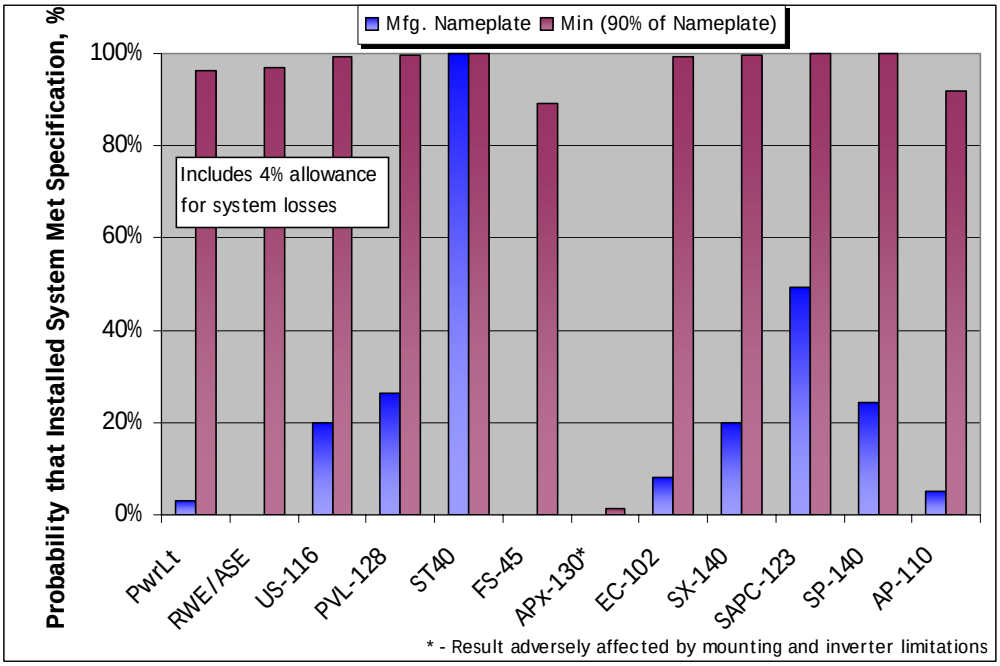


Figure 3-14 summarizes the probability that each system met the "nameplate" STC rating and the probability that the system was ten percent lower than the nameplate value (a probability distribution showed that there was a roughly three percent chance that the actual rating was within ten percent greater than the nameplate value). Figure 3-14 indicates that, after allowing for four percent of combined losses, just one of 12 systems was likely to have met their nameplate rating. A third showed 49 percent likelihood, and all others were far lower. With the yardstick set an additional 10 percent lower to correspond to manufacturers' minimum binning specifications, the translated field ratings suggest that all but one of the twelve systems met the more forgiving criteria. The SIT/Astropower APx-130 system's field rating came in 20% below the nominal sum-of-all-modules nameplate, but an indeterminately large element of this shortfall came from having the array voltage depressed below the inverter maximum power tracking range by high temperatures. Therefore, this result should not be used to draw conclusions regarding the APx-130 module rating.

This analysis suggests that it is common for consumers to receive PV modules that are on the lower end of published specifications. Although these data are limited, field experience over the past few decades support this conclusion. This situation is further complicated in a world market where module rating requirements differ. Both Germany and Japan have significantly

more strict tolerance allowances on modules than does California. This lack of a strict tolerance in California is almost certain to have the undesirable effect of leaving the California program with those modules that do not meet the grade for Japan or Germany. In other words, if Germany requires modules to be within 3% of nameplate rating and California requires 10%, then California is most likely to receive modules that are between 3 and 10% below rating.

Figure 3-14: Probability that field -based STC dc ratings agree with two factory-based thresholds



Small Systems 12 Month Performance Summary

The starting date for operation was taken to be June 1, 2004 and the period of performance covered in this report is from that date through May 30, 2005.

Table 3-20 summarizes the evaluated small systems. The Sharp and RWE Schott systems both employ Sharp polycrystalline silicon modules in arrays of nearly identical size with two different inverters conditioning the array power: the Sharp JH-3500U inverter in the Sharp system, and the SMA SB2500U inverter on the RWE Schott system. The other system under test is provided by Kyocera using Kyocera polycrystalline silicon modules with an SMA SB2500U inverter. All three systems were packaged with UniRac SolarMount mounting systems.

Table 3-20: Summary of Systems in Small PV System Comparison

System	Module		Inverter		Tech	Mount	Area	P_{CEC}	P_{STC}
	Mfr.	Model	Mfr.	Model			m^2	kW	kW
1	Sharp	ND-123U1	Sharp	JH-3500U	pc-Si	SolarMount	33.8	2.38	2.95
2	Kyocera	KC167G	SMA	SWR-2500U	pc-Si	SolarMount	30.2	2.11	2.51
3	RWE/Schott	SAPC-165	SMA	SWR-2500U	pc-Si	SolarMount	29.2	2.45	2.97
Total							93.2	6.9	8.4

As Table 3-21 for small systems clearly shows, all three have very similar ratings relative to one another. The ratio of PTC/STC rating is about 0.8 which is consistent with previous experience for well-designed and properly performing systems. PTC ratings were about 5% lower than CEC rating illustrating the point that the CEC rating misses several smaller losses captured in the PTC rating. The ratio of CEC/STC rating is approximately 0.83 which is consistent with the two primary adjustments made in the CEC rating: 1) approximately 0.88 for the adjustment of module rating from STC to CEC conditions; and, 2) approximately 0.94 for inverter efficiency (taken together 0.88 x 0.94 = 0.83).

Table 3-21: Summary of System Efficiencies and Ratings

Array	Manufacturer	Model	Tech	Mount	Area	EffSYS	RatingPTC	RatingCEC	RatingSTC	PTC/STC
					sq. m.	%	kW	kW	kW	rating ratio
Sharp	Sharp	ND-123U1	pc-Si	SolarMount	33.8	6.80	2.3	2.4	3.0	0.78
Kyocera	Kyocera	KC167G	pc-Si	SolarMount	30.2	6.66	2.0	2.1	2.5	0.80
RWE/Schott	RWE/Schott	SAPC-165	pc-Si	SolarMount	29.2	8.22	2.4	2.5	3.0	0.81
TOT					93.2	7.20	6.7	6.9	8.4	0.80

Figure 3-15 shows the initial and final PTC ratings after one year of operation. The most obvious feature is the apparent decline in ratings after one year of operation, but the confidence intervals overlap enough that we cannot yet conclude that this is anything more than expected statistical variation. Typical crystalline silicon module degradation rates are 1-2%/year.

