



A Study of Air Emissions From Conversion Technologies Compared to Baseline Solid Waste Infrastructure Emissions

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HDR

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Prepared for the

Western Placer Waste Management Authority

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Placer County Air Pollution Control District

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List of Abbreviations

AD – Anaerobic Digestion
APC – Air Pollution Control
ATR – Advanced Thermal Recycling
BACT - Best Available Control Technologies
BTU – British Thermal Units
BTU/lb – British Thermal Units per Pound (Calorific Value)
CARB - California Air Resources Board
CCR – California Code of Regulations
CEC – California Energy Commission
CH_4 – Methane
Char – Carbon-based By-Product from Thermal Process
CI – Activated Carbon Injection
CO – Carbon Monoxide
CO_2 - Carbon Dioxide
CO_2e – Carbon Dioxide Equivalents
CPI – Consumer Price Index
CT – Conversion Technology
^oC - Degree Celsius
Demo/Pilot – Demonstration or Pilot Scaled Facility
DF - Dry Fermentation Digestion
DOE - Department of Energy
EPA - Environmental Protection Agency
ERC – Emissions Reduction Credits (Emissions Offset Credits)
^oF - Degree Fahrenheit
FB – Filter Baghouse
GHG - Greenhouse Gas
GT – Gas Turbine
H_2 - Hydrogen Gas
H_2S – Hydrogen Sulfides
HAP – Hazardous Air Pollutants
HCl – Hydrogen Chloride
HDR - HDR Engineering Inc.
HHW - Household Hazardous Waste
HRSG – Heat Recovery Steam Generator
IC - Internal Combustion
K – thousand (example: $1,000)
KW – Kilowatt
kWh – Kilowatt-hour
lb – Pound

lb/ft^3 – Pound per Cubic Foot
LFG - Landfill Gas
MWC - Municipal Waste Combustor
m^2/g – Square Meter per Gram
MG – Mega gram
mg/L^3-Milligrams per Cubic Liter
mL - Milliliters
MMBTU - Million Metric British Thermal Units
MR - Methanogenic Reactor
MRF – Materials Recovery Facility
MSW - Municipal Solid Waste
$MTCO_2E$ - Metric Tons of Carbon Dioxide Equivalent
$MMTCO_2E$ – Million Metric Tons of Carbon Dioxide Equivalent
MCFC - Molten Carbonate Fuel Cells
MW - Megawatt
N_2 or N - Nitrogen
NDFE – Non-Disposal Facility Element
NH_2 – Nitrogen hydroxide
NH_3 – Ammonia
NMOC – Non Methane Organic Compounds
NO_x - Nitrogen Oxides
O_2 – Oxygen Gas
PAG – Plasma Arc Gasification
PCACPD – Placer County Air Pollution Control District
PEM - Polymer Exchange Membrane
PG&E – Pacific Gas & Electric Company
PPBV – Parts per Billion by Volume
PPM – Parts per Million
PM – Particulate Matter
PM_{10} - Particulate Matter with maximum diameter of 10 microns
PRC – Public Resources Code
ROC – Reactive Organic Compounds
scfd - Standard Cubic Feet per Day
scfm - Standard Cubic Feet per Month
SB – Senate Bill
SCR – Selective Catalytic Reduction
SDA – Spray Down Absorbers
SNCR – Selective Non-Catalytic Reduction
SO_x – Oxides of Sulfur
SOFC - Solid Oxide Fuel Cells
Syngas – Synthesis Gas
tpd- Tons per Day

tpy- Tons per Year
TS- Total Solids
VOC – Volatile Organic Compounds
VS - Volatile Solids
WARM - WAste Reduction Model
WET – Waste Extraction Test
WPWMA – Western Placer Waste Management Authority
WRSL – Western Regional Sanitary Landfill
WTE – Waste-to-Energy (also referred to as Direct Com)
WWTP - Waste Water Treatment Plant

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Executive Summary

The Western Placer Waste Management Authority (WPWMA), with assistance from HDR Engineering Inc. (HDR), has prepared this Study for the Placer County Air Pollution Control District (PCAPCD) by means of a Grant issued by the District. The purpose of the Study is to support the WPWMA's ongoing research of the emissions associated with converting municipal solid waste (MSW) residuals currently being landfilled into energy as compared to current waste disposal practices.

In preparing this Study, certain assumptions and methodologies were used (as detailed in the main body of this report) to develop emissions profiles for the baseline case of continued landfilling of all municipal solid waste (MSW) residuals as well as diverting 500 tons per day (tpd) from landfill to conversion technologies (CT) for the production of energy.

The conversion technologies considered included 1) Direct Combustion/Waste-to-Energy (WTE), 2) Gasification and Plasma Arc Gasification (both thermal CTs) and 3) Anaerobic Digestion (AD). It was assumed that WTE would directly combust the residual waste. Gasification and plasma arc gasification would produce a syngas (synthetic gas) and anaerobic digestion would produce a biogas, either of which could be used as fuel in energy producing devices. The most appropriate energy producing devices for the syngas and biogas were assumed to be internal combustion (IC) engines, turbines and fuel cells; although it is critical to recognize that fuel cells have not been used in conjunction with gasification and plasma arc gasification technologies that generate a syngas and even their use in biogas applications is limited. From these considerations the following scenarios were developed to compare emissions to the baseline landfill emissions estimates:

- WTE
- Thermal CT producing Syngas to IC Engine
- Thermal CT producing Syngas to Turbine
- Thermal CT producing Syngas to Fuel Cell
- Anaerobic Digestion producing Biogas to IC Engine
- Anaerobic Digestion producing Biogas to Turbine
- Anaerobic Digestion producing Biogas to Fuel Cell

In general, the WTE and CT syngas scenarios show emissions higher than baseline for almost all pollutants. The main reason for the higher emissions is that these technologies (WTE and thermal Conversion Technologies) convert all of the carbon based (or combustible) materials contained in the MSW residual to usable energy. So for example, the conversion of plastics, rubber, and other carbon based materials into energy by the thermal technologies will produce emissions that otherwise would not occur in the landfill. In contrast, in landfilling where only a portion of the biodegradable content of the MSW residual is converted to usable energy, less emissions are generated. Similarly, the anaerobic digestion process generates lower quantities of usable energy (in the form of biogas) than the thermal technologies. In the AD process, the biodegradable fraction is converted to usable energy faster than it would be in the landfill. Consequently, although the WTE and thermal CT processes produce more pollutants, they also produce more energy.

Overall, based upon assumptions made in the Study, WTE emissions are higher than both thermal and biological processes, particularly in NOx, SOx, CO, total HAP's. Consequently, we conclude the WTE is not as attractive from the perspective of emissions as thermal and biological conversion processes.

Fuel cells appear to be the most attractive from an air emissions standpoint, both for syngas and AD biogas application. However, as described in the body of the report, a number of significant technical, economic, and potential air emissions issues must be addressed and resolved in order to truly determine the potential use of fuel cells. For example, some of the more challenging aspects of the use of fuel cell technology include: 1) gas cleanup, 2) gas cleanup impact on gas heat content, 3) cost of gas treatment, and 4) the potential air emissions associated with the treatment system.

Insomuch as fuel cells are questionable in terms of their ability to operate on syngas, turbines appear to provide the lowest emissions from a power generation facility along with at least limited commercial operational history.

Although IC engines appear to have somewhat moderate but higher emissions than turbines, IC engines provide the most proven commercial viability operating on both biogas and syngas in terms of proven experience.

Regarding the CO_2e emission information presented in this Study, the results are presented for CO_2e emissions as a pollutant regulated under the Clean Air Act. As such, the CO_2e emission estimates include both anthropogenic and biogenic emissions, do not account for carbon storage in the landfill, and do not account for any offsets for electricity that would otherwise be generated by fossil fuels. Therefore, the CO_2e emissions presented in this Study should be used only for air quality permitting requirement purposes.

1.0 Introduction

The Western Placer Waste Management Authority (WPWMA), with assistance from HDR Engineering Inc. (HDR), has prepared this Study for the Placer County Air Pollution Control District (PCAPCD) by means of a Grant issued by the District. The purpose of the Study is to support the WPWMA's ongoing research of the emissions associated with converting municipal solid waste (MSW) residuals currently being landfilled into energy as compared to current waste disposal practices. The effort is part of a feasibility study that explores the conversion of MSW to energy using synthetic gas (syngas) or biogas produced by thermal conversion of these MSW residuals as a feedstock to produce electricity. Specifically, this Study will support the evaluation of pollutants produced in alternative electric generation processes and the cost of controlling them from a project-permitting perspective.

1.1 Background

The WPWMA was established in 1978 pursuant to the Joint Exercise of Powers Agreement between the County of Placer and the Cities of Roseville, Rocklin, and Lincoln (which are collectively referred to as the

Member Agencies) for the purposes of acquiring, owning, operating, and maintaining a sanitary landfill and all related improvements for use by the Member Agencies. Non-member agencies also utilizing WPWMA's facility include the cities of Auburn and Colfax and the Town of Loomis. The Member and non-member agencies are collectively referred to as the "Participating Agencies".

As a result of the California Integrated Waste Management Act of 1989, the WPWMA constructed a materials recovery facility (MRF) to assist the Participating Agencies in achieving the goal of diverting solid waste from land disposal. Nortech Waste, LLC, under contract to the WPWMA, operates the MRF. The facility is classified as a "dirty" or "mixed-waste" MRF which was designed and is operated to recover recyclable materials from the mixed municipal solid waste stream. No residential curbside recyclable sorting and collection programs other than residential curbside green waste collection exist within the WPWMA's service area. Recyclable materials including cardboard, paper, plastics (both California Redemption Value and other rigid plastics), commercial and industrial grade film plastic, glass, ferrous and non-ferrous metals, wood, concrete and other inert materials, electronic wastes and household hazardous wastes are recovered from the waste stream during the sorting process at the MRF. Residual (non-recovered) wastes are hauled, by Nortech Waste, to the WPWMA's Western Regional Sanitary Landfill (WRSL), which is adjacent to the MRF, for final disposal. After the sorting process, the residual material is generally cleaner and dryer than typical unprocessed MSW and, based on a recent limited test, has a higher heating value. The limited testing of the residual wastes suggests the material has a heating value of between 6,000 and 6,500 British thermal units per pound.

With additional processing, the MSW residual can potentially be turned into a processed material that may prove to be an acceptable feedstock for thermal conversion. The output of thermal conversion is synthetic gas (syngas), which has less than half of the energy content of natural gas. With additional processing, the synthetic gas can be used as fuel for various energy-producing technologies including internal combustion (IC) generators, gas turbine (GT) generators and fuel cells. In addition, non-thermal conversion technologies such as anaerobic digestion (AD) can produce a biogas that can be used in these same applications to produce electricity.

The WRSL is a Class II/Class III municipal solid waste landfill with a total capacity of approximately 38 million cubic yards. As of July 1, 2011, approximately 10 million cubic yards of air space has been consumed. The WPWMA estimates that, at the current waste acceptance and disposal rates, the WRSL will reach capacity in 2061. Nortech Landfill, Inc., under contract to the WPWMA, operates the WRSL. The WPWMA has installed and currently operates a landfill gas (LFG) collection system at the WRSL. The LFG collection system is designed to accommodate a flow rate of approximately 2,500 cubic feet per minute of LFG. The estimated current available flow rate of LFG is approximately 1,500 to 1,600 with a methane concentration between 40 and 50 percent by volume. The WPWMA leases land to an independent private party (Energy 2001), and provides them with LFG for the purpose of producing and selling electricity generated from the combustion of LFG. Currently, Energy 2001 has the capability to accept and process approximately 950 scfm of LFG at a methane content of 45 percent. Excess LFG is currently being flared by the WPWMA (via a 2,500 scfm enclosed ground flare) or Energy 2001 (via a 450 scfm enclosed ground flare). The agreement between Energy 2001 and the WPWMA is scheduled to expire in April 2017. Understanding the current and future projected amount of LFG available for producing and flaring operations (as well as fugitive emissions) provides a good emissions baseline projection for comparison to emissions produced with the proposed conversion technologies.

Currently, the WPWMA accepts an average of 820 tons of municipal solid waste per weekday at the MRF. Of this amount, approximately 540 tons is considered residue and is subsequently transported to the WRSL for disposal.

The WPWMA has initiated a separate study to assess the technical and economic viability of using part of its MSW residual waste stream to create green energy. WPWMA's ongoing study includes identifying and evaluating thermal conversion technologies and the production of syngas, the processing requirements to transform the syngas into fuel, and identifying and evaluating alternative technologies to transform the syngas fuel into renewable energy. Of particular interest is the impact of these processes on air emissions and permitting requirements as well as overall economic and operational feasibility.

The work supported by this grant is intended to fit into the WPWMA's ongoing assessment of using MSW to generate renewable energy. Specifically, the WPWMA proposes to utilize the requested grant funds to: 1) identify technologies for producing electricity from syngas, 2) evaluate the air pollutant profiles of each of the identified technologies, and 3) use a life-cycle approach to compare these pollutant profiles to the pollutants generated from the WPWMA's current waste management methodology of landfilling.

1.2 General Assumptions

Various technologies have been proposed and designed to process MSW for the purpose of generating useful products, such as energy (e.g., electricity and/or heat), fuel (solid, liquid, or gaseous), by-product recyclables, construction aggregate (for roads and other construction activities), and soil amendments (compost). HDR identified and described a reasonably broad range of technologies for consideration at the initiation of the WPWMA overall study; however, this list of technologies was reduced through an evaluation of technologies considering the goals and objectives of the WPWMA. The technologies under review for this Study have been identified as: 1) Waste-to-Energy (WTE), 2) Anaerobic Digestion (AD), 3) Gasification, and 4) Plasma Arc Gasification (PAG). In addition, the following assumptions were made:

- The feedstock for the proposed conversion project is the WPWMA material recovery facility (MRF) residue stream, approximately 500 tons/day.
- No outside tonnage will be accepted at the WRSL.
- From the 25 samples taken from the MRF residue processed by the laboratory on April 19, 2010, the range of heat values were from 4,704 BTU/lb to 8,435 BTU/lb, averaging out to approximately 5,752 BTU/lb. This is within the range that should be expected from the project.
- The primary form of energy generated by the proposed processing facility would be electricity; however, some fuel product alternatives are also under consideration and are discussed in this report.

- The landfill gas generated by the Western Regional Sanitary Landfill (WRSL) is potentially available to the project for use as a fuel source in and of itself, or as a supplemental fuel that can be co-mixed with gases produced from the MRF residues.
- The landfill is equipped with a LFG collection system that has 75 percent LFG collection efficiency; the remaining 25 percent of the LFG passes through the cap as fugitive emissions. The methane in the fugitive emissions is oxidized during passage through the landfill cap by 10 percent, per the Environmental Protection Agency (EPA) greenhouse gas inventory rule calculation methodology (40 CFR Part 98, Subpart HH).
- For the baseline scenario of continued operation of the WRSL with energy conversion using an internal combustion (IC) system in combination with flaring of surplus LFG, the net LFG collected will be modeled assuming a split of the gas of 80 percent to the IC system and the remaining 20 percent sent to the WRSL flare. For calculation purposes, emissions from the large and small flares were assumed to be identical.
- For the Alternative Energy Scenarios, three waste processing technologies will be modeled: WTE (incineration) with energy recovery, gasification (including plasma arc gasification), and anaerobic digestion.
- The start date of the conversion technology project will be 2020.
- The conversion technology project will be sized at 500 tpd, operating 365 days per year.
- The conversion technology project availability ("runtime efficiency") of 100 percent for ease of calculation, although in actuality it would be somewhat lower.
- The conversion technology scenarios that produce a secondary fuel (gasification and digestion) will be modeled assuming the syngas and biogas produced is combusted through three different power systems; an internal combustion (IC) engine , a gas turbine, and a fuel cell.
- After review of the syngas produced by both Gasification and Plasma Arc Gasification technologies we concluded that the syngas from the two technologies are similar enough to treat as a single syngas type.
- A methane-based biogas will be produced by anaerobic digestion process that is different from the syngas which is primarily a hydrogen based gas.
- The WTE scenario emissions will be handled by adding these emissions to the LFG emissions calculated assuming the LFG is utilized in IC engines with a portion being flared.
- The totals for each of the emission components listed in the scope (including NO_x, SO_x, CO, CO_2 equivalent, VOCs, total HAPs, and PM_{10}) are calculated on an annual basis.
- The emissions comparison will be only for the landfill gas-related emissions and the CT related emissions. No emissions for the transport of waste, material handling, on-site truck emissions, etc. will be included in the emissions model.
- The modeling will be for years 2020 through 2061, which represent the estimated capacity of the WRSL.

1.3 Report Organization

The PCAPCD Grant Report is organized by the tasks outlined in the Grant Application to the PCAPCD for the WPWMA in the Study Description and WPWMA's Scope of Work. The task information is organized into the following report sections:

- Section 1.0 – Introduction;
- Section 2.0 – Establish Baseline Emissions Profile (Task 1);
- Section 3.0 – Identify Alternative Fuel Cell and Power Generation Technologies (Task 2);
- Section 4.0 – Emissions and Control Measures (Task 3);
- Section 5.0 - Emissions Comparisons (Task 4); and
- Section 6.0 - Summary.

2.0 Establish Baseline Emissions Profile

2.1 Existing Landfill Conditions and Assumptions

To establish a baseline emissions profile for the WPWMA's WRSL, the existing conditions of the landfill without consideration of a conversion technology facility or acceptance of outside waste was assumed. This includes the landfill information used to model and project the amount of LFG produced at the site. The WPWMA modeled the amount of LFG at the WRSL using the EPA's Landfill Gas Emissions Model (LandGEM). LandGEM calculates LFG generation rates using the historical and projected amount of waste disposal at the site, the methane generation rate (k) factor, and the potential methane generation capacity (L_O) factor. For the WRSL, the historical waste disposed was entered into the model; in addition, projected future waste disposal rates without the conversion technology project or new waste from outside the WPWMA was entered. The WPWMA assumed only modest increases in waste generation rates through the closure year 2061, which is the projected date of closure for the WRSL. The k factor was assumed at 0.04 $year^{-1}$ and the L_o was assumed at 100 cubic meters per megagram (MG). Although the landfill is projected to close in 2061, LFG will continue to be produced into the future, albeit at ever decreasing levels.

Using these factors, the baseline amount of LFG produced was projected as shown below for 2020 through 2061.

Table 1 - Baseline LFG Generated from the Western Regional Sanitary Landfill Using LandGEM Model

Year	LFG (cfm)	Year	LFG (cfm)	Year	LFG (cfm)	Year	LFG (cfm)
2020	1,997	2031	2,415	2042	2,978	2053	3,686
2021	2,028	2032	2,461	2043	3,036	2054	3,759
2022	2,060	2033	2,507	2044	3,095	2055	3,833
2023	2,094	2034	2,555	2045	3,155	2056	3,909
2024	2,129	2035	2,604	2046	3,217	2057	3,986
2025	2,166	2036	2,654	2047	3,280	2058	4,065
2026	2,204	2037	2,705	2048	3,344	2059	4,145
2027	2,243	2038	2,757	2049	3,410	2060	4,227
2028	2,284	2039	2,811	2050	3,477	2061	4,311
2029	2,326	2040	2,865	2051	3,545		
2030	2,370	2041	2,921	2052	3,615		

Based on data provided by the WPWMA the methane and carbon dioxide content of the LFG was assumed to be 46.9 percent and 53.1 percent, respectively.

2.2 Baseline Emissions Profile

The baseline emissions profile is presented in Appendix A for each year from 2020 to 2061. The emissions were calculated using the general assumptions discussed in Section 1.2 and the following specific information for each emitting segment (i.e., collected LFG to IC engine, collected LFG to flare, and fugitive LFG) of the LFG.

2.2.1 LFG to IC Engine

PCAPCD provided results from a number of stack tests performed on the IC engines for NO_x, CO, and VOC in 2007 and 2009. The average emission factors from these stack test results were used to calculate engine emissions for these pollutants.

Because the stack testing did not include PM_{10} emissions, an emission factor was derived from the permit to operate, which limits PM_{10} emissions from all three engines combined to 6,358 lb per quarter. The G3516 engine technical sheet obtained from Caterpillar has a maximum flow rate of 331 scfm. Assuming that the engines operate at capacity every hour during a quarter, 91.25 days per quarter, an emission factor, in terms of lb/MM scf LFG, was calculated.

The CO_2 contained in the LFG is assumed to pass through the IC engine unchanged. The LFG organic HAP, mercury, HCl, and SO_2 emission factors were calculated using EPA's current AP-42 information for MSW landfills. Destruction of the methane and organic HAPs in the LFG is assumed equivalent to that of the flares as discussed in Section 2.2.2 below. The mercury is not controlled by the IC engine and combustion of the chlorine-containing constituents in the LFG produces the HCl. Therefore, no destruction efficiency was used for either of these HAPs. All of the carbon in the combusted methane was assumed to be converted to CO_2.

2.2.2 LFG to Flare

The large flare currently operates under PCAPCD Permit to Operate PLWR-01-01. PCAPCD provided results from a number of stack tests performed on the large and small flares for NO_x, CO, and VOC in 2006, 2008, 2009, and 2010. The average emission factors from these stack test results were used to calculate flare emissions for these pollutants. The average tested destruction efficiency was used to estimate flare methane and organic HAP emissions.

Because the stack testing did not include PM_{10} emissions, EPA's current AP-42 emission factor for LFG flares was used. The CO_2 contained in the LFG is assumed to pass through the flare unchanged. The LFG organic HAP, mercury, HCl, and SO_2 emission factors were calculated using EPA's current AP-42 information for MSW landfills. The mercury is not controlled by the flare and combustion of the chlorine-containing constituents in the LFG produces the HCl. Therefore, no destruction efficiency was used for either of these HAPs. All of the carbon in the combusted methane was assumed to be converted to CO_2.

2.2.3 Fugitive LFG

The historic stack test results (i.e., flare and IC engine inlet concentrations) were used as the basis to calculate fugitive emissions of VOC (i.e., NMOC). The CO_2 and NMOC contained in the LFG are assumed to pass through the landfill cover unchanged. The LFG organic HAP and mercury emission factors were calculated using EPA's current AP-42 information for MSW landfills. HCl, SO_2, NO_x, CO, and PM_{10} are not present in the fugitive LFG because they are produced when the LFG is combusted and so are not contained in the fugitive LFG.

2.2.4 Baseline Emissions Profile

The baseline emissions profile is presented in Table 2.

Table 2 - Baseline Emissions Profile in Tons per Year (tpy)

Year	NO_x (tpy)	SO_2 (tpy)	CO (tpy)	CO_2e (tpy)	VOC (tpy)	Total HAP (tpy)	PM_{10} (tpy)
2020	16.7	2.99	93	97,491	24.9	14.9	16.0
2021	16.9	3.04	94	99,005	25.3	15.1	16.2
2022	17.2	3.09	96	100,567	25.7	15.4	16.5
2023	17.5	3.14	97	102,227	26.1	15.6	16.7
2024	17.8	3.19	99	103,935	26.6	15.9	17.0
2025	18.1	3.24	101	105,742	27.0	16.2	17.3
2026	18.4	3.30	103	107,597	27.5	16.5	17.6
2027	18.7	3.36	104	109,501	28.0	16.7	17.9
2028	19.1	3.42	106	111,502	28.5	17.1	18.3
2029	19.4	3.48	108	113,553	29.0	17.4	18.6
2030	19.8	3.55	110	115,701	29.6	17.7	18.9
2031	20.2	3.62	112	117,898	30.1	18.0	19.3
2032	20.5	3.69	114	120,143	30.7	18.4	19.7
2033	20.9	3.76	117	122,389	31.3	18.7	20.0
2034	21.3	3.83	119	124,732	31.9	19.1	20.4
2035	21.7	3.90	121	127,124	32.5	19.4	20.8
2036	22.2	3.98	123	129,565	33.1	19.8	21.2
2037	22.6	4.05	126	132,055	33.7	20.2	21.6
2038	23.0	4.13	128	134,594	34.4	20.6	22.0
2039	23.5	4.21	131	137,230	35.1	21.0	22.5
2040	23.9	4.29	133	139,866	35.7	21.4	22.9
2041	24.4	4.38	136	142,600	36.4	21.8	23.3
2042	24.9	4.46	139	145,383	37.1	22.2	23.8
2043	25.3	4.55	141	148,214	37.9	22.7	24.3
2044	25.8	4.64	144	151,094	38.6	23.1	24.7
2045	26.3	4.73	147	154,023	39.3	23.6	25.2
2046	26.9	4.82	150	157,050	40.1	24.0	25.7
2047	27.4	4.91	153	160,126	40.9	24.5	26.2
2048	27.9	5.01	156	163,250	41.7	25.0	26.7
2049	28.5	5.11	159	166,472	42.5	25.5	27.3
2050	29.0	5.21	162	169,743	43.4	26.0	27.8
2051	29.6	5.31	165	173,063	44.2	26.5	28.3
2052	30.2	5.42	168	176,480	45.1	27.0	28.9
2053	30.8	5.52	171	179,946	46.0	27.5	29.5
2054	31.4	5.63	175	183,510	46.9	28.1	30.0
2055	32.0	5.74	178	187,123	47.8	28.6	30.6
2056	32.6	5.86	182	190,833	48.8	29.2	31.2
2057	33.3	5.97	185	194,592	49.7	29.8	31.9
2058	33.9	6.09	189	198,449	50.7	30.3	32.5
2059	34.6	6.21	193	202,354	51.7	30.9	33.1
2060	35.3	6.33	197	206,357	52.7	31.6	33.8
2061	36.0	6.46	201	210,458	53.8	32.2	34.5

3.0 Selected Conversion Technologies

As part of the overall WPWMA Conversion Technology Assessment, a wide variety of potentially viable technologies were initially screened to select waste conversion technologies with the potential to produce useful energy and that may be feasible for implementation by the WPWMA. Considerations in choosing potential technologies included: local conditions, characteristics and quantities of the MSW residue, commercial viability of the technology, ability for materials processed using the technology to qualify as diverted, ability of the technology to use landfill gas, permitting feasibility in California, marketability of end and by-products, and economics. The technologies selected for further review and analysis included:

- Waste-to-Energy (WTE)/Direct Combustion;
- Anaerobic Digestion (AD);
- Gasification; and
- Plasma Arc Gasification (PAG).

Each of these technologies is described in summary form below.

Waste-to-Energy/Direct Combustion - Direct combustion or waste-to-energy (WTE), now referred to in many cases as Advanced Thermal Recycling (ATR), is the complete oxidation of a fuel at high temperatures under controlled conditions yielding substantial net energy production. The direct combustion process results in the production of hot gases (CO_2, water vapor, and some products of incomplete combustion) from which heat is recovered and converted to steam to be used in industrial processes or sent through a turbine/generator to produce electricity, or both. Direct combustion is the most demonstrated and commercially viable of the thermal conversion technologies assessed. Projects of various sizes are currently operating in the U.S. and throughout the world. Large-scale and modular combustion technology is used in commercial operations at more than 80 facilities in the U.S., two in Canada, and more than 500 in Europe, as well as a number in Asia. By-products from these facilities include ash (bottom ash and fly ash), ferrous scrap, heat, and electricity.

Anaerobic Digestion - A typical anaerobic digestion process is one in which the organic matter contained in the MSW stream is biologically converted, using bacteria in an aqueous environment in the absence of oxygen, into a combustible biogas. Potential waste derived organic feedstocks for anaerobic digestion include MSW-derived organics, wastewater treatment plant biosolids, manure, and food waste. Biologically inert materials that might be contained in the digestion feedstock such as metals, glass, and plastics are undesirable and considered contamination. These materials either must be removed prior to digestion or be dealt with during and after digestion. In essence, only the organic fraction of the MSW stream is considered capable of being converted into biogas. The anaerobic digestion process occurs in two-phases whereby the first phase blends into the second one without a noticeable interruption. These two phases are known as the “acidification phase” and the “methane-producing phase” (methanogenic phase). Generally in a digester that is working on a continuous basis, the distinction between the two phases is not noticeable since “raw” wastes are added to wastes already in the process of being broken down. There are several factors that influence the design and performance of anaerobic digestion. Some of these factors include: the concentration and composition of nutrients in the feedstock, temperature of the digesting mass, retention time of the material in the reactor, pH, acid concentration, and oxygen level. The end products of anaerobic digestion are: biogas, compost, and slurry. The biogas consists primarily of methane (approximately 50 to 60 percent by volume), carbon dioxide (approximately 40 percent), and trace amounts of hydrogen, hydrogen sulfide, and other gases (typically less than one percent). Anaerobic digestion can be categorized into two types of processes; 1) wet systems of either low-solids or high-solids content, and 2) dry systems, often referred to as Dry Fermentation.

Gasification - Conventional thermal gasification is the process whereby solid carbonaceous matter (such as that contained in MSW) is converted under controlled conditions of partial oxidation into fuel gases and other by-products. Partial oxidation is carried out by using less air than required for complete combustion of the fuel (i.e., sub-stoichiometric conditions), or by indirectly heating the organic matter. The gas that is produced is known as synthesis gas, or syngas. Syngas consists primarily of carbon monoxide, hydrogen, methane, and other hydrocarbons, as well as CO_2 and N_2 in some gasification processes. The relative concentration of each gas depends upon the composition of the feedstock used and process operating conditions (temperature, pressure, etc.). Although gasification of various feedstocks has been demonstrated at different scales over the years, the thermal gasification of MSW in the United States has been limited to low processing capacities or at pilot types of operations, and has had limited operational history and success. Thermal gasification has shown some success in Japan. However, they mostly utilize feedstocks of industrial type waste consisting of higher energy/BTU components, such as plastics, with a mix of smaller amounts of MSW, which allows their gasification facilities to operate more efficiently with the larger amount of heat available from the feedstock. The use of power is purportedly on the level with direct combustion, with water usage purportedly less than that used with direct combustion.

Plasma Arc Gasification - One special type of gasification technology being offered recently by the industry to handle MSW is plasma arc gasification; it is considered a subset of thermal gasification. Although plasma arc gasification (PAG) technology has been operating in the metal industry since the late 19th century for a range of industrial and disposal applications (such as the gasification of hazardous waste, auto shredder, and other types of homogeneous wastes, mostly overseas), it has only been in the last 10 years or so that this technology has been applied to using MSW as a feedstock at the pilot and bench-scale testing level. The technology uses an electrical arc process to generate extremely high temperatures (9000° to 18000°F.) that gasify the feedstock to create a very high temperature syngas that is subsequently converted to heat and electrical energy using conventional energy conversion systems. In the case of MSW processed using plasma arc gasification, the organic materials in the waste are broken down into basic compounds, while the inorganic materials form a slag or aggregate type of material. As with conventional thermal gasification described above, the syngas could be combusted and the heat recovered in a waste heat boiler. Alternatively, the syngas can be combusted to generate electricity. As previously discussed, plasma arc technology has been used primarily to treat hazardous waste, auto shredder waste, and to heat steel melting furnaces. Plasma arc gasification has not been applied successfully to the processing of MSW on a significant commercial scale and as such is not proven for that application. The US military is working with technology vendors to demonstrate this technology utilizing MSW feedstock at a very small scale at some of its bases, and there are a few facilities throughout the world that are also trying to demonstrate this technology utilizing MSW. This technology can be modular and we have seen units at a pilot scale up to the 100 tpd level.

4.0 Identify Alternative Fuel Cell and Power Generating Technologies

HDR prepared estimates of emissions profiles based on the different conversion technologies that were identified as discussed above. These include: 1) WTE/Direct Combustion), 2) Anaerobic Digestion, 3) Gasification, and 4) Plasma Arc Gasification. To prepare the emission profiles for these technologies, HDR employed estimates of the different fuel types produced from these technologies as well as identified the potential power generation technologies that may be able to operate using these fuel types from the different conversion technologies.

4.1 Fuel Types from Conversion Technologies

The fuel type generated by each technology is listed below:

- **Waste-to-Energy/Direct Combustion** – The WTE/Direct Combustion technology does not produce a separate product gas for capture and energy conversion in the same sense that AD and Gasification/Plasma Arc Gasification technologies produce. WTE technology is usually considered as a single technology that converts the carbon in the MSW through a combustion process at furnace temperatures into heat that converts water into steam to drive a turbine generator for producing electricity. Since the WTE process will not generate a separate gas to be utilized through a power generating technology, the emissions of this technology will be directly added to those of handling the excess LFG. The emissions calculated for WTE in this analysis were derived from HDR's library of information on WTE/Direct Combustion projects.
- **Anaerobic Digestion (AD)** – AD generates a methane based biogas from the digestion of the MSW supplied to the system. The biogas assumed produced for use in this analysis was derived through identification of those digestable components such as food waste (13.8 percent), wood waste (3.4 percent), yard waste (1.0 percent), mixed paper (35.9 percent), cardboard/Kraft paper (4.6 percent), and newspaper (0.6 percent) from the April 2010 MRF Residue Composition Report provided by WPWMA as conducted by Columbia Analytical Services. Each of these components were combined with assumptions from a recent anaerobic digestion laboratory demonstration project, including solids content to calculate total solids (TS), assumptions for volatile solids (VS) - those that will digest, the amount of standard cubic feet (scf) of CH_4 or methane produced per lb of VS of each component, and a methane content for each component that averages to about 60 percent overall. The remainder of the biogas is primarily CO_2 with small amounts of H_2S (200-4000 parts per million (ppm)). Since these assumptions were derived from a laboratory basis, it was assumed that in the field only about 60 percent of the potential biogas would actually be generated for use. The digestate (i.e., the materials remaining after digestion) was assumed to be disposed of by landfilling, a portion of which will be degraded in the landfill to produce LFG. The amount of methane produced by the anaerobic digestion of a ton of MSW was compared to the amount of methane that would be produced by a ton of MSW that was landfilled. This comparison shows that the predicted anaerobic digestion biogas

contains approximately 50 percent of the methane production potential of MSW that is landfilled. Therefore, the remaining 50 percent of methane potential was assumed to be produced as LFG after the digestate is landfilled.

- **Gasification/Plasma Arc Gasification** – The gasification process generates a synthesis gas (or syngas). The syngas is produced through gasification of a carbon containing fuel (such as MSW) to a gaseous product that has some heating value. The gas product or syngas is usually composed of carbon monoxide, carbon dioxide, and hydrogen. For this analysis, we are assuming that the syngas produced from gasification and by plasma arc gasification technologies is similar enough in nature to consider it as a single syngas product. The syngas assumed produced for use in this analysis was derived from HDR's library of information on proposed gasification and plasma arc gasification projects that produce syngas. The composition of the syngas was derived from HDR's library of information on gasification projects. A typical syngas composition is 10-15 percent CO_2, 25-45 percent CO, 10-15 percent H_2, 10-50 percent N_2, and 10-25 percent H_2O.

