Rio Rico Landfill
Landfill Gas to Energy and Carbon Credit Feasibility Study

Prepared for:
Santa Cruz County
Public Works Department

Prepared by:
C.L. Williams Consulting, Inc.
Civil Engineering and Resource Management
621 S. Hillside Lane
Pinetop, Arizona 85935
928-367-2248
and

Stantec Consulting Inc.
8211 S. 48th Street
Phoenix, AZ 85044
602-438-2200

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Executive Summary

The Rio Rico Landfill (RRLF) occupies approximately 25 acres and has been receiving municipal solid waste (MSW) since 1981. It is estimated that the site has accumulated approximately 707,000 tons through the end of 2008. The total capacity of the Rio Rico landfill is estimated as 1.92 Million Tons, including the vertical expansion recently approved by ADEQ, which is sufficient to allow continued filling of the landfill at current rates through 2029.

A landfill gas collection and control system (GCCS) was installed in 1998 / 1999 and consists of two interior landfill gas extraction wells and 13 perimeter extraction wells along the northwest, west and southern boundary of the landfill. Collected LFG is directed to a landfill gas flare and carbon adsorption system. The two interior wells were decommissioned in 2005 to allow placement of waste while the remaining 13 wells are able to support combustion in the flare. Recent monitoring of LFG recovery at the flare station of between 420 and 500 scfm at a methane content that varies from around 20% to over 40%.

A model was prepared to determine whether there is sufficient landfill gas generated at the Rio Rico landfill to sustain an electric generation rate that is viable for sale. The model considers the annual waste deposition quantities, the percent dry weigh of each waste decomposition category, the total potential gas generation amounts from each waste category, the decay half life and the initial gas generation lag time.

Waste filling history was used to estimate the projected quantity. The estimates took into account that the City of Nogales contractor, Tucson Recycling, is no longer disposing of solid waste at the Rio Rico Landfill, Waste Management has a new arrangement for transporting their waste and have left the system, and the Town of Patagonia has resorted to placing solid waste in their own landfill. The lost combined tonnages of Nogales, Tucson Recycling, Waste Management and Patagonia represent nearly 21,000 tons per year (tpy). Recent information indicates that the Nogales waste may return to the Rio Rico Landfill. The composition of the waste considers the percentage that is decomposable, the anticipated rate of decomposition and the rate of landfill gas generation associated with different types of waste. The model is based on an equivalent gas composition with 50% methane.

The model predicts that landfill gas generation at the Rio Rico Landfill is viable to support energy recovery. The peak LFG generation from the site in 2030 is estimated at a rate of approximately 500 scfm. The model also predicts that LFG will be recoverable at a rate of at least 300 scfm starting in 2010 for 28 years. A recovery rate of 300 scfm at 50% methane is sufficient to sustain an electric generation rate of approximately 800 kW.

The LFG to Electrical options for small to medium sized landfills such as Rio Rico include reciprocating engine-generators, micro-turbines and fuel cells. LFG reciprocating generators are the most common and have a long-proven history of operation. Micro-turbines are more recent technology and are more portable and suit a modular installation better than reciprocating generators. Fuel cells are very new technology and not practical for consideration.

Additional options such as direct use of methane, combined heat and power and treatment of LFG to pipeline quality gas were considered as options, however as there are no users in the immediate area, none of these potential options are practical for the Rio Rico landfill.

A matrix evaluation comparing a reciprocating electricity generating system to a micro turbine electricity generating system indicate that a reciprocating generating system best suits the Rio Rico landfill site. As the anticipated output for Rio Rico does not vary significantly, the advantages associated with the modular micro turbines do not impact enough to offset the decrease in efficiency, increased capital cost and increased operational costs.

An analysis was completed comparing an 800 kW system to a 1000 kW system for a reciprocating system. With the reciprocating system the system is either over or undersized to meet average and peak conditions. For the current loads, the analysis indicates an 800 kW system is best, however if the City of Nogales returns to Rio Rico, it is likely that a 1000 kW system will be better. The analysis also indicates that planning for the installation of a 1000 kW system although slightly oversized to allow for the return of Nogales is more practical.

The preliminary cost estimate for development of a LFGTE system at Rio Rico based on a 1000 kW reciprocating generator system including improvements to the existing well field is $3.36 Million. A preliminary pro forma economic analysis indicates potential net worth of $122,000, $1.4 million and $3.0 million after 10, 20 and 30 years of operation.

The financial analysis focused on the actual costs and revenues associated with the LFGTE system. In addition the LFGTE system, there is a potential for the County to achieve Environmental Credits. However, the environmental markets are currently in a great deal of flux due to the rapidly changing regulatory and compliance environment at the national and regional levels. It is anticipated that at a minimum, Santa Cruz County will be able to achieve Renewable Energy Certificates (RECs) and that it is likely that Tucson Electric, would want to purchase the RECs' with the purchase of the power.

Implementation of a Landfill Gas to Energy (LFGTE) project requires several key steps to be completed and milestone decisions to be made. The entire process can take up to 2 years to complete from initial planning to installation and start-up. A summary of the implementation steps is as follows;

- Gas modeling and initial assessment as included in this report.
- Prepare preliminary (25%) design plans and more detailed economic assessment.
- Decide whether or not to proceed based on the updated financial projections.
- Establish the project structure on how the project is to be developed and managed. There are three options available to the County for development: a) self development with contractual development and operations; b) full service developer-operator with ownership and control of the LFG and resulting electrical energy output from the facility or; c) a public-private partnership.
- Prepare development contract documents that include the preliminary design plans, performance specifications, regulatory and construction permitting requirements, insurance and bonding criteria, agreement terms and conditions, and performance guarantees.
- Assess financing options and loan/grant opportunities,
- Negotiate an energy sales contract,
- Secure required environmental, siting and other related permits
- Award the EPC contract
- Install the LFGTE facilities and wellfield improvements and start-up of commercial operations.

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1.0 Introduction

1.1 BACKGROUND

The Rio Rico Landfill (RRLF) occupies approximately 25 acres and has been receiving municipal solid waste (MSW) since 1981. Since 1996, when record-keeping was started, the site has accumulated approximately 707,000 tons through the end of 2008. The landfill originally had a design capacity of around 998,500 tons. On November 4, 2009, ADEQ approved the County's application for vertical expansion to increase the volumetric capacity to approximately 2,849,500 cubic yards which is equivalent to about 1.92 million tons and extends its estimated useful life to 2029 at current filling rates.

A landfill gas collection and control system (GCCS) was installed in 1998 / 1999 and consists of two interior landfill gas extraction wells and 13 perimeter extraction wells along the northwest, west and southern boundary of the landfill. Collected LFG is directed to a landfill gas flare and carbon adsorption system. The two interior wells were decommissioned in 2005 to allow placement of waste while the remaining 13 wells are able to support combustion in the flare. Recent monitoring of LFG recovery at the flare station of between 420 and 500 scfm at a methane content that varies from around 20% to over 40%.

1.2 OBJECTIVE OF STUDY

Santa Cruz County has been awarded a Technical Assistance Grant from the North American Development Bank for the purpose of preparing a study on the feasibility of recovering landfill gas (LFG) from the Rio Rico Landfill for beneficial utilization through implementation of a Landfill Gas to Energy (LFGTE) Project and assessing the associated carbon and renewable energy credit eligibility.

It is the County's objective for this study to result in a determination of the project's technical, economic, institutional and regulatory viability as presented in an Action Plan upon which the County Board of Supervisors will make a *go-no go* decision to proceed with implementation. With this project, the County fully intends to take maximum advantage of the financial stimulus support available through the energy provisions of the 2009 American Recovery and Reinvestment Act.

1.3 DOCUMENT REVIEW

The following documents furnished by Santa Cruz County and CL Williams for the Rio Rico Landfill were reviewed as part of this project:

- Historical and projected annual waste disposal tonnages by Santa Cruz County SWD from 1996 – 2029
- Landfill flare station blower gas recovery rates and quality data from 2003 – 2009
- Gas collection system monitoring records from 2002 – 2006
- Gas collection and control system site plan and cross sections prepared by SCS Engineers for Santa Cruz County dated 1998
- Existing conditions site plan from the proposed Rio Rico Landfill vertical expansion permit application by SCS Engineers dated July 2009
- Summary tables and category descriptions from the Santa Cruz County Solid Waste Characterization Study dated 1987
- "Santa Cruz County – Rio Rico Landfill - Master Customer Disposal Data for FYE 03 – 09" including summary of major waste categories for each year
- "Alternate Final Cover Demonstration – Rio Rico Landfill", SCS Engineers, October 2007
- Excerpt from a drawing with final cover details showing the type and thickness of material to be placed on top and slope areas of the landfill
- A topographic site plan of the Rio Rico Landfill existing conditions titled "Existing Conditions – Vertical Expansion Design, Rio Rico Sanitary Landfill", Dwg. 2 of 7, SCS Engineers, July 2009

Each of the preceding documents was studied for the purpose of obtaining relevant information to be used in the development and analysis of the gas generation model and preparation of this report.

2.0 LFG Production and Recovery Estimates

This chapter of the report presents the findings and conclusions regarding the Landfill Gas Generation Modeling for the Santa Cruz County Landfill Gas to Energy (LFGTE) Feasibility Study at the Rio Rico Landfill. The Rio Rico Sanitary Landfill is operated by the Santa Cruz County Solid Waste Division (SWD). Stantec, as a subconsultant to CL Williams, has developed a LFG Generation Model for the purpose of projecting the long-term prospects for recovery at commercially viable levels.

2.1 WASTE FILLING HISTORY AND PROJECTION

Waste filling history for the Rio Rico Landfill between 1996 and 2009 (through April 2009) was provided in a spreadsheet table by Santa Cruz County. The tonnage for 2009 was annualized by the County by extrapolating the data through April 2009 and discounting for the departure of the City of Nogales solid waste from the Rio Rico Landfill. In addition, it is understood that the City of Nogales contractor, Tucson Recycling, is no longer disposing of solid waste at the Rio Rico LF, Waste Management has a new arrangement for transporting their waste and have left the system, and the Town of Patagonia has resorted to placing solid waste in their own landfill. The lost combined tonnages of Nogales, Tucson Recycling, Waste Management and Patagonia represent nearly 21,000 tons per year (tpy). The future annual waste disposal tonnages for 2010 through 2029 were projected by the County SWD from the 2009 data by first excluding the combined lost tonnage noted above and then assuming no growth in disposal in 2010, a one percent increase in 2011, a 2 percent increase in 2012 and a 3 percent increase in each subsequent year through 2029.

Table 2.1 presents a summary of the waste filling history and projections from the start of filling in 1981 through the estimated closure in 2029.

As reported in Table 2.1, as of the end of 2008, the Rio Rico Landfill contains approximately 707,000 tons of waste in place. The County estimates as of mid-2008, the landfill has a remaining capacity of around 1.07 million tons which is sufficient capacity for the landfill to continue operating well into 2032. However, for planning purposes the County is still assuming the landfill will close at the end of 2029. At closure in 2029 with the future projected waste disposal rates, the landfill would have a total of around 1.55 million tons in place.

The existing Rio Rico Landfill had a design capacity of around 998,500 tons as derived from the 2003 Operations Plan. The County has received approval from ADEQ for a vertical expansion to the landfill that increases the total capacity to around 2,849,500 cubic yards. According to the County PWD, the average in-place density of wastes and cover materials is 1,350 pounds per cubic yard or 0.675 tons/cy. At this density factor, with the recently approved vertical expansion, the Rio Rico Landfill has a total equivalent capacity of approximately 1.92 million tons. Should the filling rates continue as presented in Table 2.1, the County would have sufficient capacity to continue operating the site through 2029 and beyond.

2.2 WASTE COMPOSITION

The Stantec Landfill Gas Generation Model segregates landfilled waste into three classes of decomposability: Readily Decomposable, Moderately Decomposable and Slowly Decomposable. The decomposability classification influences the rate and longevity of gas generation as explained in further detail below. Therefore, it is necessary to classify the various materials that make up each general organic category into its respective decomposability classification.

TABLE 2.1
SANTA CRUZ COUNTY
RIO RICO LANDFILL
FILL HISTORY AND PROJECTED GROWTH

Fill Year	Annual Tons	Assumed Growth Rate	Cumulative Tons	Fill Year	Annual Tons	Assumed Growth Rate	Cumulative Tons
1981	5,866	N/A	5,866	2006	60,069	N/A	583,191
1982	6,335	N/A	12,201	2007	61,105	N/A	644,296
1983	6,842	N/A	19,043	2008	62,311	N/A	706,607
1984	7,389	N/A	26,433	2009	47,609	N/A	754,216
1985	7,981	N/A	34,413	2010	30,528	N/A	784,744
1986	8,619	N/A	43,033	2011	30,833	1%	815,578
1987	9,309	N/A	52,341	2012	31,450	2%	847,028
1988	10,053	N/A	62,394	2013	32,393	3%	879,421
1989	10,858	N/A	73,252	2014	33,365	3%	912,786
1990	11,726	N/A	84,978	2015	34,366	3%	947,152
1991	12,664	N/A	97,642	2016	35,397	3%	982,550
1992	13,677	N/A	111,320	2017	36,459	3%	1,019,009
1993	14,772	N/A	126,091	2018	37,553	3%	1,056,562
1994	15,953	N/A	142,045	2019	38,679	3%	1,095,241
1995	17,230	N/A	159,274	2020	39,840	3%	1,135,081
1996	29,361	N/A	188,635	2021	41,035	3%	1,176,116
1997	26,080	N/A	214,715	2022	42,266	3%	1,218,382
1998	19,286	N/A	234,001	2023	43,534	3%	1,261,916
1999	22,072	N/A	256,073	2024	44,840	3%	1,306,756
2000	30,967	N/A	287,040	2025	46,185	3%	1,352,942
2001	44,867	N/A	331,907	2026	47,571	3%	1,400,512
2002	41,025	N/A	372,932	2027	48,998	3%	1,449,510
2003	43,232	N/A	416,164	2028	50,468	3%	1,499,978
2004	53,982	N/A	470,146	2029	51,982	3%	1,551,960
2005	52,976	N/A	523,122				

For the purposes of modeling, waste filling at Rio Rico Landfill was divided into four eras to reflect changing characteristics of the waste stream over time. The different eras included 1981 – 1995, 1996 – 2002, 2003 – 2006 and 2007 – 2029 (projected landfill closure). The 1987 waste composition study provided by Santa Cruz County was used as a basis for determining the waste breakdown of organic (decomposable) wastes for each of the four filling eras.

However, the County has indicated that the 1987 waste composition study was conducted during the non-growing and harvesting season so it did not include the significant quantities of produce and vegetable wastes normally seen each year. Information was provided by the County on the major categories of waste disposal for fiscal years ending 2003 – 2009 from the landfill site customer database records. The major categories included Municipal Solid Waste (MSW), Construction and Demolition Waste (C&D), Produce Waste, and Vegetative Waste. The findings from the 1987 waste composition study organic waste percentages breakdown were adjusted to include allowances for produce and vegetative wastes based on the average for each of those categories seen from the 2003 – 2009 waste disposal records. Produce wastes and vegetative wastes for FYE 2003 – 2009 represented an average of around 13.9% and 1.1%, respectively, of the total organic wastes. Table 2.2 shows the organic composition breakdown from the 1987 Waste Composition Study and the adjusted organic composition breakdown including produce and vegetative wastes. The last column of Table 2.2 shows the equivalent dry weight percentages of the organic wastes.

TABLE 2.2
DECOMPOSABLE WASTE BREAKDOWN
1987 WASTE COMPOSITION STUDY - ADJUSTED DATA

Decomposable Material	Decomposable Category	1987 Study % Disposed (Wet Wt.)	% MSW Excluding Prod. & Veg.	Adjusted % Disposed (Wet Wt.)	Percent Moisture(1)	Adjusted % Disposed (Dry Wt.)
Food	Readily	8.4%	88.1%	7.4%	60%	3.0%
Produce	Readily			13.9%	60%	5.6%
Misc. Organics	Moderately	15.8%	88.1%	13.9%	25%	10.4%
Paper and paperboard	Moderately	39.4%	88.1%	34.7%	6%	32.6%
Wood	Moderately	3.4%	88.1%	3.0%	20%	2.4%
Yard waste	Moderately	7.5%	88.1%	6.6%	50%	3.3%
Vegetative	Moderately			1.1%	50%	0.6%
Textiles	Slowly	2.4%	88.1%	2.1%	10%	1.9%
Total Decomposable		76.9%		82.7%		59.7%

1. Moisture content based on averages from the table “Typical Data on Moisture Content of Municipal Solid Waste Components” in the engineering textbook “Solid Wastes: Engineering Principles and Management Issues”, McGraw-Hill, Inc.

The adjusted 1987 waste composition data in Table 2.2 was used as the basis for the waste disposed at the Rio Rico Landfill for the years 1981 through 1995. For the other 3 filling eras, the waste composition was derived from the national trends in waste disposal as found from data obtained from the EPA report "Municipal Solid Waste in the United States: 2007 Facts and Figures" published in 2008[1]. This report provides characterization data of Municipal Solid Waste (MSW) disposed in U.S. landfills (after recycling and composting) covering the years 1960 to 2007.

Starting with the waste composition results from the County's 1987 Study as a base year, the changing waste characterizations of the three filling eras at the Rio Rico Landfill starting in 1996 were assumed to be comparable to the trends on a national scale. Decomposable waste composition data from the EPA report from 1985 and 1990 were averaged to represent the composition comparable to the County's in the base year 1987. Waste composition for filling from 1996 - 2002 was assumed to be comparable to the trend represented by the 2008 EPA report data for the year 2000. Similarly, the waste composition for filling between 2003 and 2006 and the waste composition for the filling between 2007 and 2029 (closure), comparable to the trends represented by the 2008 EPA report data for the years 2005 and 2007, respectively.

In order to estimate the waste composition for the above noted 3 filling eras starting in 1996 for each of the decomposable materials (i.e., food waste, paper, yard waste, etc.), the ratio of the percentage change seen with the national data between the base year (1987) and the filling era representative year was applied to the Santa Cruz County base year waste composition percentage for that same decomposable material. For example, the 1987 Santa Cruz County Waste Composition Study determined the average paper and paperboard content was 39.4%. In comparison, the EPA report for the same timeframe (average of 1985 and 1990 national data), showed the average paper and paperboard content was 31.1%. For year 2000, the EPA report noted the paper and paperboard content was 29.6% of disposed waste. Therefore, there was a downward trend in paper and paperboard disposal of 0.95 (29.5% / 31.1%) over the time period from 1987 to 2000. This paper and paperboard content from the 1987 County Composition Study of 39.5% was multiplied by the 0.95 downward trend factor to calculate the paper and paperboard content in 2000 of 37.5%. This same approach was used for the other decomposable materials for estimating the waste composition for individual eras.