Figure 3-15: Initial and One-Year PTC Ratings Comparison

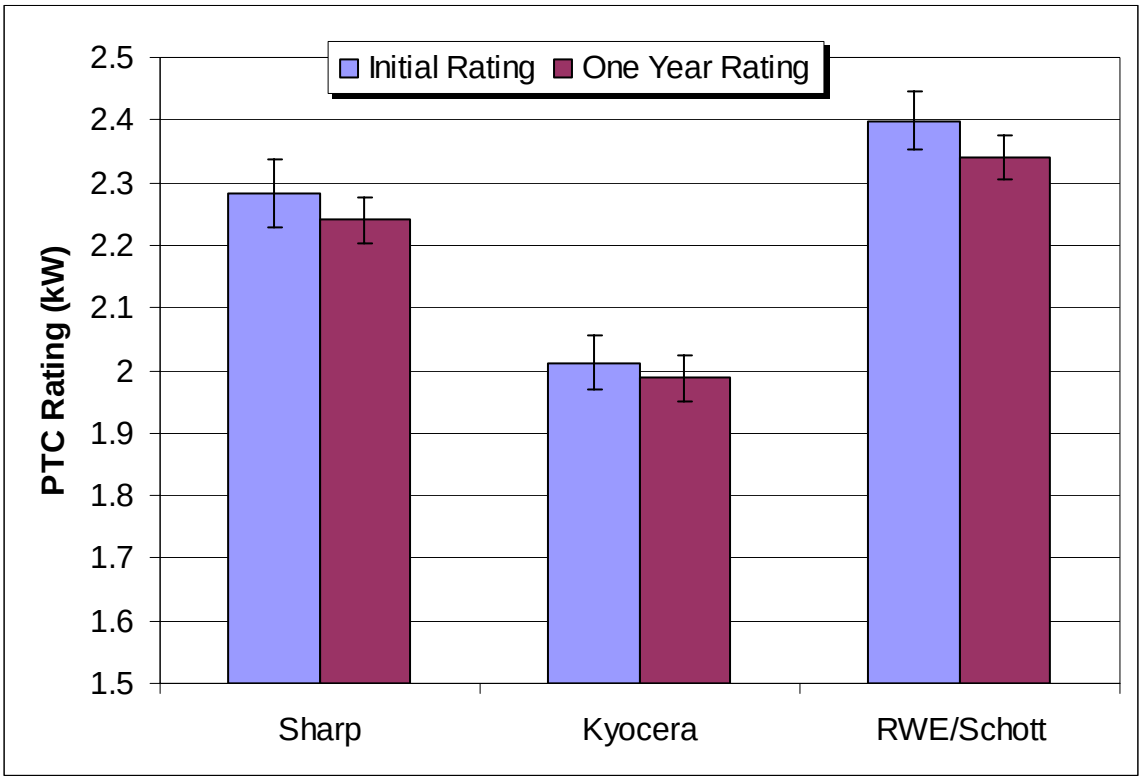
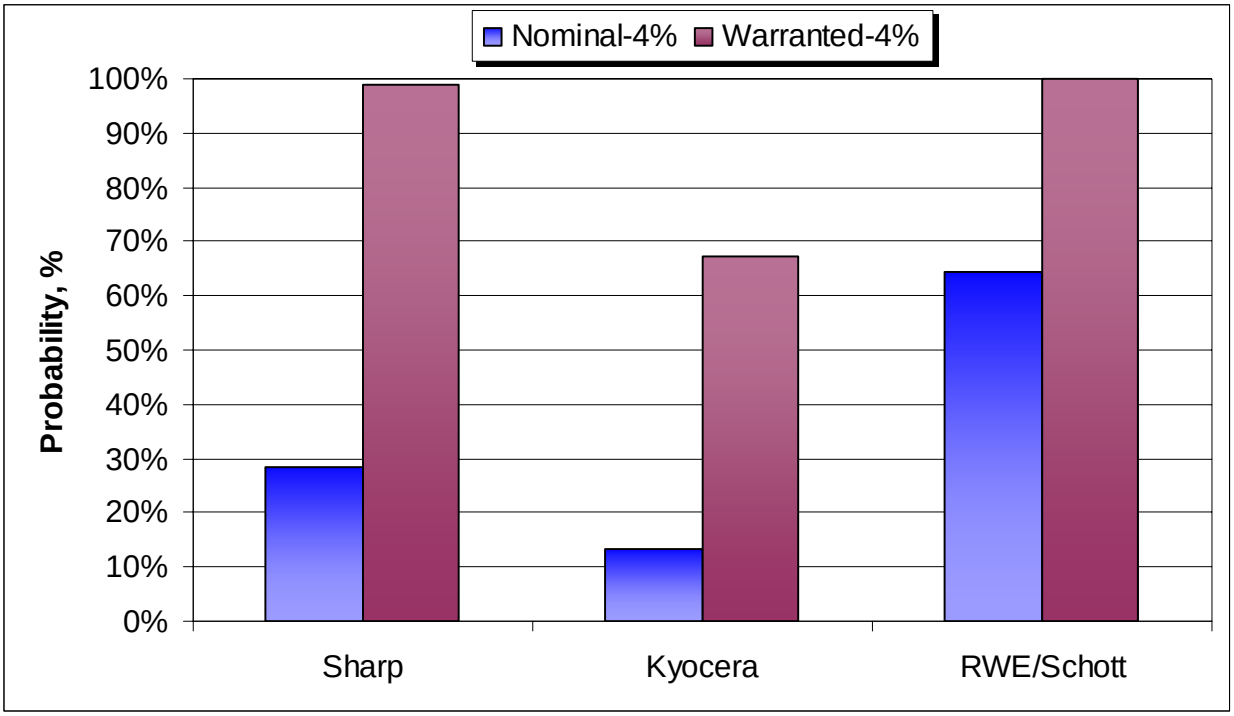


Figure 3-16 summarizes the probability that each system met the "nameplate" STC rating and the probability that the system was ten percent lower than the nameplate value. The field-based rating will always be a few percent short of the nominal nameplate rating simply due to the unavoidable effects of mismatch, wiring, inverter maximum power point tracking accuracy, LID, dust and shading losses. As before, we allowed 4% for these effects. This figure indicates that, after allowing for the 4% combined losses, only one of three systems were likely to have met their nameplate rating. With the yardstick set an additional 10% lower to correspond to manufacturers' minimum binning specifications, the translated field ratings indicate that all of the systems met (had a better than 50% chance of exceeding) the more forgiving criteria.

Figure 3-16: Probability that field -based STC dc ratings agree with two factory-based thresholds



Technology Transfer

Besides the project reports and presentations, project results were communicated to the public through the PIER Program website and with targeted workshops.

Web Presentation

The project website, www.pierminigrid.showdata.org, was tremendously successful at describing the systems under test, presenting the real time performance information, and generally documenting project results. Graphs were automatically updated four times per hour, and notes on system operation were added manually as information about operational events was communicated to project personnel. Website activity included visits from almost 4500 distinct users downloading 400 copies of the available documents.