In summary, two different types of gases; 1) biogas from the anaerobic digestion process and 2) syngas from either the gasification or the plasma arc gasification process are used for modeling through the Power Generating Technologies discussed in the following section.

4.2 Power Generating Technologies

The most probable power generating technologies were identified to handle the biogas and syngas fuels generated from the selected conversion technologies under study. These include internal combustion (IC) engines, gas turbines, and fuel cells. The most widely used power generating technology for these fuels is the IC engine, which is used broadly in the generation of electricity from LFG as well as biogas from anaerobic digestion. The gas turbine has been utilized in Japan and other countries outside the US for handling syngas, although syngas is also being processed into electricity using IC engines in many countries. Fuel cells have been heavily discussed in reference literature, tests, and demonstration of fuel cells and operations of some fuel cells have occurred on limited gas types and qualities, including methane based biogas (mostly LFG). However, we have only been able to locate minimal information regarding limited bench scale testing of laboratory manufactured syngas with fuel cells (no actual commercial demonstration). The following sections describe in a summarized form the power generating technologies being assessed to process the two fuel types produced from the conversion technologies.

4.2.1 Internal Combustion Engines

The internal combustion (IC) engine is an engine in which the combustion of a fuel, such as a gas, occurs with an oxidizer, usually air, in a combustion chamber. An IC engine gains its energy from heat released during the combustion of the oxidizer/fuel mixture. This process occurs within the engine (thus internal combustion) and is part of the thermodynamic cycle of the device. Useful work generated by an IC engine results from the hot gaseous products of combustion acting on moving surfaces of the engine, such as a piston (a turbine blade or a nozzle is used in some instances), transforming chemical energy into useful mechanical energy. The term IC engine refers to an engine in which combustion is intermittent, such as the more familiar two or four stroke (and sometimes six stroke) piston engines.

The IC engine is quite different from external combustion devices in which the energy is delivered to a working fluid and not mixed with or contaminated by combustion products. Working fluids can be air, hot water, pressurized water or others, heated in a boiler. A large number of different designs for IC engines have been developed and built that allow for different fuel blends, sizes, and operations. The thermal efficiency, which is the ratio of net output energy to fuel input energy for the cycle, measures the engine's ability to minimize wasted energy. A thermal efficiency of 50 percent means that for every 100 units of added energy, 50 units will be available as useful output while 50 units will leave the engine as high-temperature exhaust. The thermal efficiency of the CAT G3516 engines currently installed at WRSL is 47.6 percent, according to the engine data sheet obtained from the engine vendor.

4.2.2 Gas Turbines

Gas turbines are one of a class of heat engines which use fuel energy to produce mechanical output power, as torque through a rotating shaft. They also can be used to produce jet power in the form of velocity through an exhaust nozzle, as in aircraft jet engines. The fuel energy is added to the working substance, which is gaseous in form and most often air, either by direct internal combustion or indirectly through a heat exchanger. The heated working substance, air co-mixed with combustion products in the usual case of internal combustion, acts on a continuously rotating turbine to produce power. The gas turbine is thus distinguished from heat engine types where the working substance produces mechanical power by acting intermittently on an enclosed piston, and from steam turbine engines where the working substance is water in liquid and vapor form. Gas turbine engines depend on the principle of the air cycle, where ambient air is first compressed to a maximum pressure level, at which point fuel heat energy is added to raise its temperature, also to a maximum level. The air is then expanded from high to low pressure through a turbine. The expansion process through the turbine extracts energy from the air, while the compression process requires energy input. As the air moves through the engine, the turbine continuously provides energy to drive the compressor. At the point where the turbine has provided sufficient energy to power the compressor, the air pressure remains higher than the outside ambient level. This higher pressure represents available energy in the air that can be turned into useful output power by a final expansion process that returns the air pressure to ambient. The exhaust air leaves the engine with pressure equal to the outside, but at a higher temperature. For any completed cycle, the total energy added from the fuel sources will always be equal to the sum of the useful output energy and the wasted exhaust energy. The thermal efficiency of combined cycle turbines (i.e., equipped with a heat recovery steam generator to optimize efficiency) is 50-60 percent.

4.2.3 Fuel Cells

A fuel cell is a device that converts the chemical energy from a fuel into electricity through a chemical reaction with oxygen or another oxidizing agent. Hydrogen is the most common fuel, but hydrocarbons such as natural gas and alcohols like methanol are sometimes used. Fuel cells require a constant source of fuel and oxygen to run, but they can produce electricity continually for as long as these inputs are supplied. Although there are many types of fuel cells they all consist of an anode (negative side), a cathode (positive side) and an electrolyte that allows charges to move between the two sides of the fuel cell. Electrons are drawn from the anode to the cathode through an external circuit, producing electricity. Using a Polymer Exchange Membrane (PEM) Fuel Cell as an example, hydrogen gas (H_2)

enters the fuel cell on the anode side, this gas is forced to come in contact with the electrolyte, splitting it into two positive H ions (protons) and two negatively charged electrons. The electrons are conducted through the anode, where they make their way through the external circuit (doing useful work such as turning a motor, etc) and return to the cathode side of the fuel cell. Meanwhile, on the cathode side of the fuel cell, oxygen gas (O_2) is being forced through the electrolyte, where it forms two oxygen atoms. Each of these atoms has a strong negative charge. This negative charge attracts the two positive H ions through the membrane, where they combine with an oxygen atom and two of the electrons from the external circuit to form a water molecule (H_2O).

As the main difference among fuel cell types is the electrolyte, fuel cells are classified by the type of electrolyte they use. Phosphoric Acid Fuel Cells have been used for at least demonstration purposes with LFG and could potentially be used with biogas generated from anaerobic digestion as assumed for this assessment. Other types of fuel cells, classified as high temperature fuel cells such as Solid Oxide Fuel Cells (SOFC) or Molten Carbonate Fuel Cells (MCFC) are reported in literature searches and vendor information as having the ability to process a wide variety of fuels such as a syngas; although we understand that syngas clean-up technology as well as the overall process of using syngas in a fuel cell has not been commercially demonstrated to date. It is **critical** to recognize that fuel cells have not been used in conjunction with gasification and plasma arc gasification technologies that generate a syngas beyond laboratory type testing. Thus the emissions information provided in this report is supplied as only theoretical and can only be verified through commercial operational means. One company purports that they manufactured a syngas and have tested the gas in a MCFC. The company claims that endothermic as well as exothermic reactions took place which caused the fuel cell to overheat. Their results point to being able to use the MCFC using syngas up to only 75 percent on a heat input basis to prevent overheating and damage to the fuel cell. The company theorizes that the other 25 percent of the heat input could be supplied by natural gas, by using the excess heat generated by the syngas oxidation as energy to convert the natural gas into hydrogen. However, this conjecture remains to be proven in practice. Thus, our analysis considers the use of syngas in a fuel cell as theoretical and we assume that the use of only syngas, with the corresponding 75 percent reduction in heat input, would be addressed by increasing the size of the equipment to approximately 1.33 times to overcome the 75 percent reduction.

4.3 Estimated Fuel Requirements

Fuel requirements for power generation are typically described in terms of the energy potential, and contaminant level. Energy potential of fuel is typically expressed on a British Thermal Unit (Btu) per standard cubic foot value basis. The energy potential of biogas and landfill gas is a function of the quantity of methane contained in the gas. The methane level of digester or biogas is generally higher than landfill gas with a relatively narrow range of 55 to 65 percent methane. Biogas has an energy value in the range of 500 to 650 Btu/scf. The methane level of landfill gas can vary in a much larger range (35 to 57 percent)[1]. Consequently, landfill gas has an energy value in the range of 400 to 600 Btu/scf. The energy potential of syngas is a function of the quantity of a combination of hydrogen, carbon monoxide,

[1] Siloxanes in Landfill and Digester Gas, Wheless and Pierce, 2004

and other trace gases (methane, ethylene, ethane, butane, etc.). The energy value of syngas can range in the 250 to 450 Btu/scf; however, depending upon the quantity of nitrogen in the syngas, the energy value can be below 200 Btu/scf [2]. This lower energy value of syngas may adversely impact the operation of an IC engine or turbine if the combination of nitrogen and water in the gas lowers the peak flame potential of the gas resulting from the reduction of the Btu value. As a result, the IC engine or turbine must be specifically designed to handle the lower BTU content syngas.

The three power generating devices modeled (IC engines, turbines, fuel cell) have varying levels of fuel requirements to perform. In general, IC engines are the most tolerant of varying levels of the fuel energy value and contaminant, followed by turbines with less tolerance for variances in energy values and contaminants. Fuel cells have the most stringent requirements in terms of fuel quality.

The IC engines have the most tolerance for low Btu energy fuel. Fuel requirements of an IC engine can vary according to different manufacturers of various engines. IC engines can accept biogas or landfill gas containing methane as low as 40 percent. On a Btu value, this equates to a Btu value of approximately 400 Btu/scf gas. Fuels below this level would typically lack adequate combustible gas for engine operations to function. However, according to some vendors of gasification technologies, IC manufacturers have been able to modify their engines to take a much lower quality, down to roughly 200 Btu/scf; however, they have not been tested at commercial levels.

Turbines are similar to IC engines, but typically have less tolerance for low Btu energy fuel. Fuel requirements of the turbines also vary according to manufacturers of various turbines. One manufacturer (General Electric) reports their gas turbines have experience operating on syngas with a Lower Heating values in the range of 200Btu/scf.[3]

Fuel cells have more stringent requirements than turbines for low Btu energy fuel. Fuel requirements of the fuel cells also vary according to manufacturers of various fuel cells, but in general require natural gas equivalent or gas containing methane at or near 95 percent. On a Btu value, if methane is the fuel, this equates to a Btu value of approximately 1,000 Btu/scf gas. Subsequently, if biogas or landfill gas is used as the fuel for a fuel cell, a very robust purification process is required to prepare the gas prior to use in the fuel cell. To date, the use of low Btu value syngas on fuel cell has been researched, but has not been performed at continuous or commercial scale.

In addition to the energy value of the fuel, the presence of contaminants affects the performance of the power generation process. Contaminants consist of a wide variety of possible deleterious materials. The most prominent contaminants include moisture, various trace gases such as hydrogen sulfides (H_2S), hydrochloric acids (HCl), ammonia (NH_3), siloxanes, and particulates. Moisture and particulates are relatively easy to remove and therefore are not of great concern. Various trace gases and siloxanes are more challenging to remove.

2 Syngas Quality of Gasification of High Moisture Municipal Solid Wastes, Yun, Chung, Yoo, 2003

3 General Electric Integrated Gasification Combined Cycle Experience with Advanced Gas Turbines, Brdar and Jones, 2000

In addition to energy quantity, power generating units have differing tolerances for contaminants. One of the most destructive contaminants found in landfill gas and digester gas are siloxanes. Siloxanes consist of a variety of man-made organic compounds that contain silicon. Siloxanes are used to manufacture personal products, health care products, personal hygiene products, and a variety of industrial products and are therefore are common in waste. In the digestion process, low molecular weight siloxanes volatize into digester gas. Consequently, siloxanes are present in both landfill gas and digester gas. In the power generation phase, siloxanes volatilize in the fuel and crystallize as silicon dioxide causing buildup of a silicon layer on the inside of the engine or turbine causing rapid wear and premature wearing of the engine or turbine. Similarly, siloxanes build up in the fuel cell as a part of the chemical process and accelerate the deterioration of the fuel cell.

Gas turbines and microturbines operate at higher speeds and with higher tolerances than IC engines and consequently have less tolerance for contaminants. For example, one microturbine manufacturer (Capstone) reported as an established fuel specification that requires less than 5 parts per billion by volume (ppbv) (or 0.03 mg/m3) of siloxanes. This requirement is essentially the same as a 100 percent siloxane removal. Similarly, another microturbine manufacturer Ingersoll-Rand, requires fuel restriction of 10 ppbv of siloxane. The following table provides a summary of siloxane levels of various power generating devices according to different manufacturers.[4]:

Table 3 - Manufacturer Siloxane Limits

Type of Power Generating Device	Manufacturer	Siloxane level (mg/m3)
IC Engine	Caterpillar	28
IC Engine	Jenbacher	10
IC Engine	Deutz	25
Gas Turbine	Solar	0.1
Microturbine	Ingersoll-Rand	0.06
Microturbine	Capstone	0.03

Especially for syngas, the removal of other trace gases is critical. Many gasification technologies rely on an acid scrubbing system to remove HCl, a desulphurization process to remove H_2S and a dust or particulate removal system to remove PM.

4.4 Estimated Energy Production

The conversion of MRF residuals into energy will vary according to the type of conversion process employed. The three types of power generation include:

- Direct Combustion (WTE): the direct combustion process incinerates the organic components of the feedstock, converting them into heat which is transferred into steam that drives a steam powred electric turbine. Direct combustion can generate in the range of 500 to 600 net kWh/ton of waste.

[4] Ibid

- Gasification: The gasification and plasma arc gasification process uses heat to convert organic components of the feedstock into a syngas which is then fed as a fuel into a power generating device (IC engine, turbine or fuel cell) that converts the fuel into electricity. The technology proponents claim that gasification can generate energy in the range of between 550 and 650 net kWh/ton of waste, while the plasma arc gasification proponent claim up to 700 kWh/ton of waste or higher; however, these claims have not been achieved in commercial operating scenarios.
- Digestion: The anaerobic digestion process uses bacteria to consume the volatile portion of the organic components of the feedstock and emit biogas which is then fed as a fuel into a power generating device (IC engine, turbine or fuel cell) that converts the fuel into electricity. The electric power production rate of an anaerobic digestion system is approximately 200 to 300 net kWh/ton of feedstock. This lower range of power production per ton is caused by the fact that only a portion of the feedstock is able to be consumed by the bacteria in the digestion process. Organic materials such as carpet and plastics are not capable of being digested. In contrast, the thermal processes above are able to convert all the organic components of the feedstock into either a syngas (for gasification and plasma arch gasification) or heat (incineration). These electric energy power production ranges can be summarized in the following table.

Table 4 - Energy Production by Conversion Process

Conversion Process	Gas-Fuel Energy (Btu/scf gas)	Electric Production Range (kWh/ton MSW)
WTE-Incineration	NA *	500 to 600
Gasification and Plasma Arc Gasification	250 to 450	550 to 700
Anaerobic Digestion	500 to 600	200 to 300

*Uses sold waste as fuel

5.0 Emissions and Control Measures

Each of the technologies will generate air emissions during the conversion of MSW to energy (WTE), generated syngas or biogas-to-energy. Therefore, each of the technologies would require an air quality permit to construct and permit to operate. Permitting requirements may include a demonstration of Best Available Control Technologies (BACT) and if necessary purchasing of Emission Reduction Credits (ERCs), depending upon the level of pollutant emissions associated with a given technology. Summaries of estimated emissions and discussions of anticipated control equipment and ERC requirements are included in the following sections for each CT evaluated.

5.1 Emissions from Conversion Technologies and Associated Power Generators

5.1.1 WTE/Direct Combustion

Table 5 summarizes the air pollutant emission rates estimated for WTE. These estimates reflect the use of SCR for the control of NO_x to approximately 50 ppm (in compliance with Rule 206, Section 301.1 of the PCAPCD rules). In addition, the emission estimates reflect the use of advance pollution controls for municipal waste combustor (MWC) acid gases (i.e., SO_2 and HCl), mercury, and particulate matter. Review of the estimated emissions indicates that NO_x, SO^2, and VOC exceed PCAPCD's BACT trigger. In addition, WTE would be required to obtain ERCs for NO_x.

The following assumptions and sources of information were used to estimate emissions for WTE:

- All of the generated landfill gas continues to be collected and routed to an IC engine and flare for modeling consistency, as outlined in Section 1.2 and the associated emissions were calculated using the same method as outlined in Section 2.1. However, the amount of LFG generated is reduced because of the 500 tpd diversion to the WTE technology.
- Emission factors for NO_x, SO_2, CO, VOC, total HAP, and PM_{10} were developed from confidential information available from two different vendors of operating facilities.
- The emission factor for CO_2e is based on the average MRF residue carbon content of 32.43 percent and assuming that essentially all of the carbon is oxidized to CO_2.

Table 5 - Estimated Air Emissions for WTE Technology

Pollutant	Estimated Emissions		PCAPCD Regulatory Trigger	
	lb/day	tpy	BACT – lb/day	ERC – tpy
NO_x	395	72	10	10
SO_2	90	16	80	27.5
CO	390	71	550	99
VOC	24	4	10	10
PM_{10}	26	5	80	15
Lead	0.001		3.3	NA
CO_2e	1,189,100	217,000		
Total HAP	73	13		

5.1.2 Syngas to IC Engines

Table 6 summarizes the air pollutant emission rates estimated for the syngas to IC engine scenario. These estimates include the application of SCR for NO_x control and oxidation catalyst for the control of CO, VOC, and organic HAP. Review of the estimated emissions indicates that NO_x, VOC, and PM_{10} exceed PCAPCD's BACT trigger. In addition, syngas to IC engines would be required to obtain ERCs for NO_x, VOC, and PM_{10}.

The following assumptions and sources of information were used to estimate emissions for the syngas to IC engine scenario:

- All of the generated landfill gas continues to be collected and routed to an IC engine and flare, as outlined in Section 1.2 and the associated emissions were calculated using the same method as outlined in Section 2.1. However, the amount of LFG generated is reduced because of the 500 tpd diversion to the conversion technology (gasification or plasma arc gasification).
- The syngas heat content (MMBtu/yr) was estimated based on the average MRF residue heat content of 5,752 Btu/lb and assuming that essentially all of the heat potential is converted to syngas.

- The emission factor for CO_2e was estimated based on the average MRF residue carbon content of 32.43 percent and assuming that essentially all of the carbon is oxidized to CO_2.
- No readily usable emission factor for SO_2 emissions resulting from the combustion of syngas in an IC engine was found. Therefore, the SO_2 emission factor used corresponds to EPA's default emission factor for turbines combusting digester gas along with the assumption that the syngas would be cleaned to a level equivalent to that emission factor.
- The syngas total HAP emission factor was developed from confidential information available from two different vendors of operating facilities.
- The NO_x, CO, VOC, and PM_{10} emission factors are vendor guarantees for a recently permitted large natural gas-fired IC engine equipped with SCR and an oxidation catalyst.

Table 6 - Estimated Air Emissions for Syngas to IC Engines

Pollutant	Estimated Emissions		PCAPCD Regulatory Trigger	
	lb/day	tpy	BACT – lb/day	ERC – tpy
NO_x	92	17	10	10
SO_2	37	6.8	80	27.5
CO	173	31	550	99
VOC	173	31	10	10
PM_{10}	144	26	80	15
CO_2e	1,189,100	217,000		
Total HAP	14	3		

5.1.3 Syngas to Turbines

Table 7 summarizes the air pollutant emission rates estimated for the syngas to turbines scenario. These estimates include the application of SCR for NO_x control and oxidation catalyst for the control of CO, VOC, and organic HAP. Review of the estimated emissions indicates that NO_x exceed PCAPCD's BACT trigger. In addition, syngas to turbine would be required to obtain ERCs for NO_x.

The following assumptions and sources of information were used to estimate emissions for the syngas to turbine scenario:

- All of the generated landfill gas continues to be collected and routed to an IC engine and flare, as outlined in Section 1.2 and the associated emissions were calculated using the same method as outlined in Section 2.1. However, the amount of LFG generated is reduced because of the 500 tpd diversion to the conversion technology (gasification or plasma arc gasification).
- The syngas heat content (MMBtu/yr) was estimated based on the average MRF residue heat content of 5,752 Btu/lb and assuming that essentially all of the heat potential is converted to syngas.
- The emission factor for CO_2e was estimated based on the average MRF residue carbon content of 32.43 percent and assuming that essentially all of the carbon is oxidized to CO_2.

- The SO_2 emission factor used corresponds to EPA's default emission factor for turbines combusting digester gas along with the assumption that the syngas would be cleaned to a level equivalent to that emission factor.
- The syngas total HAP emission factor was developed from confidential information available from two different vendors of operating facilities.
- The NO_x, CO, VOC, and PM_{10} emission factors are EPA's default uncontrolled emission factors for turbines combusting digester gas. Based on the assumption that the turbine will be equipped with SCR and an oxidation catalyst, a 90 percent control efficiency was applied to the uncontrolled NO_x, CO, and VOC emission factors.

Table 7 - Estimated Air Emissions for Syngas to Turbines

Pollutant	Estimated Emissions		PCAPCD Regulatory Trigger	
	lb/day	tpy	BACT – lb/day	ERC – tpy
NO_x	92	17	10	10
SO_2	37	6.8	80	27.5
CO	10	2	550	99
VOC	3	1	10	10
PM_{10}	69	13	80	15
CO_2e	1,189,100	217,000		
Total HAP	14	3		

5.1.4 Syngas to Fuel Cell

Table 8 summarizes the air pollutant emission rates estimated for the syngas to fuel cell scenario. Review of the estimated emissions indicates that no pollutant exceeds PCAPCD's BACT trigger. Syngas to fuel cell would not be required to obtain ERCs for any pollutant. **<u>It is critical to recognize that fuel cells have not been used in conjunction with gasification and plasma arc gasification technologies that generate a syngas.</u>** Thus, the emissions information provided in this report is supplied as only theoretical. Prior to considering this technology, a demonstration of the technology at a commercial level is recommended.

The following assumptions and sources of information were used to estimate emissions for the syngas to fuel cell scenario:

- All of the generated landfill gas continues to be collected and routed to an IC engine and flare, as outlined in Section 1.2 and the associated emissions were calculated using the same method as outlined in Section 2.1. However, the amount of LFG generated is reduced because of the 500 tpd diversion to the conversion technology (gasification or plasma arc gasification).
- The syngas heat content (MMBtu/yr) was estimated based on the average MRF residue heat content of 5,752 Btu/lb and assuming that essentially all of the heat potential is converted to syngas.
- The emission factor for CO_2e was estimated based on the average MRF residue carbon content of 32.43 percent and assuming that essentially all of the carbon is oxidized to CO_2.

- The NO_x, SO_2, and PM_{10} emission factors were developed from confidential information from a fuel cell vendor for equipment operating on natural gas (not syngas as this information is not available at this time). Use of these emission factors is based on the assumption that gas cleanup technology exists that can clean up the syngas to a level such that the fuel cell emissions are equivalent to those of natural gas use.
- None of the syngas heat content would be lost during the gas cleanup process and that the gas cleanup process will not generate air emissions.
- The gas cleanup process would remove essentially all VOC and HAP compounds contained in the syngas in order to assure proper operation of the fuel cell.
- It was assumed that essentially all of the CO would be oxidized to CO_2 by the fuel cell.

Table 8 - Estimated Air Emissions for Syngas to Fuel Cell

Pollutant	Estimated Emissions		PCAPCD Regulatory Trigger	
	lb/day	tpy	BACT – lb/day	ERC – tpy
NO_x	8	1	10	10
SO_2	0.1	0.01	80	27.5
CO	0	0	550	99
VOC	0	0	10	10
PM_{10}	0.02	0.003	80	15
CO_2e	1,189,100	217,000		
Total HAP	0	0		

5.1.5 AD Biogas to IC Engines

Table 9 summarizes the air pollutant emission rates estimated for the AD biogas to IC engine scenario. These estimates include the application of SCR for NO_x control and oxidation catalyst for the control of CO, VOC, and organic HAP. Review of the estimated emissions indicates that NO_x and VOC exceed PCAPCD's BACT trigger. AD biogas to IC engine would not be required to obtain ERCs for any pollutant.

The following assumptions and sources of information were used to estimate emissions for the AD biogas to IC engine scenario:

- All of the generated landfill gas continues to be collected and routed to an IC engine and flare, as outlined in Section 1.2 and the associated emissions were calculated using the same method as outlined in Section 2.1. However, the amount of LFG generated is reduced because of the 500 tpd diversion to the anaerobic digestion system.
- The amount of AD biogas production rate was estimated to be 2,615 scf/ton MSW. This value was derived from laboratory testing results and an assumption that an actual production system would produce approximately 60 percent of the amount of biogas produced by the controlled laboratory test.
- The AD biogas heat content was estimated assuming a 60 percent methane concentration.
- A comparison of the estimated amount of produced methane to the methane potential of the MRF residue indicates that the previous assumptions result in approximately 50 percent of the

MRF residue's methane potential being converted to biogas. The remaining 50 percent was assumed to be landfilled in the form of digestate, where the residual portion of the organic material would decompose in the landfill forming LFG.

- The emission factor for CO_2e was estimated based on the assumption that essentially all of the methane in the biogas is oxidized to CO_2 and that the CO_2 in the biogas (40 percent) passes through the engine unchanged.
- No readily usable emission factor for SO_2 emissions resulting from the combustion of biogas in an IC engine was found. Therefore, the SO_2 emission factor used corresponds to EPA's default emission factor for turbines combusting digester gas.
- No readily usable emission factor for total HAP emissions resulting from the combustion of biogas in an IC engine was found. Therefore, the total HAP emission factor used corresponds to EPA's default uncontrolled emission factor of 4 stroke lean burn natural gas engines with 90 percent control assumed for oxidation catalyst.
- The NO_x, CO, VOC, and PM_{10} emission factors are vendor guarantees for a recently permitted large natural gas-fired IC engine equipped with SCR and oxidation catalyst.

Table 9 - Estimated Air Emissions for AD Biogas to IC Engines

Pollutant	Estimated Emissions		PCAPCD Regulatory Trigger	
	lb/day	tpy	BACT – lb/day	ERC – tpy
NO_x	11	2	10	10
SO_2	5	1	80	27.5
CO	21	4	550	99
VOC	21	4	10	10
PM_{10}	18	3	80	15
CO_2e	137,026	25,007		
Total HAP	52	1		

5.1.6 AD Biogas to Turbines

Table 10 summarizes the air pollutant emission rates estimated for the AD biogas to turbines scenario. These estimates include the application of SCR for NO_x control and oxidation catalyst for the control of CO, VOC, and organic HAP. Review of the estimated emissions indicates that NO_x exceeds PCAPCD's BACT trigger. AD biogas to turbine would not be required to obtain ERCs for any pollutant.

The following assumptions and sources of information were used to estimate emissions for the AD biogas to turbine scenario:

- All of the generated landfill gas continues to be collected and routed to an IC engine and flare, as outlined in Section 1.2 and the associated emissions were calculated using the same method as outlined in Section 2.1. However, the amount of LFG generated is reduced because of the 500 tpd diversion to the anaerobic digestion system.
- The amount of AD biogas production rate was estimated to be 2,615 scf/ton MSW. This value was derived from laboratory testing results and an assumption that an actual production system

would produce approximately 60 percent of the amount of biogas produced by the controlled laboratory test.

- The AD biogas heat content was estimated assuming a 60 percent methane concentration.
- A comparison of the estimated amount of produced methane to the methane potential of the MRF residue indicates that the previous assumptions result in approximately 50 percent of the MRF residue's methane potential being converted to biogas. The remaining 50 percent was assumed to be landfilled in the form of digestate, where it would form LFG.
- The emission factor for CO_2e was estimated based on the assumption that essentially all of the methane in the biogas is oxidized to CO_2 and that the CO_2 in the biogas (40 percent) passes through the engine unchanged.
- The SO_2 emission factor used corresponds to EPA's default emission factor for turbines combusting digester gas.
- The NO_x, CO, VOC, total HAP, and PM_{10} emission factors are EPA's default uncontrolled emission factors for turbines combusting digester gas. Based on the assumption that the turbine will be equipped with SCR and an oxidation catalyst; in addition, a 90 percent control efficiency was applied to the uncontrolled NO_x, CO, total HAP, and VOC emission factors.

Table 10 - Estimated Air Emissions for AD biogas to Turbines

	Estimated Emissions		PCAPCD Regulatory Trigger	
Pollutant	**lb/day**	**tpy**	**BACT – lb/day**	**ERC – tpy**
NO_x	11	2	10	10
SO_2	5	1	80	27.5
CO	1	0.2	550	99
VOC	0.4	0.1	10	10
PM_{10}	9	2	80	15
CO_2e	137,026	25,007		
Total HAP	0.2	0.003		

5.1.7 AD Biogas to Fuel Cell

Table 11 summarizes the air pollutant emission rates estimated for the AD biogas to fuel cell scenario. Review of the estimated emissions indicates that no pollutant exceeds PCAPCD's BACT trigger. AD biogas to fuel cell would not be required to obtain ERCs for any pollutant. As described above, it is **critical** to recognize that fuel cells have not been used commercially with MSW anaerobic digestion technologies that generate associated biogas. Thus, the emissions information provided in this report is supplied as only theoretical and can only be verified through commercial operational means.

The following assumptions and sources of information were used to estimate emissions for the AD biogas to fuel cell scenario:

- All of the generated landfill gas continues to be collected and routed to an IC engine and flare, as outlined in Section 1.2 and the associated emissions were calculated using the same method as outlined in Section 2.1. However, the amount of LFG generated is reduced because of the 500 tpd diversion to the anaerobic digestion system.

- The amount of AD biogas production rate was estimated to be 2,615 scf/ton MSW. This value was derived from laboratory testing results and an assumption that an actual production system would produce approximately 60 percent of the amount of biogas produced by the controlled laboratory test.
- The AD biogas heat content was estimated assuming a 60 percent methane concentration.
- A comparison of the estimated amount of produced methane to the methane potential of the MRF residue indicates that the previous assumptions result in approximately 50 percent of the MRF residue's methane potential being converted to biogas. The remaining 50 percent was assumed to be landfilled in the form of digestate, where it would form LFG.
- The emission factor for CO_2e was estimated based on the assumption that essentially all of the methane in the biogas is oxidized to CO_2 and that the CO_2 in the biogas (40 percent) passes through the engine unchanged.
- The NO_x, SO_2, and PM_{10} emission factors were developed from confidential information received from a fuel cell vendor for equipment operating on natural gas (not biogas from MSW). Use of these emission factors is based on the assumption that gas cleanup technology exists that can clean up the AD biogas to a level such that the fuel cell emissions are equivalent to those of natural gas use.
- None of the AD biogas heat content would be lost during the gas cleanup process and that the gas cleanup process will not generate air emissions.
- The gas cleanup process would remove essentially all VOC and HAP compounds contained in the AD biogas in order to assure proper operation of the fuel cell.
- It was assumed that essentially all of the CO would be oxidized to CO_2 by the fuel cell.

Table 11 - Estimated Air Emissions for AD Biogas to Fuel Cell

	Estimated Emissions		PCAPCD Regulatory Trigger	
Pollutant	**lb/day**	**tpy**	**BACT – lb/day**	**ERC – tpy**
NO_x	1	0.2	10	10
SO_2	0.01	0.002	80	27.5
CO	0	0	550	99
VOC	0	0	10	10
PM_{10}	0.002	0.0004	80	15
CO_2e	137,026	25,007		
Total HAP	0	0		

5.2 Potential Control Measures for Each Technology

As discussed previously, the anticipated required control equipment was included in the estimated emissions calculated for the various CT scenarios. The control equipment included is anticipated to meet the definition of BACT for purposes of PCAPCD's regulations. A discussion of the costs associated with the various control technologies, as well as an estimate of projected ERC costs, is presented in the following sections.

ERC costs were estimated based on information obtained from CARB's "Emission Reduction Offset Transaction Costs Summary Report for 2008", the most recent summary of ERC costs available at this time. The following average ERC cost values, obtained from Table 1 of the referenced document, were used to estimate ERC costs ($ per ton of pollutant) for each CT scenario, as applicable.

NOx - $47,143 per ton

HC - $43,435 per ton

PM10 – $40,025 per ton

The estimated cost of emissions control equipment is presented in 2011 dollars. For cost estimation purposes it was assumed that permanent ERCs would be purchased and would involve minimal annual operational costs. Therefore the ERC purchases were considered a capital cost and were annualized into capital recovery costs using EPA default assumptions. Assumptions for the costs of emissions controls for WTE/Direct combustion facilities were acquired from a similar type and size project through a confidential source.

EPA has developed budgetary cost information (in 1999 dollars) for the application of SCR on boilers, large turbines, and small (less than 5MW) turbines. Because no such information has been developed for IC engines, the EPA cost information for small turbines was used to estimate the cost of installing SCR on IC engines as well as turbines. All cost information from the source in 1999 dollars was escalated to 2011 dollars using the CPI (Consumer Price Index).

Vendor information obtained in connection with other projects was reviewed to estimate the capital cost of oxidation catalyst. There are minimal annual operations and maintenance costs anticipated for oxidation catalyst operation.

The overall capital and annual operating and maintenance costs for each scenario were calculated based on the average electrical production rates listed in Table 4 of Section 4.4. The normalized operating costs, in terms of dollars per MWh produced, were calculated based on an assumed 90 percent capacity factor.

5.2.1 WTE/Direct Combustion

WTE is anticipated to have advanced emissions control equipment including SCR, acid gas control, carbon injection, and fabric filter baghouse. As previously discussed, the WTE scenario will require the purchase of ERCs for NO_x. The estimated costs associated with the anticipated pollution control equipment for the WTE/Direct combustion scenario are:

Capital Cost - $23,700,000

Annual Cost - $1,400,000

Normalized Cost - $14.40 per MWh produced

5.2.2 Syngas to IC Engines

Review of California Air Resources Board (CARB) BACT databases reveals no determinations for IC engines fired on syngas. However, SCR is considered potentially technologically feasible for control of NO_x and oxidation catalyst for CO and VOC. Application of these control technologies was included in the estimated emission calculations. As discussed previously, the syngas to IC engines scenario will require the purchase of ERCs for NO_x, VOC, and PM_{10}. The estimated costs associated with the anticipated pollution control equipment and ERCs for the syngas to IC engines scenario are:

Capital Cost - $8,200,000

Annual Cost - $865,000

Normalized Cost - $8.24 per MWh produced

5.2.3 Syngas to Turbine

Review of CARB BACT databases reveals no determinations for turbines fired on syngas. However, SCR is considered potentially technologically feasible for control of NO_x and oxidation catalyst for CO and VOC. Application of these control technologies was included in the estimated emission calculations. As discussed previously, the syngas to turbine scenario will require the purchase of ERCs for NO_x. The estimated costs associated with the anticipated pollution control equipment and ERCs for the syngas to turbine scenario are:

Capital Cost - $5,700,000

Annual Cost - $640,000

Normalized Cost - $6.20 per MWh produced

5.2.4 Syngas to Fuel Cell

Review of CARB BACT databases reveals no determinations for fuel cells using syngas. No control emissions control equipment is anticipated for the fuel cells, although a robust gas cleanup system will be required, the cost of which is currently unknown. As discussed previously, the syngas to fuel cell scenario will not require the purchase of ERCs. Therefore, no control equipment or ERC costs were developed for the syngas to fuel cell scenario. **Again, it is critical to recognize that fuel cells have not been used in conjunction with gasification and plasma arc gasification technologies that generate a syngas.** Thus the emissions clean-up information provided in this report is supplied as only theoretical and can only be verified through demonstration of a facility operating at a commercial level.