Table 2.3 presents the percentage breakdown of the organic materials as derived from the waste composition study trend changes. Identified next to each organic material item in the table is its decomposability classification. It should be noted that the percentages of MSW organics are based on their wet weight.

[1] "Municipal Solid Waste in the United States: 2007 Facts and Figures" EPA 530-R-08-010, Nov. 2008

TABLE 2.3

LANDFILL MSW ORGANICS DETAILED COMPOSITION AND DECOMPOSABILITY CLASS

MSW Organic Component	MSW Component Percentage				Decomposability Class
	1981-1995 Era	1996-2002 Era	2003-2006 Era	2007 – Closure Era	
Food	7.4%	10.6%	11.8%	11.9%	Readily
Produce	13.9%	16.7%	16.6%	16.9%	Readily
Misc. Organics	13.9%	14.5%	10.7%	15.8%	Moderately
Paper & Paperboard	34.7%	33.0%	27.9%	23.8%	Moderately
Wood	3.0%	3.5%	3.7%	3.6%	Moderately
Yard Waste	6.6%	3.0%	2.5%	2.3%	Moderately
Vegetative	1.1%	0.7%	0.0%	0.1%	Moderately
Textiles	2.1%	4.3%	5.0%	5.1%	Slowly
Totals	**82.7%**	**86.3%**	**78.3%**	**79.5%**	

The Stantec gas generation model input for decomposable waste is determined from dry weight percentages. The wet weight values in Table 2.3 were converted to equivalent dry weight numbers after applying estimated average moisture content percentages to the respective waste components as shown in Table 2.4. The decomposable categories for each landfill era were then summed to derive the totals.

2.3 GAS GENERATION MODEL

The generation of landfill gas at the Rio Rico Landfill was estimated by Stantec using a customized first-order decay model which assumes the rate of gas generation decreases exponentially as the organic fraction of the refuse decomposes. Stantec's model is similar to the EPA LANDGEM model for projecting methane and non-methane organic compounds (NMOC's) emissions with one major exception. The model classifies the waste into three decomposability categories: readily decomposable; moderately decomposable; slowly decomposable. In comparison, the EPA model treats the entire refuse mass as a single category.

2.3.1 Model Inputs

The basic inputs to the model include the annual waste deposition quantities (tons per year), the percent dry weight of each waste decomposition category, the total potential gas generation

TABLE 2.4
DECOMPOSABLE DRY WASTE COMPOSITION BY FILLING ERA

1987 Composition Data (Santa Cruz County Waste Composition Study - 1987)

Material	Decomposable Category	% Disposed (Wet Wt.)	Santa Cruz MSW %	Santa Cruz Adjusted	Percent Moisture	% Disposed (Dry Wt.)
Food	Readily	8.4%	88.1%	7.4%	60%	3.0%
Produce	Readily			13.9%	60%	5.6%
Misc. Organics	Moderately	15.8%	88.1%	13.9%	25%	10.4%
Paper and paperboard	Moderately	39.4%	88.1%	34.7%	6%	32.6%
Wood	Moderately	3.4%	88.1%	3.0%	20%	2.4%
Yard waste	Moderately	7.5%	88.1%	6.6%	50%	3.3%
Vegetative	Moderately			1.1%	50%	0.6%
Textiles	Slowly	2.4%	88.1%	2.1%	10%	1.9%
Total Decomposable		76.9%		82.7%		59.7%

Avg 1985 + 1990 Composition Data (MSW in the US - 2007 Facts and Figures, US EPA OSW Nov. 2008)

Material	Decomposable Category	% Disposed (Wet Wt.)	Percent Moisture	% Disposed (Dry Wt.)
Food	Readily	10.8%	60%	4.3%
Misc. Organics	Moderately	1.5%	25%	1.1%
Paper and paperboard	Moderately	31.1%	6%	29.2%
Wood	Moderately	6.1%	20%	4.8%
Yard waste	Moderately	19.0%	50%	9.5%
Textiles	Slowly	2.4%	10%	2.1%
Total Decomposable		70.8%		51.1%

2000 Composition Data (MSW in the US - 2007 Facts and Figures, US EPA OSW Nov. 2008 - Adjusted to Santa Cruz)

Material	Decomposable Category	% Disposed EPA (Wet Wt.)	% Disposed SCC Calc (Wet Wt.)	Santa Cruz MSW %	Santa Cruz Adjusted	Percent Moisture	% Disposed (Dry Wt.)
Food	Readily	15.4%	12.0%	88.1%	10.6%	60%	4.2%
Produce	Readily				14.5%	60%	5.8%
Misc. Organics	Moderately	1.8%	19.0%	88.1%	16.7%	25%	12.5%
Paper and paperboard	Moderately	29.6%	37.5%	88.1%	33.0%	6%	31.1%
Wood	Moderately	7.0%	3.9%	88.1%	3.5%	20%	2.8%
Yard waste	Moderately	8.7%	3.4%	88.1%	3.0%	50%	1.5%
Vegetative	Moderately				0.7%	50%	0.3%
Textiles	Slowly	4.8%	4.9%	88.1%	4.3%	10%	3.9%
Total Decomposable		67.3%	80.7%		86.3%		62.1%

2005 Composition Data (MSW in the US - 2007 Facts and Figures, US EPA OSW Nov. 2008- Adjusted to Santa Cruz)

Material	Decomposable Category	% Disposed (Wet Wt.)	% Disposed SCC Calc (Wet Wt.)	Santa Cruz MSW %	Santa Cruz Adjusted	Percent Moisture	% Disposed (Dry Wt.)
Food	Readily	17.3%	13.5%	87.8%	11.8%	60%	4.7%
Produce	Readily				10.7%	60%	4.3%
Misc. Organics	Moderately	1.8%	19.0%	87.8%	16.6%	25%	12.5%
Paper and paperboard	Moderately	25.1%	31.8%	87.8%	27.9%	6%	26.2%
Wood	Moderately	7.5%	4.2%	87.8%	3.7%	20%	3.0%
Yard waste	Moderately	7.1%	2.8%	87.8%	2.5%	50%	1.2%
Vegetative	Moderately				0.0%	50%	0.0%
Textiles	Slowly	5.6%	5.7%	87.8%	5.0%	10%	4.5%
Total Decomposable		64.4%	77.0%		78.3%		56.4%

2007 Composition Data (MSW in the US - 2007 Facts and Figures, US EPA OSW Nov. 2008 - Adjusted to Santa Cruz)

Material	Decomposable Category	% Disposed (Wet Wt.)	% Disposed SCC Calc (Wet Wt.)	Santa Cruz MSW %	Santa Cruz Adjusted	Percent Moisture	% Disposed (Dry Wt.)
Food	Readily	18.2%	14.2%	84.4%	11.9%	60%	4.8%
Produce	Readily				15.8%	60%	6.3%
Misc. Organics	Moderately	1.9%	20.0%	84.4%	16.9%	25%	12.7%
Paper and paperboard	Moderately	22.3%	28.3%	84.4%	23.8%	6%	22.4%
Wood	Moderately	7.6%	4.3%	84.4%	3.6%	20%	2.9%
Yard waste	Moderately	6.9%	2.7%	84.4%	2.3%	50%	1.1%
Vegetative	Moderately				0.1%	50%	0.0%
Textiles	Slowly	5.9%	6.0%	84.4%	5.1%	10%	4.6%
Total Decomposable		62.8%	75.4%		79.5%		54.8%

Summary of Decomposable Dry Waste by Filling Era

Decomposable Category	1987	2000	2005	2007
Readily	8.5%	10.0%	9.0%	11.1%
Moderately	49.3%	48.2%	42.9%	39.2%
Slowly	1.9%	3.9%	4.5%	4.6%
Total	59.7%	62.1%	56.4%	54.8%

amounts from each waste category, (cubic feet per dry ton), the decay half life, (years), and the initial gas generation lag time (years). The annual waste input quantities are shown in Table 2.1.

A summary of the input factors used for the Rio Rico Landfill Gas Generation model is shown below in Table 2.5. As noted in Table 2.5, the total potential LFG generation from all decomposable waste categories for the first two modeling eras (1981 – 2002) remains relatively constant at around 9,300 cf/ton (4.7 cf/lb) and then declines in the third era (2003 – 2006) to around 8,300 cf/ton (4.2 cf/lb) and finally declines again in the last era (2007 – closure) to around 7,700 cf/ton (3.9 cf/lb). The decline from the older waste to the newer waste reflects the changing characteristics of the waste composition as the total decomposable fraction is reduced. The major reason for the reduction of decomposable waste in the landfilled wastestream on a national trend basis is the increased diversion of yard waste and paper waste through composting and recycling efforts. Although Santa Cruz County does not have comprehensive public yard waste composting and paper recycling programs in place, it is believed the wastestream has experienced a similar downward trend in decomposable waste disposal such as manufacturers' and suppliers' increased recycling of post-production waste products for cost-savings and to be considered "green", reduction in consumer packaging materials and switching from paper based to plastic packaging, the increase in electronic communications reducing office paper waste, and homeowners becoming more environmentally aware about conserving resources.

The Base Case gas generation model reflects the conditions that are most likely to occur given the waste quantities and characteristics assumed for the Rio Rico Landfill and the existing physical and environmental conditions of the landfill site itself (site configuration, moisture levels, climate, etc.). However, over time it can be expected that there will be deviations from the base case conditions due to changes in the waste characteristics, annual precipitation levels, seasonal climate changes, affects of the gas system operations (i.e. overdrawing and air inducement), impact of capping, and other external influences. The impacts of the physical and environmental variations year to year on the rate of gas generation are modeled by adjusting the decomposable waste decay rate (or half-life). Under favorable conditions, such as higher than normal precipitation and reduced air infiltration, an accelerated rate of decomposition would be expected. Conversely, extended dry weather and more permeable surface conditions leading to increased air intrusion would be expected to decelerate decomposition. To account for changing physical conditions low and high range decay half life and lag period factors for accelerated and decelerated decomposition, respectively, are used in place of the Base Case values. Table 5 presents a summary of the half life and lag period factors used for the accelerated and decelerated cases in comparison to the base case values.

TABLE 2.5
RIO RICO LANDFILL
SUMMARY LFG GENERATION MODEL INPUT FACTORS

Waste Decomposability Category	Percent Dry Weight	Potential[1] LFG Generation (cf/dry ton)	Decay Half Life[2] (years)			Lag Period[2] (years)		
			Base	Accel.	Decel.	Base	Accel.	Decel.
1981 – 1995 (1987 Data)								
Readily Decomposable	8.5%	5,000	1.5	1.2	2	0.3	0.2	0.5
Moderately Decomposable	49.3%	18,000	20	15	25	1.1	0.9	1.3
Slowly Decomposable	1.9%	3,000	40	35	50	6.0	4.5	7.5
All Decomposable Waste	59.7%	9,360	18.0	13.7	22.5	1.14	0.91	1.38
1996 - 2002 (2000 Data)								
Readily Decomposable	10.0%	5,000	1.5	1.2	2	0.3	0.2	0.5
Moderately Decomposable	48.2%	18,000	20	15	25	1.1	0.9	1.3
Slowly Decomposable	3.9%	3,000	40	35	50	6.0	4.5	7.5
All Decomposable Waste	62.1%	9,295	18.3	14.0	22.9	1.28	1.01	1.56
2002 - 2006 (2005 Data)								
Readily Decomposable	9.0%	5,000	1.5	1.2	2	0.3	0.2	0.5
Moderately Decomposable	42.9%	18,000	20	15	25	1.1	0.9	1.3
Slowly Decomposable	4.5%	3,000	40	35	50	6.0	4.5	7.5
All Decomposable Waste	56.4%	8,313	18.7	14.4	23.3	1.36	1.08	1.67
2007 - 2029 (2007 Data)								
Readily Decomposable	11.1%	5,000	1.5	1.2	2	0.3	0.2	0.5
Moderately Decomposable	39.2%	18,000	20	15	25	1.1	0.9	1.3
Slowly Decomposable	4.6%	3,000	40	35	50	6.0	4.5	7.5
All Decomposable Waste	54.8%	7,739	17.9	13.9	22.4	1.35	1.06	1.66

1. Calculation for All Decomposable Waste based on summation of percent dry weight multiplied by the Potential LFG Generation for each decomposable category. (Ex. 8.5% x 5,000 + 49.3% x 18,000 + 1.9% x 3,000 = 9,360).
2. Calculation for All Decomposable Waste based on summation of each decomposable category pro-rated for the individual percent dry weight to the total percent dry weight. (Ex. (8.5% / 59.7% x 1.5) + (49.3%/ 59.7% x 20) + (1.9% / 59.7% x 40) = 18.0).

The LFG generation model was run with initial assumed values for the decay half life's and lag periods for each of the decomposition scenarios. The model output results, adjusted for estimated recovery efficiency, were then compared to Rio Rico Landfill flare blower system LFG recovery flow rates (normalized to 50% methane content). The decay half life's and lag periods were then varied and the model re-run in an attempt to better match the model output with the flare blower system recovery records. After several iterations, the decay half life's and lag periods provided in Table 5 were found to provide a good correlation between the model projection and actual recovery records.

2.3.2 Model Results

The historical and projected annual waste deposition amounts from 1981 through 2029 along with the input parameters noted in Table 2.5 were plugged into the first order decay gas generation model to project the generation of LFG from the Rio Rico Landfill under the Base Case conditions. Similarly, the model was re-run for the Accelerated Case and Decelerated Case scenarios for both landfill closure dates using the associated parameters identified in Table 2.5. The landfill gas generation model was run individually for each filling era and then the results were compiled into a composite output for the overall site. The results are presented in Table 2.6 and shown graphically in Figure 2.1.

Under the Base Case conditions the peak LFG generation from the site is projected to occur in 2030, a year after closure, at a rate of 500 scfm. Peak LFG generation is calculated at approximately 550 scfm for the Accelerated Case conditions and at approximately 440 scfm for the Decelerated Case conditions. Table 6 shows the current gas generation estimates (2009) as 375 scfm, 458 scfm and 319 scfm for the Base Case, Accelerated Case and Decelerated Case conditions, respectively. It should be noted that all the gas production rate results from the model are based on a gas composition with 50% methane.

As seen from the gas generation curves in Figure 2.1, the rate of LFG production has a fairly rapid rise from 2000 – 2009 and then levels off with a more gradual rise from the present year to their respective peaks a year or so after closure when the rate is projected to decline for each case, more rapidly for the Accelerated Case and less rapidly for the Decelerated Case. The leveling off of the rate of increase in LFG generation after 2009 can be directly attributed to the significant loss of waste disposal with the departure of the City of Nogales MSW from the Rio Rico Landfill.

TABLE 2.6
LFG GENERATION AND RECOVERY PROJECTIONS

	LFG GENERATION (SCFM)			LFG RECOVERABLE (SCFM)		
YEAR	BASE CASE	ACCELERATED	DECELERATED	BASE CASE	ACCELERATED	DECELERATED
1981	0	0	0	0	0	0
1982	0	0	0	0	0	0
1983	7	7	7	5	5	5
1984	7	14	7	5	10	5
1985	14	21	14	10	15	10
1986	21	28	14	16	21	10
1987	21	28	21	16	21	16
1988	28	35	21	21	26	16
1989	35	42	28	26	31	21
1990	42	49	35	31	36	26
1991	49	56	35	36	42	26
1992	49	63	42	36	47	31
1993	56	76	49	42	57	36
1994	63	83	56	47	63	42
1995	76	90	63	57	68	47
1996	83	104	69	63	78	52
1997	90	118	76	68	89	57
1998	111	139	90	83	104	68
1999	125	153	104	94	115	78
2000	125	153	111	94	115	83
2001	139	174	118	104	130	89
2002	153	194	132	115	146	99
2003	181	229	153	135	172	115
2004	215	264	181	161	198	135
2005	264	347	222	187	247	156
2006	313	389	257	223	279	183
2007	333	403	278	250	302	208
2008	361	431	299	271	323	224
2009	375	458	319	281	344	240
2010	389	472	340	292	354	255
2011	389	465	333	292	349	250
2012	396	465	340	297	349	255
2013	389	465	340	292	349	255
2014	389	451	340	292	339	255
2015	396	458	347	297	344	260
2016	396	458	340	297	344	255
2017	403	465	347	302	349	260
2018	396	458	347	297	344	260
2019	403	472	361	302	354	271
2020	417	479	368	313	359	276
2021	417	479	368	313	359	276
2022	431	486	382	323	365	286
2023	444	486	389	333	365	292
2024	438	493	389	328	370	292
2025	451	514	396	339	385	297
2026	458	514	410	344	385	307
2027	472	521	410	354	391	307
2028	479	535	424	371	413	328
2029	486	542	438	390	434	351
2030	500	549	444	411	450	365
2031	486	542	444	413	460	378
2032	458	507	431	390	431	366
2033	438	472	403	372	401	342
2034	424	451	396	360	384	336
2035	403	424	375	342	360	319
2036	389	403	368	331	342	313
2037	375	389	347	319	331	295
2038	354	375	340	301	319	289
2039	347	354	326	295	301	277
2040	340	333	319	289	283	272
2041	326	326	313	277	277	266
2042	319	306	306	272	260	260
2043	292	292	306	248	248	260
2044	285	285	285	242	242	242
2045	278	271	271	236	230	230
2046	271	250	264	230	213	224
2047	264	236	257	224	201	218
2048	257	229	257	218	195	218
2049	250	222	250	213	189	213
2050	236	215	243	201	183	207
2051	229	208	236	195	177	201
2052	222	194	229	189	165	195
2053	215	181	222	183	153	189
2054	208	174	215	177	148	183
2055	201	167	208	171	142	177
2056	188	160	208	159	136	177
2057	188	160	201	159	136	171
2058	181	153	194	153	130	165
2059	181	146	188	153	124	159