Training (Workshops)

Workshops were held in Sacramento and Chino, respectively. Key outcomes include the fact that 170 motivated and interested workshop participants were exposed to the PIER results. Key findings from the project were discussed in detail during the workshop sessions, and many participants were able to see the project testing facilities first hand. Tours were conducted at the PVUSA site for the Sacramento workshop attendees and at the IEUA site for the Chino attendees. Since neither of these facilities is open to the public for tours, this provided an important opportunity to display various aspects of the project.

Project 3.3 Building Integrated Photovoltaics (BI-PV) on Public Facilities

Project 3.3 was designed to yield up to four public sector BI-PV projects ranging in size from 10 kW to 150 kW. Each project would address an infrastructure or commercialization barrier. Project 3.3 did not progress past the planning stage due to the receipt of a stop-work order in May 2005. Although the Project 3.3 Team was ready to move ahead with the project, many deliverables were held up in the review process, causing significant project delays, which would have prevented the project from being completed within the Program time-frame.

4

Conclusions and Recommendations

4.1 Commerce Program Conclusions by Project Area

This section discusses the conclusions reached under each project that was completed as well as the commercialization potential of each tested system.

Chino Basin Mini-Grid Distribution System Assessment

The results of the T&D system power flow studies conducted under Project 1.1 indicate that there are no major barriers for the expected, high, and low biogas and BI-PV generation penetration scenarios studied in this project. Key conclusions and observations resulting from this power flow study are as follows:

- Since the renewable penetration scenarios evaluated in this study are less than 10% of the mini-grid loads, the resulting mini-grid loss reductions are relatively small. Potential distribution system loss reduction benefits during peak and light loadings were calculated assuming expected wholesale electricity rates for 2007 and 2012. These calculations indicate that potential annual distribution system loss benefits will be small for the renewable penetration scenarios studied.
- No voltage regulation or power factor correction benefits or penalties were identified in this study.
- Potential voltage regulation problems were identified when a large several MW distributed generator was operated at the end of Feeder D6 in this study. Thus, distribution system voltage control problems may occur if large MW-scale distributed generators are added near the end of distribution feeders in the mini-grid. This potential voltage regulation problem is location-specific and may limit DG penetration on some utility feeders.
- Flicker is not expected to be a problem for the expected, high and low renewable penetration scenarios assumed in this study.
- Several instances of reverse power flow in feeders were observed in this study. The reverse power flows were linked with the voltage regulation problems observed for the renewable penetration scenarios studied in this project. Voltage regulators and LTC transformers are not used in the mini-grid, so voltage regulator or LTC controls do not have to be modified to accommodate reverse power flows. However, distribution relaying schemes may need to be changed to properly

accommodate reverse power flows resulting from large penetrations of distributed generation.

- Significant potential distribution facility deferral benefits were identified in this study, especially for 2012 expected and high renewable penetration scenarios. The results of this study indicate that the BI-PV output and the biogas generation output will correlate nicely with the mini-grid annual early afternoon peak loads, and that several new substation transformers and feeder additions will be required over the study period. If future operating experience and studies with BI-PV and biogas generation convince SCE that the generation can be counted on during the peak periods, future mini-grid distribution facility additions can be deferred.
- Transmission and subtransmission facility deferral benefits are difficult to identify and quantify for the small, distributed generation penetration scenarios considered in this study, due to the order of magnitude difference between transmission and subtransmission facility ratings and distributed generation size (up to 54 MW). No transmission and subtransmission facility deferral benefits were identified in this study.
- Transmission and subtransmission loss benefits are also difficult to identify and quantify for the small, distributed generation penetration scenarios considered in this study, due to the order of magnitude difference between transmission and subtransmission losses and transmission loss impacts of the distributed generation size (up to 54 MW). Potential transmission and subtransmission system loss reduction benefits during peak loadings were calculated assuming expected wholesale electricity rates for 2007 and 2012. These calculations indicate that potential annual transmission system loss benefits will be smaller than the distribution loss benefits for the renewable penetration scenarios studied.
- A number of interconnection issues exist. All appear solvable for high penetrations of biogas and BI-PV installed on the urban distribution circuits studied.

Comment [h1]: Insert key conclusions from Hank's 3.1 work

- Interconnection requirements are location specific.
- System impacts are more severe for biogas with synchronous generators.
- Transfer trip is required. This entails the use of protective relays capable of detecting abnormal conditions.
- A SCADA system is recommended to provide monitoring and control functions on circuits with high penetrations of renewable distributed generation.

Biogas to Energy Projects: Project 2.1 through Project 3.1

Three biogas to energy projects were planned, but only two were implemented. The three projects were: Project 2.1 *Enhanced Landfill Gas Production*, Project 2.2 *Enhanced Digestion and Gas Cleaning*, and Project 3.1 *Dairy Waste to Energy*. Project 2.1 was not implemented due to the need for the selected landfill to accept waste in the area where the

bioreactor would be implemented by early 2005 and the inability of the bioreactor to be installed under this timeline.

Project 2.1 Landfill Bioreactor

The overall goal of Project 2.1 was to enhance landfill gas production and advance the state-of-the-art technology for landfill bioreactors. This project did not continue past the advanced planning/mid-design stage due to the need for the selected landfill to accept waste in Unit 3 expansion by early 2005 and the inability of the bioreactor to be installed under this timeline.

Project 2.2 Enhanced Anaerobic Digestion and Gas Cleaning

The overall goal of Project 2.2 was to increase biogas power generation at wastewater treatment plants by testing gas cleaning systems for microturbines and testing processes that could optimize anaerobic digestion and therefore increase gas production. Four key findings were reached as a result of this project: two key findings for enhanced anaerobic digestion using ultrasound, and two key findings for gas cleaning. Each is discussed below.

- **Ultrasound offers potential for increased gas production in "stressed systems," but does not lead to increased solids destruction or significant increase in biogas production in systems with adequate holding times.**

  Testing showed that in systems with adequate holding times, ultrasound did not significantly increase biogas production or solids destruction over what would be expected without ultrasound.

  - *Results of Project Activities:* The IWE Tec system, which employs newer technology that utilizes larger sonic horns, did not operate reliably during the testing period. The Sonico system also had some operational challenges, but operated more reliably than the IWE Tech system. Results of the testing suggested that the ultrasound systems were effective in increasing solids reduction when the systems were stressed (holding times of 15 days or less), however, later in the test when the holding time was longer, biogas production and solids destruction were not significantly higher for the ultrasound treated sludge than for the control system.
  - *Commercialization Potential*: The findings confirmed that ultrasound technology can improve digester performance in some instances, but is not justified under normal operating conditions.

- **If ultrasound is to be employed, sonic horns, in the size range of 6 kW or less, are more reliable than the larger sized horns**.