5.2.5 AD Biogas to IC Engines

Review of CARB BACT databases reveals a number of determinations for IC engines fired on landfill or digester gas. None of these determinations to date have required the installation of SCR or oxidation catalyst. However, SCR is considered potentially technologically feasible for control of NO_x and oxidation catalyst for CO and VOC. Application of these control technologies was included in the estimated emission calculations. As discussed previously, the AD biogas to IC engines scenario will not require the purchase of ERCs. The estimated costs associated with the anticipated pollution control equipment for the AD biogas to IC engines scenario are:

Capital Cost - $380,000

Annual Cost - $43,000

Normalized Cost - $5.47 per MWh produced

5.2.6 AD Biogas to Turbine

Review of CARB BACT databases reveals one determination for turbines fired on landfill or digester gas. That determination did not require the installation of SCR or oxidation catalyst. However, SCR is considered potentially technologically feasible for control of NO_x and oxidation catalyst for CO and VOC. Application of these control technologies was included in the estimated emission calculations. As discussed previously, the AD biogas to turbine scenario will not require the purchase of ERCs. The estimated costs associated with the anticipated pollution control equipment for the AD biogas to turbine scenario are:

Capital Cost - $380,000

Annual Cost - $43,000

Normalized Cost - $5.47 per MWh produced

5.2.7 AD Biogas to Fuel Cell

Review of CARB BACT databases reveals no determinations for fuel cells using digester gas. No control equipment is anticipated for the fuel cells, although a robust gas cleanup system will be required, the cost of which is currently unknown. As discussed previously, the AD biogas to fuel cell scenario will not require the purchase of ERCs. Therefore, no control equipment or ERC costs were developed for the syngas to fuel cell scenario.

6.0 Emissions Comparison

6.1 Comparison of Baseline to Conversion Technologies Emissions Profile

The total emissions (i.e., reduced emissions from the continued LFG generation plus the emissions from the given power generating technology) were calculated for each year from 2020 to 2061. The year 2020 was assumed as the first year that a conversion technology project could potentially be implementable. The end year of 2061 was used as it is the assumed year of the WRSL closure.

A summary of the estimated emissions are presented in tabular form in the following sections. A discussion of these emissions is included in the Summary Section 7.0.

6.1.1 WTE/Direct Combustion

The estimated emissions for WTE are presented in Table 12.

Table 12- WTE Emissions Profile (tpy)

Year	NO_x (tpy)	SO_2 (tpy)	CO (tpy)	CO_2e (tpy)	VOC (tpy)	Total HAP (tpy)	PM_{10} (tpy)
2020	88.8	19.4	164	314,502	29.3	28.1	20.7
2021	89.0	19.5	166	316,015	29.7	28.4	21.0
2022	88.6	19.4	163	313,574	29.0	28.0	20.6
2023	88.2	19.3	161	311,378	28.5	27.7	20.2
2024	87.9	19.3	159	309,425	28.0	27.4	19.9
2025	87.6	19.2	158	307,619	27.5	27.1	19.6
2026	87.3	19.2	156	306,056	27.1	26.8	19.3
2027	87.1	19.1	155	304,689	26.8	26.6	19.1
2028	86.9	19.1	154	303,518	26.5	26.5	18.9
2029	86.7	19.0	153	302,541	26.2	26.3	18.7
2030	86.6	19.0	152	301,809	26.0	26.2	18.6
2031	86.5	19.0	151	301,174	25.9	26.1	18.5
2032	86.4	19.0	151	300,735	25.8	26.0	18.5
2033	86.4	19.0	151	300,442	25.7	26.0	18.4
2034	86.3	19.0	151	300,296	25.7	26.0	18.4
2035	86.3	19.0	151	300,296	25.7	26.0	18.4
2036	86.4	19.0	151	300,442	25.7	26.0	18.4
2037	86.4	19.0	151	300,735	25.8	26.0	18.5
2038	86.5	19.0	151	301,174	25.9	26.1	18.5
2039	86.6	19.0	152	301,711	26.0	26.2	18.6
2040	86.7	19.0	153	302,444	26.2	26.3	18.7
2041	86.8	19.1	153	303,274	26.4	26.4	18.9
2042	87.0	19.1	154	304,250	26.7	26.6	19.0
2043	87.2	19.1	155	305,324	26.9	26.7	19.2
2044	87.4	19.2	157	306,593	27.3	26.9	19.4
2045	87.6	19.2	158	307,911	27.6	27.1	19.6
2046	87.9	19.3	159	309,376	28.0	27.4	19.9
2047	88.2	19.3	161	310,987	28.4	27.6	20.1
2048	88.4	19.4	162	312,696	28.8	27.9	20.4
2049	88.8	19.4	164	314,551	29.3	28.1	20.7
2050	89.1	19.5	166	316,504	29.8	28.4	21.0
2051	89.5	19.5	168	318,603	30.3	28.8	21.4
2052	89.8	19.6	170	320,800	30.9	29.1	21.7
2053	90.2	19.7	172	323,143	31.5	29.5	22.1
2054	90.6	19.8	175	325,535	32.1	29.8	22.5
2055	91.1	19.8	177	328,122	32.8	30.2	22.9
2056	91.5	19.9	180	330,759	33.4	30.6	23.4
2057	92.0	20.0	182	333,541	34.1	31.1	23.8
2058	92.5	20.1	185	336,470	34.9	31.5	24.3
2059	93.0	20.2	188	339,448	35.7	32.0	24.8
2060	93.6	20.3	191	342,622	36.5	32.4	25.3
2061	94.1	20.4	194	345,844	37.3	32.9	25.8

6.1.2 Syngas to IC Engines

The estimated emissions for syngas to IC engines are presented in Table 13.

Table 13 - Syngas to IC Engines Emissions Profile (tpy)

Year	NO_x (tpy)	SO_2 (tpy)	CO (tpy)	CO_2e (tpy)	VOC (tpy)	Total HAP (tpy)	PM_{10} (tpy)
2020	33.5	9.81	124	314,502	56.4	17.5	42.2
2021	33.7	9.86	126	316,015	56.8	17.7	42.5
2022	33.3	9.79	123	313,574	56.2	17.3	42.1
2023	32.9	9.72	121	311,378	55.6	17.0	41.7
2024	32.6	9.66	120	309,425	55.1	16.7	41.4
2025	32.3	9.60	118	307,619	54.6	16.4	41.1
2026	32.0	9.56	116	306,056	54.2	16.2	40.8
2027	31.8	9.51	115	304,689	53.9	16.0	40.6
2028	31.6	9.48	114	303,518	53.6	15.8	40.4
2029	31.4	9.45	113	302,541	53.3	15.6	40.2
2030	31.3	9.43	112	301,809	53.2	15.5	40.1
2031	31.2	9.41	112	301,174	53.0	15.4	40.0
2032	31.1	9.39	111	300,735	52.9	15.4	40.0
2033	31.1	9.38	111	300,442	52.8	15.3	39.9
2034	31.0	9.38	111	300,296	52.8	15.3	39.9
2035	31.0	9.38	111	300,296	52.8	15.3	39.9
2036	31.1	9.38	111	300,442	52.8	15.3	39.9
2037	31.1	9.39	111	300,735	52.9	15.4	40.0
2038	31.2	9.41	112	301,174	53.0	15.4	40.0
2039	31.3	9.42	112	301,711	53.1	15.5	40.1
2040	31.4	9.44	113	302,444	53.3	15.6	40.2
2041	31.5	9.47	114	303,274	53.5	15.8	40.4
2042	31.7	9.50	115	304,250	53.8	15.9	40.5
2043	31.9	9.53	116	305,324	54.1	16.1	40.7
2044	32.1	9.57	117	306,593	54.4	16.3	40.9
2045	32.3	9.61	118	307,911	54.7	16.5	41.1
2046	32.6	9.66	119	309,376	55.1	16.7	41.4
2047	32.9	9.71	121	310,987	55.5	16.9	41.6
2048	33.2	9.76	123	312,696	55.9	17.2	41.9
2049	33.5	9.82	124	314,551	56.4	17.5	42.2
2050	33.8	9.88	126	316,504	56.9	17.8	42.5
2051	34.2	9.94	128	318,603	57.4	18.1	42.9
2052	34.5	10.0	130	320,800	58.0	18.4	43.2
2053	34.9	10.1	133	323,143	58.6	18.8	43.6
2054	35.4	10.2	135	325,535	59.2	19.2	44.0
2055	35.8	10.2	137	328,122	59.9	19.6	44.4
2056	36.2	10.3	140	330,759	60.6	20.0	44.9
2057	36.7	10.4	143	333,541	61.3	20.4	45.3
2058	37.2	10.5	145	336,470	62.0	20.8	45.8
2059	37.7	10.6	148	339,448	62.8	21.3	46.3
2060	38.3	10.7	151	342,622	63.6	21.8	46.8
2061	38.8	10.8	154	345,844	64.4	22.3	47.3

6.1.3 Syngas to IC Turbine

The estimated emissions for syngas to IC turbine are presented in Table 14.

Table 14 – Syngas to Turbine Emissions Profile (tpy)

Year	NO_x (tpy)	SO_2 (tpy)	CO (tpy)	CO_2e (tpy)	VOC (tpy)	Total HAP (tpy)	PM_{10} (tpy)
2020	33.5	9.81	94.7	314,502	25.5	17.5	28.6
2021	33.7	9.86	96.1	316,015	25.9	17.7	28.8
2022	33.3	9.79	93.8	313,574	25.3	17.3	28.4
2023	32.9	9.72	91.7	311,378	24.7	17.0	28.0
2024	32.6	9.66	89.8	309,425	24.2	16.7	27.7
2025	32.3	9.60	88.1	307,619	23.8	16.4	27.4
2026	32.0	9.56	86.6	306,056	23.4	16.2	27.2
2027	31.8	9.51	85.3	304,689	23.0	16.0	27.0
2028	31.6	9.48	84.2	303,518	22.7	15.8	26.8
2029	31.4	9.45	83.3	302,541	22.5	15.6	26.6
2030	31.3	9.43	82.6	301,809	22.3	15.5	26.5
2031	31.2	9.41	82.0	301,174	22.1	15.4	26.4
2032	31.1	9.39	81.6	300,735	22.0	15.4	26.3
2033	31.1	9.38	81.3	300,442	21.9	15.3	26.3
2034	31.0	9.38	81.1	300,296	21.9	15.3	26.2
2035	31.0	9.38	81.1	300,296	21.9	15.3	26.2
2036	31.1	9.38	81.3	300,442	21.9	15.3	26.3
2037	31.1	9.39	81.6	300,735	22.0	15.4	26.3
2038	31.2	9.41	82.0	301,174	22.1	15.4	26.4
2039	31.3	9.42	82.5	301,711	22.2	15.5	26.5
2040	31.4	9.44	83.2	302,444	22.4	15.6	26.6
2041	31.5	9.47	84.0	303,274	22.6	15.8	26.7
2042	31.7	9.50	84.9	304,250	22.9	15.9	26.9
2043	31.9	9.53	85.9	305,324	23.2	16.1	27.1
2044	32.1	9.57	87.1	306,593	23.5	16.3	27.3
2045	32.3	9.61	88.4	307,911	23.8	16.5	27.5
2046	32.6	9.66	89.8	309,376	24.2	16.7	27.7
2047	32.9	9.71	91.3	310,987	24.6	16.9	28.0
2048	33.2	9.76	92.9	312,696	25.1	17.2	28.3
2049	33.5	9.82	94.7	314,551	25.5	17.5	28.6
2050	33.8	9.88	96.6	316,504	26.0	17.8	28.9
2051	34.2	9.94	98.6	318,603	26.6	18.1	29.2
2052	34.5	10.0	101	320,800	27.1	18.4	29.6
2053	34.9	10.1	103	323,143	27.7	18.8	30.0
2054	35.4	10.2	105	325,535	28.3	19.2	30.4
2055	35.8	10.2	108	328,122	29.0	19.6	30.8
2056	36.2	10.3	110	330,759	29.7	20.0	31.2
2057	36.7	10.4	113	333,541	30.4	20.4	31.7
2058	37.2	10.5	116	336,470	31.1	20.8	32.2
2059	37.7	10.6	118	339,448	31.9	21.3	32.6
2060	38.3	10.7	121	342,622	32.7	21.8	33.2
2061	38.8	10.8	125	345,844	33.5	22.3	33.7

6.1.4 Syngas to Fuel Cell

The estimated emissions for syngas to fuel cell are presented in Table 15.

Table 15 – Syngas to Fuel Cell Emissions Profile (tpy)

Year	NO_x (tpy)	SO_2 (tpy)	CO (tpy)	CO_2e (tpy)	VOC (tpy)	Total HAP (tpy)	PM_{10} (tpy)
2020	18.1	3.01	92.9	314,502	24.9	14.9	16.0
2021	18.4	3.05	94.3	316,015	25.3	15.1	16.2
2022	18.0	2.98	92.0	313,574	24.7	14.8	15.8
2023	17.6	2.91	89.9	311,378	24.1	14.4	15.5
2024	17.2	2.85	88.0	309,425	23.6	14.1	15.1
2025	16.9	2.79	86.3	307,619	23.1	13.9	14.8
2026	16.7	2.75	84.8	306,056	22.7	13.6	14.6
2027	16.4	2.70	83.5	304,689	22.4	13.4	14.4
2028	16.2	2.67	82.4	303,518	22.1	13.2	14.2
2029	16.1	2.64	81.5	302,541	21.9	13.1	14.0
2030	15.9	2.62	80.8	301,809	21.7	13.0	13.9
2031	15.8	2.60	80.2	301,174	21.5	12.9	13.8
2032	15.8	2.58	79.8	300,735	21.4	12.8	13.7
2033	15.7	2.57	79.5	300,442	21.3	12.8	13.7
2034	15.7	2.57	79.4	300,296	21.3	12.7	13.6
2035	15.7	2.57	79.4	300,296	21.3	12.7	13.6
2036	15.7	2.57	79.5	300,442	21.3	12.8	13.7
2037	15.8	2.58	79.8	300,735	21.4	12.8	13.7
2038	15.8	2.60	80.2	301,174	21.5	12.9	13.8
2039	15.9	2.61	80.7	301,711	21.6	13.0	13.9
2040	16.1	2.64	81.4	302,444	21.8	13.1	14.0
2041	16.2	2.66	82.2	303,274	22.0	13.2	14.1
2042	16.4	2.69	83.1	304,250	22.3	13.3	14.3
2043	16.5	2.72	84.1	305,324	22.6	13.5	14.5
2044	16.8	2.76	85.4	306,593	22.9	13.7	14.7
2045	17.0	2.80	86.6	307,911	23.2	13.9	14.9
2046	17.2	2.85	88.0	309,376	23.6	14.1	15.1
2047	17.5	2.90	89.5	310,987	24.0	14.4	15.4
2048	17.8	2.95	91.2	312,696	24.4	14.6	15.7
2049	18.1	3.01	92.9	314,551	24.9	14.9	16.0
2050	18.5	3.07	94.8	316,504	25.4	15.2	16.3
2051	18.8	3.13	96.8	318,603	26.0	15.5	16.6
2052	19.2	3.20	98.9	320,800	26.5	15.9	17.0
2053	19.6	3.27	101	323,143	27.1	16.2	17.4
2054	20.0	3.34	103	325,535	27.7	16.6	17.8
2055	20.4	3.42	106	328,122	28.4	17.0	18.2
2056	20.9	3.50	108	330,759	29.1	17.4	18.6
2057	21.4	3.59	111	333,541	29.8	17.8	19.1
2058	21.9	3.68	114	336,470	30.5	18.3	19.6
2059	22.4	3.77	117	339,448	31.3	18.7	20.1
2060	22.9	3.87	120	342,622	32.1	19.2	20.6
2061	23.5	3.97	123	345,844	32.9	19.7	21.1

6.1.5 AD Biogas to IC Engines

The estimated emissions for AD biogas to IC engines are presented in Table 16.

Table 16 – AD Biogas to IC Engines Emissions Profile (tpy)

Year	NO_x (tpy)	SO_2 (tpy)	CO (tpy)	CO_2e (tpy)	VOC (tpy)	Total HAP (tpy)	PM_{10} (tpy)
2020	18.8	3.84	96.8	122,498	28.8	15.9	19.2
2021	19.0	3.89	98.2	124,012	29.2	16.1	19.5
2022	18.9	3.87	97.7	123,475	29.1	16.0	19.4
2023	18.9	3.86	97.4	123,133	29.0	15.9	19.3
2024	18.8	3.85	97.2	122,889	28.9	15.9	19.3
2025	18.8	3.85	97.1	122,791	28.9	15.9	19.3
2026	18.8	3.85	97.1	122,840	28.9	15.9	19.3
2027	18.8	3.86	97.3	123,036	29.0	15.9	19.3
2028	18.9	3.87	97.6	123,377	29.0	16.0	19.4
2029	19.0	3.88	98.1	123,817	29.2	16.1	19.4
2030	19.1	3.90	98.7	124,451	29.3	16.2	19.5
2031	19.2	3.92	99.3	125,135	29.5	16.3	19.7
2032	19.3	3.95	100	125,965	29.7	16.4	19.8
2033	19.5	3.97	101	126,892	29.9	16.5	19.9
2034	19.7	4.01	102	127,917	30.2	16.7	20.1
2035	19.9	4.04	103	129,040	30.5	16.9	20.3
2036	20.1	4.08	104	130,310	30.8	17.0	20.5
2037	20.3	4.12	105	131,628	31.2	17.2	20.7
2038	20.6	4.16	107	133,043	31.5	17.5	21.0
2039	20.8	4.21	108	134,606	31.9	17.7	21.2
2040	21.1	4.26	110	136,217	32.3	17.9	21.5
2041	21.4	4.31	112	137,974	32.8	18.2	21.8
2042	21.7	4.37	113	139,780	33.2	18.5	22.1
2043	22.0	4.43	115	141,684	33.7	18.8	22.4
2044	22.4	4.49	117	143,686	34.2	19.1	22.7
2045	22.7	4.56	119	145,834	34.8	19.4	23.0
2046	23.1	4.62	121	148,031	35.3	19.8	23.4
2047	23.5	4.69	123	150,325	35.9	20.1	23.8
2048	23.9	4.77	126	152,717	36.5	20.5	24.2
2049	24.3	4.84	128	155,207	37.2	20.9	24.6
2050	24.8	4.92	130	157,795	37.8	21.2	25.0
2051	25.3	5.01	133	160,480	38.5	21.7	25.4
2052	25.7	5.09	136	163,213	39.2	22.1	25.9
2053	26.2	5.18	138	166,094	40.0	22.5	26.4
2054	26.7	5.27	141	169,072	40.7	23.0	26.9
2055	27.2	5.36	144	172,098	41.5	23.4	27.3
2056	27.8	5.46	147	175,272	42.3	23.9	27.9
2057	28.3	5.56	150	178,543	43.1	24.4	28.4
2058	28.9	5.66	153	181,862	44.0	24.9	28.9
2059	29.5	5.77	157	185,328	44.9	25.5	29.5
2060	30.1	5.88	160	188,843	45.8	26.0	30.1
2061	30.7	5.99	164	192,505	46.7	26.6	30.7

6.1.6 AD Biogas to Turbine

The estimated emissions for AD biogas to turbine are presented in Table 17.

Table 17 – AD Biogas to Turbine Emissions Profile (tpy)

Year	NO_x (tpy)	SO_2 (tpy)	CO (tpy)	CO_2e (tpy)	VOC (tpy)	Total HAP (tpy)	PM_{10} (tpy)
2020	18.8	3.84	93.1	122,498	25.0	14.9	17.5
2021	19.0	3.89	94.5	124,012	25.4	15.1	17.8
2022	18.9	3.87	94.0	123,475	25.2	15.1	17.7
2023	18.9	3.86	93.7	123,133	25.1	15.0	17.6
2024	18.8	3.85	93.5	122,889	25.1	15.0	17.6
2025	18.8	3.85	93.4	122,791	25.1	15.0	17.6
2026	18.8	3.85	93.4	122,840	25.1	15.0	17.6
2027	18.8	3.86	93.6	123,036	25.1	15.0	17.6
2028	18.9	3.87	93.9	123,377	25.2	15.0	17.7
2029	19.0	3.88	94.4	123,817	25.3	15.1	17.7
2030	19.1	3.90	95.0	124,451	25.5	15.2	17.8
2031	19.2	3.92	95.6	125,135	25.7	15.3	18.0
2032	19.3	3.95	96.4	125,965	25.9	15.4	18.1
2033	19.5	3.97	97.3	126,892	26.1	15.6	18.2
2034	19.7	4.01	98.3	127,917	26.4	15.7	18.4
2035	19.9	4.04	99.3	129,040	26.7	15.9	18.6
2036	20.1	4.08	101	130,310	27.0	16.1	18.8
2037	20.3	4.12	102	131,628	27.3	16.3	19.0
2038	20.6	4.16	103	133,043	27.7	16.5	19.3
2039	20.8	4.21	105	134,606	28.1	16.8	19.5
2040	21.1	4.26	106	136,217	28.5	17.0	19.8
2041	21.4	4.31	108	137,974	28.9	17.3	20.1
2042	21.7	4.37	110	139,780	29.4	17.6	20.4
2043	22.0	4.43	111	141,684	29.9	17.8	20.7
2044	22.4	4.49	113	143,686	30.4	18.2	21.0
2045	22.7	4.56	115	145,834	30.9	18.5	21.3
2046	23.1	4.62	117	148,031	31.5	18.8	21.7
2047	23.5	4.69	120	150,325	32.1	19.2	22.1
2048	23.9	4.77	122	152,717	32.7	19.5	22.5
2049	24.3	4.84	124	155,207	33.3	19.9	22.9
2050	24.8	4.92	127	157,795	34.0	20.3	23.3
2051	25.3	5.01	129	160,480	34.7	20.7	23.7
2052	25.7	5.09	132	163,213	35.4	21.1	24.2
2053	26.2	5.18	135	166,094	36.1	21.6	24.7
2054	26.7	5.27	137	169,072	36.9	22.0	25.2
2055	27.2	5.36	140	172,098	37.7	22.5	25.7
2056	27.8	5.46	143	175,272	38.5	23.0	26.2
2057	28.3	5.56	147	178,543	39.3	23.5	26.7
2058	28.9	5.66	150	181,862	40.1	24.0	27.2
2059	29.5	5.77	153	185,328	41.0	24.5	27.8
2060	30.1	5.88	156	188,843	41.9	25.1	28.4
2061	30.7	5.99	160	192,505	42.9	25.6	29.0

6.1.7 AD Biogas to Fuel Cell

The estimated emissions for AD biogas to fuel cell are presented in Table 18.

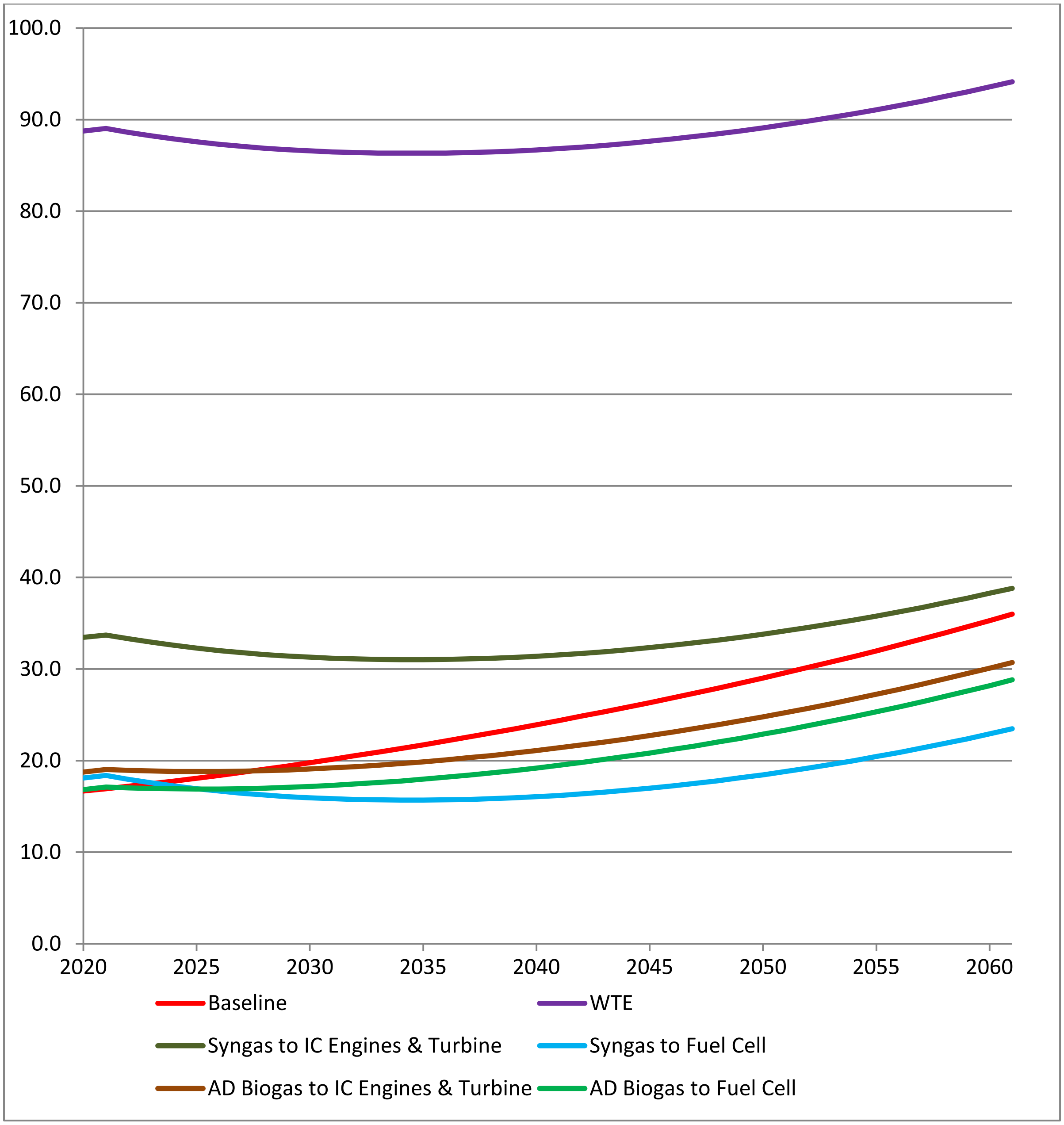
Table 18 – AD Biogas to Fuel Cell Emissions Profile (tpy)

Year	NO_x (tpy)	SO_2 (tpy)	CO (tpy)	CO_2e (tpy)	VOC (tpy)	Total HAP (tpy)	PM_{10} (tpy)
2020	16.8	2.99	92.9	122,498	24.9	14.9	16.0
2021	17.1	3.04	94.3	124,012	25.3	15.1	16.2
2022	17.0	3.02	93.8	123,475	25.2	15.1	16.1
2023	17.0	3.01	93.5	123,133	25.1	15.0	16.1
2024	16.9	3.01	93.3	122,889	25.0	15.0	16.0
2025	16.9	3.00	93.2	122,791	25.0	15.0	16.0
2026	16.9	3.00	93.2	122,840	25.0	15.0	16.0
2027	16.9	3.01	93.4	123,036	25.0	15.0	16.1
2028	17.0	3.02	93.7	123,377	25.1	15.0	16.1
2029	17.1	3.03	94.1	123,817	25.2	15.1	16.2
2030	17.2	3.05	94.7	124,451	25.4	15.2	16.3
2031	17.3	3.07	95.4	125,135	25.6	15.3	16.4
2032	17.4	3.10	96.2	125,965	25.8	15.4	16.5
2033	17.6	3.13	97.1	126,892	26.0	15.6	16.7
2034	17.8	3.16	98.0	127,917	26.3	15.7	16.9
2035	18.0	3.19	99.1	129,040	26.6	15.9	17.0
2036	18.2	3.23	100	130,310	26.9	16.1	17.2
2037	18.4	3.27	102	131,628	27.2	16.3	17.5
2038	18.7	3.32	103	133,043	27.6	16.5	17.7
2039	18.9	3.36	104	134,606	28.0	16.8	17.9
2040	19.2	3.41	106	136,217	28.4	17.0	18.2
2041	19.5	3.47	108	137,974	28.9	17.3	18.5
2042	19.8	3.52	109	139,780	29.3	17.6	18.8
2043	20.1	3.58	111	141,684	29.8	17.8	19.1
2044	20.5	3.64	113	143,686	30.3	18.1	19.4
2045	20.8	3.71	115	145,834	30.9	18.5	19.8
2046	21.2	3.78	117	148,031	31.4	18.8	20.1
2047	21.6	3.85	119	150,325	32.0	19.2	20.5
2048	22.0	3.92	122	152,717	32.6	19.5	20.9
2049	22.4	4.00	124	155,207	33.3	19.9	21.3
2050	22.9	4.08	127	157,795	33.9	20.3	21.7
2051	23.3	4.16	129	160,480	34.6	20.7	22.2
2052	23.8	4.24	132	163,213	35.3	21.1	22.6
2053	24.3	4.33	134	166,094	36.0	21.6	23.1
2054	24.8	4.42	137	169,072	36.8	22.0	23.6
2055	25.3	4.52	140	172,098	37.6	22.5	24.1
2056	25.9	4.61	143	175,272	38.4	23.0	24.6
2057	26.4	4.71	146	178,543	39.2	23.5	25.1
2058	27.0	4.81	149	181,862	40.1	24.0	25.7
2059	27.6	4.92	153	185,328	41.0	24.5	26.3
2060	28.2	5.03	156	188,843	41.9	25.1	26.8
2061	28.8	5.14	160	192,505	42.8	25.6	27.4

6.2 Emissions Profile Comparison

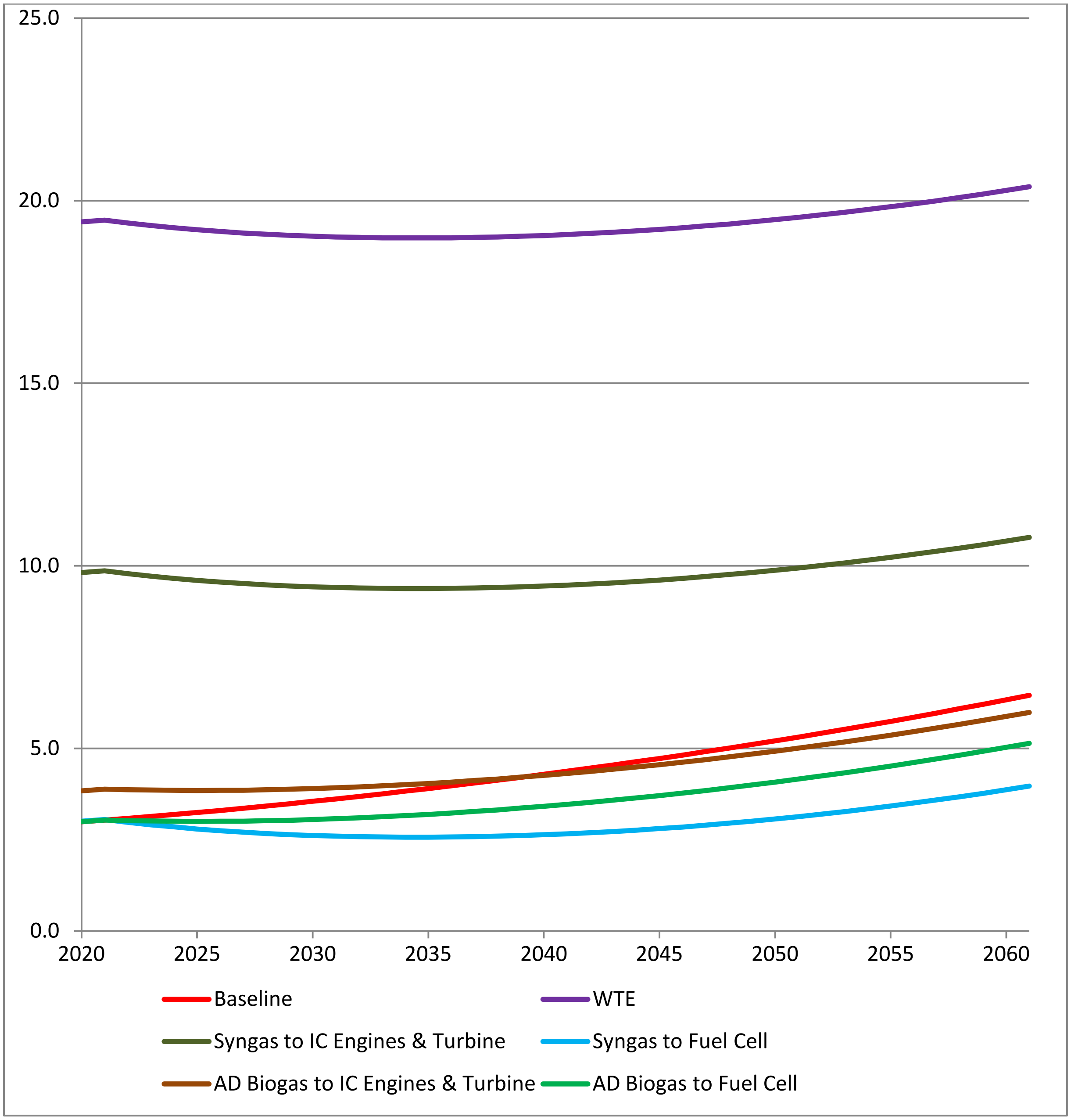
A comparison of the baseline emissions profile to each of the conversion technologies (including continued LFG production at reduced rates) is presented in the following charts. A separate chart is provided for each pollutant analyzed.