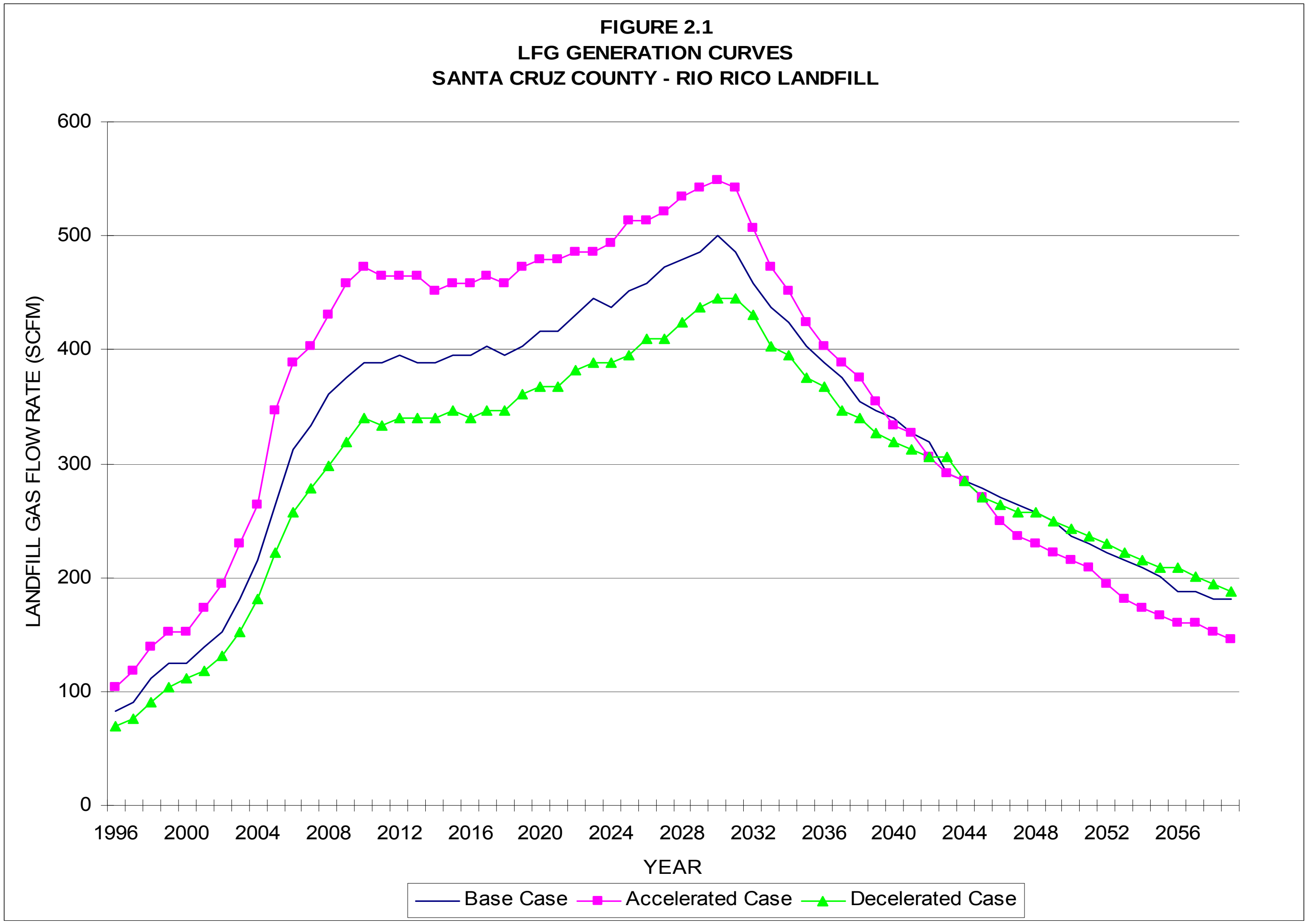


FIGURE 2.1
LFG GENERATION CURVES
SANTA CRUZ COUNTY - RIO RICO LANDFILL
LANDFILL GAS FLOW RATE (SCFM)
600
500
400
300
200
100
0
1996
2000
2004
2008
2012
2016
2020
2024
2028
2032
2036
2040
2044
2048
2052
2056
YEAR
Base Case
Accelerated Case
Decelerated Case

The efficiency of recovering landfill gas generated at the Rio Rico Landfill site will depend upon several factors including: the coverage of the site by landfill gas collection system; the ability of the gas recovery equipment (i.e., blowers) to handle peak flows and exert sufficient vacuum to achieve the full zone of influence around the wells and trenches; the operating conditions of the gas collection and recovery systems; the type and thickness of the cover materials; the landfill surface conditions (i.e., uncapped versus capped).

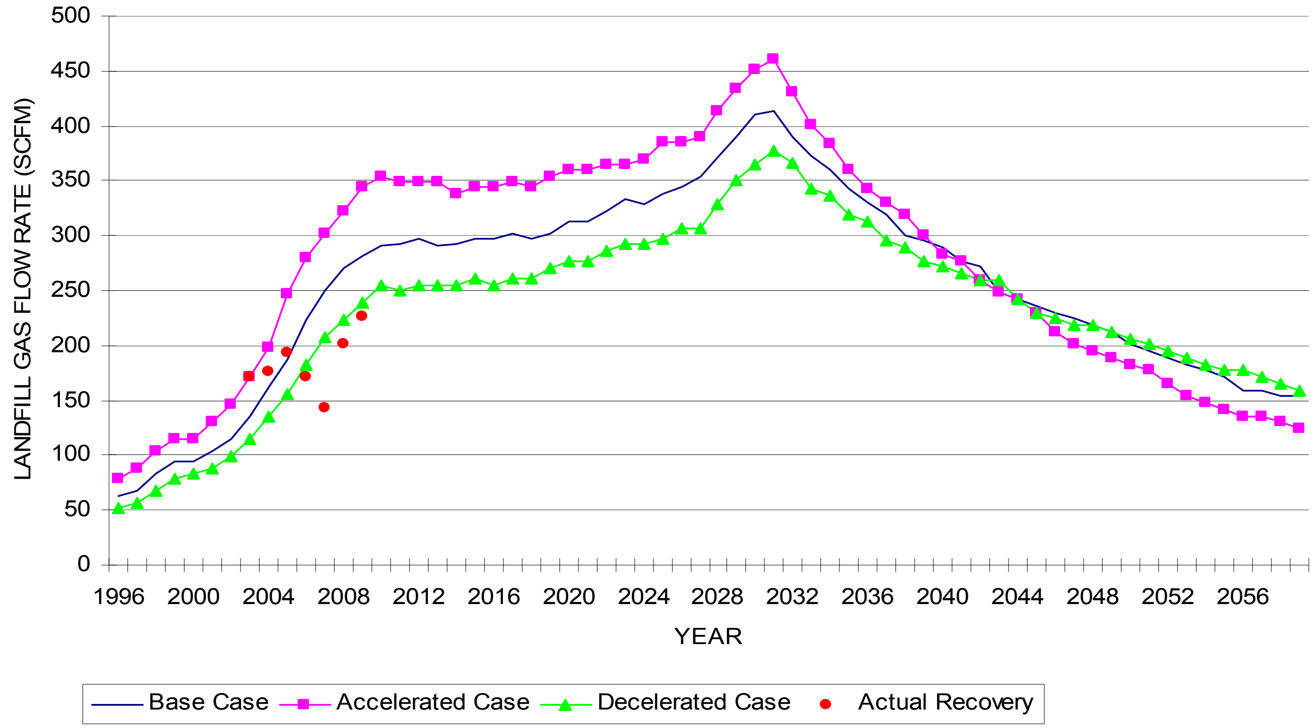
For purposes of maximizing gas collection for LFGTE utilization, if deemed feasible to develop, it is assumed the landfill gas collection system will be expanded to be comprehensive and encompassing the filled areas to achieve effective coverage and zones of influence. Therefore, the capping status of the landfill will be the dominating factor in establishing the collection efficiency. A fully capped area with a complete gas collection system is expected to provide a recovery efficiency of 85 percent or better. In comparison, an uncapped area (daily and intermittent cover only) with gas collection should provide around 75 percent collection efficiency. Recovery efficiencies are assumed to steadily improve from 75 percent to 85 percent as filling reaches capacity, final gas recovery infrastructure is installed and areas are capped.

The construction details of the landfill top cap provided by the County indicate a 30-inch thick cover soil layer having a minimum permeability of 8.8 x 10-5 cm/sec will be placed over the 12-inch operational soil cover. The sideslope cap consists of covering the 12-inch operational soil cover with a 24-inch infiltration barrier soil layer (5.2 x 10-4 cm/sec) and then covering with a 6-inch thick cover soil layer. Achieving a recovery efficiency of 85 percent with this type of final capping and a fully functional and balanced gas collection system covering the site is a reasonable assumption.

For purposes of determining gas recovery rates from the gas generation model results, it has been assumed, based on information provided by the County, that the entire site would be capped when it reaches final capacity and not capped in intermediate phases. Accordingly, it has been assumed capping of the sideslopes would start a year before final closure in 2029 and be fully capped 2 years after closure in 2031. The recovery efficiency was assumed to rise steadily from 75% to 85% over the 4 year capping period.

LFG recovery factors were applied to the landfill gas generation rates of the individual landfill filling eras for the three model cases (base, accelerated and decelerated) to develop estimated landfill gas recovery rates for each case. Table 6 includes the landfill gas recovery projections of the entire site for the three model cases from the start of the landfill operations through 2059, 30 years after closure. The results are shown graphically in Figure 2.2.

FIGURE 2.2
RECOVERABLE LFG CURVES
SANTA CRUZ COUNTY - RIO RICO LANDFILL



Under the Base Case, the projected peak recovery rate is around 410 scfm in the year 2031. By comparison, the projected peak recovery rates for the Accelerated Case and Decelerated Case are around 460 scfm and 380 scfm, respectively. The estimated present (2009) recoverable rates of landfill gas from the entire site are 281 scfm, 344 scfm and 240 scfm for the Base, Accelerated and Decelerated Cases, respectively.

In order to assess the validity of the gas generation model, actual gas recovery data from the Rio Rico Landfill was referenced and compared to the modeled values for the corresponding years. Gas recovery data from the flare blower system for the years 2003 through 2009 (March) was provided by the County that included the rate of gas recovery in standard cubic feet per minute (scfm) and the methane content in percent CH4. In order to provide a direct comparison to the model results, the blower system gas flow readings were normalized to 50% methane content. The normalized individual gas flow readings for each yearly period were then averaged to provide average annual gas recovery rates for 2003 – 2009. The normalized actual gas recovery rates are plotted as points on the LFG model gas recovery curves in Figure 2.

As seen on Figure 2.2, the actual gas recovery values track closely with the Base Case gas recovery curve for 2004 and 2005 and then there is a sudden decline starting in 2006. It is understood that the two interior gas extraction wells (LFGEW 14 and LFGEW 15) were disconnected from the blower system at the end of 2005 to allow waste filling to progress in the area. The timing on the disconnection of these wells corresponds to dramatic reduction in gas recovery at the blower system. The average annual gas recovery dropped around 26 percent from 194 scfm in 2005 to 143 scfm in 2007. Based on this decline in actual gas recovery, it is estimated the effective recovery efficiency dropped from around 75% to around 55%. Applying the lower recovery efficiency factor of 55% to the Base Case curve for the years 2006 – 2009 brings the model in line with the actual gas recovery points for those years.

The model results for the Base Case project LFG will be recoverable at a rate of at least 300 scfm starting in 2010 for 28 years and recoverable gas of at least 340 scfm from 2026 to 2035. A recovery rate of 300 scfm at 50% methane is sufficient to sustain an electric generation rate of around 800 kW.

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3.0 Energy Market Analyses

This chapter of the report provides:

- Overview and background of environmental commodity markets;
- Opportunities in environmental commodity markets specific to the Rio Rico Landfill;
- Recommendations for how to move forward to further develop these environmental commodities;
- Sample costs associated with developing some prospective environmental commodities at the Rio Rico Landfill;

Because of a rapidly changing regulatory and compliance environment at the national and regional levels, this section of the report will focus on general trends and recommendations rather than specific scenarios or case studies. ***It cannot be stressed enough that the following analysis should serve as a foundation upon which the decision makers for the Rio Rico Sanitary Landfill monitor developments in environmental markets and adapt their approach appropriately.***

3.1 ENVIRONMENTAL COMMODITY MARKETS BACKGROUND

Demand for environmental commodity markets have developed for several reasons:

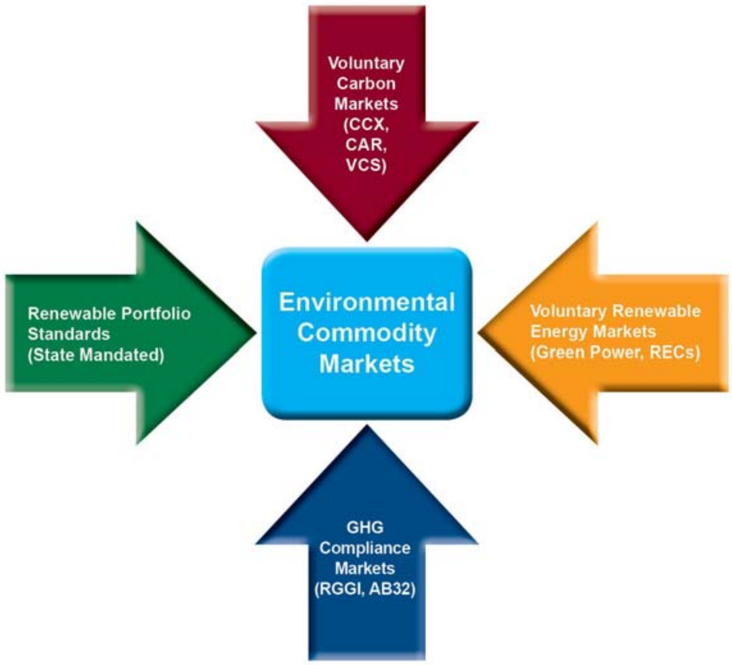
- Voluntary markets for companies and individuals committed to accounting for their entire environmental impact;

- Companies interested in developing new marketing strategies and making product based environmental claims in order to add distinction and separation from their competition;

- Regulatory legislation requiring both the use of renewable electricity by power generation firms in a given jurisdiction, and the mandated reduction of greenhouse gases from larger emitters;

- Companies looking forward to expected compliance requirements have engaged the voluntary markets to learn how they work in order to help prepare for the future.

There are four major sectors that make up environmental commodities markets, comprised of voluntary and compliance markets on one hand, and greenhouse gas and renewable energy commodities on the other. In addition, there are nascent markets developing in water and land use, as well as small air compliance markets in California, but for the most part drivers of environmental market development are those illustrated below.



3.1.1 Renewable Portfolio Standards

Renewable portfolio standards (RPS) are typically state mandates that require power generation firms to source a certain percentage of their generated power from renewable sources such as solar, wind, landfill gas, geothermal, etc. A typical compliance option for power companies that do not have the requisite capacity of renewable energy in-house is to purchase Renewable Energy Certificates (RECs) from 3rd parties. RECs monetize the environmental attributes associated with renewable power generation, and are certified by 3rd parties such as Green-e or Environmental Resources Trust.

There are currently 33 states (including the District of Columbia) with legislated Renewable Portfolio Standards. Arizona adopted rules in November of 2006 that requires 15% use of renewables by 2025. In 2008, 22,926 GWh of renewable electricity were transacted due to compliance requirements, an increase of over 500 percent since 2003.[2]

[2] Lori Bird. et al., “Green Power Marketing in the United States: A Status Report (11th Edition). Technical Report

3.1.2 Voluntary Renewable Energy Markets

Voluntary renewable energy markets are similar to RPS in that they typically use RECs as the transaction vehicle, but the drivers are not compliance but rather corporate social responsibility and business differentiation from competitors. These markets (mostly over the counter and through retailers) have grown similarly to RPS markets, with an increase from 3,840 GWh in 2003 to 22,926 GWh in 2008.[3] Another metric is EPA's Green Power Program, with 1,300 GWh purchased in 2004 by the program's Top 25, compared to 8,800 GWh purchased by the program's Top 25 in 2008.[4] Firms that comprise EPA Green Power Program include Cisco, Pepsi, Johnson & Johnson, and Kohl's Department Stores.

3.1.3 Voluntary Carbon Markets

Like voluntary renewable energy markets, voluntary carbon markets have developed to respond to businesses looking to separate themselves via civic responsibility, as well as companies seeking to understand how regulation may impact their firms in the future, especially with compliance mechanisms already in place across the world with the exception of the United States and Australia. Moreover, there is only one true voluntary marketplace in North America, the Chicago Climate Exchange. The remainders of transactions occur over the counter and revolve around carbon reduction project standards and protocols established by organizations such as the Climate Action Reserve or the Voluntary Carbon Standard. Registries and marketplaces are developing that support these standards. In 2008 123.4 million metric tons of carbon dioxide equivalent ($MtCO_2e$) was transacted in voluntary markets worldwide, an increase of 87% over 2007.[5]

3.1.4 GHG Compliance Markets

Currently in the United States there is one established compliance market, the Regional Greenhouse Gas Initiative (RGGI). Developed by a group of states in the Northeast, RGGI provides for a cap on GHG emissions from power generation facilities, with a requirement to reduce emissions within a repeating three year compliance window. Early compliance windows seek to stabilize GHG emissions, with reductions coming in later years. Companies under the compliance rules may reduce emissions directly; buy 'allowances' from other companies that have reduced beyond their assigned threshold or purchase approved carbon offsets. Allowances (and hence carbon offsets allowed into RGGI) are currently trading at $2.50 a short ton, with daily volumes ranging between 2 and 4 million short tons daily.[6]

NREL/TP-6A2-44094. October 2008. 2008 data are preliminary. Claire Kreycik, National Renewable Energy Laboratory, July 2009
[3] Ibid.
[4] EPA, "Green Power Partner Top 50," http://www.epa.gov/grnpower/toplists/top50.htm
[5] Fortifying the Foundation: State of the Voluntary Carbon Markets 2009. EcoSystems MarketPlace & New Carbon Finance. May 20, 2009.
[6] Carbon Market North America. Point Carbon News, September 18, 2009.

In addition to RGGI, several other states have also mandated GHG reductions and are in the process of developing their implementation plans. California passed AB32 and is about to start its own cap & trade over a variety of industries, followed by the Western Climate Initiative (WCI) which includes California, Oregon, Washington, Arizona, Utah, New Mexico, Montana, and four Canadian provinces.

Lastly, this past summer the US House of Representatives narrowly passed the American Clean Energy and Security Act (ACES), which would implement both a national RPS and cap & trade systems. The Senate introduced the Clean Energy Jobs and American Power Act (CEJAPA) in October. Unlike the House bill, which is a comprehensive clean energy and climate bill, the Senate bill focuses primarily on reducing greenhouse gas emissions. The Senate bill has not yet been debated or voted upon by the Senate. In short, the legislative activity is still all over the place and it's too early to predict any potential impacts on the Rio Rico project.

Overall, while the development of environmental markets has been rapid, these markets are currently in a great deal of flux. Because of the specter of federal legislation, coupled with the economic downturn, both voluntary and regulated markets have provided mixed market signals. On one hand, many analysts believe environmental markets are following the overall economy and are slowing down, evidenced by the halving of carbon permit prices in regulated European markets.[7] On the other hand, some analysts expect global carbon markets to be relatively insulated from the downturn as many companies prepare for new legislation in the US and Australia.[8]

Furthermore, ACES legislation in the US House of Representatives does not provide a concrete interpretation of which voluntary carbon standards may or may not be grandfathered in under the new legislation. The bill reads, "The administrator may approve types of offsets under any such program that are subject to criteria and methodologies of at least equal stringency to the criteria and methodologies for such types of offsets applied under the programs established under State or tribal law or regulation that the Administrator determines meet the criteria of subsection19 (a)(2)".[9]

Most analysts believe this language means only RGGI and CAR (originally established via the State of California) carbon offsets will be allowed into a national program. Others argue that CCX and VCS credits would also qualify. This dilemma is now forcing project owners and developers to make tough decisions as to which program they will characterize their projects for, and forcing many to take a wait and see approach.