  Vendors appear to have taken the findings of the Commerce Energy PIER Program into account and have scaled back their offering of larger sized sonic horns in the wastewater treatment market.

- *Results of Project Activities*: The IWE Tec system, which employs larger sonic horns did not operate reliably during the testing period. The Sonico system had some operational challenges, but operated more reliably than the IWE Tec system. Larger horns were less reliable, consumed more power and did not provide significant benefits. Results of the testing suggested that the ultrasound systems were effective in increasing solids reduction when the systems were stressed (holding times of 15 days or less). When the holding time was longer, biogas production and solids destruction were not significantly higher for the ultrasound treated sludge than for the control system.
- *Commercialization Potential*: There are a relatively small number of wastewater treatment plants in California where the systems are stressed and consequently where ultrasound technology could be cost effective. In general it is a technology where specialized, rather than general applications are warranted, and pay back time can be long if the conditions are not right.

Table 4-1 documents the technical, environmental, and economic performance of ultrasound units, as tested at full-scale implementation at Riverside WWTP.

Table 4-1: Technical, Environmental and Economic Performance of Ultrasound units as Tested at Full Scale at Riverside WWTP

Engineering/Economic Consideration	Baseline - each digester, as tested, no ultrasound	Ultrasound - Sonico Unit (as tested)	Ultrasound – IWETec Unit (as tested)	Baseline – full-scale (all Riverside WWT digesters)	With Ultrasound - selected unit (Sonico) at full scale
Operational Parameters					
Volatile Solids Reduction (VSR), %	54 - 57%	52 - 58%	54 - 58%	54 - 57%	52 - 58%
Biogas Production Yield (cfd/lbVSR)	14 - 17	13 - 15	13 - 15	14 - 16	13 - 16
Increase in biogas production	N/A	0	0	N/A	0
Reliability of Unit	N/A	66%	21%	N/A	75 - 85%
*Some values are rounded.					

- **Improved gas cleaning technologies are very important to the economics of biogas projects.**

  The gas cleaning technologies tested enable technologies with lower air pollutant emissions, such as microturbines, to be deployed and also improve the overall life cycle cost for other generation systems such as reciprocating engines. Improved technology allows existing projects to operate more reliably and more projects to become economic. All of the gas cleaning systems tested performed well. In general, the biological scrubber was the most cost effective, reliable, and low labor unit, and its use eliminated the need for chemical use thereby saving money and reducing environmental impacts. SagPak monitoring results showed siloxane removal. However, media capacity was not completely determined within the Project test period, and the unit useful life was not completely assessed. The other system functioned well, but as shown in Table 4-2 did not have the rate of return and was not as reliable.

  - *Results of Project Activities:* Three different gas treatment technologies were tested and evaluated in terms of their performance and life cycle costs. Of the systems tested, the biological scrubber offered the most significant advantages from operational and economic standpoints. With the shutdown of the H_2S control with $FeCl_3$ addition, the H_2S concentration in the Digester 4 gas increased significantly. Later in the study the H_2S level increased beyond the detection level of the H_2S meter, yet the H_2S level at the scrubber outlet was below 15 ppm.

    The chiller also was cost effective because it served two functions: moisture removal and siloxane removal. Table 4-2 summarizes the performance and cost-effectiveness of the moisture removal system.
  - *Commercialization Potential*: The results of the gas cleaning tests showed that biological H_2S scrubbers could be very efficient, easy to operate, non-labor intensive and cost effective units for implementation at other facilities where H_2S removal from biogas is needed prior to cogeneration. Siloxane removal systems, though not as reliably, functioned to remove siloxane from the gas stream. With further assessment of media useful life, these units can be readily implemented at other California facilities.

- **Biological scrubbers, as compared to iron sponges or other more standard control technologies, reduce the life cycle cost of H2S removal systems.**

  By using biological media to capture the H2S, chemical media purchases are reduced substantially. There is less solid waste generated and there is also a potential for recovering the sulfur. The biological scrubber performed very well and is a very cost effective system. It has capacity to be an easily implementable technology with robust performance controls, allowing reliable H2S removal from digester gas without daily use of chemicals.

- *Results of Project Activities:* Table 4-2 presents the results of the testing of the biological scrubber. The unit performed exceptionally well in terms of reliability, ease of operation, and removal capacity. Because the unit operation was automated to allow injection of air at pre-set levels and pH data to be recorded continuously, any changes in operation were detected quickly allowing any corrective actions to be taken rapidly when needed.

- *Commercialization Potential*: The biological scrubber has significant economic and environmental benefits and is a good candidate to be installed at many other locations in California. The testing of the unit at IEUA RP-1 documented that it could be installed efficiently at existing facilities meaning that it could be used in a variety of applications where H_2S removal from gas streams is needed with low operational cost.

Table 4-2: Summary of Gas System Operation and Performance

					With Project SagPak HOX-Based		With Project SagPak C-Based		With Project Chiller		With Project H_2S Scrubber		
		Baseline	Baseline	Baseline	Inlet	Outlet	Inlet	Outlet	Inlet			Baseline	Baseline
	Units	(July/04 - May/05)	12-Oct-04	16-Nov-04	(July/05 - Dec/05)		(July/05 - Dec/05)		(July/05 - Dec/05)		(July/05 - Dec/05)		(July/05 - Dec/05)
Operational Parameters													
Biogas Production Total	cfd	707,000	230,000	640,000									
Biogas Production Digester 4	cfd	107,000	97,000	116,000									
H_2S [1]	ppmv	-	77	26	-	-	-	-	-	H_2S [1]	ppmv	-	77
Moisture	mg/mL	-	0.016		0.008	0.008	0.008	0.008	0.009	Moisture	mg/mL	-	0.016
Siloxane	ppbv	518	36,000[2]	5,000[3]	-	-	-	-	2,885	Siloxane	ppbv	518	36,000[2]
Siloxane	ppbv	518	36,000[2]	5,000[3]	2,470	613	1,470	181	3,660	Siloxane	ppbv	518	36,000[2]
Cost As Tested													
												5	
Installation Cost	$	-	-	-	53,815 [4]		53,815 [4]		151,570		417,860		157,500 [7]
Annual Operating Cost	$	-	-	-	8,750		8,750		8,750		8,750		8,750
Environmental Benefits													
SOX Reduction		-	-	-					8				
Annual Chemical/ Media Use Reduction	$/year	-	-	-	-		-		53,815		79,200		NA
Reliability													
Percentage of Days Operated	%	NA	NA	NA	47%		47%		47%		100%		
Economic Analysis													
Total Annual Savings (= Environmental benefits	$/year								$45,065		$70,450		

					With Project SagPak HOX-Based		With Project SagPak C-Based		With Project Chiller		With Project H_2S Scrubber		
		Baseline	Baseline	Baseline	Inlet	Outlet	Inlet	Outlet	Inlet			Baseline	Baseline
	Units	(July/04 - May/05)	12-Oct-04	16-Nov-04	(July/05 - Dec/05)		(July/05 - Dec/05)		(July/05 - Dec/05)		(July/05 - Dec/05)		(July/05 - Dec/05)
less operating costs)													
Present value of annual savings; 6% discount rate, 10 project life	$								$331,682		$518,518		
Net Present Value (NPV) of investment	$								$180,112		$100,658		
Simple Payback	years								3.36		5.93		
Rate of Return (IRR)									27%		11%		

NA: Not applicable

[1] Digester 4 data; with $FeCl_3$ addition for H_2S control during baseline, and without $FeCl_3$ addition after project implementation.