Chart 1 - Comparison of Baseline to Conversion Technologies – NOx Emissions Profile (tpy)



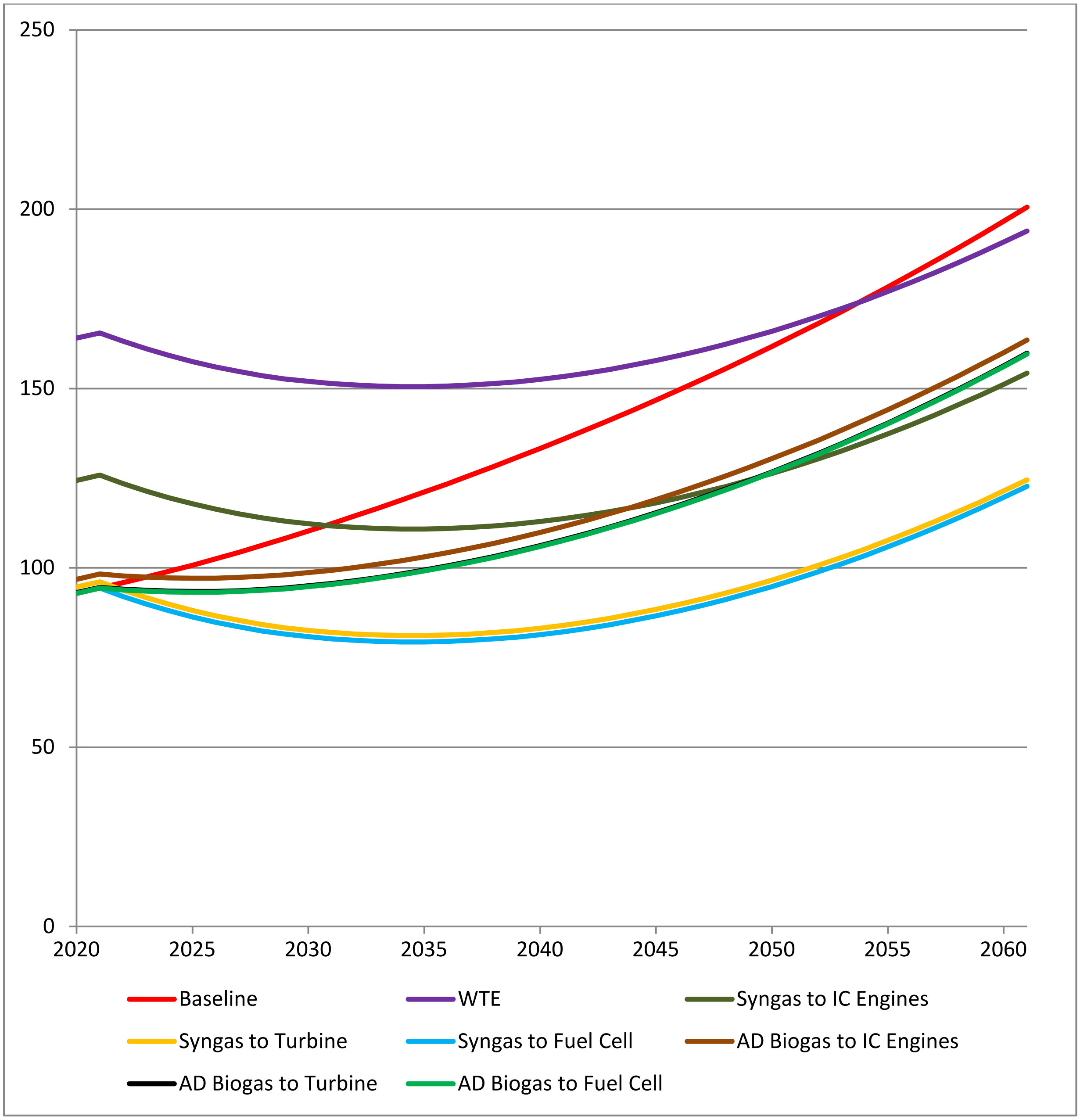
As shown in Chart 1, the WTE, syngas to IC engines, and syngas to turbine scenarios each have estimated NO_x emissions greater than baseline emissions. In general, this reflects the conversion of the carbon based (or combustible) materials contained in the MSW residual to usable energy in contrast to biological processes such as AD and landfilling where only the bio-degradable portion of the MSW is converted into energy.

Chart 2 - Comparison of Baseline to Conversion Technologies – SO_2 Emissions Profile (tpy)



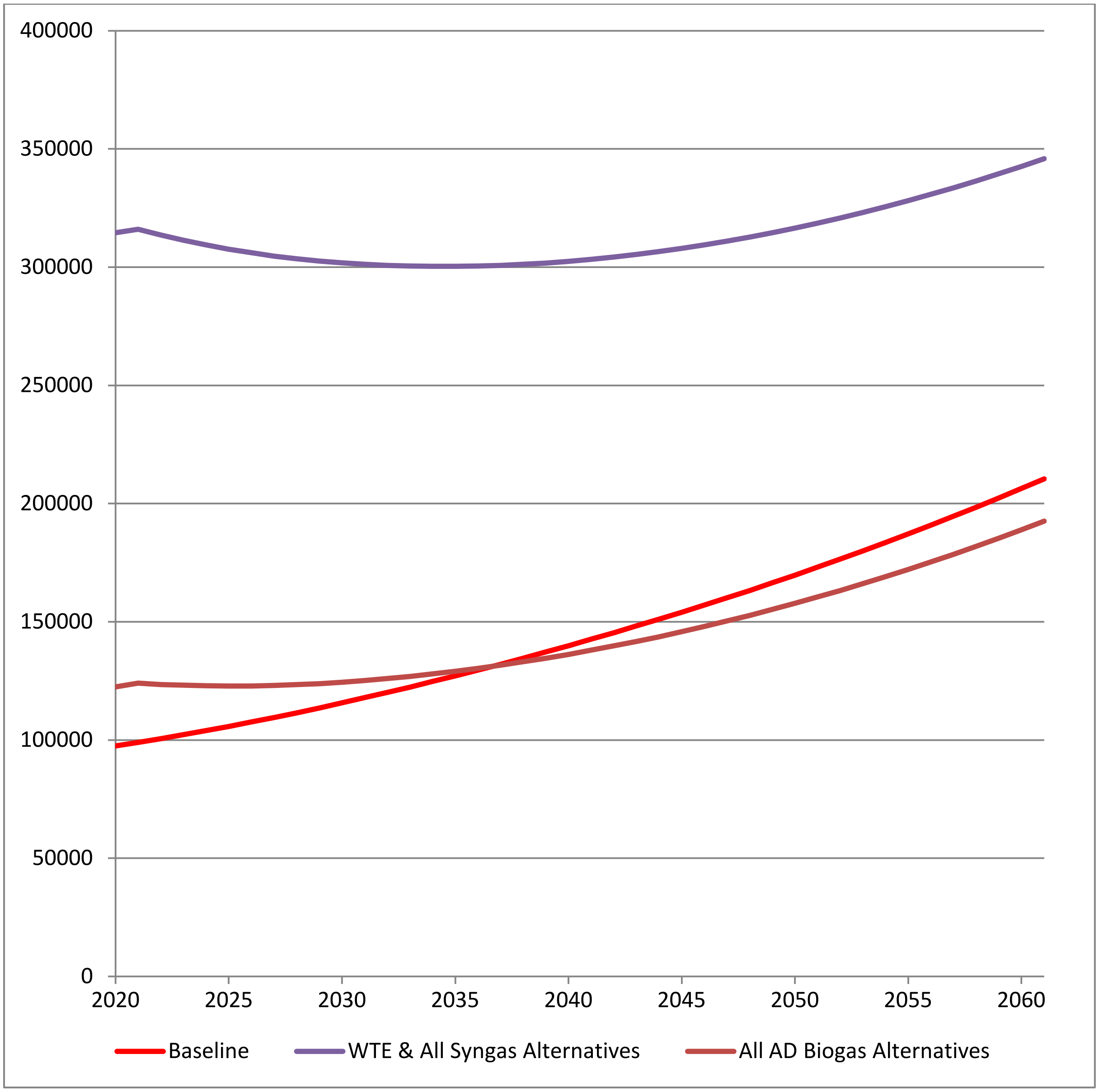
As shown in Chart 2, the WTE, syngas to IC engines, and syngas to turbine scenarios each have estimated SO_2 emissions greater than baseline emissions. In addition, the AD biogas to IC engines and AD biogas to turbine scenarios each have estimated SO_2 emissions greater than the baselines until 2039 when the amount of LFG produced in the landfill pushes the baseline emissions higher than the AD biogas scenarios.

Chart 3 - Comparison of Baseline to Conversion Technologies – CO Emissions Profile (tpy)



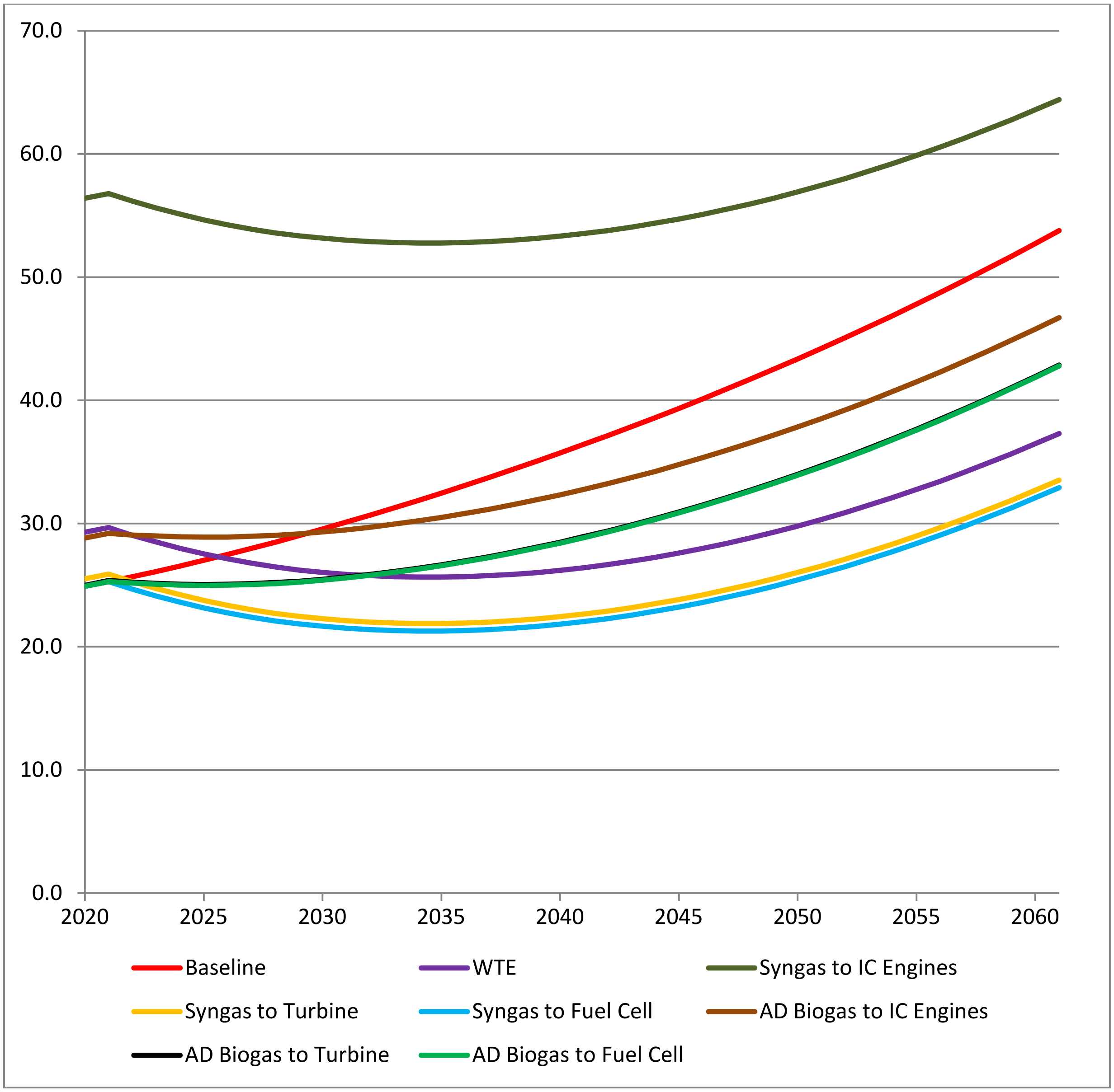
As shown in Chart 3, the WTE and syngas to IC engines scenarios each have estimated CO emissions greater than baseline emissions at the beginning of the evaluation period. However, the amount of LFG produced in the landfill pushes the baseline emissions higher than the syngas to IC engines in 2032 and higher than WTE in 2055.

Chart 4 - Comparison of Baseline to Conversion Technologies – CO2e Emissions Profile (tpy)



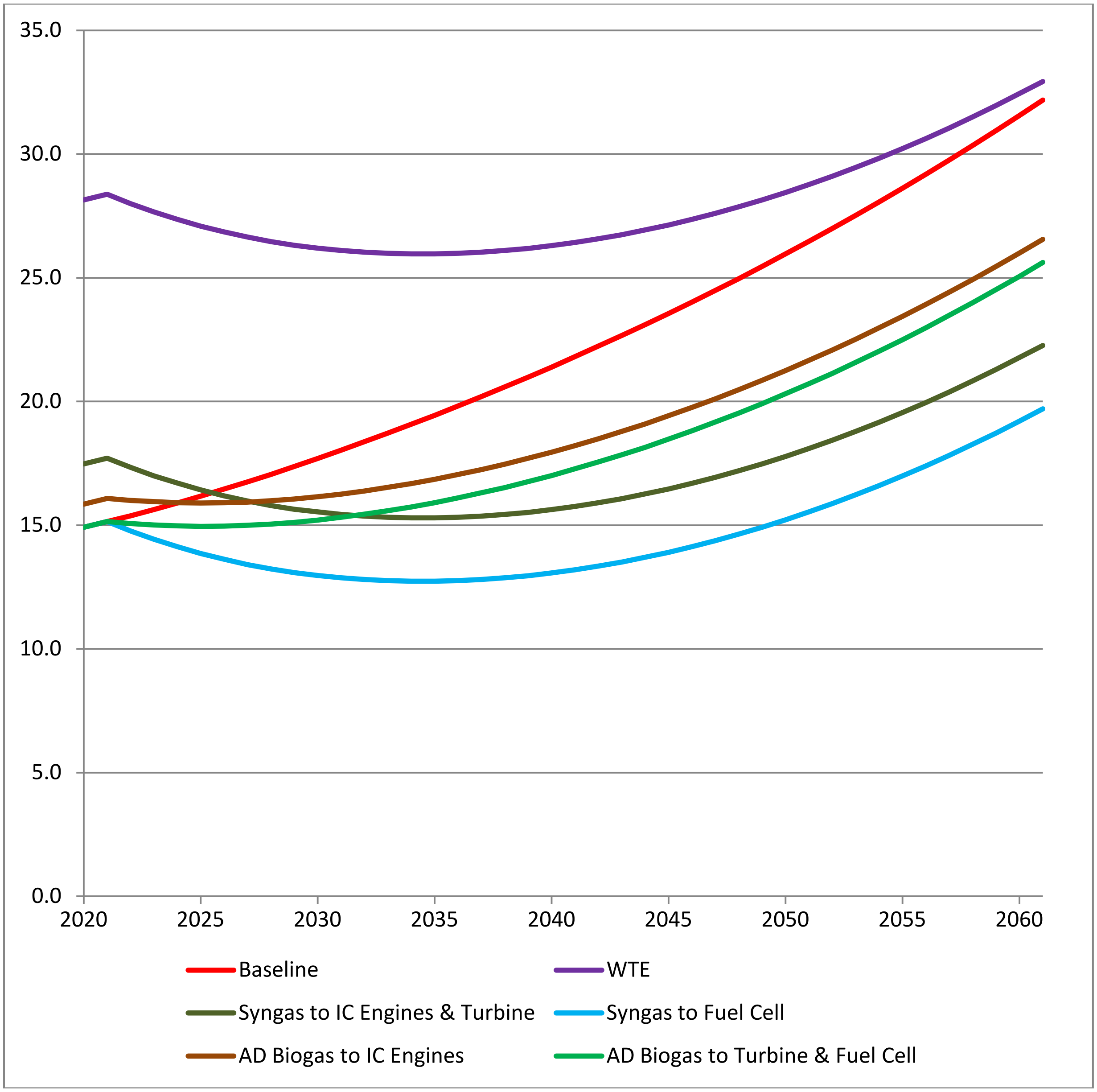
As shown in Chart 4, the WTE and all thermal CT processes producing syngas scenarios have estimated CO_2e emissions greater than baseline emissions. In addition, the AD biogas scenarios each have estimated CO_2e emissions greater than the baseline until 2037 when the amount of LFG produced in the landfill pushes the baseline emissions higher than the AD biogas scenarios. In general, this reflects the conversion of the carbon based (or combustible) materials contained in the MSW residual to usable energy in contrast to biological processes such as AD and landfilling where only the biodegradeable portion of the MSW is converted into energy.

Chart 5 - Comparison of Baseline to Conversion Technologies – VOC Emissions Profile (tpy)



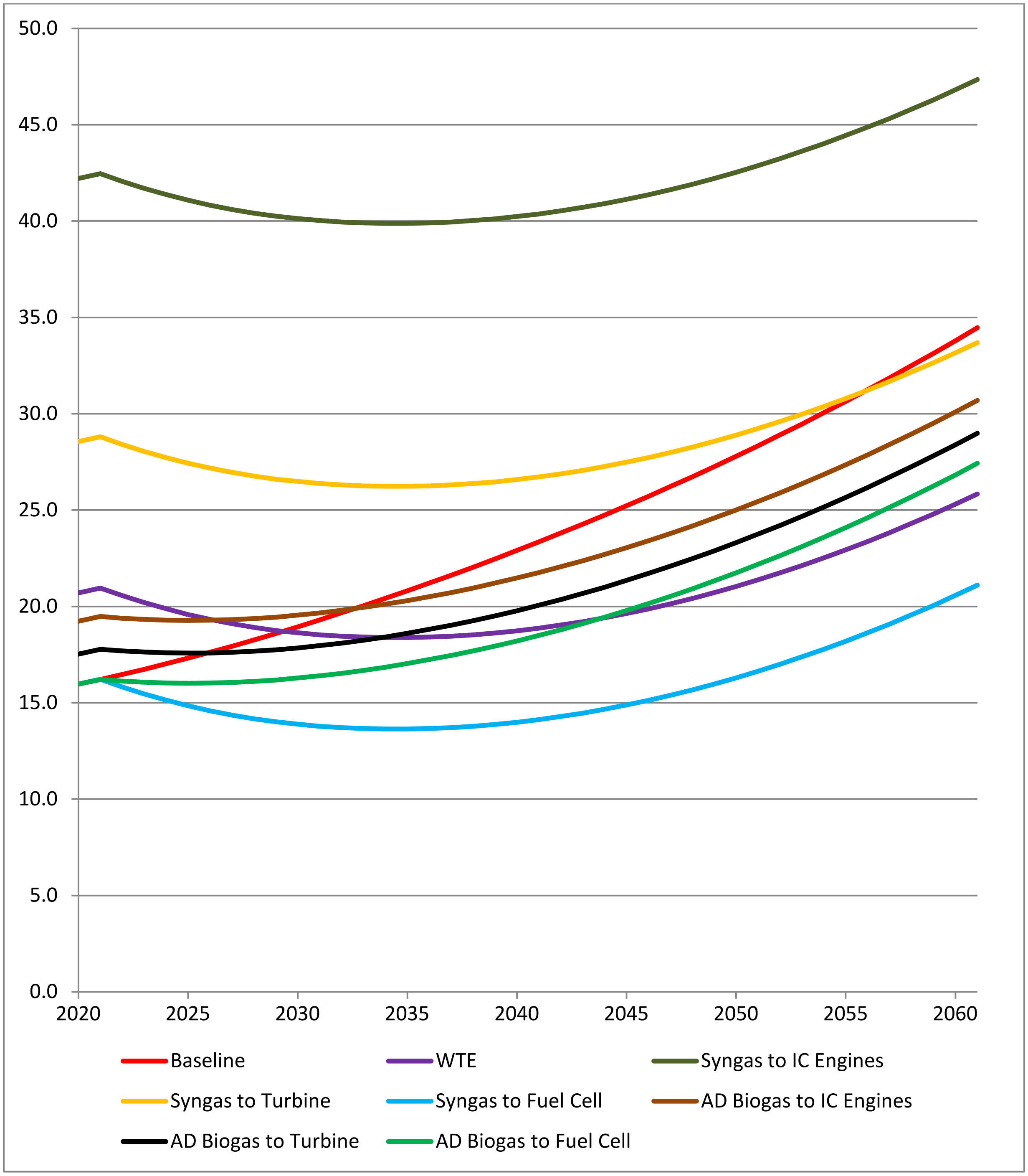
As shown in Chart 5, the syngas to IC engine scenario has estimated VOC emissions greater than baseline emissions. The WTE and AD biogas to IC engines scenarios each have estimated VOC emissions greater than baseline emissions at the beginning of the evaluation period. However, the amount of LFG produced in the landfill pushes the baseline emissions higher than WTE in 2026 and higher than AD biogas to IC engines in 2030. The VOC emissions associated with syngas to IC engines appears high compared to the other scenarios shown in Chart 6. Partly, this reflects the conversion of the carbon based (or combustible) materials contained in the MSW residual to usable energy in contrast to biological processes such as AD and landfilling where only the biodegradable portion of the MSW is converted into energy. Additionally, these emissions were calculated based on a guarantee provided by recently by an IC engine vendor for a natural gas fired unit equipped with an oxidation catalyst. While the characteristics of combusting syngas in an IC will be different from those of natural gas, use of the value is reasonable in the absence of a specific emission factor. The VOC emissions of IC engines, as well as turbines, will be refined based on vendor proposals specific to WPWMA's thermal Conversion Technologies chosen for further investigation.

Chart 6 - Comparison of Baseline to Conversion Technologies – Total HAP Emissions Profile (tpy)



As shown in Chart 6, the WTE scenario has estimated total HAP emissions greater than baseline emissions. The syngas to IC engines and syngas to turbine and AD biogas to IC engines scenarios each have estimated total HAP emissions greater than baseline emissions at the beginning of the evaluation period. However, the amount of LFG produced in the landfill pushes the baseline emissions higher than AD biogas to IC engines in 2025 and higher than syngas to IC engines and syngas to turbine in 2026.

Chart 7 - Comparison of Baseline to Conversion Technologies – PM10 Emissions Profile (tpy)



As shown in Chart 7, the syngas to IC engines scenario has estimated PM_{10} emissions greater than baseline emissions. The syngas to turbine, AD biogas to IC engines, WTE, and AD biogas to turbine scenarios each have estimated total PM_{10} emissions greater than baseline emissions at the beginning of the evaluation period. However, the amount of LFG produced in the landfill pushes the baseline emissions higher than syngas to turbine in 2057, higher than AD biogas to IC engines in 2023, higher than WTE in 2030, and higher than AD biogas to turbine in 2027.

7.0 Summary

The purpose of this Study was to support WPWMA's ongoing research of the emissions associated with converting MSW residuals currently being landfilled into energy as compared to current waste disposal practices. Using the assumptions and methodology detailed in this Study, emissions profiles were developed for the baseline case of continued landfilling of all MSW residual and for the following energy production scenarios, each of which would divert 500 tpd of MSW residual from landfilling.

- WTE
- Thermal CT producing Syngas to IC Engine
- Thermal CT producing Syngas to Turbine
- Thermal CT producing Syngas to Fuel Cell
- AD producing Biogas to IC Engine
- AD producing Biogas to Turbine
- AD producing Biogas to Fuel Cell

In each of these energy production scenarios, the LFG produced by the landfill was assumed to continue to be sent to flare and IC engine. Additionally, all MSW residue in excess of 500 tpd was assumed to be sent to the landfill where it would produce LFG. The emissions profiles were compared to identify trends and the resulting conclusions are summarized below.

In general, the WTE and syngas scenarios show emissions higher than baseline for almost all pollutants. The reason for the higher emissions is that these technologies (WTE and thermal Conversion Technologies) convert all of the carbon based (or combustible) materials contained in the MSW residual to usable energy. So for example, the conversion of plastics, rubber, and other carbon based materials into energy will produce emissions that otherwise would not occur in the landfill. In contrast, in landfilling where only a portion of the biodegradable content of the MSW residual is converted to usable energy, less emissions are generated. Similarly, the quantity of emissions is comparable to the landfill emissions where the AD process generating biogas. In AD biogas, the biodegradable fraction is converted to usable energy faster than it would be in the landfill. Consequently, although the WTE and thermal CT processes produce more pollutants, they also produce more energy.

Generally, emissions from WTE facilities appear to be higher in most every category. The elevated levels of WTE can be attributed to the direct combustion of the feedstock whereby NOx, SOx, CO are generated at relatively high quantities. PM can be scrubbed from the emissions in the emissions control systems to levels similar to the other power generating systems.

Many of the pollutant emissions exhibit a dip in values during the first years of implementation, followed by increased emissions over time. This behavior, especially prominent in Chart 3 for CO, is attributed to the fact that the LFG to energy emissions portion of the total estimated emissions for each scenario represents a significant portion of those total emissions. In the beginning years, almost all of the MSW residual is diverted from landfilling to the energy production technology, resulting in a reduction in LFG production and associated reduction in emissions. In later years as projected increases in MSW residual to landfilling occur, the amount of LFG produced occurs resulting in increased emissions. This behavior reflects the assumption that no expansion of the energy production technologies beyond the initial 500 tpd occurs.

Overall, the fuel cells appear to be the most attractive from an air emissions standpoint, both for syngas and AD biogas application. However, as described in more detail above, a number of significant technical, economic, and potential air emissions issues must addressed and resolved in order to truly determine the potential use of fuel cells. For example the following text describes some of the more challenging aspects of the use of fuel cell technology:

- Gas Cleanup – Fuel cells will require extensive cleanup of either syngas or AD biogas prior to use to ensure proper operation of the fuel cell. Based on studies of fuel cell systems installed and tested at landfills in California, gas treatment systems have been developed that could probably be used to clean the AD biogas. However, although it is theoretically possible to develop a similar gas cleanup system for syngas, no such system has yet been demonstrated in practice for syngas. Because of the number of contaminants present in syngas that could potentially harm a fuel cell (including, but not limited to, HCl, sulfur compounds, metals, and ash), cleaning of the syngas to a quality required by fuel cells may or may not be possible.
- Gas Cleanup Impact on Gas Heat Content – The studies on LFG treatment systems for use in fuel cells reviewed indicate that up to one third of the LFG was removed in the treatment process. The treatment of syngas or AD biogas would be expected to have at least a similar impact on gas flow. With the removed gas flow would also be some portion of the heat content contained in the syngas or AD biogas. This would reduce the amount of electricity generated by the fuel cells. In addition, the gas treatment system is expected to require a significant electric load, further reducing the net electrical production of the fuel cell system.
- Cost of Gas Treatment – No gas treatment system has been developed or used in practice for syngas. The application of such systems for biogas is still in the development phase. Therefore, the cost of such a system for treating either the syngas or AD biogas cannot be accurately determined at this point in time. The cost of the treatment system could significantly impact the overall cost of energy production by fuel cells to such an extent as to make the technology impractical.
- Treatment System Air Emissions – No air emissions were attributed to the gas treatment system for syngas or AD biogas in this Study. However, the LFG treatment systems that have been tested to date do have a stream of waste gas that is sent to a flare for destruction. As discussed previously, up to one third of the LFG was removed and flared in order to clean the gas sufficiently for use in the fuel cell technology. The resulting air emissions associated with this flaring would increase the total emissions associated with the use of fuel cells.

Insomuch as fuel cells are questionable in terms of their ability to operate on syngas, turbines appear to provide the lowest emissions from a power generation facility along with at least limited commercial operational history.

Although IC engines appear to have somewhat moderate but higher emissions than turbines, IC engines provide the most proven commercial viability operating on both biogas and syngas in terms of proven experience.

Regarding the CO_2e emission information presented in this Study, the results are presented for CO_2e emissions as a pollutant regulated under the Clean Air Act. As such, the CO_2e emission estimates including both anthropogenic and biogenic emissions, does not account for carbon storage in the landfill, and does not account for any offsets for electricity that would otherwise be generated by fossil fuels. Therefore, the CO_2e emissions presented in this Study should be used only for air quality permitting requirement purposes.

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Appendix A Baseline Scenario

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Western Placer Waste Management Authority
Alternate Energy Feasibility Study
Pollutant Profile - Baseline

Assumptions		Units	
LFG Collection Efficiency:	75%	%	
LFG Methane Content:	46.9%	%	Average of 1 minute minimum and maximum values from "June 2010.xlsx".
LFG CO_2 Content:	53.1%	%	Calculated from the average methane content and the assumption that CO2 is the remainder of the landfill gas.
Collected LFG to IC Engines:	80%	%	Assumed.
Collected LFG to Flare:	20%	%	All LFG not directed to IC engines assumed to flare.
Cover Oxidation Factor:	10%	%	40 CFR Part 98, Subpart HH, Table HH-1.
LFG Heat Content:	433	Btu/cf	Stack Test Results
Flare and IC Engine Destruction Efficiency:	99.81%	%	Stack Test Results
LFG CO2 Content Emission Factor:	29.8	ton/MM cf LFG	Based on average of 1 minute minimum and maximum values from "June 2010.xlsx".
LFG Methane Content Emission Factor:	9.58	ton/MM cf LFG	Based on methane content and the assumption that CO2 is the remainder of the landfill gas.
LFG Combustion SO2 Emission Factor:	0.0038	ton/MM cf LFG	AP-42 Default Value
LFG Uncontrolled NMOC Content Emission Factor:	148	lb/MM cf LFG	Stack Test Results
LFG Uncontrolled Organic HAP Content Emission Factor:	0.0128	ton/MM cf LFG	AP-42 Default Value
LFG Mercury Content Emission Factor:	7.53E-08	ton/MM cf LFG	AP-42 Default Value
LFG Combustion HCl Emission Factor:	0.0020	ton/MM cf LFG	AP-42 Default Value
Flare NOx Emission Factor:	0.045	lb/MMBtu	Stack Test Results
Flare CO Emission Factor:	0.0050	lb/MMBtu	Stack Test Results
Flare VOC Emission Factor:	0.0010	lb/MMBtu	Stack Test Results
Flare PM10 Emission Factor:	17.0	lb/MM cf CH4	AP-42, Table 2.4-5
IC Engine NOx Emission Factor:	0.111	lb/MMBtu	Stack Test Results
IC Engine CO Emission Factor:	0.680	lb/MMBtu	Stack Test Results
IC Engine VOC Emission Factor:	0.040	lb/MMBtu	Stack Test Results
IC Engine PM10 Emission Factor:	48.7	lb/MM cf LFG	Based on engine quarterly permit limits