Together, these conflicting signals, coupled with a rapidly changing economic and regulatory environment, should make any new market entrant cautious over the next two to five years.

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[7] "Carbon Prices Tumble as Global Downturn Bites," New York Times. January 21, 2009.
[8] "Carbon market to shrug off downturn and top $150 billion this year." Report by New Carbon Finance, reported by BusinessGreen. January 12, 2009.
[9] HR 2454, 11th Congress, 1st Session. July 6, 2009.

3.2 OPPORTUNITIES FOR RIO RICO LANDFILL

Each of the aforementioned environmental markets may play an impact on Santa Cruz County's decision making process. It is important to note that flaring, or capture and use of methane from the landfill may satisfy two separate environmental project opportunities that may be monetized:

3.2.1 Methane Flaring or Destruction

There are established protocols under the Chicago Climate Exchange, Climate Action Reserve and the Voluntary Carbon Standard for the flaring of methane from landfills. Under these protocols, a baseline is established assuming the amount of CO2e that would be released if the methane was not flared, followed by a calculation of the actual or expected methane flared, with the difference being the amount of CO2e reduced. More specifically, the Climate Action Reserve establishes that the GHG reductions are equal to:

- the total amount of uncontrolled methane collected from the landfill and destroyed by the project landfill gas control system, minus
- the portion of methane oxidized in the baseline scenario, minus
- carbon dioxide emissions from fossil fuel consumption, minus
- methane emissions from incomplete destruction of natural gas, if applicable, minus
- indirect carbon dioxide emissions from the use of electricity from the grid, minus
- the effective radius of influence adjustment, if applicable, minus
- the discount factor to account for uncertainties associated with the project monitoring equipment[10]

3.2.2 RECs derived from Electricity Generated from Methane Destruction

Assuming Santa Cruz County builds a LFGTE system; electricity would be generated and sold to the local distributor, Tucson Electric Power (TEP). However, the environmental benefits associated with the electricity generation may be monetized as RECs, certified, and sold on voluntary markets or to satisfy RPS requirements in Arizona.

Given the uncertain economic and regulatory environment over the next several years, it is difficult to predict a definitive course of action as to whether or not to develop one or both of these project types. However, the following observations can be made:

- Santa Cruz County has two potential environmental benefit projects, methane destruction and RECs via renewable energy generation.
- However, a methane flaring or destruction project would likely only be viable if Santa Cruz County were to install additional flares or destruction equipment and new gas collection system. (The existing gas collection and control system at the Rio Rico

[10] "Landfill Project Reporting Protocol – Collecting and Destroying Methane from Landfills. Version 2.0" Climate Action Reserve, November 18, 2008.

Landfill was installed and placed into operation by March 1999. Under most existing protocols, any gas collection and flaring system installed prior to 2001 is ineligible for the project.)

- All other project requirements (ie additionality requirements) for a landfill methane destruction project would need to be met, such as clear ownership of the project, and no regulatory requirements to flare or destroy the methane.
- Santa Cruz County management needs to separate the sale of methane or electricity from the environmental benefits associated with those commodities. There are now two commodities that generate a revenue stream. (ie electricity AND environmental benefits)
- However, in a negotiation of the sale of electricity from a LFGTE system, the distribution company (likely TEP) would want to BUNDLE the purchase of the environmental benefits along with the electricity. (In order to meet their own RPS requirements)
- It is highly likely that these observations may need to be modified in the near future once the regulatory environment becomes clearer.

3.3 RECOMMENDATIONS

Given the uncertainty around upcoming regulations and environmental markets, the following is a recommended course of action over the short term:

- Proceed with a cost estimate to install a LFTGE system. This cost estimate is already absorbed within the project costs for this study, and the outcome helps facilitate next steps.
- Since the LFGTE project provides positive cash flow strictly from the bundled sale of electricity and environmental benefits (it is assumed TEP will purchase both), then further exploration of a methane destruction project can wait until there is more clarity in the market.
- If the LFGTE project is not cash flow positive, exploring the unbundling of the environmental benefits from the electricity sale might yield more revenue.
- Under a non cash flow positive LFGTE scenario, doing a validation of a methane destruction project may also yield additional revenue that would make the entire project viable. Please note that under this scenario, there are restrictions on the life of the project, which are typically 10 years or until the landfill hits a regulatory requirement to flare the methane, whichever comes first.

- It is understood that Santa Cruz County management is exploring government funding for the LFGTE project equipment. Please note that the receipt of government funds for this purpose may invalidate the opportunity to develop a separate methane destruction project.
- Be prepared to negotiate both the sale of electricity AND the sale of the associated environmental benefits as two separate commodities.
- Assign resources to monitor the GHG and renewable energy regulatory and voluntary markets so that this approach may be updated when appropriate.

3.4 COSTS ASSOCIATED WITH GHG & REC PROJECT DEVELOPMENT

It is assumed that like the proposed LFGTE project, any GHG reduction or REC project developed by Santa Cruz County management would be done jointly with a project developer. The following are some ballpark costs that can be expected in the development of such projects.

The process to establish a carbon reductions project includes:

- **Ownership** – Clarifying ownership of the reductions; this can and should be done in-house.
- **Validation** – Performing an informal project assessment or a formalized validation, depending upon which standard the carbon reduction project is looking to use. Stantec project validation work ranges from $5,000 to $10,000 depending on the type of project and the protocol looking to be used.
- **Project Development** – The project developer will manage the project development process, including hiring the validation and verification firms, writing up the project documentation, and shepherding the project through various approvals until it is approved.

  There are two main options for sourcing this work: specialized project aggregators, or consulting firms with knowledge in the area. Typically project aggregators assume more risk, but in return receive a percentage of the project credits rather than straight fee for service. The costs have varied widely within the industry, but expect to pay between 10%-25% of the credit stream to a project developer, and they may request additional fees. In this scenario, they would likely do the assessment/validation themselves.

  Under a straight consulting arrangement, expect to pay between $20,000 and $30,000 for the project development portion only, with the understanding that if the project does pass the verification step, Santa Cruz County would still have to pay those fees.

- **Verification** – Verification is the final step in the process before a project may be serialized and monetized. Stantec regularly performs GHG project verification work, and a ballpark estimate for a project like this would range between $8,000 and $12,000 not including travel costs.

It should be noted that any firm that contributed to the project strategically or with project development would not be eligible to do the verification work due to conflict of interest. In other words, because Stantec has provided guidance on these issues, Stantec would not be able to contract for the verification work down the road specific to this project.

Lastly, there is no requirement to certify the environmental benefits from generating renewable electricity prior to the sale to another party. Certification provides an assurance to a buyer that the benefits have been characterized correctly, but oftentimes the certification takes place in retail rather than wholesale situations.

If Santa Cruz County wanted to sell RECs directly, the Center for Resource Solutions provides a step by step walk through of the process via their Green-e certification program. The documentation can be found at http://www.green-e.org/getcert_re_6steps.shtml**.**

4.0 Project Concepts

The LFG Generation Modeling assessment of the Rio Rico Landfill concluded a recoverable rate of landfill gas of around 300 scfm and above should be available starting in 2010 and continuing for up to 28 years. Recoverable LFG is projected to increase with future filling to a peak of around 400 scfm shortly after the site is expected to close in 2029 and decline steadily back to around 300 scfm by 2038. As previously noted, an LFG recovery rate of 300 scfm (at 50% methane content) is sufficient to sustain an electric production capacity of 800 kW in an engine-generator set.

The purpose of this chapter of the Feasibility Study is to present and evaluate technologies for conversion of landfill gas into usable energy, including electricity, for development of project concepts. This section describes the alternative project concepts for beneficial LFG utilization consistent with the projected rate of recovery and appropriate to energy market conditions. The County will be able to review the alternative project concepts along with technical, economic, regulatory and institutional factors for making decisions on proceeding with the implementation of the most favorable LFGTE project.

The latest LFGTE technologies applicable to the Rio Rico Landfill in terms of gas production quantity and quality as well as utilization are presented along with their advantages and disadvantages, costs, reliability, modularity, implementability and risks. Information on the LFGTE options deemed potentially viable for Santa Cruz County are compiled into a matrix to allow ready comparison between the options for identifying the preferred alternative. Weighted numeric values have been assigned to each rating criteria to facilitate evaluating the options.

The project concept analysis considers the changing LFG production and recovery levels as projected from the model, rising with future waste filling and diminishing after site closure, and how best to optimize LFGTE facility sizing to gas availability over the project's life-cycle.

Various options, including conversion of LFG to Electricity and direct use of landfill gas are presented and discussed in this section.

4.1 LFG TO ELECTRICITY

4.1.1 LFG to Electricity Options

LFG to Electricity options for small to medium size landfills include reciprocating engine-generators, micro-turbines and fuel cells. The most common electric generation system for LFG applications is reciprocating engine-generators which have a proven long-term history of operation. LFG reciprocating generators generally range in size from 500 kW to over 2.0 MW. Micro-turbines are a more recent development in the industry and are gaining popularity, particularly on the smaller sites with lower gas generation rates insufficient to support the minimum flow requirements of a reciprocating generator. Micro-turbines range in size from around 30 kW to 350 kW and have the option of being equipped with a waste heat recovery unit for hot water production. The major advantages of micro-turbines over the reciprocating technology includes its portability and modularity for smaller landfills, ability to combust lower methane content LFG, lower emissions, and less moving parts lowering O&M needs. On the downside, micro-turbines are up to 25% less efficient, have significantly higher per kW installation costs, require high pressure gas delivery and a higher level of gas conditioning to remove contaminants such as siloxanes[11] and do not have the time-tested reliance of reciprocating engines.

Fuel cells fed by LFG are still considered to be in the development stage and not generally available for commercial applications. In addition, they are at a distinct cost disadvantage to the other LFGTE options. Fuel cell installed capital costs are more than double those of a comparably sized reciprocating engine generator system. In consideration of fuel cell technology still being in the development stage and not yet proven for long term reliable service for landfill applications, this technology will not be discussed further for this project.

4.1.2 LFG to Electricity Gas Conditioning and Treatment

Raw landfill gas is generally moist and contains various levels of physical and chemical contaminants that are harmful to combustion equipment for electric generation. Gas conditioning and treatment is conducted upstream of the electric generation equipment to meet genset manufacturer fuel specifications, reduce engine or turbine maintenance and increase operating reliability. Pre-combustion conditioning of landfill gas is necessary for both the reciprocating genset and turbine LFGTE technologies. As noted above, turbines are more sensitive to contaminants that reciprocating engines and thus require a higher level of treatment.

Gas conditioning and treatment for the reciprocating gen-set application would generally include the following:

[11] Siloxanes are derived from silica containing compounds that are found in municipal solid waste such as cosmetic products and are formed in the heat of combustion depositing a hard coating on the internal surfaces of the engine or turbine unit and deteriorating performance.

- Sufficiently sized knockout tank[12] with mist elimination for primary moisture removal
- Gas compression with suction scrubber to meet the engine fuel pressure requirements (3 – 5 psig)
- Air-to-air heat exchanger aftercooling for reducing gas relative humidity
- Post-cooling moisture separator with fine particulate coalescing filter
- Gas re-heater upstream of the engine fuel intake to raise the dew point.

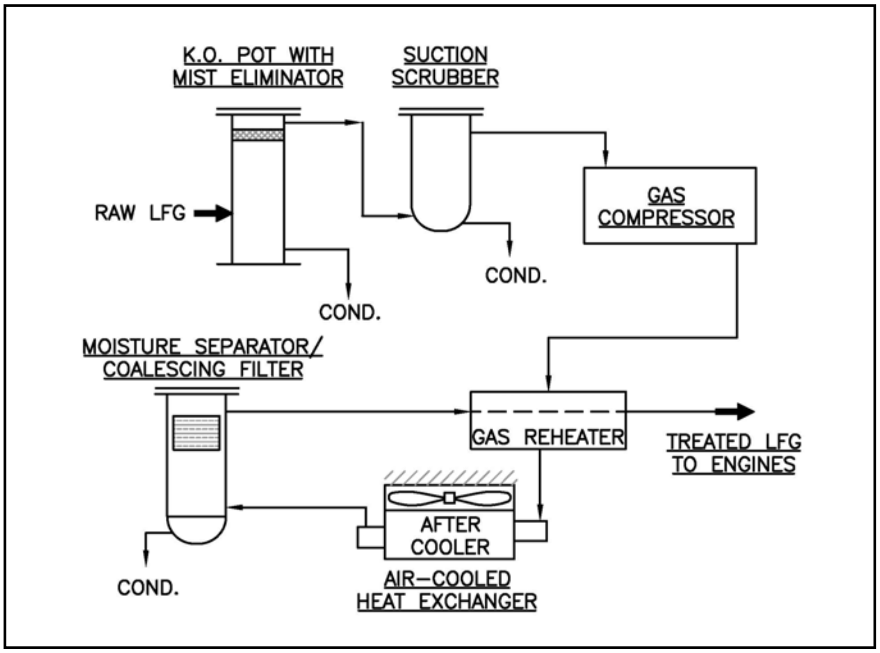
A schematic of a typical LFG treatment system for a reciprocating engine-generator is shown in Figure 4.1.

If hydrogen sulfide levels in the gas are excessive (>2,000 ppm), then additional pre-treatment would be required. Genset manufacturer's also set a limit on the maximum acceptable Siloxane content in the fuel to less than 0.60 ug Si/Btu. At most MSW landfill sites with LFGTE systems, chilling of the gas to 40 deg. F is sufficient to meet the Siloxane threshold of 0.60 ug Si/Btu. Cleaning the gas to meet the Siloxane threshold will limit harmful deposits in the engine combustion chamber.

Gas conditioning requirements for mircoturbines operating on LFG are more extensive than reciprocating engine gen-sets. In addition to the treatment and conditioning requirements noted for the reciprocating engine, microturbines require fuel delivery pressures of around 80 psig necessitating the use of a high-pressure gas compressor system. Booster compressor units are commonly provided by microturbine manufacturers as opposed to having to be purchased separately. Microturbines are also less tolerant to Siloxanes than reciprocating engines and typically require polishing the gas with activated carbon or other suitable process.

[12] A knockout tank is a vessel (typically vertically oriented) used to significantly reduce the velocity of gas flow from the landfill to induce dropping out of water particles and mist in the gas. The knockout tank is usually equipped with a mesh pad above the gas pipe inlet to encourage coalescing of mist.

FIGURE 4.1 - LFG TREATMENT SCHEMATIC FOR RECIPROCATING GENSET



4.1.3 LFG to Electricity Project Costs

The typical installed project cost of a landfill gas fueled reciprocating engine generator system with standard gas pre-treatment equipment comparable to that in Figure 1 is $2,600 per kW of installed capacity or $2.1 million for an 800 kW plant with a single genset. In comparison, the estimated installed project cost for a microturbine based LFGTE facility is $3,700 per kW of installed capacity or $3.0 million for an 800 kW plant with 4 – 200 kW microturbine units. The capital costs include the gas recovery, compression and treatment equipment, electric generating system, grid interconnection and paralleling with TEP within 1 mile of the LFGTE plant, equipment foundations, site work (electrical, mechanical and civil), and utilities. In addition to the installed capital costs, total project costs include engineering design and permitting fees, project and construction management, financing and contingency costs which add between 35% and 40% to the capital costs.

Operation and maintenance costs for LFGTE electric generating systems can be quite variable depending upon the technology and level of gas treatment required. For reciprocating engine genset systems in the 1.0 MW size range, total O&M costs are between 2.0 to 2.5 cents per kWh generated with conventional gas treatment per Figure 4.1. The O&M costs include:

- Maintenance labor (part-time)
- Consumables (oil, filters, plugs, gaskets, rings, valves, etc.)
- Overhauls
- Miscellaneous costs (insurance, fees, etc.)

Maintenance is typically contracted out to equipment manufacturers or packagers, distributors and dealers under multi-year service contracts that are tied to the production of power. Typical service contracts include routine short-interval inspections/adjustments by technicians with periodic replacement of engine oil and filter, coolant, and spark plugs, as well as equipment overhauls at recommended intervals or more frequent if conditions warrant. For reciprocating engine gensets, top-end overhauls (cylinder heads and turbocharger rebuilds) are performed at 12,000 to 15,000 hour intervals and major overhauls (piston/liner replacement, crankshaft inspection, bearings and seals) are performed at 30,000 to 50,000 hour intervals.

Microturbine maintenance includes periodic inspection of the combustors (and associated hot section parts for wear or damage), air and oil filter replacements, overhauls. Due to their sensitivity to contaminants in the air stream, microturbines operating in dry, dusty environments, require frequent air filter replacements. Microturbine overhauls are performed 20,000 to 30,000 hour intervals and include replacing the main shaft with compressor and turbine attached, inspecting and, if needed, replacing the combustor, and inspecting and replacing other internal components that have worn. For microturbine genset systems, total O&M costs are around 4.0 cents per kWh.

4.1.4 LFG to Electricity Capacity Right-Sizing

The results of the gas generation modeling task projected a sustainable recoverable LFG rate of 300 scfm at 50% methane for as much as 28 years starting in 2010. Based on the use of an internal combustion reciprocating engine-generator, this rate of LFG recovery can produce around 800 kW of electricity. Applying microturbine technology instead the reciprocating engine would reduce the potential electrical output to around 720 kW of electricity due to the microturbine's lower efficiency.

Although the gas model base case showed there only to be sufficient recoverable gas to produce around 800 kW in 2010, on-going filling of the Rio Rico Landfill is projected to slowly, but steadily increase the available LFG for recovery eventually reaching about 340 scfm by 2025 and over 400 scfm by 2030 before beginning to gradually taper off after closure of the landfill. If an LFGTE facility was built for Santa Cruz County with a capacity of 800 kW, then the recoverable gas above 300 scfm would not go to beneficial use and would have to be flared. However, installing an LFGTE system that is sized to handle future maximum flow conditions would be an inefficient use of capital resources since the high flow conditions would be for a limited period of time. Right-sizing of the LFGTE system installed capacity is finding the optimum balance of capital cost for additional capacity versus additional revenue from the sale of increased electric generation.

The potential electric generation capacity of an LFGTE plant (reciprocating engine genset or microturbine) was calculated from the gas generation model results assuming all recoverable LFG were converted into electric power. Tables 4.1a and 4.1b show the electric generation capacity for each of the LFG model cases (base, accelerated and decelerated) over the period of 2010 to 2040 for the reciprocating engine and microturbine electric generation options, respectively. The tables also show the percent of the potential electric generation to the installed capacity for 800 kW and 1,000 kW plant sizes for each model case.