[2] Combined gas at the flare.

[3] Combined gas after the compressors.

[4] Price of media replacement.

[5] Price of one complete unit.

[6] No change from baseline gas loop measurements. Field test period was insufficient to determine useful life of test unit.

[7] Price of modifications to existing system and media addition.

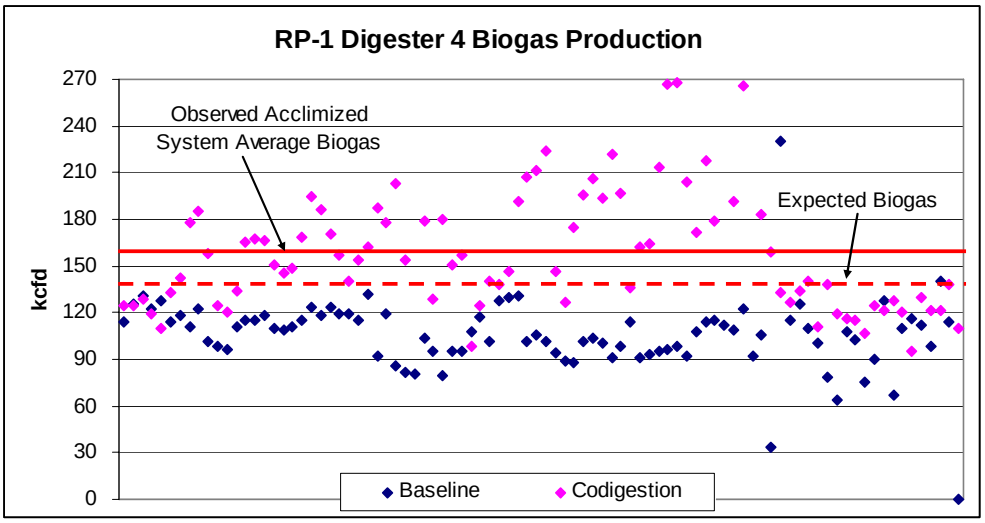
[8] Assumes chiller saves 1 change-out per year of SagPak media.

Project 3.1 Dairy Waste to Energy and Co-Digestion

Project 3.1 was designed to evaluate selected technologies available for the conversion of animal waste to energy. Animal waste is becoming a larger problem due to the trend toward larger dairy operations and due to the number of dairies that are located near urban areas. Six key findings resulted from this project. Each is highlighted and discussed below.

- **Co-Digestion of Food Waste and Manure Produces More Gas than Anticipated**
  - *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 Figure 4-1:

Figure 4-1: Manure Co-Digestion Biogas Generation at RP-1 Digestion Facility



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. 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 did not occur with the co-digestion of biosolids and food waste.

  - *Commercialization Potential*: 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.

- **The added gas production resulting from the 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.**

  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.

  – *Results of Project Activities:* The testing led to increased biogas production as shown in the Figure 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 system operation 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. This situation can be avoided in future projects by following these three steps:

    1. 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.

    2. 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.

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

  – *Commercialization Potential*: The amount of biogas that can be produced through co-digestion is significant, but the lessons learned, as summarized above, should be applied.

- **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.

- *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.

- *Commercialization Potential*: The model is a key tool that is applicable to other projects throughout California.

- **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 have recently been traded by IEUA around $2.00 per MWh ($0.002 per kWh)

  - GHG Credit prices have been low in the U.S., around $1.00 - $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_2$e) in early 2006. The $1.00 - $2.50 range is used in this report.

  - PM_{10} emissions credits can be generated by reductions in ammonia emissions from dairy manure. Trading 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.[1]

  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 4-3, but financial impact from corresponding PM_{10} emissions is not included in economic performance shown in Table 4-4 and Table 4-5.

- *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

[1] 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.

and biosolids co-digestion at RP-1 were determined and they are summarized in Table 4-3:

Table 4-3: 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				
CO_2 equivalent of CH_4 reduction (tonsCO_2E/year)	0	542.8	542.8	542.8
CO_2 equivalent of N_2O reduction (tonsCO_2E/year)	0	2,658.7	2,658.7	2,658.7
Reductions From Food Waste Management				
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				
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)				
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 & truck traffic less increases from combustion), (tons CO_2E/year)	0	3,200	3,100 - 4,300	3,100 - 6,100
NO_x emissions increase (tons/year)	0	0.78	0.94	1.2
SO_x emissions increase (tons/year)	0	0.24	0.27	0.3
Ammonia emission reductions	0	58	58	58

Environmental Benefits	IEUA Regional Plant #1 without Manure (Base case)	IEUA Regional Plant #1 with Manure	IEUA Regional Plant #1 with Manure and Food Processing Waste (as tested)	IEUA Regional Plant #1 with Manure and Food Processing Waste (full scale)
(tons/year) (reductions from dairy stockpiles)				
TDS reduction in groundwater (tons/year)	0	5.2	5.2	5.2

In Table 4-3 and Table 4-4, the base case is no 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 in Table 4-3 is for digesting manure with no food waste added at the facility. The second analysis in Table 4-3 is for co-digestion of manure with food waste, 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.

The first analysis in Table 4-4 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 4-4: 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			
CO_2 equivalent of CH_4 reduction (tonsCO_2E/year)	0	**Up to 10,900**	Up to 22,730
Increases From truck traffic			
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)			

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
CO_2 equivalent of CH_4 emissions increase (tonsCO_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
NO_x emissions increase (tons/year) (from increased energy recovery and reductions from truck traffic)	0	**1.8**	2.9
SO_2 emissions increase (tons/year) (from increased energy recovery and reductions from truck traffic)	0	**0.5**	0.5

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.

– *Commercialization Potential:* The benefits described 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 PM10 emissions restrictions. 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.

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

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.

Results of Project Activities: The economic performance of the dairy waste and food processing waste co-digestion project at IEUA's RP-1 facility is shown in Table 4-5. This research is being used to demonstrate the economic viability of these projects to potential developers and thereby expand the market.

Table 4-5: 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% CH4))	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

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 -
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)				
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**

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 -
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%**

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.