	Calculated Uncontrolled LFG			Uncollected LFG					Collected LFG - Flare										Collected LFG - IC Engines										Total Emissions						
Year	LFG cfm	LFG MM cf/yr	CO2 tpy	LFG MMcf/yr	Methane tpy	Methane From Cover tpy	VOC (NMOC) tpy	Total HAP tpy	LFG MMcf/yr	Methane MMcf/yr	NOx tpy	SO2 tpy	CO tpy	CO2 Combustion tpy	Methane tpy	VOC tpy	Total HAP tpy	PM10 tpy	LFG MMcf/yr	Methane MMcf/yr	NOx tpy	SO2 tpy	CO tpy	CO2 Combustion tpy	Methane tpy	VOC tpy	Total HAP tpy	PM10 tpy	NOx tpy	SO2 tpy	CO tpy	CO2e tpy	VOC tpy	Total HAP tpy	PM10 tpy
2020	1,997	1,050	31,279	262	2,514	2,262	19.4	3.36	157	73.8	1.53	0.598	0.170	3,680	2.87	0.034	2.31	0.628	630	295	15.1	2.39	92.7	14,720	11.5	5.45	9.24	15.3	16.7	2.99	92.9	97,491	24.9	14.9	16.0
2021	2,028	1,066	31,764	266	2,553	2,298	19.7	3.41	160	75.0	1.56	0.608	0.173	3,737	2.91	0.035	2.35	0.637	640	300	15.4	2.43	94.2	14,948	11.6	5.54	9.38	15.6	16.9	3.04	94.3	99,005	25.3	15.1	16.2
2022	2,060	1,083	32,266	271	2,593	2,334	20.0	3.46	162	76.2	1.58	0.617	0.176	3,796	2.96	0.035	2.38	0.647	650	305	15.6	2.47	95.6	15,184	11.8	5.63	9.53	15.8	17.2	3.09	95.8	100,567	25.7	15.4	16.5
2023	2,094	1,101	32,798	275	2,636	2,372	20.4	3.52	165	77.4	1.61	0.627	0.179	3,859	3.00	0.036	2.42	0.658	660	310	15.9	2.51	97.2	15,435	12.0	5.72	9.69	16.1	17.5	3.14	97.4	102,227	26.1	15.6	16.7
2024	2,129	1,119	33,346	280	2,680	2,412	20.7	3.58	168	78.7	1.64	0.638	0.182	3,923	3.06	0.036	2.46	0.669	671	315	16.1	2.55	98.8	15,693	12.2	5.81	9.85	16.3	17.8	3.19	99.0	103,935	26.6	15.9	17.0
2025	2,166	1,138	33,926	285	2,727	2,454	21.1	3.64	171	80.1	1.66	0.649	0.185	3,991	3.11	0.037	2.51	0.681	683	320	16.4	2.60	101	15,966	12.4	5.92	10.0	16.6	18.1	3.24	101	105,742	27.0	16.2	17.3
2026	2,204	1,158	34,521	290	2,774	2,497	21.4	3.71	174	81.5	1.69	0.660	0.188	4,061	3.16	0.038	2.55	0.693	695	326	16.7	2.64	102	16,246	12.7	6.02	10.2	16.9	18.4	3.30	103	107,597	27.5	16.5	17.6
2027	2,243	1,179	35,132	295	2,824	2,541	21.8	3.77	177	82.9	1.72	0.672	0.191	4,133	3.22	0.038	2.59	0.705	707	332	17.0	2.69	104	16,533	12.9	6.13	10.4	17.2	18.7	3.36	104	109,501	28.0	16.7	17.9
2028	2,284	1,200	35,774	300	2,875	2,588	22.2	3.84	180	84.5	1.75	0.684	0.195	4,209	3.28	0.039	2.64	0.718	720	338	17.3	2.74	106	16,835	13.1	6.24	10.6	17.5	19.1	3.42	106	111,502	28.5	17.1	18.3
2029	2,326	1,223	36,432	306	2,928	2,635	22.6	3.91	183	86.0	1.79	0.697	0.199	4,286	3.34	0.040	2.69	0.731	734	344	17.6	2.79	108	17,145	13.4	6.35	10.8	17.9	19.4	3.48	108	113,553	29.0	17.4	18.6
2030	2,370	1,246	37,121	311	2,983	2,685	23.0	3.99	187	87.6	1.82	0.710	0.202	4,367	3.40	0.040	2.74	0.745	747	351	18.0	2.84	110	17,469	13.6	6.47	11.0	18.2	19.8	3.55	110	115,701	29.6	17.7	18.9
2031	2,415	1,269	37,826	317	3,040	2,736	23.5	4.06	190	89.3	1.85	0.724	0.206	4,450	3.47	0.041	2.79	0.759	762	357	18.3	2.89	112	17,801	13.9	6.60	11.2	18.5	20.2	3.62	112	117,898	30.1	18.0	19.3
2032	2,461	1,294	38,546	323	3,098	2,788	23.9	4.14	194	91.0	1.89	0.737	0.210	4,535	3.53	0.042	2.85	0.773	776	364	18.7	2.95	114	18,140	14.1	6.72	11.4	18.9	20.5	3.69	114	120,143	30.7	18.4	19.7
2033	2,507	1,318	39,267	329	3,156	2,840	24.4	4.22	198	92.7	1.93	0.751	0.214	4,620	3.60	0.043	2.90	0.788	791	371	19.0	3.00	116	18,479	14.4	6.85	11.6	19.3	20.9	3.76	117	122,389	31.3	18.7	20.0
2034	2,555	1,343	40,019	336	3,216	2,895	24.8	4.30	201	94.5	1.96	0.765	0.218	4,708	3.67	0.044	2.96	0.803	806	378	19.4	3.06	119	18,833	14.7	6.98	11.8	19.6	21.3	3.83	119	124,732	31.9	19.1	20.4
2035	2,604	1,369	40,786	342	3,278	2,950	25.3	4.38	205	96.3	2.00	0.780	0.222	4,799	3.74	0.044	3.01	0.818	821	385	19.7	3.12	121	19,194	14.9	7.11	12.0	20.0	21.7	3.90	121	127,124	32.5	19.4	20.8
2036	2,654	1,395	41,569	349	3,341	3,007	25.8	4.46	209	98.1	2.04	0.795	0.227	4,891	3.81	0.045	3.07	0.834	837	393	20.1	3.18	123	19,563	15.2	7.25	12.3	20.4	22.2	3.98	123	129,565	33.1	19.8	21.2
2037	2,705	1,422	42,368	355	3,405	3,065	26.3	4.55	213	100	2.08	0.810	0.231	4,985	3.88	0.046	3.13	0.850	853	400	20.5	3.24	126	19,939	15.5	7.39	12.5	20.8	22.6	4.05	126	132,055	33.7	20.2	21.6
2038	2,757	1,449	43,183	362	3,471	3,123	26.8	4.64	217	102	2.12	0.826	0.235	5,080	3.96	0.047	3.19	0.867	869	408	20.9	3.30	128	20,322	15.8	7.53	12.8	21.2	23.0	4.13	128	134,594	34.4	20.6	22.0
2039	2,811	1,477	44,028	369	3,539	3,185	27.3	4.73	222	104	2.16	0.842	0.240	5,180	4.03	0.048	3.25	0.883	886	416	21.3	3.37	131	20,720	16.1	7.68	13.0	21.6	23.5	4.21	131	137,230	35.1	21.0	22.5
2040	2,865	1,506	44,874	376	3,606	3,246	27.9	4.82	226	106	2.20	0.858	0.245	5,279	4.11	0.049	3.31	0.900	904	424	21.7	3.43	133	21,118	16.4	7.82	13.3	22.0	23.9	4.29	133	139,866	35.7	21.4	22.9
2041	2,921	1,535	45,751	384	3,677	3,309	28.4	4.91	230	108	2.24	0.875	0.249	5,383	4.19	0.050	3.38	0.918	921	432	22.1	3.50	136	21,531	16.8	7.98	13.5	22.4	24.4	4.38	136	142,600	36.4	21.8	23.3
2042	2,978	1,565	46,644	391	3,749	3,374	29.0	5.01	235	110	2.29	0.892	0.254	5,488	4.27	0.051	3.44	0.936	939	440	22.6	3.57	138	21,951	17.1	8.13	13.8	22.9	24.9	4.46	139	145,383	37.1	22.2	23.8
2043	3,036	1,596	47,553	399	3,822	3,440	29.5	5.11	239	112	2.33	0.910	0.259	5,595	4.36	0.052	3.51	0.954	957	449	23.0	3.64	141	22,378	17.4	8.29	14.0	23.3	25.3	4.55	141	148,214	37.9	22.7	24.3
2044	3,095	1,627	48,477	407	3,896	3,506	30.1	5.21	244	114	2.38	0.927	0.264	5,703	4.44	0.053	3.58	0.973	976	458	23.5	3.71	144	22,813	17.8	8.45	14.3	23.8	25.8	4.64	144	151,094	38.6	23.1	24.7
2045	3,155	1,658	49,416	415	3,972	3,574	30.7	5.31	249	117	2.42	0.945	0.269	5,814	4.53	0.054	3.65	0.992	995	467	23.9	3.78	146	23,256	18.1	8.62	14.6	24.2	26.3	4.73	147	154,023	39.3	23.6	25.2
2046	3,217	1,691	50,387	423	4,050	3,645	31.3	5.41	254	119	2.47	0.964	0.275	5,928	4.62	0.055	3.72	1.01	1,015	476	24.4	3.86	149	23,713	18.5	8.79	14.9	24.7	26.9	4.82	150	157,050	40.1	24.0	25.7
2047	3,280	1,724	51,374	431	4,129	3,716	31.9	5.52	259	121	2.52	0.983	0.280	6,044	4.71	0.056	3.79	1.03	1,034	485	24.9	3.93	152	24,177	18.8	8.96	15.2	25.2	27.4	4.91	153	160,126	40.9	24.5	26.2
2048	3,344	1,758	52,377	439	4,209	3,789	32.5	5.62	264	124	2.57	1.00	0.285	6,162	4.80	0.057	3.87	1.05	1,055	495	25.3	4.01	155	24,649	19.2	9.13	15.5	25.7	27.9	5.01	156	163,250	41.7	25.0	26.7
2049	3,410	1,792	53,410	448	4,293	3,863	33.2	5.74	269	126	2.62	1.02	0.291	6,284	4.89	0.058	3.94	1.07	1,075	504	25.8	4.09	158	25,135	19.6	9.31	15.8	26.2	28.5	5.11	159	166,472	42.5	25.5	27.3
2050	3,477	1,828	54,460	457	4,377	3,939	33.8	5.85	274	129	2.67	1.04	0.297	6,407	4.99	0.059	4.02	1.09	1,097	514	26.4	4.17	161	25,629	20.0	9.50	16.1	26.7	29.0	5.21	162	169,743	43.4	26.0	27.8
2051	3,545	1,863	55,525	466	4,462	4,016	34.5	5.96	279	131	2.72	1.06	0.303	6,533	5.09	0.061	4.10	1.11	1,118	524	26.9	4.25	165	26,130	20.3	9.68	16.4	27.2	29.6	5.31	165	173,063	44.2	26.5	28.3
2052	3,615	1,900	56,621	475	4,551	4,096	35.2	6.08	285	134	2.78	1.08	0.309	6,662	5.19	0.062	4.18	1.14	1,140	535	27.4	4.33	168	26,646	20.8	9.87	16.7	27.8	30.2	5.42	168	176,480	45.1	27.0	28.9
2053	3,686	1,937	57,733	484	4,640	4,176	35.8	6.20	291	136	2.83	1.10	0.315	6,792	5.29	0.063	4.26	1.16	1,162	545	27.9	4.42	171	27,170	21.2	10.1	17.1	28.3	30.8	5.52	171	179,946	46.0	27.5	29.5
2054	3,759	1,976	58,877	494	4,732	4,259	36.6	6.32	296	139	2.89	1.13	0.321	6,927	5.39	0.064	4.35	1.18	1,185	556	28.5	4.50	175	27,708	21.6	10.3	17.4	28.9	31.4	5.63	175	183,510	46.9	28.1	30.0
2055	3,833	2,015	60,036	504	4,825	4,343	37.3	6.45	302	142	2.94	1.15	0.327	7,063	5.50	0.065	4.43	1.20	1,209	567	29.0	4.59	178	28,253	22.0	10.5	17.7	29.4	32.0	5.74	178	187,123	47.8	28.6	30.6
2056	3,909	2,055	61,226	514	4,921	4,429	38.0	6.57	308	145	3.00	1.17	0.334	7,203	5.61	0.067	4.52	1.23	1,233	578	29.6	4.68	181	28,813	22.4	10.7	18.1	30.0	32.6	5.86	182	190,833	48.8	29.2	31.2
2057	3,986	2,095	62,432	524	5,018	4,516	38.8	6.70	314	147	3.06	1.19	0.340	7,345	5.72	0.068	4.61	1.25	1,257	590	30.2	4.78	185	29,381	22.9	10.9	18.4	30.6	33.3	5.97	185	194,592	49.7	29.8	31.9
2058	4,065	2,137	63,670	534	5,117	4,605	39.5	6.84	320	150	3.12	1.22	0.347	7,491	5.83	0.069	4.70	1.28	1,282	601	30.8	4.87	189	29,963	23.3	11.1	18.8	31.2	33.9	6.09	189	198,449	50.7	30.3	32.5
2059	4,145	2,179	64,923	545	5,218	4,696	40.3	6.97	327	153	3.18	1.24	0.354	7,638	5.95	0.071	4.79	1.30	1,307	613	31.4	4.97	192	30,553	23.8	11.3	19.2	31.8	34.6	6.21	193	202,354	51.7	30.9	33.1
2060	4,227	2,222	66,207	555	5,321	4,789	41.1	7.11	333	156	3.25	1.27	0.361	7,789	6.07	0.072	4.89	1.33	1,333	625	32.0	5.07	196	31,157	24.3	11.5	19.6	32.5	35.3	6.33	197	206,357	52.7	31.6	33.8
2061	4,311	2,266	67,523	566	5,427	4,884	41.9	7.25	340	159	3.31	1.29	0.368	7,944	6.19	0.074	4.99	1.35	1,360	638	32.7	5.17	200	31,776	24.7	11.8	19.9	33.1	36.0	6.46	201	210,458	53.8	32.2	34.5

Appendix B WTE Scenarios

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Western Placer Waste Management Authority
Alternate Energy Feasibility Study
Pollutant Profile - WTE

Assumptions		Units	
LFG Collection Efficiency:	75%	%	
LFG Methane Content:	46.9%	%	Average of 1 minute minimum and maximum values from "June 2010.xlsx".
LFG CO_2 Content:	53.1%	%	Calculated from the average methane content and the assumption that CO2 is the remainder of the landfill gas.
Collected LFG to IC Engines:	80%	%	Assumed.
Collected LFG to Flare:	20%	%	All LFG not directed to IC engines assumed to flare.
Cover Oxidation Factor:	10%	%	40 CFR Part 98, Subpart HH, Table HH-1.
LFG Heat Content:	433	Btu/cf	Stack Test Results
Flare and IC Engine Destruction Efficiency:	99.81%	%	Stack Test Results
LFG CO2 Content Emission Factor:	29.8	ton/MM cf LFG	Based on average of 1 minute minimum and maximum values from "June 2010.xlsx".
LFG Methane Content Emission Factor:	9.58	ton/MM cf LFG	Based on methane content and the assumption that CO2 is the remainder of the landfill gas.
LFG Combustion SO2 Emission Factor:	0.0038	ton/MM cf LFG	AP-42 Default Value
LFG Uncontrolled NMOC Content Emission Factor:	148	lb/MM cf LFG	Stack Test Results
LFG Uncontrolled Organic HAP Content Emission Factor:	0.0128	ton/MM cf LFG	AP-42 Default Value
LFG Mercury Content Emission Factor:	7.53E-08	ton/MM cf LFG	AP-42 Default Value
LFG Combustion HCl Emission Factor:	0.0020	ton/MM cf LFG	AP-42 Default Value
Flare NOx Emission Factor:	0.045	lb/MMBtu	Stack Test Results
Flare CO Emission Factor:	0.0050	lb/MMBtu	Stack Test Results
Flare VOC Emission Factor:	0.0010	lb/MMBtu	Stack Test Results
Flare PM10 Emission Factor:	17.0	lb/MM cf CH4	AP-42, Table 2.4-5
IC Engine NOx Emission Factor:	0.111	lb/MMBtu	Stack Test Results
IC Engine CO Emission Factor:	0.680	lb/MMBtu	Stack Test Results
IC Engine VOC Emission Factor:	0.040	lb/MMBtu	Stack Test Results
IC Engine PM10 Emission Factor:	48.7	lb/MM cf LFG	Based on engine quarterly permit limits
CT MSW Throughput:	182,500	tons per year	Based on 500 tpd, 365 days per year
WTE NOx Emission Factor:	0.790	lb/ton MSW	HDR Library
WTE SO2 Emission Factor:	0.180	lb/ton MSW	HDR Library
WTE CO Emission Factor:	0.780	lb/ton MSW	HDR Library
WTE CO2e Emission Factor:	2,378	lb/ton MSW	Based on average MRF residue carbon content of 32.43% and assuming that 100% of the carbon is converted to CO2.
WTE VOC Emission Factor:	0.048	lb/ton MSW	HDR Library
WTE Total HAP Emission Factor:	0.145	lb/ton MSW	HDR Library
WTE PM10 Emission Factor:	0.052	lb/ton MSW	HDR Library

	Calculated Uncontrolled LFG			Uncollected LFG					Collected LFG									
									Flare									
Year	LFG cfm	LFG MM cf/yr	CO2 tpy	LFG MMcf/yr	Methane tpy	Methane From Cover tpy	VOC (NMOC) tpy	Total HAP tpy	LFG MMcf/yr	Methane MMcf/yr	NOx tpy	SO2 tpy	CO tpy	CO2 Combustion tpy	Methane tpy	VOC tpy	Total HAP tpy	PM10 tpy
2020	1,997	1,050	31,279	262	2,514	2,262	19.4	3.36	157	73.8	1.53	0.598	0.170	3,680	2.87	0.034	2.31	0.628
2021	2,028	1,066	31,764	266	2,553	2,298	19.7	3.41	160	75.0	1.56	0.608	0.173	3,737	2.91	0.035	2.35	0.637
2022	1,978	1,040	30,981	260	2,490	2,241	19.2	3.33	156	73.1	1.52	0.593	0.169	3,645	2.84	0.034	2.29	0.622
2023	1,933	1,016	30,276	254	2,433	2,190	18.8	3.25	152	71.5	1.48	0.579	0.165	3,562	2.77	0.033	2.24	0.608
2024	1,893	995	29,650	249	2,383	2,145	18.4	3.18	149	70.0	1.45	0.567	0.162	3,488	2.72	0.032	2.19	0.595
2025	1,856	976	29,070	244	2,336	2,103	18.0	3.12	146	68.6	1.43	0.556	0.158	3,420	2.66	0.032	2.15	0.583
2026	1,824	959	28,569	240	2,296	2,066	17.7	3.07	144	67.4	1.40	0.546	0.156	3,361	2.62	0.031	2.11	0.573
2027	1,796	944	28,131	236	2,261	2,035	17.5	3.02	142	66.4	1.38	0.538	0.153	3,310	2.58	0.031	2.08	0.564
2028	1,772	931	27,755	233	2,231	2,008	17.2	2.98	140	65.5	1.36	0.531	0.151	3,265	2.54	0.030	2.05	0.557
2029	1,752	921	27,441	230	2,205	1,985	17.0	2.95	138	64.8	1.35	0.525	0.150	3,228	2.51	0.030	2.03	0.551
2030	1,737	913	27,206	228	2,187	1,968	16.9	2.92	137	64.2	1.33	0.520	0.148	3,201	2.49	0.030	2.01	0.546
2031	1,724	906	27,003	227	2,170	1,953	16.8	2.90	136	63.7	1.32	0.516	0.147	3,177	2.47	0.029	1.99	0.542
2032	1,715	901	26,862	225	2,159	1,943	16.7	2.88	135	63.4	1.32	0.514	0.146	3,160	2.46	0.029	1.98	0.539
2033	1,709	898	26,768	225	2,151	1,936	16.6	2.87	135	63.2	1.31	0.512	0.146	3,149	2.45	0.029	1.98	0.537
2034	1,706	897	26,721	224	2,148	1,933	16.6	2.87	135	63.1	1.31	0.511	0.146	3,144	2.45	0.029	1.97	0.536
2035	1,706	897	26,721	224	2,148	1,933	16.6	2.87	135	63.1	1.31	0.511	0.146	3,144	2.45	0.029	1.97	0.536
2036	1,709	898	26,768	225	2,151	1,936	16.6	2.87	135	63.2	1.31	0.512	0.146	3,149	2.45	0.029	1.98	0.537
2037	1,715	901	26,862	225	2,159	1,943	16.7	2.88	135	63.4	1.32	0.514	0.146	3,160	2.46	0.029	1.98	0.539
2038	1,724	906	27,003	227	2,170	1,953	16.8	2.90	136	63.7	1.32	0.516	0.147	3,177	2.47	0.029	1.99	0.542
2039	1,735	912	27,175	228	2,184	1,966	16.9	2.92	137	64.2	1.33	0.520	0.148	3,197	2.49	0.030	2.01	0.545
2040	1,750	920	27,410	230	2,203	1,983	17.0	2.94	138	64.7	1.34	0.524	0.149	3,225	2.51	0.030	2.02	0.550
2041	1,767	929	27,676	232	2,224	2,002	17.2	2.97	139	65.3	1.36	0.529	0.151	3,256	2.54	0.030	2.04	0.555
2042	1,787	939	27,990	235	2,249	2,025	17.4	3.01	141	66.1	1.37	0.535	0.153	3,293	2.56	0.031	2.07	0.562
2043	1,809	951	28,334	238	2,277	2,049	17.6	3.04	143	66.9	1.39	0.542	0.154	3,334	2.60	0.031	2.09	0.569
2044	1,835	964	28,741	241	2,310	2,079	17.8	3.09	145	67.9	1.41	0.550	0.157	3,381	2.63	0.031	2.12	0.577
2045	1,862	979	29,164	245	2,344	2,110	18.1	3.13	147	68.8	1.43	0.558	0.159	3,431	2.67	0.032	2.15	0.585
2046	1,892	994	29,634	249	2,382	2,144	18.4	3.18	149	70.0	1.45	0.567	0.161	3,486	2.72	0.032	2.19	0.59
2047	1,925	1,012	30,151	253	2,423	2,181	18.7	3.24	152	71.2	1.48	0.577	0.164	3,547	2.76	0.033	2.23	0.61
2048	1,960	1,030	30,699	258	2,467	2,221	19.1	3.30	155	72.5	1.51	0.59	0.167	3,612	2.81	0.033	2.27	0.62
2049	1,998	1,050	31,294	263	2,515	2,264	19.4	3.36	158	73.9	1.53	0.60	0.171	3,682	2.87	0.034	2.31	0.63
2050	2,038	1,071	31,921	268	2,565	2,309	19.8	3.43	161	75.4	1.57	0.61	0.174	3,756	2.92	0.035	2.36	0.64
2051	2,081	1,094	32,594	273	2,620	2,358	20.2	3.50	164	76.9	1.60	0.62	0.178	3,835	2.99	0.036	2.41	0.65
2052	2,126	1,117	33,299	279	2,676	2,409	20.7	3.58	168	78.6	1.63	0.64	0.181	3,918	3.05	0.036	2.46	0.67
2053	2,174	1,143	34,051	286	2,737	2,463	21.1	3.66	171	80.4	1.67	0.65	0.186	4,006	3.12	0.037	2.51	0.68
2054	2,223	1,168	34,819	292	2,798	2,519	21.6	3.74	175	82.2	1.71	0.67	0.190	4,096	3.19	0.038	2.57	0.70
2055	2,276	1,196	35,649	299	2,865	2,579	22.1	3.83	179	84.2	1.75	0.68	0.194	4,194	3.27	0.039	2.63	0.72
2056	2,330	1,225	36,495	306	2,933	2,640	22.7	3.92	184	86.2	1.79	0.70	0.199	4,294	3.34	0.040	2.70	0.73
2057	2,387	1,255	37,387	314	3,005	2,704	23.2	4.01	188	88.3	1.83	0.72	0.204	4,399	3.43	0.041	2.76	0.75
2058	2,447	1,286	38,327	322	3,080	2,772	23.8	4.12	193	90.5	1.88	0.73	0.209	4,509	3.51	0.042	2.83	0.77
2059	2,508	1,318	39,283	330	3,157	2,841	24.4	4.22	198	92.7	1.93	0.75	0.214	4,622	3.60	0.043	2.90	0.79
2060	2,573	1,352	40,301	338	3,239	2,915	25.0	4.33	203	95.1	1.98	0.77	0.220	4,741	3.69	0.044	2.98	0.81
2061	2,639	1,387	41,334	347	3,322	2,990	25.7	4.44	208	97.6	2.03	0.79	0.225	4,863	3.79	0.045	3.05	0.83

	Collected LFG										WTE							Total Emissions						
	IC Engines																							
Year	LFG MMcf/yr	Methane MMcf/yr	NOx tpy	SO2 tpy	CO tpy	CO2 Combustion tpy	Methane tpy	VOC tpy	Total HAP tpy	PM10 tpy	NOx tpy	SO2 tpy	CO tpy	CO2e tpy	VOC tpy	Total HAP tpy	PM10 tpy	NOx tpy	SO2 tpy	CO tpy	CO2e tpy	VOC tpy	Total HAP tpy	PM10 tpy
2020	630	295	15.1	2.39	92.7	14,720	11.5	5.45	9.24	15.3	72.1	16.4	71.2	217,011	4.38	13.2	4.75	88.8	19.4	164	314,502	29.3	28.1	20.7
2021	640	300	15.4	2.43	94.2	14,948	11.6	5.54	9.38	15.6	72.1	16.4	71.2	217,011	4.38	13.2	4.75	89.0	19.5	166	316,015	29.7	28.4	21.0
2022	624	293	15.0	2.37	91.8	14,580	11.4	5.40	9.15	15.2	72.1	16.4	71.2	217,011	4.38	13.2	4.75	88.6	19.4	163	313,574	29.0	28.0	20.6
2023	610	286	14.6	2.32	89.7	14,248	11.1	5.28	8.94	14.8	72.1	16.4	71.2	217,011	4.38	13.2	4.75	88.2	19.3	161	311,378	28.5	27.7	20.2
2024	597	280	14.3	2.27	87.9	13,953	10.9	5.17	8.76	14.5	72.1	16.4	71.2	217,011	4.38	13.2	4.75	87.9	19.3	159	309,425	28.0	27.4	19.9
2025	585	275	14.1	2.22	86.2	13,681	10.7	5.07	8.6	14.3	72.1	16.4	71.2	217,011	4.38	13.2	4.75	87.6	19.2	158	307,619	27.5	27.1	19.6
2026	575	270	13.8	2.19	84.7	13,445	10.5	4.98	8.4	14.0	72.1	16.4	71.2	217,011	4.38	13.2	4.75	87.3	19.2	156	306,056	27.1	26.8	19.3
2027	566	266	13.6	2.15	83.4	13,238	10.3	4.90	8.3	13.8	72.1	16.4	71.2	217,011	4.38	13.2	4.75	87.1	19.1	155	304,689	26.8	26.6	19.1
2028	559	262	13.4	2.12	82.3	13,061	10.2	4.84	8.2	13.6	72.1	16.4	71.2	217,011	4.38	13.2	4.75	86.9	19.1	154	303,518	26.5	26.5	18.9
2029	553	259	13.3	2.10	81.3	12,914	10.1	4.78	8.1	13.5	72.1	16.4	71.2	217,011	4.38	13.2	4.75	86.7	19.0	153	302,541	26.2	26.3	18.7
2030	548	257	13.2	2.08	80.6	12,803	10.0	4.74	8.0	13.3	72.1	16.4	71.2	217,011	4.38	13.2	4.75	86.6	19.0	152	301,809	26.0	26.2	18.6
2031	544	255	13.1	2.07	80.0	12,708	9.9	4.71	8.0	13.2	72.1	16.4	71.2	217,011	4.38	13.2	4.75	86.5	19.0	151	301,174	25.9	26.1	18.5
2032	541	254	13.0	2.06	79.6	12,641	9.8	4.68	7.9	13.2	72.1	16.4	71.2	217,011	4.38	13.2	4.75	86.4	19.0	151	300,735	25.8	26.0	18.5
2033	539	253	13.0	2.05	79.3	12,597	9.8	4.67	7.9	13.1	72.1	16.4	71.2	217,011	4.38	13.2	4.75	86.4	19.0	151	300,442	25.7	26.0	18.4
2034	538	252	12.9	2.04	79.2	12,575	9.8	4.66	7.9	13.1	72.1	16.4	71.2	217,011	4.38	13.2	4.75	86.3	19.0	151	300,296	25.7	26.0	18.4
2035	538	252	12.9	2.04	79.2	12,575	9.8	4.66	7.9	13.1	72.1	16.4	71.2	217,011	4.38	13.2	4.75	86.3	19.0	151	300,296	25.7	26.0	18.4
2036	539	253	13.0	2.05	79.3	12,597	9.8	4.67	7.9	13.1	72.1	16.4	71.2	217,011	4.38	13.2	4.75	86.4	19.0	151	300,442	25.7	26.0	18.4
2037	541	254	13.0	2.06	79.6	12,641	9.8	4.68	7.9	13.2	72.1	16.4	71.2	217,011	4.38	13.2	4.75	86.4	19.0	151	300,735	25.8	26.0	18.5
2038	544	255	13.1	2.07	80.0	12,708	9.9	4.71	8.0	13.2	72.1	16.4	71.2	217,011	4.38	13.2	4.75	86.5	19.0	151	301,174	25.9	26.1	18.5
2039	547	257	13.1	2.08	80.6	12,789	10.0	4.74	8.0	13.3	72.1	16.4	71.2	217,011	4.38	13.2	4.75	86.6	19.0	152	301,711	26.0	26.2	18.6
2040	552	259	13.3	2.10	81.2	12,899	10.0	4.78	8.1	13.4	72.1	16.4	71.2	217,011	4.38	13.2	4.75	86.7	19.0	153	302,444	26.2	26.3	18.7
2041	557	261	13.4	2.12	82.0	13,025	10.1	4.83	8.2	13.6	72.1	16.4	71.2	217,011	4.38	13.2	4.75	86.8	19.1	153	303,274	26.4	26.4	18.9
2042	564	264	13.5	2.14	83.0	13,172	10.3	4.88	8.3	13.7	72.1	16.4	71.2	217,011	4.38	13.2	4.75	87.0	19.1	154	304,250	26.7	26.6	19.0
2043	570	268	13.7	2.17	84.0	13,334	10.4	4.94	8.4	13.9	72.1	16.4	71.2	217,011	4.38	13.2	4.75	87.2	19.1	155	305,324	26.9	26.7	19.2
2044	579	271	13.9	2.20	85.2	13,526	10.5	5.01	8.5	14.1	72.1	16.4	71.2	217,011	4.38	13.2	4.75	87.4	19.2	157	306,593	27.3	26.9	19.4
2045	587	275	14.1	2.23	86.4	13,725	10.7	5.09	8.6	14.3	72.1	16.4	71.2	217,011	4.38	13.2	4.75	87.6	19.2	158	307,911	27.6	27.1	19.6
2046	597	280	14.3	2.27	87.8	13,946	10.9	5.17	8.8	14.5	72.1	16.4	71.2	217,011	4.38	13.2	4.75	87.9	19.3	159	309,376	28.0	27.4	19.9
2047	607	285	14.6	2.31	89.4	14,189	11.0	5.3	8.9	14.8	72.1	16.4	71.2	217,011	4.38	13.2	4.75	88.2	19.3	161	310,987	28.4	27.6	20.1
2048	618	290	14.9	2.35	91.0	14,447	11.3	5.4	9.1	15.1	72.1	16.4	71.2	217,011	4.38	13.2	4.75	88.4	19.4	162	312,696	28.8	27.9	20.4
2049	630	296	15.1	2.39	92.8	14,727	11.5	5.5	9.2	15.3	72.1	16.4	71.2	217,011	4.38	13.2	4.75	88.8	19.4	164	314,551	29.3	28.1	20.7
2050	643	301	15.4	2.44	94.6	15,022	11.7	5.6	9.4	15.6	72.1	16.4	71.2	217,011	4.38	13.2	4.75	89.1	19.5	166	316,504	29.8	28.4	21.0
2051	656	308	15.8	2.49	96.6	15,339	11.9	5.7	9.6	16.0	72.1	16.4	71.2	217,011	4.38	13.2	4.75	89.5	19.5	168	318,603	30.3	28.8	21.4
2052	670	314	16.1	2.55	98.7	15,671	12.2	5.8	9.8	16.3	72.1	16.4	71.2	217,011	4.38	13.2	4.75	89.8	19.6	170	320,800	30.9	29.1	21.7
2053	686	322	16.5	2.61	101	16,025	12.5	5.9	10.1	16.7	72.1	16.4	71.2	217,011	4.38	13.2	4.75	90.2	19.7	172	323,143	31.5	29.5	22.1
2054	701	329	16.8	2.66	103	16,386	12.8	6.1	10.3	17.1	72.1	16.4	71.2	217,011	4.38	13.2	4.75	90.6	19.8	175	325,535	32.1	29.8	22.5
2055	718	337	17.2	2.73	106	16,776	13.1	6.2	10.5	17.5	72.1	16.4	71.2	217,011	4.38	13.2	4.75	91.1	19.8	177	328,122	32.8	30.2	22.9
2056	735	345	17.7	2.79	108	17,174	13.4	6.4	10.8	17.9	72.1	16.4	71.2	217,011	4.38	13.2	4.75	91.5	19.9	180	330,759	33.4	30.6	23.4
2057	753	353	18.1	2.86	111	17,595	13.7	6.5	11.0	18.3	72.1	16.4	71.2	217,011	4.38	13.2	4.75	92.0	20.0	182	333,541	34.1	31.1	23.8
2058	772	362	18.5	2.93	114	18,037	14.0	6.7	11.3	18.8	72.1	16.4	71.2	217,011	4.38	13.2	4.75	92.5	20.1	185	336,470	34.9	31.5	24.3
2059	791	371	19.0	3.01	116	18,486	14.4	6.8	11.6	19.3	72.1	16.4	71.2	217,011	4.38	13.2	4.75	93.0	20.2	188	339,448	35.7	32.0	24.8
2060	811	381	19.5	3.08	119	18,966	14.8	7.0	11.9	19.8	72.1	16.4	71.2	217,011	4.38	13.2	4.75	93.6	20.3	191	342,622	36.5	32.4	25.3
2061	832	390	20.0	3.16	123	19,452	15.1	7.2	12.2	20.3	72.1	16.4	71.2	217,011	4.38	13.2	4.75	94.1	20.4	194	345,844	37.3	32.9	25.8

Appendix C Gasification Scenario using IC Engine

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Western Placer Waste Management Authority
Alternate Energy Feasibility Study
Pollutant Profile - Syngas to IC Engine

Assumptions		Units	
LFG Collection Efficiency:	75%	%	
LFG Methane Content:	46.9%	%	Average of 1 minute minimum and maximum values from "June 2010.xlsx".
LFG CO_2 Content:	53.1%	%	Calculated from the average methane content and the assumption that CO2 is the remainder of the landfill gas.
Collected LFG to IC Engines:	80%	%	Assumed.
Collected LFG to Flare:	20%	%	All LFG not directed to IC engines assumed to flare.
Cover Oxidation Factor:	10%	%	40 CFR Part 98, Subpart HH, Table HH-1.
LFG Heat Content:	433	Btu/cf	Stack Test Results
Flare and IC Engine Destruction Efficiency:	99.81%	%	Stack Test Results
LFG CO2 Content Emission Factor:	29.8	ton/MM cf LFG	Based on average of 1 minute minimum and maximum values from "June 2010.xlsx"
LFG Methane Content Emission Factor:	9.58	ton/MM cf LFG	Based on methane content and the assumption that CO2 is the remainder of the landfill gas
LFG Combustion SO2 Emission Factor:	0.0038	ton/MM cf LFG	AP-42 Default Value
LFG Uncontrolled NMOC Content Emission Factor:	148	lb/MM cf LFG	Stack Test Results
LFG Uncontrolled Organic HAP Content Emission Factor:	0.0128	ton/MM cf LFG	AP-42 Default Value
LFG Mercury Content Emission Factor:	7.53E-08	ton/MM cf LFG	AP-42 Default Value
LFG Combustion HCl Emission Factor:	0.0020	ton/MM cf LFG	AP-42 Default Value
Flare NOx Emission Factor:	0.045	lb/MMBtu	Stack Test Results
Flare CO Emission Factor:	0.0050	lb/MMBtu	Stack Test Results
Flare VOC Emission Factor:	0.0010	lb/MMBtu	Stack Test Results
Flare PM10 Emission Factor:	17.0	lb/MM cf CH4	AP-42, Table 2.4-5
IC Engine NOx Emission Factor:	0.111	lb/MMBtu	Stack Test Results
IC Engine CO Emission Factor:	0.680	lb/MMBtu	Stack Test Results
IC Engine VOC Emission Factor:	0.040	lb/MMBtu	Stack Test Results
IC Engine PM10 Emission Factor:	48.7	lb/MM cf LFG	Based on engine quarterly permit limits
CT MSW Throughput:	182,500	tons per year	Based on 500 tpd, 365 days per year
Syngas Heat Content:	2,099,480	MMBtu/yr	Based on average MRF residue heat content of 5752 Btu/lb and assuming that all of the heat potential is converted to syngas.
Syngas Combustion SO2 Emission Factor:	0.0065	lb/MMBtu	Based on EPA's AP-42 SO2 emission factor for gas turbine combusting digester gas. Assumes the syngas is cleaned to an equivalent level.
Syngas Combustion HAP Emission Factor:	1.40E-05	lb/lb MSW	HDR Library. Consists primarily of HCl.
Syngas Combustion CO2 Emission Factor:	2,378	lb/ton MSW	Based on average MRF residue carbon content of 32.43% and assuming that all of the carbon is converted to CO2.
Syngas IC Engine PM10 Emission Factor:	0.025	lb/MMBtu	Vendor guarantee for recently permitted large natural gas-fired IC engine with oxidation catalyst and SCR
Syngas IC Engine NOx Emission Factor:	0.016	lb/MMBtu	Vendor guarantee for recently permitted large natural gas-fired IC engine with oxidation catalyst and SCR
Syngas IC Engine CO Emission Factor:	0.030	lb/MMBtu	Vendor guarantee for recently permitted large natural gas-fired IC engine with oxidation catalyst and SCR
Syngas IC Engine VOC Emission Factor:	0.030	lb/MMBtu	Vendor guarantee for recently permitted large natural gas-fired IC engine with oxidation catalyst and SCR