For the reciprocating engine generator option base case condition, an installed capacity of 800 kW close to optimum size (potential electric generation of 98% to 100% of installed capacity) for the first 10 years of operation (2010 – 2019), as shown in Table 4.1a. By 2024, an 800 kW reciprocating engine genset plant would be undersized by about 10% losing the opportunity of approximately 80 kW of generating capacity and by 2031, the lost opportunity of electric generation is over 300 kW. Alternatively, installing a 1,000 kW reciprocating engine genset plant will provide sufficient reserve capacity to handle all recoverable LFG under the base case condition for each of the project years with the exception of the 4 peak years from 2029 through 2032. Much of the infrastructure between installing an 800 kW genset and 1,000 kW genset would be similarly sized so the incremental project cost of adding 200 kW capacity is estimated at around $200,000. In order to determine if this premium in capital costs would be justified, the potential gained revenue for the sale of power (and other credits) above 800 kW would need to be evaluated in a present worth analysis.

TABLE 4.1a
POTENTIAL ELECTRIC GENERATION CAPACITY
RECIPROCATING ENGINE GENERATOR OPTION

	RECIP. ENG. ELEC. GENERATION CAP. (KW)			Base Case Percent of Installed Engines if Capacity =		Accel Case Percent of Installed Engines if Capacity =		Decel Case Percent of Installed Engines if Capacity =	
YEAR	BASE CASE	ACCELERATED	DECELERATED	800	1,000	800	1,000	800	1,000
2010	781	949	684	97.7%	78.1%	118.6%	94.9%	85.5%	68.4%
2011	781	935	670	97.7%	78.1%	116.9%	93.5%	83.7%	67.0%
2012	795	935	684	99.4%	79.5%	116.9%	93.5%	85.5%	68.4%
2013	781	935	684	97.7%	78.1%	116.9%	93.5%	85.5%	68.4%
2014	781	907	684	97.7%	78.1%	113.4%	90.7%	85.5%	68.4%
2015	795	921	698	99.4%	79.5%	115.1%	92.1%	87.2%	69.8%
2016	795	921	684	99.4%	79.5%	115.1%	92.1%	85.5%	68.4%
2017	809	935	698	101.2%	80.9%	116.9%	93.5%	87.2%	69.8%
2018	795	921	698	99.4%	79.5%	115.1%	92.1%	87.2%	69.8%
2019	809	949	726	101.2%	80.9%	118.6%	94.9%	90.7%	72.6%
2020	837	963	740	104.7%	83.7%	120.4%	96.3%	92.5%	74.0%
2021	837	963	740	104.7%	83.7%	120.4%	96.3%	92.5%	74.0%
2022	865	977	768	108.2%	86.5%	122.1%	97.7%	95.9%	76.8%
2023	893	977	781	111.6%	89.3%	122.1%	97.7%	97.7%	78.1%
2024	879	991	781	109.9%	87.9%	123.9%	99.1%	97.7%	78.1%
2025	907	1,033	795	113.4%	90.7%	129.1%	103.3%	99.4%	79.5%
2026	921	1,033	823	115.1%	92.1%	129.1%	103.3%	102.9%	82.3%
2027	949	1,047	823	118.6%	94.9%	130.8%	104.7%	102.9%	82.3%
2028	995	1,108	880	124.3%	99.5%	138.5%	110.8%	110.0%	88.0%
2029	1,046	1,164	942	130.7%	104.6%	145.5%	116.4%	117.7%	94.2%
2030	1,101	1,207	979	137.6%	110.1%	150.9%	120.7%	122.3%	97.9%
2031	1,107	1,234	1,012	138.4%	110.7%	154.2%	123.4%	126.5%	101.2%
2032	1,044	1,155	981	130.5%	104.4%	144.3%	115.5%	122.6%	98.1%
2033	996	1,075	917	124.6%	99.6%	134.4%	107.5%	114.7%	91.7%
2034	965	1,028	902	120.6%	96.5%	128.5%	102.8%	112.7%	90.2%
2035	917	965	854	114.7%	91.7%	120.6%	96.5%	106.8%	85.4%
2036	886	917	838	110.7%	88.6%	114.7%	91.7%	104.8%	83.8%
2037	854	886	791	106.8%	85.4%	110.7%	88.6%	98.8%	79.1%
2038	807	854	775	100.8%	80.7%	106.8%	85.4%	96.9%	77.5%
2039	791	807	743	98.8%	79.1%	100.8%	80.7%	92.9%	74.3%
2040	775	759	728	96.9%	77.5%	94.9%	75.9%	90.9%	72.8%

Note: 1. Electric generation capacity based on gross engine-generator heat rate of **10,200 Btu/kWh** and lower heating value (LHV) for methane of 911 Btu/scf.

TABLE 4.1b
POTENTIAL ELECTRIC GENERATION CAPACITY
SANTA CRUZ COUNTY, AZ - RIO RICO LANDFILL
MICROTURBINE OPTION

	MICROTURBINE ELEC. GENERATION CAP. (KW)			Base Case Percent of Installed Engines if Capacity =		Accel Case Percent of Installed Engines if Capacity =		Decel Case Percent of Installed Engines if Capacity =	
YEAR	BASE CASE	ACCELERATED	DECELERATED	800	1,000	800	1,000	800	1,000
2010	699	849	612	87.4%	69.9%	106.1%	84.9%	76.5%	61.2%
2011	699	837	599	87.4%	69.9%	104.6%	83.7%	74.9%	59.9%
2012	712	837	612	89.0%	71.2%	104.6%	83.7%	76.5%	61.2%
2013	699	837	612	87.4%	69.9%	104.6%	83.7%	76.5%	61.2%
2014	699	812	612	87.4%	69.9%	101.5%	81.2%	76.5%	61.2%
2015	712	824	624	89.0%	71.2%	103.0%	82.4%	78.0%	62.4%
2016	712	824	612	89.0%	71.2%	103.0%	82.4%	76.5%	61.2%
2017	724	837	624	90.5%	72.4%	104.6%	83.7%	78.0%	62.4%
2018	712	824	624	89.0%	71.2%	103.0%	82.4%	78.0%	62.4%
2019	724	849	649	90.5%	72.4%	106.1%	84.9%	81.2%	64.9%
2020	749	862	662	93.6%	74.9%	107.7%	86.2%	82.7%	66.2%
2021	749	862	662	93.6%	74.9%	107.7%	86.2%	82.7%	66.2%
2022	774	874	687	96.8%	77.4%	109.3%	87.4%	85.8%	68.7%
2023	799	874	699	99.9%	79.9%	109.3%	87.4%	87.4%	69.9%
2024	787	887	699	98.3%	78.7%	110.8%	88.7%	87.4%	69.9%
2025	812	924	712	101.5%	81.2%	115.5%	92.4%	89.0%	71.2%
2026	824	924	737	103.0%	82.4%	115.5%	92.4%	92.1%	73.7%
2027	849	936	737	106.1%	84.9%	117.1%	93.6%	92.1%	73.7%
2028	890	991	787	111.2%	89.0%	123.9%	99.1%	98.4%	78.7%
2029	936	1,041	842	117.0%	93.6%	130.2%	104.1%	105.3%	84.2%
2030	985	1,080	876	123.1%	98.5%	135.0%	108.0%	109.5%	87.6%
2031	991	1,104	906	123.8%	99.1%	138.0%	110.4%	113.2%	90.6%
2032	934	1,033	877	116.7%	93.4%	129.1%	103.3%	109.7%	87.7%
2033	892	962	821	111.4%	89.2%	120.3%	96.2%	102.6%	82.1%
2034	863	920	807	107.9%	86.3%	115.0%	92.0%	100.8%	80.7%
2035	821	863	764	102.6%	82.1%	107.9%	86.3%	95.5%	76.4%
2036	792	821	750	99.1%	79.2%	102.6%	82.1%	93.8%	75.0%
2037	764	792	708	95.5%	76.4%	99.1%	79.2%	88.4%	70.8%
2038	722	764	693	90.2%	72.2%	95.5%	76.4%	86.7%	69.3%
2039	708	722	665	88.4%	70.8%	90.2%	72.2%	83.1%	66.5%
2040	693	679	651	86.7%	69.3%	84.9%	67.9%	81.4%	65.1%

Note: 1. Electric generation capacity based on gross microturbine heat rate of **11,400 Btu/kWh** and lower heating value (LHV) for methane of 911 Btu/scf.

A preliminary pro forma economic analysis was performed to evaluate the financial gain or loss of increasing the installed capacity from 800 kW to 1,000 kW reciprocating engine genset LFGTE plant. Tables 4.2a and 4.2b present the economic pro formas for the 800 kW and 1,000 kW reciprocating genset options, respectively. For purposes of the preliminary economic analysis, revenues are based strictly on the sale of electricity to the grid and do not account for other potential revenue sources such renewable energy credits (RECs) or greenhouse gas reduction credits due to the current turmoil in the market for these environmental benefits. Assumptions applied to the pro formas are stated at the bottom of the tables. An electric sales rate of $0.06 / kWh in 2010 was assumed with an escalation rate of 2.5% per year. Operating costs are based on an O&M rate of $0.021/kWh with an inflation rate of 3.0% per year. Debt service on the total installed capital cost was assumed to be amortized over a 15 year period financed through municipal bonding at an interest rate of 1.5%.

The pro forma analysis covers a period of 30 years from an assumed project start date of 2011 through 2040. The net profit (loss) for each year was calculated by deducting from the electric sales revenues the annual operating costs and the debt service through the year 15. The net present worth of the net profit (loss) for 10 years, 20 years and 30 years was then determined by applying an assumed discount rate of 4.0%. The results of the net present worth show the 800 kW reciprocating genset option has a slight economic advantage over the 1,000 kW option from $96,000 to $126,000 for the three present worth periods. However, since this economic advantage is relatively small compared to the net present worth values, investing the $200,000 premium for the larger genset should still be considered until a more detailed economic analysis can be developed once the project is in the final design stages. The pro forma analysis tables also shows the simple payback period for the 800 kW genset at around 4 years while the 1,000 kW genset is around 4.5 years. The payback period is the number of years of the annual revenue to equal the initial capital cost of the LFGTE plant.

The LFG modeling was based on future waste filling projections without the municipal solid waste flow from the City of Nogales, Tucson Recycling, Waste Management and Patagonia which stopped sending their MSW to the Rio Rico Landfill in 2009. The City of Nogales, Tucson Recycling, Waste Management and Patagonia generate approximately 21,000 tons per year of MSW. The re-introduction of the Nogales MSW into the Rio Rico Landfill would increase the recoverable rate of LFG. Assuming the Nogales MSW returned by 2010, it is estimated recoverable LFG under the Base Case conditions would increase by around 40 scfm by 2015 adding another 100 kW of electric generating capacity. Similarly, with the addition of the Nogales MSW, recoverable LFG would increase by around 70 scfm in 2020, 95 scfm in 2025 and 130 scfm by 2030 and increase electric generating capacities by around 200 kW, 250 kW and 350 kW, respectively.

The re-introduction of the Nogales MSW to the Rio Rico Landfill and the commensurate increase in recoverable LFG and electric generation capacity would favor installation of a 1,000 kW capacity genset over an 800 kW genset. The analysis of electric generation capacity shows without the Nogales MSW, a 1,000 kW genset would operate at no more than 80% capacity for the first 10 years and wouldn't reach full capacity until 20 years. In comparison, with the Nogales MSW, the 1,000 kW genset would reach 90% capacity within 5 years and 100% capacity within 10 years.

One of the major advantages offered by the microturbine option over a reciprocating engine genset is its modularity that allows closely matching the installed capacity to the available gas recovery. The range in microturbine capacities from 30 kW to 350 kW provides maximum flexibility in right-sizing to the available amount of landfill gas over time where units can be added as gas production increases until site closure and removed as production declines after closure. Table 4.1b presents the potential electric generation capacity of the microturbine option for the three (3) gas model cases and the percent of installed capacity for an 800 kW and 1,000 kW microtubine LFGTE plant. As noted for the base case model, an 800 kW microturbine plant would provide sufficient installed capacity to meet the projected potential electric generation capacity through 2024. By 2028, the projected available recoverable LFG could generate an additional 90 kW above an installed capacity of 800 kW. This increment increases to around 190 kW of additional potential electric generation by the peak year in 2031. The benefit of the microturbine option is that a decision could be made in the future when the availability of additional gas is proven to add another 100 kW or 200 kW unit to the LFGTE plant to take maximum advantage of the recoverable gas. Offsetting the right-sizing advantage of the microturbine option over the reciprocating engine generator option is the approximately 10% loss in electric generation efficiency and over 75% premium in installed per kW project costs.

TABLE 4.2a
LANDFILL GAS TO ENERGY PRO FORMA
SANTA CRUZ COUNTY, AZ - RIO RICO LANDFILL
RECIPROCATING ENGINE GENERATOR OPTION (800 KW CAPACITY)

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
LFG Recovery - Base Case (scfm)	292	297	292	292	297	297	302	297	302	313	313	323	333	328	339
Energy Availability (mmBtu/hr)	7.980	8.123	7.980	7.980	8.123	8.123	8.265	8.123	8.265	8.550	8.550	8.835	9.120	8.978	9.263
Electric Output (kW)	782	796	782	782	796	796	810	796	810	838	838	866	894	880	908
Electric Production (kWh)	6,236,605	6,347,973	6,236,605	6,236,605	6,347,973	6,347,973	6,459,341	6,347,973	6,459,341	6,682,076	6,682,076	6,904,812	7,127,548	7,016,180	7,238,916
Loading of Gen-Set (%)	98%	100%	98%	98%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Revenues:															
Energy	$ 383,551	$400,160	$ 402,968	$413,043	$430,929	$441,702	$460,688	$464,063	$484,010	$513,217	$526,048	$557,172	$589,524	$594,821	$629,047
Environmental Credits															
REC Credits															
GHG Reduction															
TOTAL REVENUE($):	**$ 383,551**	**$400,160**	**$ 402,968**	**$413,043**	**$430,929**	**$441,702**	**$460,688**	**$464,063**	**$484,010**	**$513,217**	**$526,048**	**$557,172**	**$589,524**	**$594,821**	**$629,047**
($/kWh):	$ 0.062	$ 0.063	$ 0.065	$ 0.066	$ 0.068	$ 0.070	$ 0.071	$ 0.073	$ 0.075	$ 0.077	$ 0.079	$ 0.081	$ 0.083	$ 0.085	$ 0.087
Operating Costs:															
LFGTE Operation & Maintanence	$ 134,898	$141,426	$ 143,113	$147,406	$154,540	$159,176	$166,828	$168,870	$176,987	$188,583	$194,241	$206,737	$219,808	$222,865	$236,838
O&M Rate ($/kWh)	$ 0.0216	$ 0.0223	$ 0.0229	$ 0.0236	$ 0.0243	$ 0.0251	$ 0.0258	$ 0.0266	$ 0.0274	$ 0.0282	$ 0.0291	$ 0.0299	$ 0.0308	$ 0.0318	$ 0.0327
Operation Costs Total ($)	**134,898**	**141,426**	**143,113**	**147,406**	**154,540**	**159,176**	**166,828**	**168,870**	**176,987**	**188,583**	**194,241**	**206,737**	**219,808**	**222,865**	**236,838**
Debt Service:	**$119,162**	**$119,162**	**$119,162**	**$119,162**	**$119,162**	**$119,162**	**$119,162**	**$119,162**	**$119,162**	**$119,162**	**$119,162**	**$119,162**	**$119,162**	**$119,162**	**$119,162**
Total Annual Cost ($):	**$ 254,059**	**$260,587**	**$ 262,275**	**$266,568**	**$273,701**	**$278,338**	**$285,989**	**$288,031**	**$296,149**	**$307,745**	**$313,402**	**$325,898**	**$338,969**	**$342,026**	**$355,999**
NET PROFIT (LOSS):	**$ 129,492**	**$139,573**	**$ 140,694**	**$146,475**	**$157,228**	**$163,365**	**$174,698**	**$176,032**	**$187,861**	**$205,473**	**$212,646**	**$231,274**	**$250,555**	**$252,795**	**$273,047**
NET PRESENT VALUE (2011):	**$ 129,492**	**$134,205**	**$ 130,079**	**$130,216**	**$134,399**	**$134,274**	**$138,067**	**$133,770**	**$137,268**	**$144,362**	**$143,656**	**$150,231**	**$156,496**	**$151,822**	**$157,678**

	Year 16	Year 17	Year 18	Year 19	Year 20	Year 21	Year 22	Year 23	Year 24	Year 25	Year 26	Year 27	Year 28	Year 29	Year 30
	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
LFG Recovery - Base Case (scfm)	344	354	371	390	411	413	390	372	360	342	331	319	301	295	289
Energy Availability (mmBtu/hr)	9.405	9.690	10.156	10.678	11.240	11.305	10.659	10.175	9.852	9.367	9.044	8.721	8.237	8.075	7.914
Electric Output (kW)	922	950	996	1,047	1,102	1,108	1,045	998	966	918	887	855	808	792	776
Electric Production (kWh)	7,350,284	7,573,020	7,936,822	8,345,171	8,784,703	8,835,190	8,330,322	7,951,671	7,699,237	7,320,586	7,068,152	6,815,718	6,437,067	6,310,850	6,184,633
Loading of Gen-Set (%)	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	99%	97%
Revenues:															
Energy	$654,692	$691,395	$742,724	$800,461	$863,686	$890,365	$860,475	$841,896	$835,549	$814,317	$805,893	$796,539	$771,094	$774,874	$778,361
Environmental Credits															
REC Credits															
GHG Reduction															
TOTAL REVENUE($):	**$654,692**	**$691,395**	**$742,724**	**$800,461**	**$863,686**	**$890,365**	**$860,475**	**$841,896**	**$835,549**	**$814,317**	**$805,893**	**$796,539**	**$771,094**	**$774,874**	**$778,361**
($/kWh):	$ 0.089	$ 0.091	$ 0.094	$ 0.096	$ 0.098	$ 0.101	$ 0.103	$ 0.106	$ 0.109	$ 0.111	$ 0.114	$ 0.117	$ 0.120	$ 0.123	$ 0.126
Operating Costs:															
LFGTE Operation & Maintanence	$247,696	$262,858	$283,750	$307,299	$333,189	$345,157	$335,197	$329,560	$328,670	$321,881	$320,105	$317,933	$309,278	$312,311	$315,246
O&M Rate ($/kWh)	$ 0.0337	$ 0.0347	$ 0.0358	$ 0.0368	$ 0.0379	$ 0.0391	$ 0.0402	$ 0.0414	$ 0.0427	$ 0.0440	$ 0.0453	$ 0.0466	$ 0.0480	$ 0.0495	$ 0.0510
Operation Costs Total ($)	**247,696**	**262,858**	**283,750**	**307,299**	**333,189**	**345,157**	**335,197**	**329,560**	**328,670**	**321,881**	**320,105**	**317,933**	**309,278**	**312,311**	**315,246**
Debt Service:															
Total Annual Cost ($):	**$247,696**	**$262,858**	**$283,750**	**$307,299**	**$333,189**	**$345,157**	**$335,197**	**$329,560**	**$328,670**	**$321,881**	**$320,105**	**$317,933**	**$309,278**	**$312,311**	**$315,246**
NET PROFIT (LOSS):	**$406,996**	**$428,537**	**$458,974**	**$493,161**	**$530,496**	**$545,208**	**$525,278**	**$512,337**	**$506,878**	**$492,436**	**$485,788**	**$478,606**	**$461,816**	**$462,564**	**$463,115**
NET PRESENT VALUE (2011):	**$225,991**	**$228,799**	**$235,625**	**$243,438**	**$251,796**	**$248,826**	**$230,510**	**$216,183**	**$205,654**	**$192,110**	**$182,227**	**$172,628**	**$160,165**	**$154,255**	**$148,498**