For biosolids co-digestion, the base case is digesting biosolids with no food waste addition. 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 4-6 summarizes project economics for biosolids/food waste co-digestion projects:

Table 4-6: 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% CH4))	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
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 & transportation costs	0	$ -	0
- Less, tipping fees collected	0	$ -	$0
Digester and gas system O&M	$34,576	$69,152	$69,152

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)
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%**

- 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 is recommended. 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.

  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.

  – *Commercialization Potential*: 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 4-7.

Table 4-7: Technical and Market Potential for New Renewable Power (MW) in California from Co-Digestion of Food Waste withy Dairy Manure and Biosolids

Resource Type	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

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.

- **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.

- *Results of Project Activities:* This project has increased the interest 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 demonstrated the economic feasibility of co-digestion projects, have been presented to other prospective hosts.

- *Commercialization Potential:* The results of the testing are applicable throughout California and elsewhere. Other entities are interested in obtaining the benefits of such projects and also recognize the importance of taking advantage of the lessons learned.

Building-Applied PV Projects: Project 3.2 and Project 3.3

Two PV projects were planned, but only one was implemented. The two projects were: Project 3.2 *Building Integrated Photovoltaics Testing and Evaluation* and Project 3.3 *Building Integrated Photovoltaics on Public Facilities*. Project 3.3 did not progress past the planning stage due to the receipt of a stop-work order in May 2005. Although the Project 3.3 Team was ready to move ahead with the project, many deliverables were held up in the review process, causing significant project delays, which would have prevented the project from being completed within the Program time-frame.

Project 3.2 Building Integrated Photovoltaics Testing and Evaluation

The objective of this project was to perform side-by-side evaluations of commercially available PV systems and component technologies, and to compile objective, consumer-friendly information on the costs and performance parameters of those systems. This type of information is not currently available from any one source, and would be useful for the PV-buying public. Five key project results are highlighted and discussed below.

- **This research supports the results from other PV performance tests showing that many modules produce less than their nameplate rating when field-measured performance data are normalized to nameplate conditions.**

  While PV module rating shortfalls continue, the practice of assigning system ratings based solely on the output of PV modules under laboratory conditions will remain a source of system performance misinformation.

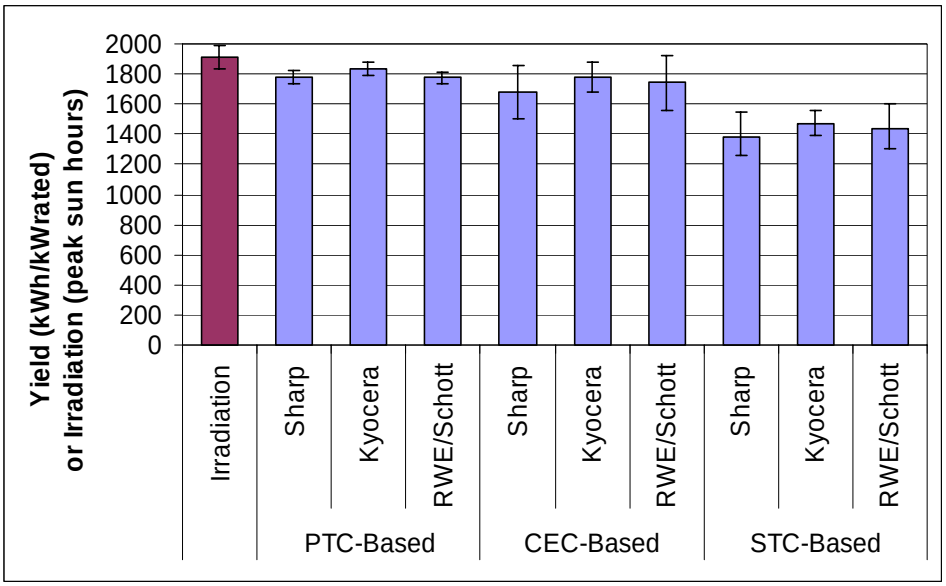
  - *Results of Project Activities:* After allowing for 4% of combined losses, just one of 12 systems was likely to have met its nameplate rating. A second system showed 49% likelihood of meeting its nameplate rating, and all others were far lower. The manufacturers' guaranteed minimum output is 10% lower than the nameplate rating, and the translated field ratings suggest that all but one of the twelve systems were within this range.

  - *Commercialization Potential:* As other markets around the world demand products with a tighter tolerance than California and the rest of the U.S., it is nearly certain that the U.S. markets will continue to receive products at the

low end of published power tolerances. This underlines the need for enforced performance requirements, and a verification process to ensure that consumers and installers are receiving products that meets these requirements.

- **The PTC and CEC ratings are significantly different from the STC ratings for each of the three small systems.**
  - *Results of Project Activities:* Figure 4-2 shows that the yields based on PTC rating are consistently proportional to the normalized delivered energy (i.e., yield in kWh/kWp) from each system. This correlation illustrates that the energy production of a variety of systems is very similar per rated PTCac Watt, but less similar per nameplate-rated STC Watt. The STC ratings are a less predictable starting point for estimating energy production, STC ratings carry larger uncertainties than PTC because the field-based PTC ratings exclude manufacturing tolerances while STC does not. Furthermore, STC ratings do not come close to accounting for the typical operational temperature of the PV array.

Figure 4-2: Summary of Yields Referenced to Different Ratings



  - *Commercialization Potential:* Consumers should be aware that the PTC or CEC ratings are more accurate than the STC ratings. The ratio of PTC/STC obtained for the various systems provides a good initial indication of consumer value by comparing actual to claimed performance.

- **For the large systems, predicted operating temperatures and voltages did not always match measured values, indicating challenges still exist in appropriately designing and rating systems.**

  This is particularly important for new systems and new mounting configurations.

  – *Results of Project Activities:* The AstroPower APx-130 array with the Solar Quilt structure operated at temperatures higher than expected, causing that system segment to operate below initial performance expectations.

  – *Commercialization Potential:* Consumers should be aware that that this condition will have some impact on the cost effectiveness of the AstroPower APx-130 array with the Solar Quilt structure.

- **There were no significant reliability issues identified during the short term of the project.**

  – *Results of Project Activities:* A few minor issues were found with some of the systems, and these problems and solutions were discussed in detail in Section 3. Although there were no significant problems during the first twelve months of operation, some issues can take time to develop and be detectable. Only continued monitoring of the installed systems will determine if there are reliability concerns with these systems.

  – *Commercialization Potential:* The systems tested under this project were properly designed and installed, which minimized the potential for operational problems due to system design or installation flaws. Consumers should be aware that although these systems operated reliably during the first year, some reliability problems can take time to develop and be detectable.

- **The Project Team has effectively communicated its results to the public.**

  Web-based information was helpful in communicating results to a broader audience, such as the PV consumer, and training was key to reaching the PV industry installer base.