	Calculated Uncontrolled LFG			Uncollected LFG					Collected LFG – Flare									
Year	LFG cfm	LFG MM cf/yr	CO2 tpy	LFG MMcf/yr	Methane tpy	Methane From Cover tpy	VOC (NMOC) tpy	Total HAP tpy	LFG MMcf/yr	Methane MMcf/yr	NOx tpy	SO2 tpy	CO tpy	CO2 Combustion tpy	Methane tpy	VOC tpy	Total HAP tpy	PM10 tpy
2020	1,997	1,050	31,279	262	2,514	2,262	19.4	3.36	157	73.8	1.53	0.598	0.170	3,680	2.87	0.034	2.31	0.628
2021	2,028	1,066	31,764	266	2,553	2,298	19.7	3.41	160	75.0	1.56	0.608	0.173	3,737	2.91	0.035	2.35	0.637
2022	1,978	1,040	30,981	260	2,490	2,241	19.2	3.33	156	73.1	1.52	0.593	0.169	3,645	2.84	0.034	2.29	0.622
2023	1,933	1,016	30,276	254	2,433	2,190	18.8	3.25	152	71.5	1.48	0.579	0.165	3,562	2.77	0.033	2.24	0.608
2024	1,893	995	29,650	249	2,383	2,145	18.4	3.18	149	70.0	1.45	0.567	0.162	3,488	2.72	0.032	2.19	0.595
2025	1,856	976	29,070	244	2,336	2,103	18.0	3.12	146	68.6	1.43	0.556	0.158	3,420	2.66	0.032	2.15	0.583
2026	1,824	959	28,569	240	2,296	2,066	17.7	3.07	144	67.4	1.40	0.546	0.156	3,361	2.62	0.031	2.11	0.573
2027	1,796	944	28,131	236	2,261	2,035	17.5	3.02	142	66.4	1.38	0.538	0.153	3,310	2.58	0.031	2.08	0.564
2028	1,772	931	27,755	233	2,231	2,008	17.2	2.98	140	65.5	1.36	0.531	0.151	3,265	2.54	0.030	2.05	0.557
2029	1,752	921	27,441	230	2,205	1,985	17.0	2.95	138	64.8	1.35	0.525	0.150	3,228	2.51	0.030	2.03	0.551
2030	1,737	913	27,206	228	2,187	1,968	16.9	2.92	137	64.2	1.33	0.520	0.148	3,201	2.49	0.030	2.01	0.546
2031	1,724	906	27,003	227	2,170	1,953	16.8	2.90	136	63.7	1.32	0.516	0.147	3,177	2.47	0.029	1.99	0.542
2032	1,715	901	26,862	225	2,159	1,943	16.7	2.88	135	63.4	1.32	0.514	0.146	3,160	2.46	0.029	1.98	0.539
2033	1,709	898	26,768	225	2,151	1,936	16.6	2.87	135	63.2	1.31	0.512	0.146	3,149	2.45	0.029	1.98	0.537
2034	1,706	897	26,721	224	2,148	1,933	16.6	2.87	135	63.1	1.31	0.511	0.146	3,144	2.45	0.029	1.97	0.536
2035	1,706	897	26,721	224	2,148	1,933	16.6	2.87	135	63.1	1.31	0.511	0.146	3,144	2.45	0.029	1.97	0.536
2036	1,709	898	26,768	225	2,151	1,936	16.6	2.87	135	63.2	1.31	0.512	0.146	3,149	2.45	0.029	1.98	0.537
2037	1,715	901	26,862	225	2,159	1,943	16.7	2.88	135	63.4	1.32	0.514	0.146	3,160	2.46	0.029	1.98	0.539
2038	1,724	906	27,003	227	2,170	1,953	16.8	2.90	136	63.7	1.32	0.516	0.147	3,177	2.47	0.029	1.99	0.542
2039	1,735	912	27,175	228	2,184	1,966	16.9	2.92	137	64.2	1.33	0.520	0.148	3,197	2.49	0.030	2.01	0.545
2040	1,750	920	27,410	230	2,203	1,983	17.0	2.94	138	64.7	1.34	0.524	0.149	3,225	2.51	0.030	2.02	0.550
2041	1,767	929	27,676	232	2,224	2,002	17.2	2.97	139	65.3	1.36	0.529	0.151	3,256	2.54	0.030	2.04	0.555
2042	1,787	939	27,990	235	2,249	2,025	17.4	3.01	141	66.1	1.37	0.535	0.153	3,293	2.56	0.031	2.07	0.562
2043	1,809	951	28,334	238	2,277	2,049	17.6	3.04	143	66.9	1.39	0.542	0.154	3,334	2.60	0.031	2.09	0.569
2044	1,835	964	28,741	241	2,310	2,079	17.8	3.09	145	67.9	1.41	0.550	0.157	3,381	2.63	0.031	2.12	0.577
2045	1,862	979	29,164	245	2,344	2,110	18.1	3.13	147	68.8	1.43	0.558	0.159	3,431	2.67	0.032	2.15	0.585
2046	1,892	994	29,634	249	2,382	2,144	18.4	3.18	149	70.0	1.45	0.567	0.161	3,486	2.72	0.032	2.19	0.595
2047	1,925	1,012	30,151	253	2,423	2,181	18.7	3.24	152	71.2	1.48	0.577	0.164	3,547	2.76	0.033	2.23	0.605
2048	1,960	1,030	30,699	258	2,467	2,221	19.1	3.30	155	72.5	1.51	0.587	0.167	3,612	2.81	0.033	2.27	0.616
2049	1,998	1,050	31,294	263	2,515	2,264	19.4	3.36	158	73.9	1.53	0.599	0.171	3,682	2.87	0.034	2.31	0.628
2050	2,038	1,071	31,921	268	2,565	2,309	19.8	3.43	161	75.4	1.57	0.611	0.174	3,756	2.92	0.035	2.36	0.641
2051	2,081	1,094	32,594	273	2,620	2,358	20.2	3.50	164	76.9	1.60	0.623	0.178	3,835	2.99	0.036	2.41	0.654
2052	2,126	1,117	33,299	279	2,676	2,409	20.7	3.58	168	78.6	1.63	0.637	0.181	3,918	3.05	0.036	2.46	0.668
2053	2,174	1,143	34,051	286	2,737	2,463	21.1	3.66	171	80.4	1.67	0.651	0.186	4,006	3.12	0.037	2.51	0.683
2054	2,223	1,168	34,819	292	2,798	2,519	21.6	3.74	175	82.2	1.71	0.666	0.190	4,096	3.19	0.038	2.57	0.699
2055	2,276	1,196	35,649	299	2,865	2,579	22.1	3.83	179	84.2	1.75	0.682	0.194	4,194	3.27	0.039	2.63	0.715
2056	2,330	1,225	36,495	306	2,933	2,640	22.7	3.92	184	86.2	1.79	0.698	0.199	4,294	3.34	0.040	2.70	0.732
2057	2,387	1,255	37,387	314	3,005	2,704	23.2	4.01	188	88.3	1.83	0.715	0.204	4,399	3.43	0.041	2.76	0.750
2058	2,447	1,286	38,327	322	3,080	2,772	23.8	4.12	193	90.5	1.88	0.733	0.209	4,509	3.51	0.042	2.83	0.769
2059	2,508	1,318	39,283	330	3,157	2,841	24.4	4.22	198	92.7	1.93	0.751	0.214	4,622	3.60	0.043	2.90	0.788
2060	2,573	1,352	40,301	338	3,239	2,915	25.0	4.33	203	95.1	1.98	0.771	0.220	4,741	3.69	0.044	2.98	0.809
2061	2,639	1,387	41,334	347	3,322	2,990	25.7	4.44	208	97.6	2.03	0.791	0.225	4,863	3.79	0.045	3.05	0.829

	Collected LFG – IC Engines										Syngas to IC Engines							Total Emissions						
Year	LFG MMcf/yr	Methane MMcf/yr	NOx tpy	SO2 tpy	CO tpy	CO2 Combustion tpy	Methane tpy	VOC tpy	Total HAP tpy	PM10 tpy	NOx tpy	SO2 tpy	CO tpy	CO2e tpy	VOC tpy	Total HAP tpy	PM10 tpy	NOx tpy	SO2 tpy	CO tpy	CO2e tpy	VOC tpy	Total HAP tpy	PM10 tpy
2020	630	295	15.1	2.39	92.7	14,720	11.5	5.45	9.24	15.3	16.8	6.82	31.5	217,011	31.49	2.56	26.24	33.5	9.81	124	314,502	56.4	17.5	42.2
2021	640	300	15.4	2.43	94.2	14,948	11.6	5.54	9.38	15.6	16.8	6.82	31.5	217,011	31.49	2.56	26.24	33.7	9.86	126	316,015	56.8	17.7	42.5
2022	624	293	15.0	2.37	91.8	14,580	11.4	5.40	9.15	15.2	16.8	6.82	31.5	217,011	31.49	2.56	26.24	33.3	9.79	123	313,574	56.2	17.3	42.1
2023	610	286	14.6	2.32	89.7	14,248	11.1	5.28	8.94	14.8	16.8	6.82	31.5	217,011	31.49	2.56	26.24	32.9	9.72	121	311,378	55.6	17.0	41.7
2024	597	280	14.3	2.27	87.9	13,953	10.9	5.17	8.76	14.5	16.8	6.82	31.5	217,011	31.49	2.56	26.24	32.6	9.66	120	309,425	55.1	16.7	41.4
2025	585	275	14.1	2.22	86.2	13,681	10.7	5.07	8.59	14.3	16.8	6.82	31.5	217,011	31.49	2.56	26.24	32.3	9.60	118	307,619	54.6	16.4	41.1
2026	575	270	13.8	2.19	84.7	13,445	10.5	4.98	8.44	14.0	16.8	6.82	31.5	217,011	31.49	2.56	26.24	32.0	9.56	116	306,056	54.2	16.2	40.8
2027	566	266	13.6	2.15	83.4	13,238	10.3	4.90	8.31	13.8	16.8	6.82	31.5	217,011	31.49	2.56	26.24	31.8	9.51	115	304,689	53.9	16.0	40.6
2028	559	262	13.4	2.12	82.3	13,061	10.2	4.84	8.20	13.6	16.8	6.82	31.5	217,011	31.49	2.56	26.24	31.6	9.48	114	303,518	53.6	15.8	40.4
2029	553	259	13.3	2.10	81.3	12,914	10.1	4.78	8.11	13.5	16.8	6.82	31.5	217,011	31.49	2.56	26.24	31.4	9.45	113	302,541	53.3	15.6	40.2
2030	548	257	13.2	2.08	80.6	12,803	10.0	4.74	8.04	13.3	16.8	6.82	31.5	217,011	31.49	2.56	26.24	31.3	9.43	112	301,809	53.2	15.5	40.1
2031	544	255	13.1	2.07	80.0	12,708	9.9	4.71	7.98	13.2	16.8	6.82	31.5	217,011	31.49	2.56	26.24	31.2	9.41	112	301,174	53.0	15.4	40.0
2032	541	254	13.0	2.06	79.6	12,641	9.8	4.68	7.94	13.2	16.8	6.82	31.5	217,011	31.49	2.56	26.24	31.1	9.39	111	300,735	52.9	15.4	40.0
2033	539	253	13.0	2.05	79.3	12,597	9.8	4.67	7.91	13.1	16.8	6.82	31.5	217,011	31.49	2.56	26.24	31.1	9.38	111	300,442	52.8	15.3	39.9
2034	538	252	12.9	2.04	79.2	12,575	9.8	4.66	7.89	13.1	16.8	6.82	31.5	217,011	31.49	2.56	26.24	31.0	9.38	111	300,296	52.8	15.3	39.9
2035	538	252	12.9	2.04	79.2	12,575	9.8	4.66	7.89	13.1	16.8	6.82	31.5	217,011	31.49	2.56	26.24	31.0	9.38	111	300,296	52.8	15.3	39.9
2036	539	253	13.0	2.05	79.3	12,597	9.8	4.67	7.91	13.1	16.8	6.82	31.5	217,011	31.49	2.56	26.24	31.1	9.38	111	300,442	52.8	15.3	39.9
2037	541	254	13.0	2.06	79.6	12,641	9.8	4.68	7.94	13.2	16.8	6.82	31.5	217,011	31.49	2.56	26.24	31.1	9.39	111	300,735	52.9	15.4	40.0
2038	544	255	13.1	2.07	80.0	12,708	9.9	4.71	7.98	13.2	16.8	6.82	31.5	217,011	31.49	2.56	26.24	31.2	9.41	112	301,174	53.0	15.4	40.0
2039	547	257	13.1	2.08	80.6	12,789	10.0	4.74	8.03	13.3	16.8	6.82	31.5	217,011	31.49	2.56	26.24	31.3	9.42	112	301,711	53.1	15.5	40.1
2040	552	259	13.3	2.10	81.2	12,899	10.0	4.78	8.10	13.4	16.8	6.82	31.5	217,011	31.49	2.56	26.24	31.4	9.44	113	302,444	53.3	15.6	40.2
2041	557	261	13.4	2.12	82.0	13,025	10.1	4.83	8.18	13.6	16.8	6.82	31.5	217,011	31.49	2.56	26.24	31.5	9.47	114	303,274	53.5	15.8	40.4
2042	564	264	13.5	2.14	83.0	13,172	10.3	4.88	8.27	13.7	16.8	6.82	31.5	217,011	31.49	2.56	26.24	31.7	9.50	115	304,250	53.8	15.9	40.5
2043	570	268	13.7	2.17	84.0	13,334	10.4	4.94	8.37	13.9	16.8	6.82	31.5	217,011	31.49	2.56	26.24	31.9	9.53	116	305,324	54.1	16.1	40.7
2044	579	271	13.9	2.20	85.2	13,526	10.5	5.01	8.49	14.1	16.8	6.82	31.5	217,011	31.49	2.56	26.24	32.1	9.57	117	306,593	54.4	16.3	40.9
2045	587	275	14.1	2.23	86.4	13,725	10.7	5.09	8.62	14.3	16.8	6.82	31.5	217,011	31.49	2.56	26.24	32.3	9.61	118	307,911	54.7	16.5	41.1
2046	597	280	14.3	2.27	87.8	13,946	10.9	5.17	8.75	14.5	16.8	6.82	31.5	217,011	31.49	2.56	26.24	32.6	9.66	119	309,376	55.1	16.7	41.4
2047	607	285	14.6	2.31	89.4	14,189	11.0	5.26	8.91	14.8	16.8	6.82	31.5	217,011	31.49	2.56	26.24	32.9	9.71	121	310,987	55.5	16.9	41.6
2048	618	290	14.9	2.35	91.0	14,447	11.3	5.35	9.07	15.1	16.8	6.82	31.5	217,011	31.49	2.56	26.24	33.2	9.76	123	312,696	55.9	17.2	41.9
2049	630	296	15.1	2.39	92.8	14,727	11.5	5.46	9.24	15.3	16.8	6.82	31.5	217,011	31.49	2.56	26.24	33.5	9.82	124	314,551	56.4	17.5	42.2
2050	643	301	15.4	2.44	94.6	15,022	11.7	5.57	9.43	15.6	16.8	6.82	31.5	217,011	31.49	2.56	26.24	33.8	9.88	126	316,504	56.9	17.8	42.5
2051	656	308	15.8	2.49	96.6	15,339	11.9	5.68	9.63	16.0	16.8	6.82	31.5	217,011	31.49	2.56	26.24	34.2	9.94	128	318,603	57.4	18.1	42.9
2052	670	314	16.1	2.55	98.7	15,671	12.2	5.81	9.84	16.3	16.8	6.82	31.5	217,011	31.49	2.56	26.24	34.5	10.0	130	320,800	58.0	18.4	43.2
2053	686	322	16.5	2.61	101	16,025	12.5	5.94	10.1	16.7	16.8	6.82	31.5	217,011	31.49	2.56	26.24	34.9	10.1	133	323,143	58.6	18.8	43.6
2054	701	329	16.8	2.66	103	16,386	12.8	6.07	10.3	17.1	16.8	6.82	31.5	217,011	31.49	2.56	26.24	35.4	10.2	135	325,535	59.2	19.2	44.0
2055	718	337	17.2	2.73	106	16,776	13.1	6.22	10.5	17.5	16.8	6.82	31.5	217,011	31.49	2.56	26.24	35.8	10.2	137	328,122	59.9	19.6	44.4
2056	735	345	17.7	2.79	108	17,174	13.4	6.36	10.8	17.9	16.8	6.82	31.5	217,011	31.49	2.56	26.24	36.2	10.3	140	330,759	60.6	20.0	44.9
2057	753	353	18.1	2.86	111	17,595	13.7	6.52	11.0	18.3	16.8	6.82	31.5	217,011	31.49	2.56	26.24	36.7	10.4	143	333,541	61.3	20.4	45.3
2058	772	362	18.5	2.93	114	18,037	14.0	6.68	11.3	18.8	16.8	6.82	31.5	217,011	31.49	2.56	26.24	37.2	10.5	145	336,470	62.0	20.8	45.8
2059	791	371	19.0	3.01	116	18,486	14.4	6.85	11.6	19.3	16.8	6.82	31.5	217,011	31.49	2.56	26.24	37.7	10.6	148	339,448	62.8	21.3	46.3
2060	811	381	19.5	3.08	119	18,966	14.8	7.03	11.9	19.8	16.8	6.82	31.5	217,011	31.49	2.56	26.24	38.3	10.7	151	342,622	63.6	21.8	46.8
2061	832	390	20.0	3.16	123	19,452	15.1	7.21	12.2	20.3	16.8	6.82	31.5	217,011	31.49	2.56	26.24	38.8	10.8	154	345,844	64.4	22.3	47.3

Appendix D Gasification Scenario using Turbine

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Western Placer Waste Management Authority
Alternate Energy Feasibility Study
Pollutant Profile - Syngas to Turbine

Assumptions		Units	
LFG Collection Efficiency:	75%	%	
LFG Methane Content:	46.9%	%	Average of 1 minute minimum and maximum values from "June 2010.xlsx".
LFG CO_2 Content:	53.1%	%	Calculated from the average methane content and the assumption that CO2 is the remainder of the landfill gas.
Collected LFG to IC Engines:	80%	%	Assumed.
Collected LFG to Flare:	20%	%	All LFG not directed to IC engines assumed to flare.
Cover Oxidation Factor:	10%	%	40 CFR Part 98, Subpart HH, Table HH-1.
LFG Heat Content:	433	Btu/cf	Stack Test Results
Flare and IC Engine Destruction Efficiency:	99.81%	%	Stack Test Results
LFG CO2 Content Emission Factor:	29.8	ton/MM cf LFG	Based on average of 1 minute minimum and maximum values from "June 2010.xlsx"
LFG Methane Content Emission Factor:	9.58	ton/MM cf LFG	Based on methane content and the assumption that CO2 is the remainder of the landfill gas
LFG Combustion SO2 Emission Factor:	0.0038	ton/MM cf LFG	AP-42 Default Value
LFG Uncontrolled NMOC Content Emission Factor:	148	lb/MM cf LFG	Stack Test Results
LFG Uncontrolled Organic HAP Content Emission Factor:	0.0128	ton/MM cf LFG	AP-42 Default Value
LFG Mercury Content Emission Factor:	7.53E-08	ton/MM cf LFG	AP-42 Default Value
LFG Combustion HCl Emission Factor:	0.0020	ton/MM cf LFG	AP-42 Default Value
Flare NOx Emission Factor:	0.045	lb/MMBtu	Stack Test Results
Flare CO Emission Factor:	0.0050	lb/MMBtu	Stack Test Results
Flare VOC Emission Factor:	0.0010	lb/MMBtu	Stack Test Results
Flare PM10 Emission Factor:	17.0	lb/MM cf CH4	AP-42, Table 2.4-5
IC Engine NOx Emission Factor:	0.111	lb/MMBtu	Stack Test Results
IC Engine CO Emission Factor:	0.680	lb/MMBtu	Stack Test Results
IC Engine VOC Emission Factor:	0.040	lb/MMBtu	Stack Test Results
IC Engine PM10 Emission Factor:	48.7	lb/MM cf LFG	Based on engine quarterly permit limits
CT MSW Throughput:	182,500	tons per year	Based on 500 tpd, 365 days per year
Syngas Heat Content:	2,099,480	MMBtu/yr	Based on average MRF residue heat content of 5752 Btu/lb and assuming that all of the heat potential is converted to syngas.
Syngas Combustion SO2 Emission Factor:	0.007	lb/MMBtu	Based on EPA's AP-42 SO2 emission factor for gas turbine combusting digester gas. Assumes the syngas is cleaned to an equivalent level.
Syngas Combustion HAP Emission Factor:	1.40E-05	lb/lb MSW	HDR Library. Consists primarily of HCl.
Syngas Combustion CO2 Emission Factor:	2,378	lb/ton MSW	Based on average MRF residue carbon content of 32.43% and assuming that all of the carbon is converted to CO2.
Syngas Turbine NOx Emission Factor:	0.016	lb/MMBtu	Based on EPA's AP-42 uncontrolled NOx emission factor for gas turbine combusting digester gas and 90% control by SCR.
Syngas Turbine CO Emission Factor:	0.0017	lb/MMBtu	Based on EPA's AP-42 uncontrolled CO emission factor for gas turbine combusting digester gas and 90% control by oxidation catalyst
Syngas Turbine PM10 Emission Factor:	0.012	lb/MMBtu	Based on EPA's AP-42 uncontrolled PM10 emission factor for gas turbine combusting digester gas.
Syngas Turbine VOC Emission Factor:	0.00058	lb/MMBtu	Based on EPA's AP-42 uncontrolled VOC emission factor for gas turbine combusting digester gas and 90% control by oxidation catalyst

	Calculated Uncontrolled LFG			Uncollected LFG					Collected LFG – Flare									
Year	LFG cfm	LFG MM cf/yr	CO2 tpy	LFG MMcf/yr	Methane tpy	Methane From Cover tpy	VOC (NMOC) tpy	Total HAP tpy	LFG MMcf/yr	Methane MMcf/yr	NOx tpy	SO2 tpy	CO tpy	CO2 Combustion tpy	Methane tpy	VOC tpy	Total HAP tpy	PM10 tpy
2020	1,997	1,050	31,279	262	2,514	2,262	19.4	3.36	157	73.8	1.53	0.598	0.170	3,680	2.87	0.034	2.31	0.628
2021	2,028	1,066	31,764	266	2,553	2,298	19.7	3.41	160	75.0	1.56	0.608	0.173	3,737	2.91	0.035	2.35	0.637
2022	1,978	1,040	30,981	260	2,490	2,241	19.2	3.33	156	73.1	1.52	0.593	0.169	3,645	2.84	0.034	2.29	0.622
2023	1,933	1,016	30,276	254	2,433	2,190	18.8	3.25	152	71.5	1.48	0.579	0.165	3,562	2.77	0.033	2.24	0.608
2024	1,893	995	29,650	249	2,383	2,145	18.4	3.18	149	70.0	1.45	0.567	0.162	3,488	2.72	0.032	2.19	0.595
2025	1,856	976	29,070	244	2,336	2,103	18.0	3.12	146	68.6	1.43	0.556	0.158	3,420	2.66	0.032	2.15	0.583
2026	1,824	959	28,569	240	2,296	2,066	17.7	3.07	144	67.4	1.40	0.546	0.156	3,361	2.62	0.031	2.11	0.573
2027	1,796	944	28,131	236	2,261	2,035	17.5	3.02	142	66.4	1.38	0.538	0.153	3,310	2.58	0.031	2.08	0.564
2028	1,772	931	27,755	233	2,231	2,008	17.2	2.98	140	65.5	1.36	0.531	0.151	3,265	2.54	0.030	2.05	0.557
2029	1,752	921	27,441	230	2,205	1,985	17.0	2.95	138	64.8	1.35	0.525	0.150	3,228	2.51	0.030	2.03	0.551
2030	1,737	913	27,206	228	2,187	1,968	16.9	2.92	137	64.2	1.33	0.520	0.148	3,201	2.49	0.030	2.01	0.546
2031	1,724	906	27,003	227	2,170	1,953	16.8	2.90	136	63.7	1.32	0.516	0.147	3,177	2.47	0.029	1.99	0.542
2032	1,715	901	26,862	225	2,159	1,943	16.7	2.88	135	63.4	1.32	0.514	0.146	3,160	2.46	0.029	1.98	0.539
2033	1,709	898	26,768	225	2,151	1,936	16.6	2.87	135	63.2	1.31	0.512	0.146	3,149	2.45	0.029	1.98	0.537
2034	1,706	897	26,721	224	2,148	1,933	16.6	2.87	135	63.1	1.31	0.511	0.146	3,144	2.45	0.029	1.97	0.536
2035	1,706	897	26,721	224	2,148	1,933	16.6	2.87	135	63.1	1.31	0.511	0.146	3,144	2.45	0.029	1.97	0.536
2036	1,709	898	26,768	225	2,151	1,936	16.6	2.87	135	63.2	1.31	0.512	0.146	3,149	2.45	0.029	1.98	0.537
2037	1,715	901	26,862	225	2,159	1,943	16.7	2.88	135	63.4	1.32	0.514	0.146	3,160	2.46	0.029	1.98	0.539
2038	1,724	906	27,003	227	2,170	1,953	16.8	2.90	136	63.7	1.32	0.516	0.147	3,177	2.47	0.029	1.99	0.542
2039	1,735	912	27,175	228	2,184	1,966	16.9	2.92	137	64.2	1.33	0.520	0.148	3,197	2.49	0.030	2.01	0.545
2040	1,750	920	27,410	230	2,203	1,983	17.0	2.94	138	64.7	1.34	0.524	0.149	3,225	2.51	0.030	2.02	0.550
2041	1,767	929	27,676	232	2,224	2,002	17.2	2.97	139	65.3	1.36	0.529	0.151	3,256	2.54	0.030	2.04	0.555
2042	1,787	939	27,990	235	2,249	2,025	17.4	3.01	141	66.1	1.37	0.535	0.153	3,293	2.56	0.031	2.07	0.562
2043	1,809	951	28,334	238	2,277	2,049	17.6	3.04	143	66.9	1.39	0.542	0.154	3,334	2.60	0.031	2.09	0.569
2044	1,835	964	28,741	241	2,310	2,079	17.8	3.09	145	67.9	1.41	0.550	0.157	3,381	2.63	0.031	2.12	0.577
2045	1,862	979	29,164	245	2,344	2,110	18.1	3.13	147	68.8	1.43	0.558	0.159	3,431	2.67	0.032	2.15	0.585
2046	1,892	994	29,634	249	2,382	2,144	18.4	3.18	149	70.0	1.45	0.567	0.161	3,486	2.72	0.032	2.19	0.595
2047	1,925	1,012	30,151	253	2,423	2,181	18.7	3.24	152	71.2	1.48	0.577	0.164	3,547	2.76	0.033	2.23	0.605
2048	1,960	1,030	30,699	258	2,467	2,221	19.1	3.30	155	72.5	1.51	0.587	0.167	3,612	2.81	0.033	2.27	0.616
2049	1,998	1,050	31,294	263	2,515	2,264	19.4	3.36	158	73.9	1.53	0.599	0.171	3,682	2.87	0.034	2.31	0.628
2050	2,038	1,071	31,921	268	2,565	2,309	19.8	3.43	161	75.4	1.57	0.611	0.174	3,756	2.92	0.035	2.36	0.641
2051	2,081	1,094	32,594	273	2,620	2,358	20.2	3.50	164	76.9	1.60	0.623	0.178	3,835	2.99	0.036	2.41	0.654
2052	2,126	1,117	33,299	279	2,676	2,409	20.7	3.58	168	78.6	1.63	0.637	0.181	3,918	3.05	0.036	2.46	0.668
2053	2,174	1,143	34,051	286	2,737	2,463	21.1	3.66	171	80.4	1.67	0.651	0.186	4,006	3.12	0.037	2.51	0.683
2054	2,223	1,168	34,819	292	2,798	2,519	21.6	3.74	175	82.2	1.71	0.666	0.190	4,096	3.19	0.038	2.57	0.699
2055	2,276	1,196	35,649	299	2,865	2,579	22.1	3.83	179	84.2	1.75	0.682	0.194	4,194	3.27	0.039	2.63	0.715
2056	2,330	1,225	36,495	306	2,933	2,640	22.7	3.92	184	86.2	1.79	0.698	0.199	4,294	3.34	0.040	2.70	0.732
2057	2,387	1,255	37,387	314	3,005	2,704	23.2	4.01	188	88.3	1.83	0.715	0.204	4,399	3.43	0.041	2.76	0.750
2058	2,447	1,286	38,327	322	3,080	2,772	23.8	4.12	193	90.5	1.88	0.733	0.209	4,509	3.51	0.042	2.83	0.769
2059	2,508	1,318	39,283	330	3,157	2,841	24.4	4.22	198	92.7	1.93	0.751	0.214	4,622	3.60	0.043	2.90	0.788
2060	2,573	1,352	40,301	338	3,239	2,915	25.0	4.33	203	95.1	1.98	0.771	0.220	4,741	3.69	0.044	2.98	0.809
2061	2,639	1,387	41,334	347	3,322	2,990	25.7	4.44	208	97.6	2.03	0.791	0.225	4,863	3.79	0.045	3.05	0.829