800 kW Genset Net Present Worth Summary	
NPW of Income (yrs 1-10)	**$1,346,131**
NPW of Income (yrs 1-20)	**$3,291,663**
NPW of Income (yrs 1-30)	**$5,202,719**

Simple Payback Period of Cap. Cost: 4 Yrs

Assumptions:
LFG recovery based on LFG Generation Model Base Case Condition

Genset Output Rating =	800 kW
Genset Heat Rate =	10,200 Btu/kWh
Landfill Gas Lower Heat Value =	456 Btu/cf
Genset Availability Factor =	91%
Electric Sales Rate (2010) =	0.06 $/kWh
Annual Energy Escalation Factor =	2.50%
Annual Inflation Factor =	3.00%
O&M Rate =	0.021 $/kWh
Total LFGTE Plant Capital Cost =	$1,590,000
Bonding Interest Rate =	1.50%
Amortization Period =	15 years
Discount Rate =	4.00%

TABLE 4.2b
LANDFILL GAS TO ENERGY PRO FORMA
SANTA CRUZ COUNTY, AZ - RIO RICO LANDFILL
RECIPROCATING ENGINE GENERATOR OPTION (1000 KW CAPACITY)

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
LFG Recovery - Base Case (scfm)	292	297	292	292	297	297	302	297	302	313
Energy Availability (mmBtu/hr)	7.980	8.123	7.980	7.980	8.123	8.123	8.265	8.123	8.265	8.550
Electric Output (kW)	782	796	782	782	796	796	810	796	810	838
Electric Production (kWh)	6,236,605	6,347,973	6,236,605	6,236,605	6,347,973	6,347,973	6,459,341	6,347,973	6,459,341	6,682,076
Loading of Gen-Set (%)	78%	80%	78%	78%	80%	80%	81%	80%	81%	84%
Revenues:										
Energy	$ 383,551	$400,160	$ 402,968	$413,043	$430,929	$441,702	$460,688	$464,063	$484,010	$513,217
Environmental Credits										
REC Credits										
GHG Reduction										
TOTAL REVENUE($):	**$ 383,551**	**$400,160**	**$ 402,968**	**$413,043**	**$430,929**	**$441,702**	**$460,688**	**$464,063**	**$484,010**	**$513,217**
($/kWh):	$ 0.062	$ 0.063	$ 0.065	$ 0.066	$ 0.068	$ 0.070	$ 0.071	$ 0.073	$ 0.075	$ 0.077
Operating Costs:										
LFGTE Operation & Maintanence	$ 134,898	$141,426	$ 143,113	$147,406	$154,540	$159,176	$166,828	$168,870	$176,987	$188,583
O&M Rate ($/kWh)	$ 0.0216	$ 0.0223	$ 0.0229	$ 0.0236	$ 0.0243	$ 0.0251	$ 0.0258	$ 0.0266	$ 0.0274	$ 0.0282
Operation Costs Total ($):	**134,898**	**141,426**	**143,113**	**147,406**	**154,540**	**159,176**	**166,828**	**168,870**	**176,987**	**188,583**
Debt Service:	**$134,150**	**$134,150**	**$134,150**	**$134,150**	**$134,150**	**$134,150**	**$134,150**	**$134,150**	**$134,150**	**$134,150**
Total Annual Cost ($):	**$ 269,048**	**$275,576**	**$ 277,263**	**$281,557**	**$288,690**	**$293,326**	**$300,978**	**$303,020**	**$311,138**	**$322,734**
NET PROFIT (LOSS):	**$ 114,503**	**$124,584**	**$ 125,705**	**$131,486**	**$142,239**	**$148,376**	**$159,710**	**$161,043**	**$172,872**	**$190,484**
NET PRESENT VALUE (2011):	**$ 114,503**	**$119,792**	**$ 116,221**	**$116,890**	**$121,586**	**$121,954**	**$126,221**	**$122,379**	**$126,316**	**$133,831**

	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
LFG Recovery - Base Case (scfm)	313	323	333	328	339	344	354	371	390	411
Energy Availability (mmBtu/hr)	8.550	8.835	9.120	8.978	9.263	9.405	9.690	10.156	10.678	11.240
Electric Output (kW)	838	866	894	880	908	922	950	996	1,047	1,102
Electric Production (kWh)	6,682,076	6,904,812	7,127,548	7,016,180	7,238,916	7,350,284	7,573,020	7,936,822	8,345,171	8,784,703
Loading of Gen-Set (%)	84%	87%	89%	88%	91%	92%	95%	100%	100%	100%
Revenues:										
Energy	$526,048	$557,172	$589,524	$594,821	$629,047	$654,692	$691,395	$742,724	$800,461	$863,686
Environmental Credits										
REC Credits										
GHG Reduction										
TOTAL REVENUE($):	**$526,048**	**$557,172**	**$589,524**	**$594,821**	**$629,047**	**$654,692**	**$691,395**	**$742,724**	**$800,461**	**$863,686**
($/kWh):	$ 0.079	$ 0.081	$ 0.083	$ 0.085	$ 0.087	$ 0.089	$ 0.091	$ 0.094	$ 0.096	$ 0.098
Operating Costs:										
LFGTE Operation & Maintanence	$194,241	$206,737	$219,808	$222,865	$236,838	$247,696	$262,858	$283,750	$307,299	$333,189
O&M Rate ($/kWh)	$ 0.0291	$ 0.0299	$ 0.0308	$ 0.0318	$ 0.0327	$ 0.0337	$ 0.0347	$ 0.0358	$ 0.0368	$ 0.0379
Operation Costs Total ($):	**194,241**	**206,737**	**219,808**	**222,865**	**236,838**	**247,696**	**262,858**	**283,750**	**307,299**	**333,189**
Debt Service:	**$134,150**	**$134,150**	**$134,150**	**$134,150**						
Total Annual Cost ($):	**$328,391**	**$340,887**	**$353,958**	**$357,015**	**$236,838**	**$247,696**	**$262,858**	**$283,750**	**$307,299**	**$333,189**
NET PROFIT (LOSS):	**$197,657**	**$216,285**	**$235,566**	**$237,806**	**$392,209**	**$406,996**	**$428,537**	**$458,974**	**$493,161**	**$530,496**
NET PRESENT VALUE (2011):	**$133,530**	**$140,495**	**$147,134**	**$142,820**	**$226,491**	**$225,991**	**$228,799**	**$235,625**	**$243,438**	**$251,796**

	Year 21	Year 22	Year 23	Year 24	Year 25	Year 26	Year 27	Year 28	Year 29	Year 30
	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
LFG Recovery - Base Case (scfm)	413	390	372	360	342	331	319	301	295	289
Energy Availability (mmBtu/hr)	11.305	10.659	10.175	9.852	9.367	9.044	8.721	8.237	8.075	7.914
Electric Output (kW)	1,108	1,045	998	966	918	887	855	808	792	776
Electric Production (kWh)	8,835,190	8,330,322	7,951,671	7,699,237	7,320,586	7,068,152	6,815,718	6,437,067	6,310,850	6,184,633
Loading of Gen-Set (%)	100%	100%	100%	97%	92%	89%	86%	81%	79%	78%
Revenues:										
Energy	$890,365	$860,475	$841,896	$835,549	$814,317	$805,893	$796,539	$771,094	$774,874	$778,361
Environmental Credits										
REC Credits										
GHG Reduction										
TOTAL REVENUE($):	**$890,365**	**$860,475**	**$841,896**	**$835,549**	**$814,317**	**$805,893**	**$796,539**	**$771,094**	**$774,874**	**$778,361**
($/kWh):	$ 0.101	$ 0.103	$ 0.106	$ 0.109	$ 0.111	$ 0.114	$ 0.117	$ 0.120	$ 0.123	$ 0.126
Operating Costs:										
LFGTE Operation & Maintanence	$345,157	$335,197	$329,560	$328,670	$321,881	$320,105	$317,933	$309,278	$312,311	$315,246
O&M Rate ($/kWh)	$ 0.0391	$ 0.0402	$ 0.0414	$ 0.0427	$ 0.0440	$ 0.0453	$ 0.0466	$ 0.0480	$ 0.0495	$ 0.0510
Operation Costs Total ($):	**345,157**	**335,197**	**329,560**	**328,670**	**321,881**	**320,105**	**317,933**	**309,278**	**312,311**	**315,246**
Debt Service:										
Total Annual Cost ($):	**$345,157**	**$335,197**	**$329,560**	**$328,670**	**$321,881**	**$320,105**	**$317,933**	**$309,278**	**$312,311**	**$315,246**
NET PROFIT (LOSS):	**$545,208**	**$525,278**	**$512,337**	**$506,878**	**$492,436**	**$485,788**	**$478,606**	**$461,816**	**$462,564**	**$463,115**
NET PRESENT VALUE (2011):	**$248,826**	**$230,510**	**$216,183**	**$205,654**	**$192,110**	**$182,227**	**$172,628**	**$160,165**	**$154,255**	**$148,498**

1000 kW Genset Net Present Worth Summary	
NPV of Income (yrs 1-10)	**$ 1,219,695**
NPV of Income (yrs 1-20)	**$ 3,195,813**
NPV of Income (yrs 1-30)	**$ 5,106,869**

Simple Payback Period of Cap. Cost: **4.5 Yrs**

Assumptions:
LFG recovery based on LFG Generation Model Base Case Condition

Genset Output Rating =	1000 kW
Genset Heat Rate =	10,200 Btu/kWh
Landfill Gas Lower Heat Value =	456 Btu/cf
Genset Availability Factor =	91%
Electric Sales Rate (2010) =	0.06 $/kWh
Annual Energy Escalation Factor =	2.50%
Annual Inflation Factor =	3.00%
O&M Rate =	0.021 $/kWh
Total LFGTE Plant Capital Cost =	$ 1,790,000
Bonding Interest Rate =	1.50%
Amortization Period =	15 years
Discount Rate =	4.00%

4.1.5 Advantages and Disadvantages of LFG to Electricity Options

Electric generation from LFG is the most widely used technology application in the industry due to its several advantages over other options. A readily available market for the energy is always available unlike the direct use option where demand for the medium Btu gas is subject to fluctuations or being completely eliminated. Other than interconnection with the grid, all development work for the LFG to Electricity option is contained on-site eliminating the need for right-of-ways or easements over private property for gas transmission pipelines. The electric generation option also offers the benefit of securing environmental based credits such as Renewable Energy Credits (RECs) bought by utility companies seeking to comply with “green” power requirements in their portfolio. The primary disadvantage of electric generation versus direct use of LFG is the potentially greater project costs and O&M costs, increased equipment requirements, and longer implementation period.

Reciprocating engine gensets have a number of advantages over microturbines for LFG to electricity generation. Reciprocating engine gensets are significantly less costly both in terms of capital costs and operation and maintenance costs. As noted above, an 800 kW reciprocating engine genset facility has an estimated project cost of around $1.7 million as compared to around $3.0 million for the microturbine facility. O&M costs of the microturbine facility are also about double that of a comparably sized reciprocating genset facility. Microturbines are still a relatively new technology that doesn’t have the long-term track record of reliability seen with reciprocating engine gensets that have been around for nearly 100 years.

On the other hand, microturbines, with their small size range, have the distinct advantage being extremely modular to closely match installed capacity to landfill gas availability. This also means that a single microturbine unit can be taken offline for servicing or repairs without a significant loss in plant production while having to service the much larger capacity reciprocating engine genset means the electric generation plant is completely offline in the case of a plant with a single 800 – 1,000 kW genset unit. Microturbines allow optimizing plant uptime and total electric production. Microturbines are also more tolerant of lower methane content in landfill gas than reciprocating engine gensets. Microturbines can combust LFG with a little as 35% methane whereas reciprocating engine gensets require at least 42% methane content. Microturbines have more favorable emission characteristics than reciprocating gensets with a much lower nitrous oxide (NOx) emissions rate. Finally, microturbines are designed to readily accommodate upgrading to combined heat and power operating mode with the furnishing of an integrated heat exchanger to capture the exhaust waste heat that can be used to generate hot water or to drive absorption cooling and dessicant drying equipment for on-site or remote utilization and increasing the overall thermal efficiency of the microturbine to over 70%.

When comparing advantages and disadvantages along with costs for the two electric generation technologies, the reciprocating genset option comes out ahead of the microturbine option.

Table 4.3 presented and discussed below provides a summary of the LFGTE technology options and ratings matrix that supports the preference for the reciprocating genset option over the microturbine.

4.2 DIRECT USE OPTION

In addition to electric generation technologies, direct use of LFG as a medium Btu fuel to reduce or offset fossil fuel usage by an offsite customer is an alternative that is worth serious consideration. Direct use of LFG by a nearby institution or manufacturer with a significant and steady demand for boiler fuel typically requires minimal pre-treatment to reduce moisture and filter particulates and modify burner equipment to accommodate the medium Btu LFG. Other direct use markets include industries with drying or kiln operations such as asphalt or cement plants such as the one immediately to the South of the landfill on the West Frontage Road. Direct use applications are typically the simplest and most cost effective to implement of the LFG utilization technologies. The primary disadvantage of the direct use option is reliance on the customer to maintain fairly continuous and long-term demand for the gas which can be difficult in fluctuating market conditions.

4.2.1 Direct Use Project Costs

Direct use project costs for a specific gas recovery capacity (i.e., 300 scfm) are much more variable than the LFGTE electric generation option due to the potential wide range in the location of the end-user and their gas quality/pressure requirements. Typical direct use gas compression and treatment systems in the 300 scfm to 500 scfm capacity range have a total installed capital cost of around $300 per scfm of gas processing capacity. This does not include costs to modify the fuel burning equipment on the customer's end (i.e., burner modifications to accommodate medium Btu LFG). The estimated capital cost of constructing a pressurized gas transmission main from the landfill to the direct use customer is around $60 per foot (assuming non-roadway routes). For example, the estimated direct use capital cost of installing a landfill gas compression and treatment facility to deliver 300 scfm of medium Btu gas at 15 psig to a manufacturing plant three (3) miles from the landfill site is around $1.0 million. The associated total project cost with engineering design and permitting fees, project and construction management, financing and contingency costs would be around $1.4 million.

4.2.2 Direct Use Capacity Right-Sizing

The optimum sizing of the equipment for processing and pressurizing landfill gas for sale to local medium Btu markets will depend upon the maximum demand of the Direct Use customer(s). The equipment for treating the gas (beyond that required for flaring) would need to be capable of handling the peak instantaneous LFG demand of the Direct Use customer to meet their maximum product manufacturing rate or an agreed upon upper rate. Once the fuel utilization loads (flow and pressure) of the potential Direct Use customer(s) is defined, optimum sizing of the gas treatment system could be evaluated. Ideally, the Direct Use market would have sufficient demand to consume all available recovered LFG. However, this is rarely the case since manufacturers generally have fluctuating energy demands over the course of a day and throughout the year. Storage of excess recovered LFG to allow matching of demand is generally impractical due to the cost of building large storage tanks and extreme high pressures required for storage.

4.2.3 Advantages and Disadvantages of the Direct Use Option

Direct use of landfill gas as a medium Btu fuel for sale to one or multiple local manufacturers or industries involves the least level of technology and usually has the lowest cost to implement as compared to other LFG utilization options. Pre-treatment of the raw gas as a supplemental or dedicated fuel for boilers, kilns, dryers or other combustion application commonly limited to removing free moisture and filtering particulates. The major disadvantages of the direct use option include the need by the user to retrofit their burner equipment to accommodate the lower Btu fuel as compared to natural gas or oil; the user must be with reasonable distance of the landfill site (i.e., <5miles) to make the project cost effective; the recovered gas must be used or it is lost; and the direct use market is subject to reduced energy demands or going out of business.

4.2.4 Direct Use Market

We have been unable to identify any potential customers within the vicinity of the landfill that would have sufficient demand for direct use of LFG, singularly or collectively, to come close to matching the projected output from the landfill. At 300 scfm of recovered LFG with 50% methane, the equivalent energy production from the site would be around 9.1 million Btu's per hour or 91 therms per hour. In addition to the lack of total energy demand by potential users within the vicinity of the landfill coming close to matching the LFG output of the site, we are not aware of any potential users such as industrial or manufacturing markets that would operate over a three-shift/day, 7-day per week operating schedule needed to sustain a direct use LFG project since downtime storage of LFG is not a viable option. As a result of the apparent lack of a suitable direct use market, it has been ruled out from further consideration.

4.3 COMBINED HEAT & POWER OPTIONS

In addition to LFG to Electricity and Direct Use options, a third less common option is known as combined heat and power (CHP). CHP typically involves capturing the waste heat produced by an LFG fed engine-generator set such as from the engine's heated jacket water or exhaust gases for thermal conversion to steam or hot water for near- or on-site use. The cogeneration of electricity with thermal energy provides CHP systems with substantially higher energy efficiencies than stand-alone electric generation units. A typical CHP installation can realize overall energy efficiencies of over 75% as compared to an LFG genset that runs at around 33%

efficiency. Recovered thermal energy can be used for on-site heating, cooling, or process needs, or piped to a nearby industry or commercial entity with thermal energy demands.

Upgrading an LFG to electricity facility with combined heat and power facilities significantly enhances the energy efficiency of the system. However, unless there is a reliable and steady demand for thermal energy either on-site or a nearby user, the CHP option is generally not justifiable. The CHP option would add approximately 25% to the installed cost of a reciprocating genset facility and about 15% to the installed cost of the microturbine facility.

4.4 PIPELINE QUALITY GAS OPTIONS

Natural gas has essentially 100 percent methane content and upgrading LFG to natural gas quality (also referred to as "pipeline") is a possible option. Achieving pipeline quality requires significant treatment of the gas to remove carbon dioxide and contaminants (including hydrogen sulfide and siloxanes) and pressurizing the LFG to the gas utility's transmission system pressure specifications. The three most common methods in the LFG industry for removal of carbon dioxide include:

- Membrane separation
- Molecular sieve
- Amine scrubbing

Membrane separation relies on the use of polymeric membranes that will trap methane under high pressure but allow the passage of carbon dioxide to pass through at approximately 20 times faster. Prior to the membrane treatment step, pre-treatment is required to remove hydrogen sulfide by an "iron sponge" or other suitable media, non-methane organic compounds (NMOCs) by activated carbon and moisture by compression, refrigeration or chemical absorption.