  – *Results of Project Activities:* 4500 internet users have visited the project web site, downloading 400 copies of the available reports and presentations.

  Hundreds of scientists, engineers, manufacturers, installers, designers, and end users have had the opportunity to review project results in three conference presentations and related papers/proceedings.

  180 installers and other interested parties have attended 3-day workshops.

– *Commercialization Potential:* The PV industry, California's various photovoltaic incentive programs, consumers, and other stakeholders are using, and will continue to use this project's on-line side-by-side systems evaluation for further refinement of solar electric goals.

Project 3.3 Building-Integrated Photovoltaics (BI-PV) on Public Facilities

Project 3.3 was designed to yield up to four public sector BI-PV projects ranging in size from 10 kW to 150 kW. Each project would address an infrastructure or commercialization barrier. The Project 3.3 Team received a request to stop-work on the project in November 2004. Although the Commerce Project Team was willing to move ahead with the final design and installation of the PV projects, earlier task deliverables were held up in the review process, thus causing significant project delays, coupled with SGIP Level 1 over subscription during the same timeframe, all of which would have prevented the project from being completed within the RD&D Program's contractual time-frame.

4.2 Recommendations by Project Area

This section discusses the recommendations for assessing and meeting the needs of future mini-grids, recommendations for future research, and recommendations to facilitate the implementation of future biogas and PV projects.

Chino Basin Mini-Grid Distribution System Assessment

It was necessary to conduct a power flow analysis study to determine where within a mini-grid the optimal benefits can be achieved and determine the magnitude of those benefits. The timing when certain distribution circuits and transformers become overloaded also assisted in the prioritization of renewable resource development and optimized the benefits.

Further detailed studies are recommended to supplement a power flow study for future mini-grids in order to ensure successful operation of a mini-grid with significant penetration of distributed generation on the feeders. A detailed interconnection study, similar to the work performed under Project 3.1, should be performed and should consider relaying requirements, integrated control of distribution system voltage, reactive power scheduling, communication requirements and short circuit duty impacts with high penetration levels of the distributed biogas and BI-PV generation installed. It is also recommended that a dynamic study, similar to the work performed under Project 3.1, of the transient response of high penetration levels of distributed biogas and BI-PV generation to disturbances on nearby feeders or substations to test the stability of the DG during appropriate transient events be performed.

Comment [h2]: Insert recommendations from Hank's 3.1 work

Biogas to Energy Projects

A technology transfer program should be initiated to communicate the effectiveness of biological scrubbers and co-digestion to potential users. The technology transfer program could be complemented by additional testing.

Future research should be conducted to optimize a combined system of chillers and media based systems to remove siloxane and hydrogen sulfide. Removing siloxane and hydrogen sulfide as part of the moisture removal system is an option because there are dual benefits when using such moisture removal systems. Therefore, further testing of combined chiller/media systems, where the chiller is operating at less than 40°F and above -40°F, would determine the optimal temperature at which media life is balanced with electricity costs.

Systems that inject air into iron sponges prolong their life and are cost effective. The major drawback to such systems is maintaining pH at proper levels with chemical that do not clog the feed nozzles. Chemicals other than lyme should be tested to determine their effectiveness in maintaining the proper pH while avoiding nozzle clogging.

Additional research using ultrasound as a tool to increase biogas production and solids destruction should be limited to “stressed” systems. Such systems, where there is limited holding time available because of digester capacity constraints, are candidates for ultrasound, but systems operating under normal operating conditions are not good candidates for ultrasound. Future ultrasound research should also focus on systems with sonic horns 6 kW or smaller. The larger horns are not as reliable or as effective as the smaller ones and should not be used in future research on wastewater treatment plant applications until the technology advances and becomes more reliable.

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. The co-digestion model produced under this project to estimate gas production rates for potential future projects should be used in planning new co-digestion projects. This model has safety factors built into it and they should be reviewed on a case-by-case basis for future projects.

Building-Applied PV Projects

Requirements for System and Component Ratings need to be established and they need to be verified through third party comparative testing. We suggest that the Energy Commission adopt a requirement for PV modules specifying that the manufacturer’s nameplate rating shall represent the minimum allowable output for that model. This rating should also include

an allowance for initial Light Induced Degradation. This rating shall also represent the value from which the warranty power tolerance is calculated.

System and component characteristics need to be evaluated to ensure that performance benefits are understood. It is recommended that a future evaluation project contain the following: an enhanced eligible module listing procedure, extension to inverter performance characterization, system-level initial evaluation, and longer-term energy yield information.

Assessment of reliability requires continued long term monitoring of installed systems. With the newer, less proven technologies, it is especially important to provide the consumer with confidence that these products will continue to perform as expected.

The information from the project needs to be transferred by additional means to the different members of the PV community. The web presence should be enhanced to automate additional analyses and to report any new results through various documentation and presentation options. Further, continued training for installers is clearly important to the long-term success of PV industry.

4.3 Program Benefits to California

This section discusses the current and future benefits to California as a result of the biogas and PV projects undertaken in this Program.

Existing and Future Benefits Derived from the Commerce Program

The PIER Commonwealth Energy Biogas/PV Mini-Grid Renewable Resources Program has and will continue to yield numerous benefits to the State of California.

- Mini-Grid Concept Development
- Employment
- Economic growth
- Fuel Diversity
- ESP and Participant Benefits
- Meeting the State's Renewable Portfolio Standard
- Identification of high-value PV and biogas applications
- T&D system deferral of capital expenditures
- T&D system reliability improvements
- Environmental improvements

Mini-Grid Concept Development

The mini-grid concept tailors resource development to the specific needs and resources of localized areas of the electric distribution system. The specific renewable resources selected (landfill gas, biogas from livestock and food processing waste, and biogas from wastewater treatment facilities) are particularly well suited for the Chino Basin. Unlike geothermal or wind resources, these selected resources tend to be located close to populated areas, relatively close to electric transmission and distribution facilities, and may be found in concentrated pockets near electric system load centers. This approach can be used for future mini-grid projects in different areas of California.

Employment

Long-term employment benefits from the development and continuation of mini-grid projects. DG system designers, installers, operation and maintenance professionals are required.

Economic growth

California's long term economic growth will benefit by the application of the mini-grid concept. There are economic benefits that will go to the State as a whole, but more importantly the local communities where the mini-grids are developed will benefit as well. Also, the environmental benefits associated with some renewable energy projects (e.g. reductions in PM_{10} concentrations) have the potential to improve the well-being of the community, therefore increasing productivity.

Fuel Diversity

No individual fuel is capable of providing the energy to meet all electricity requirements. A diverse fuel mix protects electricity producers and consumers from situations such as fuel unavailability, fuel price fluctuations, and changes in regulatory practices. The mini-grid concept promotes fuel diversity. This will become increasingly more important as natural gas prices increase and renewable fuels are used to offset the increased prices.