	Collected LFG – IC Engines										Syngas to Turbine							Total Emissions						
Year	LFG MMcf/yr	Methane MMcf/yr	NOx tpy	SO2 tpy	CO tpy	CO2 Combustion tpy	Methane tpy	VOC tpy	Total HAP tpy	PM10 tpy	NOx tpy	SO2 tpy	CO tpy	CO2e tpy	VOC tpy	Total HAP tpy	PM10 tpy	NOx tpy	SO2 tpy	CO tpy	CO2e tpy	VOC tpy	Total HAP tpy	PM10 tpy
2020	630	295	15.1	2.39	92.7	14,720	11.5	5.45	9.24	15.3	16.8	6.82	1.78	217,011	0.609	2.56	12.6	33.5	9.81	94.7	314,502	25.5	17.5	28.6
2021	640	300	15.4	2.43	94.2	14,948	11.6	5.54	9.38	15.6	16.8	6.82	1.78	217,011	0.609	2.56	12.6	33.7	9.86	96.1	316,015	25.9	17.7	28.8
2022	624	293	15.0	2.37	91.8	14,580	11.4	5.40	9.15	15.2	16.8	6.82	1.78	217,011	0.609	2.56	12.6	33.3	9.79	93.8	313,574	25.3	17.3	28.4
2023	610	286	14.6	2.32	89.7	14,248	11.1	5.28	8.94	14.8	16.8	6.82	1.78	217,011	0.609	2.56	12.6	32.9	9.72	91.7	311,378	24.7	17.0	28.0
2024	597	280	14.3	2.27	87.9	13,953	10.9	5.17	8.76	14.5	16.8	6.82	1.78	217,011	0.609	2.56	12.6	32.6	9.66	89.8	309,425	24.2	16.7	27.7
2025	585	275	14.1	2.22	86.2	13,681	10.7	5.07	8.59	14.3	16.8	6.82	1.78	217,011	0.609	2.56	12.6	32.3	9.60	88.1	307,619	23.8	16.4	27.4
2026	575	270	13.8	2.19	84.7	13,445	10.5	4.98	8.44	14.0	16.8	6.82	1.78	217,011	0.609	2.56	12.6	32.0	9.56	86.6	306,056	23.4	16.2	27.2
2027	566	266	13.6	2.15	83.4	13,238	10.3	4.90	8.31	13.8	16.8	6.82	1.78	217,011	0.609	2.56	12.6	31.8	9.51	85.3	304,689	23.0	16.0	27.0
2028	559	262	13.4	2.12	82.3	13,061	10.2	4.84	8.20	13.6	16.8	6.82	1.78	217,011	0.609	2.56	12.6	31.6	9.48	84.2	303,518	22.7	15.8	26.8
2029	553	259	13.3	2.10	81.3	12,914	10.1	4.78	8.11	13.5	16.8	6.82	1.78	217,011	0.609	2.56	12.6	31.4	9.45	83.3	302,541	22.5	15.6	26.6
2030	548	257	13.2	2.08	80.6	12,803	10.0	4.74	8.04	13.3	16.8	6.82	1.78	217,011	0.609	2.56	12.6	31.3	9.43	82.6	301,809	22.3	15.5	26.5
2031	544	255	13.1	2.07	80.0	12,708	9.90	4.71	7.98	13.2	16.8	6.82	1.78	217,011	0.609	2.56	12.6	31.2	9.41	82.0	301,174	22.1	15.4	26.4
2032	541	254	13.0	2.06	79.6	12,641	9.84	4.68	7.94	13.2	16.8	6.82	1.78	217,011	0.609	2.56	12.6	31.1	9.39	81.6	300,735	22.0	15.4	26.3
2033	539	253	13.0	2.05	79.3	12,597	9.81	4.67	7.91	13.1	16.8	6.82	1.78	217,011	0.609	2.56	12.6	31.1	9.38	81.3	300,442	21.9	15.3	26.3
2034	538	252	12.9	2.04	79.2	12,575	9.79	4.66	7.89	13.1	16.8	6.82	1.78	217,011	0.609	2.56	12.6	31.0	9.38	81.1	300,296	21.9	15.3	26.2
2035	538	252	12.9	2.04	79.2	12,575	9.79	4.66	7.89	13.1	16.8	6.82	1.78	217,011	0.609	2.56	12.6	31.0	9.38	81.1	300,296	21.9	15.3	26.2
2036	539	253	13.0	2.05	79.3	12,597	9.81	4.67	7.91	13.1	16.8	6.82	1.78	217,011	0.609	2.56	12.6	31.1	9.38	81.3	300,442	21.9	15.3	26.3
2037	541	254	13.0	2.06	79.6	12,641	9.84	4.68	7.94	13.2	16.8	6.82	1.78	217,011	0.609	2.56	12.6	31.1	9.39	81.6	300,735	22.0	15.4	26.3
2038	544	255	13.1	2.07	80.0	12,708	9.90	4.71	7.98	13.2	16.8	6.82	1.78	217,011	0.609	2.56	12.6	31.2	9.41	82.0	301,174	22.1	15.4	26.4
2039	547	257	13.1	2.08	80.6	12,789	10.0	4.74	8.03	13.3	16.8	6.82	1.78	217,011	0.609	2.56	12.6	31.3	9.42	82.5	301,711	22.2	15.5	26.5
2040	552	259	13.3	2.10	81.2	12,899	10.0	4.78	8.10	13.4	16.8	6.82	1.78	217,011	0.609	2.56	12.6	31.4	9.44	83.2	302,444	22.4	15.6	26.6
2041	557	261	13.4	2.12	82.0	13,025	10.1	4.83	8.18	13.6	16.8	6.82	1.78	217,011	0.609	2.56	12.6	31.5	9.47	84.0	303,274	22.6	15.8	26.7
2042	564	264	13.5	2.14	83.0	13,172	10.3	4.88	8.27	13.7	16.8	6.82	1.78	217,011	0.609	2.56	12.6	31.7	9.50	84.9	304,250	22.9	15.9	26.9
2043	570	268	13.7	2.17	84.0	13,334	10.4	4.94	8.37	13.9	16.8	6.82	1.78	217,011	0.609	2.56	12.6	31.9	9.53	85.9	305,324	23.2	16.1	27.1
2044	579	271	13.9	2.20	85.2	13,526	10.5	5.01	8.49	14.1	16.8	6.82	1.78	217,011	0.609	2.56	12.6	32.1	9.57	87.1	306,593	23.5	16.3	27.3
2045	587	275	14.1	2.23	86.4	13,725	10.7	5.09	8.62	14.3	16.8	6.82	1.78	217,011	0.609	2.56	12.6	32.3	9.61	88.4	307,911	23.8	16.5	27.5
2046	597	280	14.3	2.27	87.8	13,946	10.9	5.17	8.75	14.5	16.8	6.82	1.78	217,011	0.609	2.56	12.6	32.6	9.66	89.8	309,376	24.2	16.7	27.7
2047	607	285	14.6	2.31	89.4	14,189	11.0	5.26	8.91	14.8	16.8	6.82	1.78	217,011	0.609	2.56	12.6	32.9	9.71	91.3	310,987	24.6	16.9	28.0
2048	618	290	14.9	2.35	91.0	14,447	11.3	5.35	9.07	15.1	16.8	6.82	1.78	217,011	0.609	2.56	12.6	33.2	9.76	92.9	312,696	25.1	17.2	28.3
2049	630	296	15.1	2.39	92.8	14,727	11.5	5.46	9.24	15.3	16.8	6.82	1.78	217,011	0.609	2.56	12.6	33.5	9.82	94.7	314,551	25.5	17.5	28.6
2050	643	301	15.4	2.44	94.6	15,022	11.7	5.57	9.43	15.6	16.8	6.82	1.78	217,011	0.609	2.56	12.6	33.8	9.88	96.6	316,504	26.0	17.8	28.9
2051	656	308	15.8	2.49	96.6	15,339	11.9	5.68	9.63	16.0	16.8	6.82	1.78	217,011	0.609	2.56	12.6	34.2	9.94	98.6	318,603	26.6	18.1	29.2
2052	670	314	16.1	2.55	98.7	15,671	12.2	5.81	9.84	16.3	16.8	6.82	1.78	217,011	0.609	2.56	12.6	34.5	10.0	101	320,800	27.1	18.4	29.6
2053	686	322	16.5	2.61	101	16,025	12.5	5.94	10.1	16.7	16.8	6.82	1.78	217,011	0.609	2.56	12.6	34.9	10.1	103	323,143	27.7	18.8	30.0
2054	701	329	16.8	2.66	103	16,386	12.8	6.07	10.3	17.1	16.8	6.82	1.78	217,011	0.609	2.56	12.6	35.4	10.2	105	325,535	28.3	19.2	30.4
2055	718	337	17.2	2.73	106	16,776	13.1	6.22	10.5	17.5	16.8	6.82	1.78	217,011	0.609	2.56	12.6	35.8	10.2	108	328,122	29.0	19.6	30.8
2056	735	345	17.7	2.79	108	17,174	13.4	6.36	10.8	17.9	16.8	6.82	1.78	217,011	0.609	2.56	12.6	36.2	10.3	110	330,759	29.7	20.0	31.2
2057	753	353	18.1	2.86	111	17,595	13.7	6.52	11.0	18.3	16.8	6.82	1.78	217,011	0.609	2.56	12.6	36.7	10.4	113	333,541	30.4	20.4	31.7
2058	772	362	18.5	2.93	114	18,037	14.0	6.68	11.3	18.8	16.8	6.82	1.78	217,011	0.609	2.56	12.6	37.2	10.5	116	336,470	31.1	20.8	32.2
2059	791	371	19.0	3.01	116	18,486	14.4	6.85	11.6	19.3	16.8	6.82	1.78	217,011	0.609	2.56	12.6	37.7	10.6	118	339,448	31.9	21.3	32.6
2060	811	381	19.5	3.08	119	18,966	14.8	7.03	11.9	19.8	16.8	6.82	1.78	217,011	0.609	2.56	12.6	38.3	10.7	121	342,622	32.7	21.8	33.2
2061	832	390	20.0	3.16	123	19,452	15.1	7.21	12.2	20.3	16.8	6.82	1.78	217,011	0.609	2.56	12.6	38.8	10.8	125	345,844	33.5	22.3	33.7

Appendix E Gasification Scenario using Fuel Cell

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Western Placer Waste Management Authority
Alternate Energy Feasibility Study
Pollutant Profile - Syngas to Fuel Cell

Assumptions		Units	
LFG Collection Efficiency:	75%	%	
LFG Methane Content:	46.9%	%	Average of 1 minute minimum and maximum values from "June 2010.xlsx".
LFG CO_2 Content:	53.1%	%	Calculated from the average methane content and the assumption that CO2 is the remainder of the landfill gas.
Collected LFG to IC Engines:	80%	%	Assumed.
Collected LFG to Flare:	20%	%	All LFG not directed to IC engines assumed to flare.
Cover Oxidation Factor:	10%	%	40 CFR Part 98, Subpart HH, Table HH-1.
LFG Heat Content:	433	Btu/cf	Stack Test Results
Flare and IC Engine Destruction Efficiency:	99.81%	%	Stack Test Results
LFG CO2 Content Emission Factor:	29.8	ton/MM cf LFG	Based on average of 1 minute minimum and maximum values from "June 2010.xlsx"
LFG Methane Content Emission Factor:	9.58	ton/MM cf LFG	Based on methane content and the assumption that CO2 is the remainder of the landfill gas
LFG Combustion SO2 Emission Factor:	0.0038	ton/MM cf LFG	AP-42 Default Value
LFG Uncontrolled NMOC Content Emission Factor:	148	lb/MM cf LFG	Stack Test Results
LFG Uncontrolled Organic HAP Content Emission Factor:	0.0128	ton/MM cf LFG	AP-42 Default Value
LFG Mercury Content Emission Factor:	7.53E-08	ton/MM cf LFG	AP-42 Default Value
LFG Combustion HCl Emission Factor:	0.0020	ton/MM cf LFG	AP-42 Default Value
Flare NOx Emission Factor:	0.045	lb/MMBtu	Stack Test Results
Flare CO Emission Factor:	0.0050	lb/MMBtu	Stack Test Results
Flare VOC Emission Factor:	0.0010	lb/MMBtu	Stack Test Results
Flare PM10 Emission Factor:	17.0	lb/MM cf CH4	AP-42, Table 2.4-5
IC Engine NOx Emission Factor:	0.111	lb/MMBtu	Stack Test Results
IC Engine CO Emission Factor:	0.680	lb/MMBtu	Stack Test Results
IC Engine VOC Emission Factor:	0.040	lb/MMBtu	Stack Test Results
IC Engine PM10 Emission Factor:	48.7	lb/MM cf LFG	Based on engine quarterly permit limits
CT MSW Throughput:	182,500	tons per year	Based on 500 tpd, 365 days per year
Syngas Heat Content:	2,099,480	MMBtu/yr	Based on average MRF residue heat content of 5752 Btu/lb and assuming that all of the heat potential is converted to syngas.
Syngas Combustion CO2 Emission Factor:	2,378	lb/ton MSW	Based on average MRF residue carbon content of 32.43% and assuming that all of the carbon is converted to CO2.
Syngas Fuel Cell HAP Emission Factor:	0	lb/MMBtu	HDR Library. Assumes syngas is cleaned to gas quality required by the fuel cell for proper operation.
Syngas Fuel Cell SO2 Emission Factor:	1.38E-05	lb/MMBtu	HDR Library. Assumes syngas is cleaned to gas quality required by the fuel cell for proper operation.
Syngas Fuel Cell NOx Emission Factor:	1.38E-03	lb/MMBtu	HDR Library.
Syngas Fuel Cell CO Emission Factor:	0	lb/MMBtu	Assumes 100% of the CO contained in the syngas is converted to energy in the fuel cell and that the fuel cell produces negligible levels of CO.
Syngas Fuel Cell PM10 Emission Factor:	2.75E-06	lb/MMBtu	HDR Library. Assumes syngas is cleaned to gas quality required by the fuel cell for proper operation.
Syngas Fuel Cell VOC Emission Factor:	0	lb/MMBtu	HDR Library. Assumes syngas is cleaned to gas quality required by the fuel cell for proper operation.

	Calculated Uncontrolled LFG			Uncollected LFG					Collected LFG – Flare										Collected LFG – IC Engines										Syngas to Fuel Cell							Total Emissions						
Year	LFG cfm	LFG MM cf/yr	CO2 tpy	LFG MMcf/yr	Methane tpy	Methane From Cover tpy	VOC (NMOC) tpy	Total HAP tpy	LFG MMcf/yr	Methane MMcf/yr	NOx tpy	SO2 tpy	CO tpy	CO2 Combustion tpy	Methane tpy	VOC tpy	Total HAP tpy	PM10 tpy	LFG MMcf/yr	Methane MMcf/yr	NOx tpy	SO2 tpy	CO tpy	CO2 Combustion tpy	Methane tpy	VOC tpy	Total HAP tpy	PM10 tpy	NOx tpy	SO2 tpy	CO tpy	CO2e tpy	VOC tpy	Total HAP tpy	PM10 tpy	NOx tpy	SO2 tpy	CO tpy	CO2e tpy	VOC tpy	Total HAP tpy	PM10 tpy
2020	1,997	1,050	31,279	262	2,514	2,262	19.4	3.36	157	73.8	1.53	0.598	0.170	3,680	2.87	0.034	2.31	0.628	630	295	15.1	2.39	92.7	14,720	11.5	5.45	9.24	15.3	1.4	0.014	0	217,011	0	0	0.0029	18.1	3.01	92.9	314,502	24.9	14.9	16.0
2021	2,028	1,066	31,764	266	2,553	2,298	19.7	3.41	160	75.0	1.56	0.608	0.173	3,737	2.91	0.035	2.35	0.637	640	300	15.4	2.43	94.2	14,948	11.6	5.54	9.38	15.6	1.4	0.014	0	217,011	0	0	0.0029	18.4	3.05	94.3	316,015	25.3	15.1	16.2
2022	1,978	1,040	30,981	260	2,490	2,241	19.2	3.33	156	73.1	1.52	0.593	0.169	3,645	2.84	0.034	2.29	0.622	624	293	15.0	2.37	91.8	14,580	11.4	5.40	9.15	15.2	1.4	0.014	0	217,011	0	0	0.0029	18.0	2.98	92.0	313,574	24.7	14.8	15.8
2023	1,933	1,016	30,276	254	2,433	2,190	18.8	3.25	152	71.5	1.48	0.579	0.165	3,562	2.77	0.033	2.24	0.608	610	286	14.6	2.32	89.7	14,248	11.1	5.28	8.94	14.8	1.4	0.014	0	217,011	0	0	0.0029	17.6	2.91	89.9	311,378	24.1	14.4	15.5
2024	1,893	995	29,650	249	2,383	2,145	18.4	3.18	149	70.0	1.45	0.567	0.162	3,488	2.72	0.032	2.19	0.595	597	280	14.3	2.27	87.9	13,953	10.9	5.17	8.76	14.5	1.4	0.014	0	217,011	0	0	0.0029	17.2	2.85	88.0	309,425	23.6	14.1	15.1
2025	1,856	976	29,070	244	2,336	2,103	18.0	3.12	146	68.6	1.43	0.556	0.158	3,420	2.66	0.032	2.15	0.583	585	275	14.1	2.22	86.2	13,681	10.7	5.07	8.59	14.3	1.4	0.014	0	217,011	0	0	0.0029	16.9	2.79	86.3	307,619	23.1	13.9	14.8
2026	1,824	959	28,569	240	2,296	2,066	17.7	3.07	144	67.4	1.40	0.546	0.156	3,361	2.62	0.031	2.11	0.573	575	270	13.8	2.19	84.7	13,445	10.5	4.98	8.44	14.0	1.4	0.014	0	217,011	0	0	0.0029	16.7	2.75	84.8	306,056	22.7	13.6	14.6
2027	1,796	944	28,131	236	2,261	2,035	17.5	3.02	142	66.4	1.38	0.538	0.153	3,310	2.58	0.031	2.08	0.564	566	266	13.6	2.15	83.4	13,238	10.3	4.90	8.31	13.8	1.4	0.014	0	217,011	0	0	0.0029	16.4	2.70	83.5	304,689	22.4	13.4	14.4
2028	1,772	931	27,755	233	2,231	2,008	17.2	2.98	140	65.5	1.36	0.531	0.151	3,265	2.54	0.030	2.05	0.557	559	262	13.4	2.12	82.3	13,061	10.2	4.84	8.20	13.6	1.4	0.014	0	217,011	0	0	0.0029	16.2	2.67	82.4	303,518	22.1	13.2	14.2
2029	1,752	921	27,441	230	2,205	1,985	17.0	2.95	138	64.8	1.35	0.525	0.150	3,228	2.51	0.030	2.03	0.551	553	259	13.3	2.10	81.3	12,914	10.1	4.78	8.11	13.5	1.4	0.014	0	217,011	0	0	0.0029	16.1	2.64	81.5	302,541	21.9	13.1	14.0
2030	1,737	913	27,206	228	2,187	1,968	16.9	2.92	137	64.2	1.33	0.520	0.148	3,201	2.49	0.030	2.01	0.546	548	257	13.2	2.08	80.6	12,803	10.0	4.74	8.04	13.3	1.4	0.014	0	217,011	0	0	0.0029	15.9	2.62	80.8	301,809	21.7	13.0	13.9
2031	1,724	906	27,003	227	2,170	1,953	16.8	2.90	136	63.7	1.32	0.516	0.147	3,177	2.47	0.029	1.99	0.542	544	255	13.1	2.07	80.0	12,708	9.90	4.71	7.98	13.2	1.4	0.014	0	217,011	0	0	0.0029	15.8	2.60	80.2	301,174	21.5	12.9	13.8
2032	1,715	901	26,862	225	2,159	1,943	16.7	2.88	135	63.4	1.32	0.514	0.146	3,160	2.46	0.029	1.98	0.539	541	254	13.0	2.06	79.6	12,641	9.84	4.68	7.94	13.2	1.4	0.014	0	217,011	0	0	0.0029	15.8	2.58	79.8	300,735	21.4	12.8	13.7
2033	1,709	898	26,768	225	2,151	1,936	16.6	2.87	135	63.2	1.31	0.512	0.146	3,149	2.45	0.029	1.98	0.537	539	253	13.0	2.05	79.3	12,597	9.81	4.67	7.91	13.1	1.4	0.014	0	217,011	0	0	0.0029	15.7	2.57	79.5	300,442	21.3	12.8	13.7
2034	1,706	897	26,721	224	2,148	1,933	16.6	2.87	135	63.1	1.31	0.511	0.146	3,144	2.45	0.029	1.97	0.536	538	252	12.9	2.04	79.2	12,575	9.79	4.66	7.89	13.1	1.4	0.014	0	217,011	0	0	0.0029	15.7	2.57	79.4	300,296	21.3	12.7	13.6
2035	1,706	897	26,721	224	2,148	1,933	16.6	2.87	135	63.1	1.31	0.511	0.146	3,144	2.45	0.029	1.97	0.536	538	252	12.9	2.04	79.2	12,575	9.79	4.66	7.89	13.1	1.4	0.014	0	217,011	0	0	0.0029	15.7	2.57	79.4	300,296	21.3	12.7	13.6
2036	1,709	898	26,768	225	2,151	1,936	16.6	2.87	135	63.2	1.31	0.512	0.146	3,149	2.45	0.029	1.98	0.537	539	253	13.0	2.05	79.3	12,597	9.81	4.67	7.91	13.1	1.4	0.014	0	217,011	0	0	0.0029	15.7	2.57	79.5	300,442	21.3	12.8	13.7
2037	1,715	901	26,862	225	2,159	1,943	16.7	2.88	135	63.4	1.32	0.514	0.146	3,160	2.46	0.029	1.98	0.539	541	254	13.0	2.06	79.6	12,641	9.84	4.68	7.94	13.2	1.4	0.014	0	217,011	0	0	0.0029	15.8	2.58	79.8	300,735	21.4	12.8	13.7
2038	1,724	906	27,003	227	2,170	1,953	16.8	2.90	136	63.7	1.32	0.516	0.147	3,177	2.47	0.029	1.99	0.542	544	255	13.1	2.07	80.0	12,708	9.90	4.71	7.98	13.2	1.4	0.014	0	217,011	0	0	0.0029	15.8	2.60	80.2	301,174	21.5	12.9	13.8
2039	1,735	912	27,175	228	2,184	1,966	16.9	2.92	137	64.2	1.33	0.520	0.148	3,197	2.49	0.030	2.01	0.545	547	257	13.1	2.08	80.6	12,789	10.0	4.74	8.03	13.3	1.4	0.014	0	217,011	0	0	0.0029	15.9	2.61	80.7	301,711	21.6	13.0	13.9
2040	1,750	920	27,410	230	2,203	1,983	17.0	2.94	138	64.7	1.34	0.524	0.149	3,225	2.51	0.030	2.02	0.550	552	259	13.3	2.10	81.2	12,899	10.0	4.78	8.10	13.4	1.4	0.014	0	217,011	0	0	0.0029	16.1	2.64	81.4	302,444	21.8	13.1	14.0
2041	1,767	929	27,676	232	2,224	2,002	17.2	2.97	139	65.3	1.36	0.529	0.151	3,256	2.54	0.030	2.04	0.555	557	261	13.4	2.12	82.0	13,025	10.1	4.83	8.18	13.6	1.4	0.014	0	217,011	0	0	0.0029	16.2	2.66	82.2	303,274	22.0	13.2	14.1
2042	1,787	939	27,990	235	2,249	2,025	17.4	3.01	141	66.1	1.37	0.535	0.153	3,293	2.56	0.031	2.07	0.562	564	264	13.5	2.14	83.0	13,172	10.3	4.88	8.27	13.7	1.4	0.014	0	217,011	0	0	0.0029	16.4	2.69	83.1	304,250	22.3	13.3	14.3
2043	1,809	951	28,334	238	2,277	2,049	17.6	3.04	143	66.9	1.39	0.542	0.154	3,334	2.60	0.031	2.09	0.569	570	268	13.7	2.17	84.0	13,334	10.4	4.94	8.37	13.9	1.4	0.014	0	217,011	0	0	0.0029	16.5	2.72	84.1	305,324	22.6	13.5	14.5
2044	1,835	964	28,741	241	2,310	2,079	17.8	3.09	145	67.9	1.41	0.550	0.157	3,381	2.63	0.031	2.12	0.577	579	271	13.9	2.20	85.2	13,526	10.5	5.01	8.49	14.1	1.4	0.014	0	217,011	0	0	0.0029	16.8	2.76	85.4	306,593	22.9	13.7	14.7
2045	1,862	979	29,164	245	2,344	2,110	18.1	3.13	147	68.8	1.43	0.558	0.159	3,431	2.67	0.032	2.15	0.585	587	275	14.1	2.23	86.4	13,725	10.7	5.09	8.62	14.3	1.4	0.014	0	217,011	0	0	0.0029	17.0	2.80	86.6	307,911	23.2	13.9	14.9
2046	1,892	994	29,634	249	2,382	2,144	18.4	3.18	149	70.0	1.45	0.567	0.161	3,486	2.72	0.032	2.19	0.595	597	280	14.3	2.27	87.8	13,946	10.9	5.17	8.75	14.5	1.4	0.014	0	217,011	0	0	0.0029	17.2	2.85	88.0	309,376	23.6	14.1	15.1
2047	1,925	1,012	30,151	253	2,423	2,181	18.7	3.24	152	71.2	1.48	0.577	0.164	3,547	2.76	0.033	2.23	0.605	607	285	14.6	2.31	89.4	14,189	11.0	5.26	8.91	14.8	1.4	0.014	0	217,011	0	0	0.0029	17.5	2.90	89.5	310,987	24.0	14.4	15.4
2048	1,960	1,030	30,699	258	2,467	2,221	19.1	3.30	155	72.5	1.51	0.587	0.167	3,612	2.81	0.033	2.27	0.616	618	290	14.9	2.35	91.0	14,447	11.3	5.35	9.07	15.1	1.4	0.014	0	217,011	0	0	0.0029	17.8	2.95	91.2	312,696	24.4	14.6	15.7
2049	1,998	1,050	31,294	263	2,515	2,264	19.4	3.36	158	73.9	1.53	0.599	0.171	3,682	2.87	0.034	2.31	0.628	630	296	15.1	2.39	92.8	14,727	11.5	5.46	9.24	15.3	1.4	0.014	0	217,011	0	0	0.0029	18.1	3.01	92.9	314,551	24.9	14.9	16.0
2050	2,038	1,071	31,921	268	2,565	2,309	19.8	3.43	161	75.4	1.57	0.611	0.174	3,756	2.92	0.035	2.36	0.641	643	301	15.4	2.44	94.6	15,022	11.7	5.57	9.43	15.6	1.4	0.014	0	217,011	0	0	0.0029	18.5	3.07	94.8	316,504	25.4	15.2	16.3
2051	2,081	1,094	32,594	273	2,620	2,358	20.2	3.50	164	76.9	1.60	0.623	0.178	3,835	2.99	0.036	2.41	0.654	656	308	15.8	2.49	96.6	15,339	11.9	5.68	9.63	16.0	1.4	0.014	0	217,011	0	0	0.0029	18.8	3.13	96.8	318,603	26.0	15.5	16.6
2052	2,126	1,117	33,299	279	2,676	2,409	20.7	3.58	168	78.6	1.63	0.637	0.181	3,918	3.05	0.036	2.46	0.668	670	314	16.1	2.55	98.7	15,671	12.2	5.81	9.84	16.3	1.4	0.014	0	217,011	0	0	0.0029	19.2	3.2	98.9	320,800	26.5	15.9	17.0
2053	2,174	1,143	34,051	286	2,737	2,463	21.1	3.66	171	80.4	1.67	0.651	0.186	4,006	3.12	0.037	2.51	0.683	686	322	16.5	2.61	101	16,025	12.5	5.94	10.1	16.7	1.4	0.014	0	217,011	0	0	0.0029	19.6	3.3	101	323,143	27.1	16.2	17.4
2054	2,223	1,168	34,819	292	2,798	2,519	21.6	3.74	175	82.2	1.71	0.666	0.190	4,096	3.19	0.038	2.57	0.699	701	329	16.8	2.66	103	16,386	12.8	6.07	10.3	17.1	1.4	0.014	0	217,011	0	0	0.0029	20.0	3.3	103	325,535	27.7	16.6	17.8
2055	2,276	1,196	35,649	299	2,865	2,579	22.1	3.83	179	84.2	1.75	0.682	0.194	4,194	3.27	0.039	2.63	0.715	718	337	17.2	2.73	106	16,776	13.1	6.22	10.5	17.5	1.4	0.014	0	217,011	0	0	0.0029	20.4	3.4	106	328,122	28.4	17.0	18.2
2056	2,330	1,225	36,495	306	2,933	2,640	22.7	3.92	184	86.2	1.79	0.698	0.199	4,294	3.34	0.040	2.70	0.732	735	345	17.7	2.79	108	17,174	13.4	6.36	10.8	17.9	1.4	0.014	0	217,011	0	0	0.0029	20.9	3.5	108	330,759	29.1	17.4	18.6
2057	2,387	1,255	37,387	314	3,005	2,704	23.2	4.01	188	88.3	1.83	0.715	0.204	4,399	3.43	0.041	2.76	0.750	753	353	18.1	2.86	111	17,595	13.7	6.52	11.0	18.3	1.4	0.014	0	217,011	0	0	0.0029	21.4	3.6	111	333,541	29.8	17.8	19.1
2058	2,447	1,286	38,327	322	3,080	2,772	23.8	4.12	193	90.5	1.88	0.733	0.209	4,509	3.51	0.042	2.83	0.769	772	362	18.5	2.93	114	18,037	14.0	6.68	11.3	18.8	1.4	0.014	0	217,011	0	0	0.0029	21.9	3.7	114	336,470	30.5	18.3	19.6
2059	2,508	1,318	39,283	330	3,157	2,841	24.4	4.22	198	92.7	1.93	0.751	0.214	4,622	3.60	0.043	2.90	0.788	791	371	19.0	3.01	116	18,486	14.4	6.85	11.6	19.3	1.4	0.014	0	217,011	0	0	0.0029	22.4	3.8	117	339,448	31.3	18.7	20.1
2060	2,573	1,352	40,301	338	3,239	2,915	25.0	4.33	203	95.1	1.98	0.771	0.220	4,741	3.69	0.044	2.98	0.809	811	381	19.5	3.08	119	18,966	14.8	7.03	11.9	19.8	1.4	0.014	0	217,011	0	0	0.0029	22.9	3.9	120	342,622	32.1	19.2	20.6
2061	2,639	1,387	41,334	347	3,322	2,990	25.7	4.44	208	97.6	2.03	0.791	0.225	4,863	3.79	0.045	3.05	0.829	832	390	20.0	3.16	123	19,452	15.1	7.21	12.2	20.3	1.4	0.014	0	217,011	0	0	0.0029	23.5	4.0	123	345,844	32.9	19.7	21.1

Appendix F Anaerobic Digestion Scenario using IC Engine

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Western Placer Waste Management Authority
Alternate Energy Feasibility Study
Pollutant Profile - AD Biogas to IC Engine

Assumptions		Units	
LFG Collection Efficiency:	75%	%	
LFG Methane Content:	46.9%	%	Average of 1 minute minimum and maximum values from "June 2010.xlsx".
LFG CO_2 Content:	53.1%	%	Calculated from the average methane content and the assumption that CO2 is the remainder of the landfill gas.
Collected LFG to IC Engines:	80%	%	Assumed.
Collected LFG to Flare:	20%	%	All LFG not directed to IC engines assumed to flare.
Cover Oxidation Factor:	10%	%	40 CFR Part 98, Subpart HH, Table HH-1.
LFG Heat Content:	433	Btu/cf	Stack Test Results
Flare and IC Engine Destruction Efficiency:	99.81%	%	Stack Test Results
LFG CO2 Content Emission Factor:	29.8	ton/MM cf LFG	Based on average of 1 minute minimum and maximum values from "June 2010.xlsx".
LFG Methane Content Emission Factor:	9.58	ton/MM cf LFG	Based on methane content and the assumption that CO2 is the remainder of the landfill gas
LFG Combustion SO2 Emission Factor:	0.0038	ton/MM cf LFG	AP-42 Default Value
LFG Uncontrolled NMOC Content Emission Factor:	148	lb/MM cf LFG	Stack Test Results
LFG Uncontrolled Organic HAP Content Emission Factor:	0.0128	ton/MM cf LFG	AP-42 Default Value
LFG Mercury Content Emission Factor:	7.53E-08	ton/MM cf LFG	AP-42 Default Value
LFG Combustion HCl Emission Factor:	0.0020	ton/MM cf LFG	AP-42 Default Value
Flare NOx Emission Factor:	0.045	lb/MMBtu	Stack Test Results
Flare CO Emission Factor:	0.0050	lb/MMBtu	Stack Test Results
Flare VOC Emission Factor:	0.0010	lb/MMBtu	Stack Test Results
Flare PM10 Emission Factor:	17.0	lb/MM cf CH4	AP-42, Table 2.4-5
IC Engine NOx Emission Factor:	0.111	lb/MMBtu	Stack Test Results
IC Engine CO Emission Factor:	0.680	lb/MMBtu	Stack Test Results
IC Engine VOC Emission Factor:	0.040	lb/MMBtu	Stack Test Results
IC Engine PM10 Emission Factor:	48.7	lb/MM cf LFG	Based on engine quarterly permit limits
CT MSW Throughput:	182,500	tons per year	Based on 500 tpd, 365 days per year
AD Biogas Production:	477	MM cf/yr	Based on assumed 2615 scf/ton MSW AD biogas production rate
AD Biogas Heat Content:	261,049	MMBtu/yr	Based on assumed AD biogas methane content of 60% and methane LHV heat content of 912 Btu/cf
AD Biogas Combustion SO2 Emission Factor:	0.007	lb/MMBtu	Based on EPA's AP-42 SO2 emission factor for gas turbine combusting digester gas.
AD Biogas Combustion HAP Emission Factor:	0.007	lb/MMBtu	EPA's AP-42 for 4 stroke lean burn natural gas engine and 90% control by oxidation catalyst.
AD Biogas Combustion CO2 Emission Factor:	52	lb/MM cf AD Biogas	HDR Library. Assumes all of the methane in the AD biogas is oxidized to CO2 and the CO2 in the biogas passes through the device.
AD Biogas IC Engine PM10 Emission Factor:	0.025	lb/MMBtu	Vendor guarantee for recently permitted large natural gas-fired IC engine with oxidation catalyst and SCR
AD Biogas IC Engine NOx Emission Factor:	0.016	lb/MMBtu	Vendor guarantee for recently permitted large natural gas-fired IC engine with oxidation catalyst and SCR
AD Biogas IC Engine CO Emission Factor:	0.030	lb/MMBtu	Vendor guarantee for recently permitted large natural gas-fired IC engine with oxidation catalyst and SCR
AD Biogas IC Engine VOC Emission Factor:	0.030	lb/MMBtu	Vendor guarantee for recently permitted large natural gas-fired IC engine with oxidation catalyst and SCR