The molecular sieve process employs vapor phase activated carbon in combination with a molecular sieve for NMOC and carbon dioxide removal, respectively. Pre-treatment for stripping out hydrogen sulfide and moisture, as described above for membrane separation, is similar for the molecular sieve process for pipeline quality gas. The activated carbon can be regenerated on-site through depressurized heating and purge cycle.

The amine scrubbing process to convert LFG to pipeline quality gas involves the use of the liquid chemical solvent Selexol to remove both carbon dioxide and NMOCs from the gas stream through a 2-stage process. In the primary Selexol tower, NMOCs are absorbed into the liquid phase and in the secondary Selexol tower, carbon dioxide is absorbed. NMOCs range from hundreds to thousands more times soluble than methane while carbon dioxide is about 15 times more soluble. Pre-treatment is performed hydrogen sulfide and moisture removal.

Upgrading to pipeline quality gas (natural gas) is only practical and cost effective if a natural gas utility transmission pipeline is available within a reasonable distance for interconnecting with the pipeline quality treated LFG. It is our understanding that there are no gas transmission or distribution pipelines within 10 miles of the Rio Rico Landfill ruling out the Pipeline Quality LFGTE option from further consideration.

4.5 OTHER TECHNOLOGY OPTIONS

There are other technology options for beneficial utilization of LFG but these are not considered suitable for Santa Cruz County's application due to the lack of suitable markets or end users of the product or insufficient rate of LFG recovery to make it economically viable. One such technology is production of liquefied natural gas (LNG) for use as vehicle fuel including landfill based trucks and rolling stock or commercial fleet vehicles. Production of LNG is an energy intensive process for the extremely high levels of pressure required to convert methane to its liquid form and requires expensive gas processing, storage and dispensing equipment that is not cost effective for medium size LFG projects (i.e. , <1,000 scfm).

4.6 PROJECT CONCEPTS COMPARISON MATRIX

The LFGTE project concepts for the Rio Rico Landfill that are deemed viable were compiled into a matrix for comparison of project costs, revenue, advantages and disadvantages as well as ratings of relevant economic, technical and risk factors for helping in the process of selecting a preferred alternative.

Table 4.3 presents the matrix of LFGTE technologies considered potentially viable for the Rico Rico landfill with their rating criteria. The following rating criteria are included in the table:

- Costs – Project costs including capital and operation & maintenance, engineering, permitting, construction management, financing and contingencies
- Potential Annual Revenue – Revenue from first year of project operation based on gas recovery and electric generation projections for 2011
- Technical Reliability – Level of reliability based on years of operating experience
- Modularity – Capability of being configured to operate over a wide range of LFG production and/or energy market demands
- End Use Market Availability – Probability of the customer of the LFG derived energy remaining in business
- Implementability – Level of ease in bringing the project from planning to start-up
- Risks – Overall level of risks of the LFG technology from operational, marketing, regulatory and institutional factors

TABLE 4.3
SANTA CRUZ COUNTY, AZ - RIO RICO LANDFILL
SUMMARY OF VIABLE LFGTE TECHNOLOGIES AND RATINGS MATRIX

Technology	Typical Project Costs[1]	Typical Annual O&M Costs[2]	Potential Annual Revenue [3]	Advantages	Disadvantages	Rating Criteria / Weighting Factor: Costs 3	Potential Annual Revenue 3	Technical Reliability 2	Modularity 2	End Use Market Availability 3	Implement-ability 1	Risks 2	Weigthed Rating
Electric Generation													
Reciprocating Engine Generator	$1,680,000	$134,000	$373,549	Long term, proven reliable technolgy; High efficiency compared to microturbines; Significantly lower installed costs per kW than microturbines.	Limited modularity at installed capacity below 1,000 kW compared to microturbine; More sensitive to upsets at low quality gas than microturbine; Relatively high emissions compared to microturbine	4	5	4	2	5	4	4	**66**
Microturbine	$2,960,000	$272,000	$352,294	Lower end size range provides much greater modularity and flexibility to meet gas flows than recip engines; Can operate at lower methane content; Low NOx emissions compared to recip; Relatively easy interconnection; Designed to facilitate CHP upgrade for heating water.	Require fairly extensive pre-treatment of LFG; Significantly higher capital and O&M costs than recip engine; Limited long-term operating experience on LFG to prove reliability and performance.	2	4	3	5	5	5	3	**60**
Direct Use													
Medium Btu Gas to Local Users	$1,460,000	$37,000	$239,358	Potentially least cost option to implement; Lowest level of technology for improved reliability.	Need to retrofit direct use facilities for medium Btu gas; User must be within reasonable proximity of the landfill to make transporting cost effective; Direct use market subject to discontinuation or reduction in demand; Limits availability of environmental credits such as RECs.	5	3	5	4	2	3	2	**55**

Notes:
1. Typical project costs for Electric Generation technology based on 800 kW installed capacity with standard gas clean-up system and containerized genset units. Typical project costs for Direct Use technology assumes sale to manufacturer located 3 miles from the landfill site of medium Btu gas for burner fuel at a rate of 300 scfm at 15 psig.
2. Typical annual O&M costs for Electric Generation technology based on rate of $0.021/kWh for reciprocating engine generator at 8,000 hours per year operation and $0.040/kWh for microturbine at 8,500 hours per year operation. Typical annual O&M costs for Direc Use technology for operation and maintenance of a gas compression and treatment skid for delivery of medium Btu gas to the manufacturer. Annual O&M excludes direct users burner maintenance costs.
3. Potential annual revenue for electric generation based on 781 kW capacity in 2010 at 91% availability for reciprocating genset (7,972 hrs/yr) and 691 kW capacity in 2010 at 97% availability for microturbine (8,497 hrs/yr) and an electric sales price of $0.06/kWh. Potential annual revenue for direct use based on 300 scfm of LFG at 50% CH4 with a higher heating value of 506 Btu/cf of LFG of 218.6 mmBtu/day, a market availability of 75%, and a sales price of $4.00/mmBtu.

The technology receiving the highest combined weighted rating value is electric generation via a reciprocating engine generator. The reciprocating genset option is largely favored over the microturbine option due to its capital and O&M costs expected to be roughly half combined with its higher potential revenue from electric sales with the better fuel efficiency. Reciprocating gensets also benefit from a technical reliability standpoint with the vast and long-historical operating experience on LFG as compared to the microturbine. The more extensive pre-treatment of LFG for fueling a microturbine versus a reciprocating engine reduces the works against the microturbine's reliability rating.

Although the Direct Use option is the lowest in capital and O&M costs and highest technical reliability rating, it received the lowest overall weighted rating as a result of not having a committed market for sale of all the available medium Btu gas putting it at a distinct disadvantage when compared to electric generation where the electric utility is obligated to take all the power produced. The Direct Use option is also at a disadvantage of not qualifying for renewable energy credits (RECs) which only apply to electric generation projects from renewable energy sources.

As seen from the matrix, the one major benefit to the microturbine option is its inherent modularity (i.e., 4 – 200 kW microturbines vs. 1 – 800 kW reciprocating genset) that enhances optimization of matching power output to available recoverable LFG. The reciprocating genset can generally be operated over a range of full load to 50% full load (i.e., 800 kW to 400 kW). Referring to the Base Case gas recovery projections and electric generation potential for the Reciprocating Genset in Table 4.2a it is seen that electric production capacity should remain above 85% of the 800 kW full load capacity over the next 30 years which is well within the reciprocating genet's operating range.

Although the modularity aspect of the microturbine provides an annual availability advantage over the reciprocating genset for repairs and maintenance, the advantage is eliminated by the heat rate advantage of the reciprocating genset as seen from the comparison of the potential annual revenue of each.

The microturbine option is better able to tolerate LFG with lower methane content than a reciprocating genset. Microturbines can operate with as little as 35% methane while reciprocating gensets operating on LFG typically require a minimum of 42% methane. The Rio Rico Landfill flare blower system LFG monitoring records indicate a methane content range of around 20% to 30% and oxygen from around 5% to 12%. The low methane and high oxygen content are not surprising as the LFG is principally collected from perimeter gas recovery wells outside the waste limit boundary. If an LFGTE project is implemented by Santa Cruz County, it is expected new interior gas extraction wells and/or horizontal collection trenches would be installed to replace or supplement the perimeter wells. The overall gas quality with an interior gas recovery system should increase substantially with much lower air intrusion to readily allow meeting the 42% methane requirement of a reciprocating genset.

Based on the above analysis of the viable technologies and comparison of the results of the weighted ratings, the alternative would most benefit Santa Cruz County for development of an LFGTE project is generation of electricity incorporating a reciprocating engine generator.

4.7 LFG GENERATION AND RECOVERY ENHANCEMENT

Enhancing and maximizing LFG generation and recovery improves the viability and economics of the project provided adequate infrastructure is in place to make use of the increase gas flows. The availability of adequate moisture in the landfill waste mass to stimulate biological activity for methane generation is the single most limiting factor for LFG production from landfill sites in Arizona. An option for increasing availability of moisture to the waste mass may include modifying cell construction and cover placement to enhance infiltration while complying with applicable ADEQ regulations. Another option may be accepting for disposal wastewater sludges from surrounding treatment plants (such as the nearby International Wastewater Treatment Plant on the Santa Cruz River) to mix with the dry MSW to increase moisture content and provide biological seeding to stimulate anaerobic decomposition and methane generation.

On the recovery side, alternatives for enhancing and maximizing LFG extraction for optimum revenue (energy sales and credits) could be achieved with strategic expansion of the well field including placement of horizontal collector wells at appropriate spacing in active filling areas, upgrading of blower equipment to obtain maximum zone of influence, installation of additional vertical wells along the perimeter non-active landfill areas, and upgrading of headers to limit head losses and vacuum restrictions.

In conjunction with the construction of an LFGTE facility at the Rio Rico Landfill, it is anticipated a comprehensive interior gas collection system would be installed to optimize recovery of available LFG for maximum generation of power. The interior gas collection system would consist of vertical extraction wells along the outer zone of the waste filling area where the landfill is at or near its final grade, horizontal collection trenches within the active filling areas, a gas collection header looped around the limits of waste filling with lateral lines to wells and trenches, and a main feed header from the looped header to the proposed LFGTE facility site. The LFGTE facility would be equipped with its own blower system sized for the maximum design capacity to induce vacuum on the wellfield and feed the gas through a conditioning system to the engine-generator unit. Tie-ins could be made between the new looped header system and the existing exterior gas extraction flare header to enhance overall recovery. When the LFGTE plant was offline, the existing blower and flare unit would be used to control odors and emissions.

5.0 Institutional Options

There are a number of potential institutional arrangements for the development and long-term operations of the proposed energy generation facility. These would include County ownership with contractual development and operations, full service developer-operator with ownership and control of the LFG and resulting electrical energy output from the facility or a public-private partnership.

5.1 PROJECT DEVELOPMENT

Under the pure project developer option, the County would solicit full design-build-own-operate (DBOO) proposals from qualified companies in the industry who would have complete responsibility for taking the project from the preliminary design stage and financing, through permitting, final design, construction, commissioning and start-up as well as owning and operating the facility under a long-term contract for the gas rights.

5.2 SELF DEVELOPMENT

Self-development of the LFGTE project would involve the County retaining ownership of the facility, prepare construction contract documents for development and enter into an agreement with an LFGTE operator to run the plant while the County derives all the revenue from the sale of energy.

5.3 PUBLIC-PRIVATE PARTNERSHIP

There is also the hybrid option where the County teams up with a private entity to share in the development process including permitting, design, financing and construction with a proportionate share in the risks and rewards of the development.

5.4 ADVANTAGES AND DISADVANTAGES

The primary advantages to the pure developer option (DBOO) over self-development include the County does not have to front the significant costs of bringing a project from concept level through to construction, the risks for successful implementation and operation fall to the developer, the timeline to get a project up and running is generally shortened with an experienced developer managing the process, and developers/operators with multiple LFGTE facilities can take advantage of existing strong relationships with equipment and material suppliers to reduce capital and O&M costs which should ultimately translate into more favorable contract terms for the County. Further, the DBOO option would preserve eligibility for tax credits not available to the County including Section 45 Production Tax Credits or alternately Investment Tax Credits which have been recently expanded to include LFGTE projects.

Regarding the self-development option, advantages to the County would include retention of the income from energy sales, maintaining control of the entire process so the County ends up with the type of facility that best serves their needs and objectives including continual compliance with migration and odor control requirements and regulations, and maximizing project revenue for accepting the added level of risk with self-development. The County would also have the opportunity under the self-development option to take advantage of economic incentives including Clean Renewable Energy Bonds (CREBs) that can be used to finance LFGTE projects at no interest. Additional information regarding the CREBs can be found at http://www.epa.gov/landfill/docs/lmop_federal_incentive.pdf.

6.0 Cost Estimates

Two cost estimates are provided in this section. A preliminary capital cost for development of a 1,000 kW reciprocating engine-generator system and a pro-forma showing the potential returns for the development of this system. It should be noted that all costs are preliminary and should be used for budgetary purposes only. Costs are in 2009 dollars and no inflation factors have been included.

6.1 PRELIMINARY COST ESTIMATE

A preliminary cost estimate for development of a Landfill Gas to Electricity 1,000 kW reciprocating engine-generator system has been prepared for the project, including installation of a comprehensive wellfield to enhance the existing gas collection system for maximum gas recovery and connection to the Tucson Electric Power grid. The estimate is presented in Table 6.1. The preliminary budget estimate for the capital costs of the 1,000 kW LFGTE plant and wellfield improvements is approximately $2.49 million as reported in Table 6.1. The total budgetary project cost, including design, permitting, construction management and contingency is around $3.36 million.

6.2 PRELIMINARY PRO FORMA

A preliminary pro forma economic analysis is presented in Table 6.2. The pro forma covers the project capital costs for construction of the 1,000 kW reciprocating gen-set LFGTE plant and wellfield improvements. The first phase of the wellfield improvements are estimated at around $696,000 and are assumed to be amortized with the LFGTE plant capital costs over a 15-year bonding period. As the landfill expands in the future and eventually reaches capacity, the wellfield will also require expansion through future capital improvements which are shown in the pro forma at years 6, 11 and 16. The future wellfield capital improvements are assumed to be funded in the respective years. As indicated in the pro forma, the net present worth of the income from the LFGTE project is around $122,000 after the first 10 years of operation, over $1.4 million after 20 years of operation and over $3.0 million through 30 years of operation. These amounts do not include the potentially significant value of the environmental market that the project is likely to recognize including Renewable Energy Certificates (RECs) and Greenhouse Gas reduction credits.

TABLE 6.1
LANDFILL GAS TO ENERGY CAPITAL COST BUDGET ESTIMATE
SANTA CRUZ COUNTY, AZ - RIO RICO LANDFILL
RECIPROCATING ENGINE GENERATOR OPTION

A. LFGTE Plant (1,000 kW Option)				**Capital Cost**
1. Reciprocating Genset (Containerized)				$750,000
- 800 kW Reciprocating Engine-Generator				
- Roof mounted radiator				
- Critical grade exhaust silencer				
- Switchgear				
- Generator breaker				
- Motor control center				
- Systems communication package				
- Weatherproof container				
2. Gas Recovery / Treatment Skid (500 scfm)				$150,000
- Dual 500 scfm rotary lobe blowers				
- 40 hp motors				
- Inlet knockout vessel				
- Suction scrubber				
- Gas cooler / Heat exhanger				
- Coalescing filter				
- Motor starters and VFD drives				
- PLC controls				
- Interconnecting SS piping and fittings				
- Galvanized steel skid				
3. Electric Substation				$250,000
- Pad mount step-up transformer (480 V - 13.2 kV)				
- Station service transformers				
- Utility metering				
- Group operated disconnect switch				
- Reclosers				
- Panelboard and electric control panels				
4. Storage container / Office trailer				$40,000
5. Site Work				$400,000
- Civil / Sitework				
- Concrete				
- Electrical				
- Mechanical				
6. Utility Interconnect				$200,000
LFGTE Plant Capital Costs				**$1,790,000**
B. Wellfield Improvements				
	Quantity	Units	Unit Cost	
1. Gas Extraction Wells				
a. Vertical (5 @ 45 ft deep ea = 225 v.f.)	225	vf	$80.00	$18,000
b. Horizontal Collection Trenches (24 Trenches)	10,040	lf	$47.00	$471,880
c. Trench to Header Connections	24	ea	$1,500.00	$36,000
2. Gas Headers				
a. 6" HDPE SDR 17	500	lf	$20.00	$10,000
b. 8" HDPE SDR 17	3,475	lf	$24.00	$83,400
c. 10" HDPE SDR 17	1,400	lf	$33.00	$46,200
3. Wellheads	29	ea	$400.00	$11,600
4. Condensate Traps	2		$5,200.00	$10,400
5. Butterfly Valves				
a. 8" PVC BF Valve	3		$1,200.00	$3,600
b. 10" BF Valve	2		$2,300.00	$4,600
Wellfield Improvements Capital Costs				**$695,700**
Total Capital Cost				**$2,485,700**
C. Design / Permitting / Construction Management				
1. Preliminary & Final Design (6%)				$149,100
2. Permitting (2%)				$49,700
3. Construction Management (12%)				$298,300
4. Contingency (15%)				$372,900
Total Design / Permitting / C.M.				**$870,000**
Total Project Cost Budget Estimate				**$3,355,700**

TABLE 6.2
LANDFILL GAS TO ENERGY PRO FORMA
SANTA CRUZ COUNTY, AZ - RIO RICO LANDFILL
RECIPROCATING ENGINE GENERATOR OPTION (1000 KW CAPACITY)