ESP and Participant Benefits

Energy service providers and participating customers have and will continue to benefit by the business relationships that can be arranged as a result of the development of mini-grids. New business models are likely to result where greater benefits are realized by parties acting together rather than on their own. No one market actor can realize all the possible benefits without developing a business relationship with other parties. For example, tax benefits may be available to an ESP and not to the customer whereas the property ownership obstacles may exist for the ESP and not the customer. The two parties together can benefit by developing a new business relationship and developing available renewable resources.

Meeting the State's Renewable Portfolio Standard (RPS)

By promoting the mini-grid concept, the State will benefit from a regulatory perspective in that it will be further promoting the development of renewable resources and contributing to its RPS goals.

Identification of high-value PV and biogas applications

The mini-grid concept understudy provided a mechanism or process for the identification and prioritization of high-value PV and biogas applications. The benefits assessment and project prioritization processes developed here ensure that the projects with the greatest value are identified. Although this assessment was both Program- and technology-specific, it represents a good example of how to proceed with prioritizing renewable projects in the future.

T&D system deferral of capital expenditures

By assessing the local T&D system in which mini-grids are developed, the deferral of system upgrades can potentially be deferred by deliberate development of well-positioned renewable electric generation. T&D system upgrades can be very expensive and by deferring them for a number of years, the local T&D provider will not incur these capital costs and will not need to pass them on to its customers.

T&D system reliability improvements

Other electric distribution system benefits are incurred by the development of significant quantities of localized distributed generation. There are voltage and VAR support benefits which reduce the probability of outages for customers connected to the distribution system.

Environmental improvements

Air pollution and ground water contamination are two potential environmental hazards that exist in areas with high concentrations of biogas resources. By aggressively developing biogas to energy projects in these localized areas, environmental improvements can be accrued. Air quality benefits are the most immediate environmental improvements that are seen; however, groundwater and surface water quality improvements take more time to occur and therefore may be more important in the future. IEUA is expected to continue with and expand manure co-digestion, therefore water quality and air emissions improvements may be measurable within the next few years.

Potential Future Program Benefits from Market Dissemination and Transformation

It is expected that the mini-grid concept will become more viable as green tag and GHG credit markets evolve. Other financial market barriers can be addressed through continued public funding and legislative action. New ownership models similar to the one tested by Commonwealth Energy and IEUA can also remove market barriers.

4.4 Summary of Conclusions and Recommendations

The area studied under this program has an abundance of biogas (LF, WWT, Dairy waste and food waste) and PV resources. It was found that the combination of biogas and non-residential BI-PV electric generation produces an excellent match to the local electric demand profile.

It is expected that the mini-grid concept will become more viable as green tag and GHG credit markets evolve. Other financial market barriers can be addressed through continued public funding and legislative action. New ownership models similar to the one tested can also remove market barriers. Further research, such as that being performed under the Commonwealth Energy Program, can improve the cost effectiveness of renewable distributed generation suitable for use in a mini-grid. However, there is a need for more research on DG impacts to the local T&D system to ensure that system reliability is not jeopardized under very high feeder circuit penetration scenarios. In addition to power flow analysis, it was recommended following the initial assessment that a detailed interconnection study which considers relaying requirements, integrated control of distribution system voltage, reactive power scheduling, communication requirements, and short circuit duty impacts with high penetration levels of the distributed biogas and BI-PV generation installed. It was also recommended that a dynamic study of the transient response of high penetration levels of distributed biogas and BI-PV generation to disturbances on nearby feeders or substations to test the stability of the DG during appropriate transient events be performed.

For a mini-grid to achieve its full renewable energy potential, an unprecedented level of cooperation between the distributed generation hosts and owners, the local T&D owner, and the State and local government agencies is required. These market actors must work together during all phases of the process to ensure that all the benefits of the mini-grid are achieved.

The *Enhanced Anaerobic Digestion and Gas Cleaning* project found that the ultrasound systems were unreliable and did not significantly increase gas production in a system that was not stressed (had an optimal hydraulic retention time). The gas cleaning systems were found to be important to the economics of biogas projects, and the biological hydrogen sulfide removal system was the most cost-effective and reliable gas cleaning system that was tested. It is recommended that a “stressed digester” system is tested with an ultrasound

system that has sonic horns sized at 6 kW or less. An enhanced gas cleaning system, and in particular the biological hydrogen sulfide and Siloxane removal systems, are highly recommended to any wastewater treatment facility that is using biogas for energy, as these systems can improve the cost-effectiveness of biogas power generation.

The *Dairy Waste to Energy* project showed that co-digestion of manure and food-waste produces more biogas than anticipated. Environmental benefits contribute to the cost-effectiveness of manure digester gas projects, particularly for air quality improvements, although the potential is there for a water quality credit infrastructure to develop. Co-digestion potential is significant in California and economically favorable, and therefore a recommended process for dairies, food processing facilities, and wastewater treatment facilities to consider. When planning for a future co-digestion project, it is also recommended that the gas production model that was developed under this project be used to more accurately predict and plan for the amount of biogas that will be produced through the codigestion approach.

The *Building-Integrated Photovoltaics (BI-PV) Testing and Evaluation* project supported results from other PV performance tests showing that many modules produce less than their nameplate rating when field-measured performance data are normalized to nameplate conditions. The results also showed that the PTC and CEC ratings are significantly different from the STC ratings for each system. It is recommended that requirements for System and Component Ratings be established and verified through third party comparative testing. It is also recommended that a long-term PV system evaluation be conducted to compare system reliability.

Renewable energy projects and research will become increasingly important as concerns about global climate change and fossil fuel price volatility and resource availability (e.g., supply shortages) become more pressing. Implementing renewable energy demonstration projects will further the state of knowledge, help to develop and strengthen the market for these products, and improve the cost-effectiveness of renewable energy options. Improving the cost-effectiveness of electric power and/or heat from renewable energy is essential to the success of these technologies, and will benefit the State of California's ratepayers as well as positively impact the state economy.

Endnotes

The following endnotes/footnotes are contained within this Report.

References

The following documents have been referenced within this Report

- Regional Economic Research, Inc. – "*Estimation of Hurdle Rates Applicable to Energy Related Investments*", June 25, 1989.
- Itron, Inc. (formerly RER) – "*Project 1.1: Program Planning and Analysis – Final Project Report*" March 2006
- CH2M HILL – "*Project 3.1: Dairy Waste to Energy – Final Project Report*", March 2006
- CH2MHill –"*Project 2.2: Enhanced Energy Recovery through Optimization of Anaerobic Digestion and Microturbines – Final Project Report*" March 2006
- BEW – "*Project 3.2: Building Integrated PV Testing and Evaluatoin Project – Project Final Report*, February 2006