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
LFG Recovery - Base Case (scfm)	292	297	292	292	297	297	302	297	302	313
Energy Availability (mmBtu/hr)	7.980	8.123	7.980	7.980	8.123	8.123	8.265	8.123	8.265	8.550
Electric Output (kW)	782	796	782	782	796	796	810	796	810	838
Electric Production (kWh)	6,236,605	6,347,973	6,236,605	6,236,605	6,347,973	6,347,973	6,459,341	6,347,973	6,459,341	6,682,076
Loading of Gen-Set (%)	78%	80%	78%	78%	80%	80%	81%	80%	81%	84%
Revenues:										
Energy	$ 383,551	$400,160	$402,968	$413,043	$ 430,929	$ 441,702	$460,688	$464,063	$484,010	$513,217
Environmental Credits										
REC Credits										
GHG Reduction										
TOTAL REVENUE($):	**$ 383,551**	**$400,160**	**$402,968**	**$413,043**	**$ 430,929**	**$ 441,702**	**$460,688**	**$464,063**	**$484,010**	**$513,217**
($/kWh):	$ 0.062	$ 0.063	$ 0.065	$ 0.066	$ 0.068	$ 0.070	$ 0.071	$ 0.073	$ 0.075	$ 0.077
Operating Costs:										
LFGTE Operation & Maintanence	$ 134,898	$141,426	$143,113	$147,406	$ 154,540	$ 159,176	$166,828	$168,870	$176,987	$188,583
LFGTE O&M Rate ($/kWh)	$ 0.0216	$ 0.0223	$ 0.0229	$ 0.0236	$ 0.0243	$ 0.0251	$ 0.0258	$ 0.0266	$ 0.0274	$ 0.0282
Wellfield Maintenance ($/Yr)	$ 35,829	$ 36,903	$ 38,011	$ 39,151	$ 40,325	$ 41,535	$ 42,781	$ 44,065	$ 45,387	$ 46,748
Operation Costs Total ($):	**$ 170,726**	**$178,329**	**$181,124**	**$186,557**	**$194,865**	**$200,711**	**$209,609**	**$212,934**	**$222,374**	**$235,331**
Capital Costs:										
LFGTE Plant + Phase I Wellfield Capital Improvements Debt Service:	$186,289	$186,289	$186,289	$186,289	$186,289	$186,289	$186,289	$186,289	$186,289	$186,289
Future Wellfield Capital Improvements:						$383,000				
Annual Capital Costs Total ($):	**$ 186,289**	**$186,289**	**$186,289**	**$186,289**	**$186,289**	**$569,289**	**$186,289**	**$186,289**	**$186,289**	**$186,289**
Total Annual Cost ($):	**$ 357,015**	**$364,618**	**$367,413**	**$372,846**	**$ 381,154**	**$ 770,000**	**$395,898**	**$399,224**	**$408,663**	**$421,621**
NET PROFIT (LOSS):	**$ 26,536**	**$ 35,542**	**$ 35,556**	**$ 40,196**	**$ 49,775**	**$ (328,298)**	**$ 64,790**	**$ 64,840**	**$ 75,347**	**$ 91,597**
NET PRESENT VALUE (2011):	**$ 26,536**	**$ 34,175**	**$ 32,873**	**$ 35,734**	**$ 42,547**	**$ (269,837)**	**$ 51,204**	**$ 49,273**	**$ 55,055**	**$ 64,355**

	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
LFG Recovery - Base Case (scfm)	313	323	333	328	339	344	354	371	390	411
Energy Availability (mmBtu/hr)	8.550	8.835	9.120	8.978	9.263	9.405	9.690	10.156	10.678	11.240
Electric Output (kW)	838	866	894	880	908	922	950	996	1,047	1,102
Electric Production (kWh)	6,682,076	6,904,812	7,127,548	7,016,180	7,238,916	7,350,284	7,573,020	7,936,822	8,345,171	8,784,703
Loading of Gen-Set (%)	84%	87%	89%	88%	91%	92%	95%	100%	100%	100%
Revenues:										
Energy	$ 526,048	$557,172	$589,524	$594,821	$629,047	$654,692	$691,395	$742,724	$800,461	$863,686
Environmental Credits										
REC Credits										
GHG Reduction										
TOTAL REVENUE($):	**$ 526,048**	**$557,172**	**$589,524**	**$594,821**	**$629,047**	**$654,692**	**$691,395**	**$742,724**	**$800,461**	**$863,686**
($/kWh):	$ 0.079	$ 0.081	$ 0.083	$ 0.085	$ 0.087	$ 0.089	$ 0.091	$ 0.094	$ 0.096	$ 0.098
Operating Costs:										
LFGTE Operation & Maintanence	$ 194,241	$206,737	$219,808	$222,865	$236,838	$247,696	$262,858	$283,750	$307,299	$333,189
LFGTE O&M Rate ($/kWh)	$ 0.0291	$ 0.0299	$ 0.0308	$ 0.0318	$ 0.0327	$ 0.0337	$ 0.0347	$ 0.0358	$ 0.0368	$ 0.0379
Wellfield Maintenance ($/Yr)	$ 48,151	$ 49,595	$ 51,083	$ 52,615	$ 54,194	$ 55,820	$ 57,494	$ 59,219	$ 60,996	$ 62,826
Operation Costs Total ($):	**$242,391**	**$256,332**	**$270,891**	**$275,480**	**$291,032**	**$303,516**	**$320,352**	**$342,969**	**$368,295**	**$396,015**
Capital Costs:										
LFGTE Plant + Phase I Wellfield Capital Improvements Debt Service:	$186,289	$186,289	$186,289	$186,289						
Future Wellfield Capital Improvements:	$278,800					$112,900				
Annual Capital Costs Total ($):	**$465,089**	**$186,289**	**$186,289**	**$186,289**	**$0**	**$112,900**	**$0**	**$0**	**$0**	**$0**
Total Annual Cost ($):	**$ 707,480**	**$442,621**	**$457,180**	**$461,769**	**$291,032**	**$416,416**	**$320,352**	**$342,969**	**$368,295**	**$396,015**
NET PROFIT (LOSS):	**$ (181,433)**	**$114,551**	**$132,344**	**$133,051**	**$338,015**	**$238,277**	**$371,042**	**$399,755**	**$432,165**	**$467,671**
NET PRESENT VALUE (2011):	**$ (122,569)**	**$ 74,410**	**$ 82,662**	**$ 79,907**	**$195,195**	**$132,307**	**$198,103**	**$205,223**	**$213,329**	**$221,976**

	Year 21	Year 22	Year 23	Year 24	Year 25	Year 26	Year 27	Year 28	Year 29	Year 30
	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
LFG Recovery - Base Case (scfm)	413	390	372	360	342	331	319	301	295	289
Energy Availability (mmBtu/hr)	11.305	10.659	10.175	9.852	9.367	9.044	8.721	8.237	8.075	7.914
Electric Output (kW)	1,108	1,045	998	966	918	887	855	808	792	776
Electric Production (kWh)	8,835,190	8,330,322	7,951,671	7,699,237	7,320,586	7,068,152	6,815,718	6,437,067	6,310,850	6,184,633
Loading of Gen-Set (%)	100%	100%	100%	97%	92%	89%	86%	81%	79%	78%
Revenues:										
Energy	$890,365	$860,475	$841,896	$835,549	$814,317	$805,893	$796,539	$771,094	$774,874	$778,361
Environmental Credits										
REC Credits										
GHG Reduction										
TOTAL REVENUE($):	**$890,365**	**$860,475**	**$841,896**	**$835,549**	**$814,317**	**$805,893**	**$796,539**	**$771,094**	**$774,874**	**$778,361**
($/kWh):	$ 0.101	$ 0.103	$ 0.106	$ 0.109	$ 0.111	$ 0.114	$ 0.117	$ 0.120	$ 0.123	$ 0.126
Operating Costs:										
LFGTE Operation & Maintanence	$345,157	$335,197	$329,560	$328,670	$321,881	$320,105	$317,933	$309,278	$312,311	$315,246
LFGTE O&M Rate ($/kWh)	$ 0.0391	$ 0.0402	$ 0.0414	$ 0.0427	$ 0.0440	$ 0.0453	$ 0.0466	$ 0.0480	$ 0.0495	$ 0.0510
Wellfield Maintenance ($/Yr)	$ 64,710	$ 66,652	$ 68,651	$ 70,711	$ 72,832	$ 75,017	$ 77,268	$ 79,586	$ 81,973	$ 84,432
Operation Costs Total ($):	**$409,868**	**$401,849**	**$398,211**	**$399,381**	**$394,713**	**$395,122**	**$395,201**	**$388,864**	**$394,284**	**$399,679**
Capital Costs:										
LFGTE Plant + Phase I Wellfield Capital Improvements Debt Service:										
Future Wellfield Capital Improvements:										
Annual Capital Costs Total ($):	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
Total Annual Cost ($):	**$409,868**	**$401,849**	**$398,211**	**$399,381**	**$394,713**	**$395,122**	**$395,201**	**$388,864**	**$394,284**	**$399,679**
NET PROFIT (LOSS):	**$480,498**	**$458,626**	**$443,685**	**$436,168**	**$419,604**	**$410,771**	**$401,339**	**$382,230**	**$380,591**	**$378,683**
NET PRESENT VALUE (2011):	**$219,293**	**$201,261**	**$187,215**	**$176,965**	**$163,697**	**$154,087**	**$144,758**	**$132,564**	**$126,918**	**$121,425**

1000 kW Genset Net Present Worth Summary	
NPV of Income (yrs 1-10)	$ 121,915
NPV of Income (yrs 1-20)	$ 1,402,458
NPV of Income (yrs 1-30)	$ 3,030,641

Assumptions:
LFG recovery based on LFG Generation Model Base Case Condition

Genset Output Rating =	1000	kW
Genset Heat Rate =	10,200	Btu/kWh
Landfill Gas Lower Heat Value =	456	Btu/cf
Genset Availability Factor =	91%	
Electric Sales Rate (2010) =	0.06	$/kWh
Annual Energy Escalation Factor =	2.50%	
Annual Inflation Factor =	3.00%	
LFGTE O&M Rate (2010) =	0.021	$/kWh
Total LFGTE Plant Capital Cost =	$ 1,790,000	
Wellfield Improvements Capital Cost =	$ 695,700	(Phase I)
Total Project Capital Costs =	$ 2,485,700	
Bonding Interest Rate =	1.50%	
Amortization Period =	15	years
Discount Rate =	4.00%	

7.0 Conclusions and Recommendations

This chapter presents the conclusions and recommendations for implementation of a Landfill Gas to Energy project. We also briefly discuss carbon credit options, however with the current changing conditions, it is difficult to assess a recommended implementation strategy at this time.

7.1 CONCLUSIONS

7.1.1 Chapter 2 LFG Production and Recovery Estimates

1. The current capacity of the Rio Rico landfill is estimated at 998,500 tons.

2. The total capacity of the Rio Rico landfill is estimated as 1.92 Million Tons, including the vertical expansion recently approved by ADEQ, which is sufficient to allow continued filling of the landfill at current rates through 2029.

3. A waste was assessed based on what percentage is decomposable, and the anticipated rate of decomposition. Changes in percentages over time were also assessed.

4. A model was prepared which included the annual waste deposition quantities, the percent dry weigh of each waste decomposition category, the total potential gas generation amounts from each waste category, the decay half life and the initial gas generation lag time. The model assumed a gas composition with 50% methane.

5. The model predicts that the peak LFG generation from the site in 2030 at a rate of approximately 500 scfm. The model also predicts that LFG will be recoverable at a rate of at least 300 scfm starting in 2010 for 28 years. A recovery rate of 300 scfm at 50% methane is sufficient to sustain an electric generation rate of approximately 800 kW.

7.1.2 Chapter 3 Energy Market Analysis

6. The regulatory and compliance environment at the national and regional levels associated with the energy market are rapidly changing.

7. There are four major sectors that make up environmental commodities markets, voluntary carbon markets, voluntary renewable energy markets, greenhouse gas (GHG) compliance markets and renewable portolio standards (RPS).

8. Renewable Energy Certificates (RECs) are used to monetize the environmental attributes associated with renewable power generation.

9. Methane flaring or destruction is considered a Voluntary Carbon Standard, as a baseline is established based on carbon released with the flare.

10. With construction of a LFGTE system, Santa Cruz County will be able to achieve RECs. It is anticipated that the power company, Tucson Electric, would want to purchase the RECs' with the purchase of the power.

7.1.3 Chapter 4 Project Concepts

11. The LFG to Electrical options for small to medium sized landfills such as Rio Rico include reciprocating engine-generators, micro-turbines and fuel cells.

12. LFG reciprocating generators are the most common and have a long-proven history of operation.

13. Micro-turbines are more recent technology and are more portable and suit a modular installation better than reciprocating generators.

14. Raw landfill gas requires conditioning and treatment upstream of the electric generating equipment.

15. Typical costs for generating systems are $2,600 per kW for a reciprocating engine system and $3,700 per kW for a microturbine unit.

16. The maintenance costs for micro turbines are slightly higher than reciprocating generators, at 4.0 cents per kWh compared to 2.0 to 2.5 cents per kWh.

17. Since the potential output varies throughout the life of the system, a present worth analysis comparing expected revenue to capital/operating costs is required to assess the appropriately sized unit.

18. For this site, an analysis was completed comparing an 800 kW system to a 1000 kW system for a reciprocating system. With the reciprocating system the system is either over or undersized to meet average and peak conditions. For the current loads, the analysis indicates an 800 kW system is best, however if the City of Nogales returns to Rio Rico, it is likely that a 1000 kW system will be better. The analysis also indicates that planning for the installation of a 1000 kW system although slightly oversized to allow for the return of Nogales is more practical.

19. As the anticipated output for Rio Rico does not vary significantly, the advantages associated with the modular micro turbines do not impact enough to offset the decrease in efficiency, increased capital cost and increased operational costs.

20. Direct use of methane is an option, however as there are no users in the immediate area, it is not practical for the Rio Rico landfill.

21. Combined heat and power is an option that captures the waste heat generated by the waste heat for thermal conversion to steam or hot water. Similar to direct use, this option is not practical for this site, as there are no potential users in the immediate vicinity.

22. Treatment of the LFG to pipeline quality is another option presented, but it is not practical for implementation at Rio Rico.

23. A matrix evaluation comparing a reciprocating electricity generating system to a micro turbine electricity generating system and direct use was completed. The analysis indicates that a reciprocating generating system best suits the Rio Rico landfill site.

24. Modifications to the cell placement and increasing the moisture content of the waste mass may enhance the LFG generation.

25. Strategic expansion of the well field including placement of horizontal collector wells will enhance and maximize the LFG recovery.

7.1.4 Chapter 5 Institutional Options

26. There are three options available to the County for development, self development with contractual development and operations, full service developer-operator with ownership and control of the LFG and resulting electrical energy output from the facility or a public-private partnership.

7.1.5 Chapter 6 Cost Estimate

27. A preliminary cost estimate for development of a LFGTE system at Rio Rico based on a 1000 kW reciprocating generator system was completed and the estimated cost is $3.36 Million.

28. A preliminary pro forma economic analysis indicates potential net worth of $122,000, $1.4 million and $3.0 million after 10, 20 and 30 years of operation.

7.2 RECOMMENDATIONS

1. Initiate steps to implement a LFGTE system.

2. Apply for available and applicable grants.

3. Review development options and determine direction.

4. Initiate the process with Tucson Electric (TEP) for the interconnection. Information attached for reference in Appendix A.

5. Initiate bidding or design as determined by the selected development option.
6. As it appears that the LFGTE project provides positive cash flow strictly from the bundled sale of electricity and environmental benefits, wait until there is more clarity in the market to consider a methane destruction project in addition to the LFGTE.
7. Be prepared to negotiate both the sale of electricity AND the sale of the associated environmental benefits as two separate commodities.
8. Assign resources to monitor the GHG and renewable energy regulatory and voluntary markets so that this approach may be updated when appropriate.

7.3 POTENTIAL IMPLEMENTATION SCHEDULE

Implementation of a Landfill Gas to Energy (LFGTE) project requires several key steps to be completed and milestone decisions to be made. The entire process can take up to 2 years to complete from initial planning to installation and start-up. The approach to implementing an LFGTE project also depends upon whether the County chooses to self-develop, issues an Engineer-Procure-Construct (EPC) document for development (turn-key approach), or goes the Design-Build-Own-Operate (DBOO) route with full private development. For purposes of preparing the implementation schedule shown below, we have assumed the County would opt for the EPC approach. The implementation timeframe for the other options would be similar.

The first step identified in the schedule is gas modeling and initial assessment. The work performed to date and results presented in this report represent this first step. As shown on the schedule, the completion of first task is a key milestone for the County to decide on proceeding. Assuming the County elects to go forward, the next step is to prepare preliminary (25%) design plans and more detailed economic assessment. This leads to the second key milestone / decision point on whether to proceed based on the updated financial projections.

The third step is establishing the project structure on how the project is to be developed and managed. As noted above, the implementation schedule is based on the EPC approach for development. The EPC contract could also include an agreement with the developer for the operation of the LFGTE facility. Under this scenario, a turnkey LFGTE developer takes full responsibility for the financing, construction, commissioning and, if negotiated as part of the contract, operation of the facility while the County would be responsible for project funding and permitting. In return, the County would retain ownership of the project and revenues generated from the sale of electricity and environmental credits. Alternately, the County could elect to develop and manage the entire project on its own following the design-bid-build approach typically used on public works projects.

Development contract EPC documents are prepared as the next step in the process that include the preliminary design plans, performance specifications, regulatory and construction permitting requirements, insurance and bonding criteria, EPC agreement terms and conditions, and performance guarantees. A separate contract can be negotiated with the developer or a third party for operation of the LFGTE facility.

Simultaneous with the completion of the EPC documents would be assessing financing options and loan/grant opportunities, negotiating an energy sales contract, and securing required environmental, siting and other related permits (steps 5 – 7). For the EPC approach the County would be responsible for providing the project funding. Public financing options would include issuing municipal bonds, direct municipal funding, and lease financing. Low interest loans and grant opportunities could be explored to offset the costs the County would incur for the construction of the LFGTE facility and required improvements to the gas collection system.

The most critical component to the economic success of the project is energy sales contract, in this case with Tucson Electric Power (TEP). Negotiating the energy sales contract with or without the environmental attribute credits could take up a couple of months to complete to arrive at a reasonable and equitable pricing package and contract terms and conditions.

Securing permits and approvals is another critical step in the process and could take 6 months or longer to complete. The primary permit for the LFGTE plant construction and operation is issued by the ADEQ Air Quality Division for emissions from stationary sources.

The next step is awarding the EPC contract that includes soliciting comprehensive proposals for the technical and business aspects of the project, reviewing the proposals and short-listing qualified developers for interviews, selecting the preferred EPC contractor, and negotiating the contract which is the final key milestone decision point.

The final steps of the implementation schedule are installation of the LFGTE facilities and wellfield improvements and start-up of commercial operations. This phase would be expected to be completed within 8 months from the start of construction.

Santa Cruz County LFGTE Project Implementation
Preliminary Schedule
November 2, 2009

	Month																							
Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1- Gas Modeling / Initial Assessment	■	■	■	♦																				
2- Preliminary Design / Project Economics				■	■	■	♦																	
3- Establish Project Structure							■																	
4- Draft Development Contract EPC Documents								■	■	■														
5- Assess Financing Options										■														
6- Negotiate Energy Sales Contract										■	■													
7- Secure Permits / Approvals										■	■	■	■	■	■									
8- EPC Contract Award and Negotiation														■	■	♦								
9- LFGTE Facility Construction																■	■	■	■	■	■	■		
10- Wellfield Improvements Construction																■	■	■						
11- Project Start-up and Shakedown																							■	

♦ - Key Milestone / Decision Point