	Calculated Uncontrolled LFG			Uncollected LFG					Collected LFG: Flare									
Year	LFG cfm	LFG MM cf/yr	CO2 tpy	LFG MMcf/yr	Methane tpy	Methane From Cover tpy	VOC (NMOC) tpy	Total HAP tpy	LFG MMcf/yr	Methane MMcf/yr	NOx tpy	SO2 tpy	CO tpy	CO2 Combustion tpy	Methane tpy	VOC tpy	Total HAP tpy	PM10 tpy
2020	1,997	1,050	31,279	262	2,514	2,262	19.4	3.36	157	73.8	1.53	0.598	0.170	3,680	2.87	0.034	2.31	0.628
2021	2,028	1,066	31,764	266	2,553	2,298	19.7	3.41	160	75.0	1.56	0.608	0.173	3,737	2.91	0.035	2.35	0.637
2022	2,017	1,060	31,592	265	2,539	2,285	19.6	3.39	159	74.6	1.55	0.604	0.172	3,717	2.89	0.034	2.33	0.634
2023	2,010	1,056	31,482	264	2,530	2,277	19.5	3.38	158	74.3	1.54	0.602	0.172	3,704	2.88	0.034	2.33	0.632
2024	2,005	1,054	31,404	263	2,524	2,272	19.5	3.37	158	74.1	1.54	0.601	0.171	3,695	2.88	0.034	2.32	0.630
2025	2,003	1,053	31,373	263	2,521	2,269	19.5	3.37	158	74.1	1.54	0.600	0.171	3,691	2.87	0.034	2.32	0.630
2026	2,004	1,053	31,388	263	2,523	2,270	19.5	3.37	158	74.1	1.54	0.600	0.171	3,693	2.88	0.034	2.32	0.630
2027	2,008	1,055	31,451	264	2,528	2,275	19.5	3.38	158	74.2	1.54	0.602	0.171	3,700	2.88	0.034	2.32	0.631
2028	2,015	1,059	31,561	265	2,537	2,283	19.6	3.39	159	74.5	1.55	0.604	0.172	3,713	2.89	0.034	2.33	0.633
2029	2,024	1,064	31,702	266	2,548	2,293	19.7	3.40	160	74.8	1.55	0.606	0.173	3,730	2.90	0.035	2.34	0.636
2030	2,037	1,071	31,905	268	2,564	2,308	19.8	3.43	161	75.3	1.56	0.610	0.174	3,754	2.92	0.035	2.36	0.640
2031	2,051	1,078	32,125	270	2,582	2,324	19.9	3.45	162	75.8	1.58	0.614	0.175	3,779	2.94	0.035	2.37	0.645
2032	2,068	1,087	32,391	272	2,603	2,343	20.1	3.48	163	76.5	1.59	0.620	0.176	3,811	2.97	0.035	2.39	0.650
2033	2,087	1,097	32,688	274	2,627	2,364	20.3	3.51	165	77.2	1.60	0.625	0.178	3,846	2.99	0.036	2.41	0.656
2034	2,108	1,108	33,017	277	2,654	2,388	20.5	3.55	166	77.9	1.62	0.632	0.180	3,885	3.03	0.036	2.44	0.663
2035	2,131	1,120	33,378	280	2,683	2,414	20.7	3.58	168	78.8	1.64	0.638	0.182	3,927	3.06	0.036	2.47	0.670
2036	2,157	1,134	33,785	283	2,715	2,444	21.0	3.63	170	79.8	1.66	0.646	0.184	3,975	3.10	0.037	2.50	0.678
2037	2,184	1,148	34,208	287	2,749	2,474	21.2	3.67	172	80.8	1.68	0.654	0.186	4,025	3.13	0.037	2.53	0.686
2038	2,213	1,163	34,662	291	2,786	2,507	21.5	3.72	174	81.8	1.70	0.663	0.189	4,078	3.18	0.038	2.56	0.696
2039	2,245	1,180	35,163	295	2,826	2,543	21.8	3.78	177	83.0	1.72	0.673	0.192	4,137	3.22	0.038	2.60	0.706
2040	2,278	1,197	35,680	299	2,868	2,581	22.2	3.83	180	84.2	1.75	0.682	0.194	4,198	3.27	0.039	2.64	0.716
2041	2,314	1,216	36,244	304	2,913	2,622	22.5	3.89	182	85.6	1.78	0.693	0.197	4,264	3.32	0.039	2.68	0.727
2042	2,351	1,236	36,823	309	2,959	2,664	22.9	3.95	185	86.9	1.81	0.704	0.201	4,332	3.37	0.040	2.72	0.739
2043	2,390	1,256	37,434	314	3,009	2,708	23.2	4.02	188	88.4	1.84	0.716	0.204	4,404	3.43	0.041	2.76	0.751
2044	2,431	1,278	38,076	319	3,060	2,754	23.6	4.09	192	89.9	1.87	0.728	0.207	4,480	3.49	0.041	2.81	0.764
2045	2,475	1,301	38,766	325	3,116	2,804	24.1	4.16	195	91.5	1.90	0.741	0.211	4,561	3.55	0.042	2.86	0.778
2046	2,520	1,325	39,470	331	3,172	2,855	24.5	4.24	199	93.2	1.94	0.755	0.215	4,644	3.62	0.043	2.92	0.792
2047	2,567	1,349	40,207	337	3,231	2,908	25.0	4.32	202	94.9	1.97	0.769	0.219	4,730	3.68	0.044	2.97	0.807
2048	2,616	1,375	40,974	344	3,293	2,964	25.4	4.40	206	96.7	2.01	0.784	0.223	4,821	3.75	0.045	3.03	0.822
2049	2,667	1,402	41,773	350	3,357	3,022	25.9	4.49	210	98.6	2.05	0.799	0.228	4,915	3.83	0.046	3.09	0.838
2050	2,720	1,430	42,603	357	3,424	3,082	26.4	4.57	214	100.6	2.09	0.815	0.232	5,012	3.90	0.046	3.15	0.855
2051	2,775	1,459	43,464	365	3,493	3,144	27.0	4.67	219	102.6	2.13	0.831	0.237	5,114	3.98	0.047	3.21	0.872
2052	2,831	1,488	44,342	372	3,564	3,207	27.5	4.76	223	104.7	2.17	0.848	0.242	5,217	4.06	0.048	3.27	0.890
2053	2,890	1,519	45,266	380	3,638	3,274	28.1	4.86	228	106.9	2.22	0.866	0.247	5,326	4.15	0.049	3.34	0.908
2054	2,951	1,551	46,221	388	3,715	3,343	28.7	4.96	233	109.1	2.27	0.884	0.252	5,438	4.23	0.050	3.41	0.927
2055	3,013	1,584	47,192	396	3,793	3,414	29.3	5.07	238	111.4	2.31	0.903	0.257	5,552	4.32	0.051	3.49	0.947
2056	3,078	1,618	48,210	404	3,875	3,487	29.9	5.18	243	113.8	2.36	0.922	0.263	5,672	4.42	0.053	3.56	0.967
2057	3,145	1,653	49,260	413	3,959	3,563	30.6	5.29	248	116.3	2.42	0.942	0.268	5,795	4.51	0.054	3.64	0.988
2058	3,213	1,689	50,325	422	4,045	3,640	31.2	5.40	253	118.8	2.47	0.963	0.274	5,921	4.61	0.055	3.72	1.010
2059	3,284	1,726	51,437	432	4,134	3,721	31.9	5.52	259	121.4	2.52	0.984	0.280	6,052	4.71	0.056	3.80	1.032
2060	3,356	1,764	52,565	441	4,225	3,802	32.6	5.64	265	124.1	2.58	1.005	0.286	6,184	4.82	0.057	3.88	1.055
2061	3,431	1,803	53,739	451	4,319	3,887	33.4	5.77	271	126.9	2.64	1.028	0.293	6,322	4.92	0.059	3.97	1.078

	Collected LFG: IC Engines										AD Biogas to IC Engines							Total Emissions						
Year	LFG MMcf/yr	Methane MMcf/yr	NOx tpy	SO2 tpy	CO tpy	CO2 Combustion tpy	Methane tpy	VOC tpy	Total HAP tpy	PM10 tpy	NOx tpy	SO2 tpy	CO tpy	CO2e tpy	VOC tpy	Total HAP tpy	PM10 tpy	NOx tpy	SO2 tpy	CO tpy	CO2e tpy	VOC tpy	Total HAP tpy	PM10 tpy
2020	630	295	15.1	2.39	92.7	14,720	11.5	5.45	9.24	15.3	2.1	0.85	3.9	25,007	3.92	0.94	3.26	18.8	3.84	97	122,498	28.8	15.9	19.2
2021	640	300	15.4	2.43	94.2	14,948	11.6	5.54	9.38	15.6	2.1	0.85	3.9	25,007	3.92	0.94	3.26	19.0	3.89	98	124,012	29.2	16.1	19.5
2022	636	298	15.3	2.42	93.6	14,867	11.6	5.51	9.33	15.5	2.1	0.85	3.9	25,007	3.92	0.94	3.26	18.9	3.87	98	123,475	29.1	16.0	19.4
2023	634	297	15.2	2.41	93.3	14,816	11.5	5.49	9.30	15.4	2.1	0.85	3.9	25,007	3.92	0.94	3.26	18.9	3.86	97	123,133	29.0	15.9	19.3
2024	632	297	15.2	2.40	93.1	14,779	11.5	5.48	9.28	15.4	2.1	0.85	3.9	25,007	3.92	0.94	3.26	18.8	3.85	97	122,889	28.9	15.9	19.3
2025	632	296	15.2	2.40	93.0	14,764	11.5	5.47	9.27	15.4	2.1	0.85	3.9	25,007	3.92	0.94	3.26	18.8	3.85	97	122,791	28.9	15.9	19.3
2026	632	296	15.2	2.40	93.0	14,771	11.5	5.47	9.27	15.4	2.1	0.85	3.9	25,007	3.92	0.94	3.26	18.8	3.85	97	122,840	28.9	15.9	19.3
2027	633	297	15.2	2.41	93.2	14,801	11.5	5.48	9.29	15.4	2.1	0.85	3.9	25,007	3.92	0.94	3.26	18.8	3.86	97	123,036	29.0	15.9	19.3
2028	635	298	15.3	2.41	93.6	14,853	11.6	5.50	9.32	15.5	2.1	0.85	3.9	25,007	3.92	0.94	3.26	18.9	3.87	98	123,377	29.0	16.0	19.4
2029	638	299	15.3	2.43	94.0	14,919	11.6	5.53	9.37	15.5	2.1	0.85	3.9	25,007	3.92	0.94	3.26	19.0	3.88	98	123,817	29.2	16.1	19.4
2030	642	301	15.4	2.44	94.6	15,015	11.7	5.56	9.43	15.6	2.1	0.85	3.9	25,007	3.92	0.94	3.26	19.1	3.90	99	124,451	29.3	16.2	19.5
2031	647	303	15.5	2.46	95.2	15,118	11.8	5.60	9.49	15.7	2.1	0.85	3.9	25,007	3.92	0.94	3.26	19.2	3.92	99	125,135	29.5	16.3	19.7
2032	652	306	15.7	2.48	96.0	15,243	11.9	5.65	9.57	15.9	2.1	0.85	3.9	25,007	3.92	0.94	3.26	19.3	3.95	100	125,965	29.7	16.4	19.8
2033	658	309	15.8	2.50	96.9	15,383	12.0	5.70	9.66	16.0	2.1	0.85	3.9	25,007	3.92	0.94	3.26	19.5	3.97	101	126,892	29.9	16.5	19.9
2034	665	312	16.0	2.53	97.9	15,538	12.1	5.76	9.75	16.2	2.1	0.85	3.9	25,007	3.92	0.94	3.26	19.7	4.01	102	127,917	30.2	16.7	20.1
2035	672	315	16.1	2.55	98.9	15,708	12.2	5.82	9.86	16.4	2.1	0.85	3.9	25,007	3.92	0.94	3.26	19.9	4.04	103	129,040	30.5	16.9	20.3
2036	680	319	16.3	2.58	100.1	15,899	12.4	5.89	9.98	16.6	2.1	0.85	3.9	25,007	3.92	0.94	3.26	20.1	4.08	104	130,310	30.8	17.0	20.5
2037	689	323	16.6	2.62	101.4	16,098	12.5	5.96	10.11	16.8	2.1	0.85	3.9	25,007	3.92	0.94	3.26	20.3	4.12	105	131,628	31.2	17.2	20.7
2038	698	327	16.8	2.65	102.7	16,312	12.7	6.04	10.24	17.0	2.1	0.85	3.9	25,007	3.92	0.94	3.26	20.6	4.16	107	133,043	31.5	17.5	21.0
2039	708	332	17.0	2.69	104.2	16,548	12.9	6.13	10.39	17.2	2.1	0.85	3.9	25,007	3.92	0.94	3.26	20.8	4.21	108	134,606	31.9	17.7	21.2
2040	718	337	17.3	2.73	105.8	16,791	13.1	6.22	10.54	17.5	2.1	0.85	3.9	25,007	3.92	0.94	3.26	21.1	4.26	110	136,217	32.3	17.9	21.5
2041	730	342	17.5	2.77	107.4	17,056	13.3	6.32	10.71	17.8	2.1	0.85	3.9	25,007	3.92	0.94	3.26	21.4	4.31	112	137,974	32.8	18.2	21.8
2042	741	348	17.8	2.82	109.2	17,329	13.5	6.42	10.88	18.1	2.1	0.85	3.9	25,007	3.92	0.94	3.26	21.7	4.37	113	139,780	33.2	18.5	22.1
2043	754	353	18.1	2.86	111.0	17,617	13.7	6.53	11.06	18.4	2.1	0.85	3.9	25,007	3.92	0.94	3.26	22.0	4.43	115	141,684	33.7	18.8	22.4
2044	767	360	18.4	2.91	112.9	17,919	14.0	6.64	11.25	18.7	2.1	0.85	3.9	25,007	3.92	0.94	3.26	22.4	4.49	117	143,686	34.2	19.1	22.7
2045	781	366	18.8	2.97	114.9	18,243	14.2	6.76	11.45	19.0	2.1	0.85	3.9	25,007	3.92	0.94	3.26	22.7	4.56	119	145,834	34.8	19.4	23.0
2046	795	373	19.1	3.02	117.0	18,575	14.5	6.88	11.66	19.4	2.1	0.85	3.9	25,007	3.92	0.94	3.26	23.1	4.62	121	148,031	35.3	19.8	23.4
2047	810	380	19.5	3.08	119.2	18,921	14.7	7.01	11.88	19.7	2.1	0.85	3.9	25,007	3.92	0.94	3.26	23.5	4.69	123	150,325	35.9	20.1	23.8
2048	825	387	19.8	3.13	121.5	19,283	15.0	7.14	12.10	20.1	2.1	0.85	3.9	25,007	3.92	0.94	3.26	23.9	4.77	126	152,717	36.5	20.5	24.2
2049	841	394	20.2	3.20	123.8	19,658	15.3	7.28	12.34	20.5	2.1	0.85	3.9	25,007	3.92	0.94	3.26	24.3	4.84	128	155,207	37.2	20.9	24.6
2050	858	402	20.6	3.26	126.3	20,049	15.6	7.43	12.59	20.9	2.1	0.85	3.9	25,007	3.92	0.94	3.26	24.8	4.92	130	157,795	37.8	21.2	25.0
2051	875	410	21.0	3.33	128.8	20,455	15.9	7.58	12.84	21.3	2.1	0.85	3.9	25,007	3.92	0.94	3.26	25.3	5.01	133	160,480	38.5	21.7	25.4
2052	893	419	21.5	3.39	131.4	20,867	16.3	7.73	13.10	21.7	2.1	0.85	3.9	25,007	3.92	0.94	3.26	25.7	5.1	136	163,213	39.2	22.1	25.9
2053	911	427	21.9	3.46	134	21,302	16.6	7.89	13.4	22.2	2.1	0.85	3.9	25,007	3.92	0.94	3.26	26.2	5.2	138	166,094	40.0	22.5	26.4
2054	931	436	22.4	3.54	137	21,752	16.9	8.06	13.7	22.7	2.1	0.85	3.9	25,007	3.92	0.94	3.26	26.7	5.3	141	169,072	40.7	23.0	26.9
2055	950	446	22.8	3.61	140	22,209	17.3	8.23	13.9	23.1	2.1	0.85	3.9	25,007	3.92	0.94	3.26	27.2	5.4	144	172,098	41.5	23.4	27.3
2056	971	455	23.3	3.69	143	22,688	17.7	8.41	14.2	23.6	2.1	0.85	3.9	25,007	3.92	0.94	3.26	27.8	5.5	147	175,272	42.3	23.9	27.9
2057	992	465	23.8	3.77	146	23,182	18.1	8.59	14.6	24.2	2.1	0.85	3.9	25,007	3.92	0.94	3.26	28.3	5.6	150	178,543	43.1	24.4	28.4
2058	1,013	475	24.3	3.85	149	23,683	18.4	8.77	14.9	24.7	2.1	0.85	3.9	25,007	3.92	0.94	3.26	28.9	5.7	153	181,862	44.0	24.9	28.9
2059	1,036	486	24.9	3.94	152	24,206	18.9	8.97	15.2	25.2	2.1	0.85	3.9	25,007	3.92	0.94	3.26	29.5	5.8	157	185,328	44.9	25.5	29.5
2060	1,058	496	25.4	4.02	156	24,737	19.3	9.17	15.5	25.8	2.1	0.85	3.9	25,007	3.92	0.94	3.26	30.1	5.9	160	188,843	45.8	26.0	30.1
2061	1,082	507	26.0	4.11	159	25,290	19.7	9.37	15.9	26.3	2.1	0.85	3.9	25,007	3.92	0.94	3.26	30.7	6.0	164	192,505	46.7	26.6	30.7

Appendix G Anaerobic Digestion Scenario using Turbine

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Western Placer Waste Management Authority
Alternate Energy Feasibility Study
Pollutant Profile - AD Biogas to Turbine

Assumptions		Units	
LFG Collection Efficiency:	75%	%	
LFG Methane Content:	46.9%	%	Average of 1 minute minimum and maximum values from "June 2010.xlsx".
LFG CO_2 Content:	53.1%	%	Calculated from the average methane content and the assumption that CO2 is the remainder of the landfill gas.
Collected LFG to IC Engines:	80%	%	Assumed.
Collected LFG to Flare:	20%	%	All LFG not directed to IC engines assumed to flare.
Cover Oxidation Factor:	10%	%	40 CFR Part 98, Subpart HH, Table HH-1.
LFG Heat Content:	433	Btu/cf	Stack Test Results
Flare and IC Engine Destruction Efficiency:	99.81%	%	Stack Test Results
LFG CO2 Content Emission Factor:	29.8	ton/MM cf LFG	Based on average of 1 minute minimum and maximum values from "June 2010.xlsx".
LFG Methane Content Emission Factor:	9.58	ton/MM cf LFG	Based on methane content and the assumption that CO2 is the remainder of the landfill gas
LFG Combustion SO2 Emission Factor:	0.0038	ton/MM cf LFG	AP-42 Default Value
LFG Uncontrolled NMOC Content Emission Factor:	148	lb/MM cf LFG	Stack Test Results
LFG Uncontrolled Organic HAP Content Emission Factor:	0.0128	ton/MM cf LFG	AP-42 Default Value
LFG Mercury Content Emission Factor:	7.53E-08	ton/MM cf LFG	AP-42 Default Value
LFG Combustion HCl Emission Factor:	0.0020	ton/MM cf LFG	AP-42 Default Value
Flare NOx Emission Factor:	0.045	lb/MMBtu	Stack Test Results
Flare CO Emission Factor:	0.0050	lb/MMBtu	Stack Test Results
Flare VOC Emission Factor:	0.0010	lb/MMBtu	Stack Test Results
Flare PM10 Emission Factor:	17.0	lb/MM cf CH4	AP-42, Table 2.4-5
IC Engine NOx Emission Factor:	0.111	lb/MMBtu	Stack Test Results
IC Engine CO Emission Factor:	0.680	lb/MMBtu	Stack Test Results
IC Engine VOC Emission Factor:	0.040	lb/MMBtu	Stack Test Results
IC Engine PM10 Emission Factor:	48.7	lb/MM cf LFG	Based on engine quarterly permit limits
CT MSW Throughput:	182,500	tons per year	Based on 500 tpd, 365 days per year
AD Biogas Production:	477	MM cf/yr	Based on assumed 2615 scf/ton MSW AD biogas production rate
AD Biogas Heat Content:	261,049	MMBtu/yr	Based on assumed AD biogas methane content of 60% and methane LHV heat content of 912 Btu/cf
AD Biogas Combustion SO2 Emission Factor:	0.007	lb/MMBtu	Based on EPA's AP-42 SO2 emission factor for gas turbine combusting digester gas.
AD Biogas Combustion HAP Emission Factor:	2.43E-05	lb/MMBtu	AP-42 for gas turbine combusting digester gas and 90% control by oxidation catalyst. Includes only emission factors for compounds above detection limit.
AD Biogas Combustion CO2 Emission Factor:	52.4	lb/MM cf AD Biogas	HDR Library. Assumes all of the methane in the AD biogas is oxidized to CO2 and the CO2 in the biogas passes through the device.
AD Biogas Turbine NOx Emission Factor:	0.016	lb/MMBtu	Based on EPA's AP-42 uncontrolled NOx emission factor for gas turbine combusting digester gas and 90% control by SCR.
AD Biogas Turbine CO Emission Factor:	0.0017	lb/MMBtu	Based on EPA's AP-42 uncontrolled CO emission factor for gas turbine combusting digester gas and 90% control by oxidation catalyst
AD Biogas Turbine PM10 Emission Factor:	0.012	lb/MMBtu	Based on EPA's AP-42 uncontrolled PM10 emission factor for gas turbine combusting digester gas.
AD Biogas Turbine VOC Emission Factor:	0.0006	lb/MMBtu	Based on EPA's AP-42 uncontrolled VOC emission factor for gas turbine combusting digester gas and 90% control by oxidation catalyst

	Calculated Uncontrolled LFG			Uncollected LFG					Collected LFG – Flare									
Year	LFG cfm	LFG MM cf/yr	CO2 tpy	LFG MMcf/yr	Methane tpy	Methane From Cover tpy	VOC (NMOC) tpy	Total HAP tpy	LFG MMcf/yr	Methane MMcf/yr	NOx tpy	SO2 tpy	CO tpy	CO2 Combustion tpy	Methane tpy	VOC tpy	Total HAP tpy	PM10 tpy
2020	1,997	1,050	31,279	262	2,514	2,262	19.4	3.36	157	73.8	1.53	0.598	0.170	3,680	2.87	0.034	2.31	0.628
2021	2,028	1,066	31,764	266	2,553	2,298	19.7	3.41	160	75.0	1.56	0.608	0.173	3,737	2.91	0.035	2.35	0.637
2022	2,017	1,060	31,592	265	2,539	2,285	19.6	3.39	159	74.6	1.55	0.604	0.172	3,717	2.89	0.034	2.33	0.634
2023	2,010	1,056	31,482	264	2,530	2,277	19.5	3.38	158	74.3	1.54	0.602	0.172	3,704	2.88	0.034	2.33	0.632
2024	2,005	1,054	31,404	263	2,524	2,272	19.5	3.37	158	74.1	1.54	0.601	0.171	3,695	2.88	0.034	2.32	0.630
2025	2,003	1,053	31,373	263	2,521	2,269	19.5	3.37	158	74.1	1.54	0.600	0.171	3,691	2.87	0.034	2.32	0.630
2026	2,004	1,053	31,388	263	2,523	2,270	19.5	3.37	158	74.1	1.54	0.600	0.171	3,693	2.88	0.034	2.32	0.630
2027	2,008	1,055	31,451	264	2,528	2,275	19.5	3.38	158	74.2	1.54	0.602	0.171	3,700	2.88	0.034	2.32	0.631
2028	2,015	1,059	31,561	265	2,537	2,283	19.6	3.39	159	74.5	1.55	0.604	0.172	3,713	2.89	0.034	2.33	0.633
2029	2,024	1,064	31,702	266	2,548	2,293	19.7	3.40	160	74.8	1.55	0.606	0.173	3,730	2.90	0.035	2.34	0.636
2030	2,037	1,071	31,905	268	2,564	2,308	19.8	3.43	161	75.3	1.56	0.610	0.174	3,754	2.92	0.035	2.36	0.640
2031	2,051	1,078	32,125	270	2,582	2,324	19.9	3.45	162	75.8	1.58	0.614	0.175	3,779	2.94	0.035	2.37	0.645
2032	2,068	1,087	32,391	272	2,603	2,343	20.1	3.48	163	76.5	1.59	0.620	0.176	3,811	2.97	0.035	2.39	0.650
2033	2,087	1,097	32,688	274	2,627	2,364	20.3	3.51	165	77.2	1.60	0.625	0.178	3,846	2.99	0.036	2.41	0.656
2034	2,108	1,108	33,017	277	2,654	2,388	20.5	3.55	166	77.9	1.62	0.632	0.180	3,885	3.03	0.036	2.44	0.663
2035	2,131	1,120	33,378	280	2,683	2,414	20.7	3.58	168	78.8	1.64	0.638	0.182	3,927	3.06	0.036	2.47	0.670
2036	2,157	1,134	33,785	283	2,715	2,444	21.0	3.63	170	79.8	1.66	0.646	0.184	3,975	3.10	0.037	2.50	0.678
2037	2,184	1,148	34,208	287	2,749	2,474	21.2	3.67	172	80.8	1.68	0.654	0.186	4,025	3.13	0.037	2.53	0.686
2038	2,213	1,163	34,662	291	2,786	2,507	21.5	3.72	174	81.8	1.70	0.663	0.189	4,078	3.18	0.038	2.56	0.696
2039	2,245	1,180	35,163	295	2,826	2,543	21.8	3.78	177	83.0	1.72	0.673	0.192	4,137	3.22	0.038	2.60	0.706
2040	2,278	1,197	35,680	299	2,868	2,581	22.2	3.83	180	84.2	1.75	0.682	0.194	4,198	3.27	0.039	2.64	0.716
2041	2,314	1,216	36,244	304	2,913	2,622	22.5	3.89	182	85.6	1.78	0.693	0.197	4,264	3.32	0.039	2.68	0.727
2042	2,351	1,236	36,823	309	2,959	2,664	22.9	3.95	185	86.9	1.81	0.704	0.201	4,332	3.37	0.040	2.72	0.739
2043	2,390	1,256	37,434	314	3,009	2,708	23.2	4.02	188	88.4	1.84	0.716	0.204	4,404	3.43	0.041	2.76	0.751
2044	2,431	1,278	38,076	319	3,060	2,754	23.6	4.09	192	89.9	1.87	0.728	0.207	4,480	3.49	0.041	2.81	0.764
2045	2,475	1,301	38,766	325	3,116	2,804	24.1	4.16	195	91.5	1.90	0.741	0.211	4,561	3.55	0.042	2.86	0.778
2046	2,520	1,325	39,470	331	3,172	2,855	24.5	4.24	199	93.2	1.94	0.755	0.215	4,644	3.62	0.043	2.92	0.792
2047	2,567	1,349	40,207	337	3,231	2,908	25.0	4.32	202	94.9	1.97	0.769	0.219	4,730	3.68	0.044	2.97	0.807
2048	2,616	1,375	40,974	344	3,293	2,964	25.4	4.40	206	96.7	2.01	0.784	0.223	4,821	3.75	0.045	3.03	0.822
2049	2,667	1,402	41,773	350	3,357	3,022	25.9	4.49	210	98.6	2.05	0.799	0.228	4,915	3.83	0.046	3.09	0.838
2050	2,720	1,430	42,603	357	3,424	3,082	26.4	4.57	214	101	2.09	0.815	0.232	5,012	3.90	0.046	3.15	0.855
2051	2,775	1,459	43,464	365	3,493	3,144	27.0	4.67	219	103	2.13	0.831	0.237	5,114	3.98	0.047	3.21	0.872
2052	2,831	1,488	44,342	372	3,564	3,207	27.5	4.76	223	105	2.17	0.848	0.242	5,217	4.06	0.048	3.27	0.890
2053	2,890	1,519	45,266	380	3,638	3,274	28.1	4.86	228	107	2.22	0.866	0.247	5,326	4.15	0.049	3.34	0.908
2054	2,951	1,551	46,221	388	3,715	3,343	28.7	4.96	233	109	2.27	0.884	0.252	5,438	4.23	0.050	3.41	0.927
2055	3,013	1,584	47,192	396	3,793	3,414	29.3	5.07	238	111	2.31	0.903	0.257	5,552	4.32	0.051	3.49	0.947
2056	3,078	1,618	48,210	404	3,875	3,487	29.9	5.18	243	114	2.36	0.922	0.263	5,672	4.42	0.053	3.56	0.967
2057	3,145	1,653	49,260	413	3,959	3,563	30.6	5.29	248	116	2.42	0.942	0.268	5,795	4.51	0.054	3.64	0.988
2058	3,213	1,689	50,325	422	4,045	3,640	31.2	5.40	253	119	2.47	0.963	0.274	5,921	4.61	0.055	3.72	1.010
2059	3,284	1,726	51,437	432	4,134	3,721	31.9	5.52	259	121	2.52	0.984	0.280	6,052	4.71	0.056	3.80	1.032
2060	3,356	1,764	52,565	441	4,225	3,802	32.6	5.64	265	124	2.58	1.01	0.286	6,184	4.82	0.057	3.88	1.055
2061	3,431	1,803	53,739	451	4,319	3,887	33.4	5.77	271	127	2.64	1.03	0.293	6,322	4.92	0.059	3.97	1.078

	Collected LFG – IC Engines										AD Biogas to Turbine							Total Emissions						
Year	LFG MMcf/yr	Methane MMcf/yr	NOx tpy	SO2 tpy	CO tpy	CO2 Combustion tpy	Methane tpy	VOC tpy	Total HAP tpy	PM10 tpy	NOx tpy	SO2 tpy	CO tpy	CO2e tpy	VOC tpy	Total HAP tpy	PM10 tpy	NOx tpy	SO2 tpy	CO tpy	CO2e tpy	VOC tpy	Total HAP tpy	PM10 tpy
2020	630	295	15.1	2.39	92.7	14,720	11.5	5.45	9.24	15.3	2.09	0.848	0.222	25,007	0.076	0.0032	1.57	18.8	3.84	93.1	122,498	25.0	14.9	17.5
2021	640	300	15.4	2.43	94.2	14,948	11.6	5.54	9.38	15.6	2.09	0.848	0.222	25,007	0.076	0.0032	1.57	19.0	3.89	94.5	124,012	25.4	15.1	17.8
2022	636	298	15.3	2.42	93.6	14,867	11.6	5.51	9.33	15.5	2.09	0.848	0.222	25,007	0.076	0.0032	1.57	18.9	3.87	94.0	123,475	25.2	15.1	17.7
2023	634	297	15.2	2.41	93.3	14,816	11.5	5.49	9.30	15.4	2.09	0.848	0.222	25,007	0.076	0.0032	1.57	18.9	3.86	93.7	123,133	25.1	15.0	17.6
2024	632	297	15.2	2.40	93.1	14,779	11.5	5.48	9.28	15.4	2.09	0.848	0.222	25,007	0.076	0.0032	1.57	18.8	3.85	93.5	122,889	25.1	15.0	17.6
2025	632	296	15.2	2.40	93.0	14,764	11.5	5.47	9.27	15.4	2.09	0.848	0.222	25,007	0.076	0.0032	1.57	18.8	3.85	93.4	122,791	25.1	15.0	17.6
2026	632	296	15.2	2.40	93.0	14,771	11.5	5.47	9.27	15.4	2.09	0.848	0.222	25,007	0.076	0.0032	1.57	18.8	3.85	93.4	122,840	25.1	15.0	17.6
2027	633	297	15.2	2.41	93.2	14,801	11.5	5.48	9.29	15.4	2.09	0.848	0.222	25,007	0.076	0.0032	1.57	18.8	3.86	93.6	123,036	25.1	15.0	17.6
2028	635	298	15.3	2.41	93.6	14,853	11.6	5.50	9.32	15.5	2.09	0.848	0.222	25,007	0.076	0.0032	1.57	18.9	3.87	93.9	123,377	25.2	15.0	17.7
2029	638	299	15.3	2.43	94.0	14,919	11.6	5.53	9.37	15.5	2.09	0.848	0.222	25,007	0.076	0.0032	1.57	19.0	3.88	94.4	123,817	25.3	15.1	17.7
2030	642	301	15.4	2.44	94.6	15,015	11.7	5.56	9.43	15.6	2.09	0.848	0.222	25,007	0.076	0.0032	1.57	19.1	3.90	95.0	124,451	25.5	15.2	17.8
2031	647	303	15.5	2.46	95.2	15,118	11.8	5.60	9.49	15.7	2.09	0.848	0.222	25,007	0.076	0.0032	1.57	19.2	3.92	95.6	125,135	25.7	15.3	18.0
2032	652	306	15.7	2.48	96.0	15,243	11.9	5.65	9.57	15.9	2.09	0.848	0.222	25,007	0.076	0.0032	1.57	19.3	3.95	96.4	125,965	25.9	15.4	18.1
2033	658	309	15.8	2.50	96.9	15,383	12.0	5.70	9.66	16.0	2.09	0.848	0.222	25,007	0.076	0.0032	1.57	19.5	3.97	97.3	126,892	26.1	15.6	18.2
2034	665	312	16.0	2.53	97.9	15,538	12.1	5.76	9.75	16.2	2.09	0.848	0.222	25,007	0.076	0.0032	1.57	19.7	4.01	98.3	127,917	26.4	15.7	18.4
2035	672	315	16.1	2.55	98.9	15,708	12.2	5.82	9.86	16.4	2.09	0.848	0.222	25,007	0.076	0.0032	1.57	19.9	4.04	99.3	129,040	26.7	15.9	18.6
2036	680	319	16.3	2.58	100	15,899	12.4	5.89	9.98	16.6	2.09	0.848	0.222	25,007	0.076	0.0032	1.57	20.1	4.08	101	130,310	27.0	16.1	18.8
2037	689	323	16.6	2.62	101	16,098	12.5	5.96	10.1	16.8	2.09	0.848	0.222	25,007	0.076	0.0032	1.57	20.3	4.12	102	131,628	27.3	16.3	19.0
2038	698	327	16.8	2.65	103	16,312	12.7	6.04	10.2	17.0	2.09	0.848	0.222	25,007	0.076	0.0032	1.57	20.6	4.16	103	133,043	27.7	16.5	19.3
2039	708	332	17.0	2.69	104	16,548	12.9	6.13	10.4	17.2	2.09	0.848	0.222	25,007	0.076	0.0032	1.57	20.8	4.21	105	134,606	28.1	16.8	19.5
2040	718	337	17.3	2.73	106	16,791	13.1	6.22	10.5	17.5	2.09	0.848	0.222	25,007	0.076	0.0032	1.57	21.1	4.26	106	136,217	28.5	17.0	19.8
2041	730	342	17.5	2.77	107	17,056	13.3	6.32	10.7	17.8	2.09	0.848	0.222	25,007	0.076	0.0032	1.57	21.4	4.31	108	137,974	28.9	17.3	20.1
2042	741	348	17.8	2.82	109	17,329	13.5	6.42	10.9	18.1	2.09	0.848	0.222	25,007	0.076	0.0032	1.57	21.7	4.37	110	139,780	29.4	17.6	20.4
2043	754	353	18.1	2.86	111	17,617	13.7	6.53	11.1	18.4	2.09	0.848	0.222	25,007	0.076	0.0032	1.57	22.0	4.43	111	141,684	29.9	17.8	20.7
2044	767	360	18.4	2.91	113	17,919	14.0	6.64	11.2	18.7	2.09	0.848	0.222	25,007	0.076	0.0032	1.57	22.4	4.49	113	143,686	30.4	18.2	21.0
2045	781	366	18.8	2.97	115	18,243	14.2	6.76	11.5	19.0	2.09	0.848	0.222	25,007	0.076	0.0032	1.57	22.7	4.56	115	145,834	30.9	18.5	21.3
2046	795	373	19.1	3.02	117	18,575	14.5	6.88	11.7	19.4	2.09	0.848	0.222	25,007	0.076	0.0032	1.57	23.1	4.62	117	148,031	31.5	18.8	21.7
2047	810	380	19.5	3.08	119	18,921	14.7	7.01	11.9	19.7	2.09	0.848	0.222	25,007	0.076	0.0032	1.57	23.5	4.69	120	150,325	32.1	19.2	22.1
2048	825	387	19.8	3.13	121	19,283	15.0	7.14	12.1	20.1	2.09	0.848	0.222	25,007	0.076	0.0032	1.57	23.9	4.77	122	152,717	32.7	19.5	22.5
2049	841	394	20.2	3.20	124	19,658	15.3	7.28	12.3	20.5	2.09	0.848	0.222	25,007	0.076	0.0032	1.57	24.3	4.84	124	155,207	33.3	19.9	22.9
2050	858	402	20.6	3.26	126	20,049	15.6	7.43	12.6	20.9	2.09	0.848	0.222	25,007	0.076	0.0032	1.57	24.8	4.92	127	157,795	34.0	20.3	23.3
2051	875	410	21.0	3.33	129	20,455	15.9	7.58	12.8	21.3	2.09	0.848	0.222	25,007	0.076	0.0032	1.57	25.3	5.01	129	160,480	34.7	20.7	23.7
2052	893	419	21.5	3.39	131	20,867	16.3	7.73	13.1	21.7	2.09	0.848	0.222	25,007	0.076	0.0032	1.57	25.7	5.1	132	163,213	35.4	21.1	24.2
2053	911	427	21.9	3.46	134	21,302	16.6	7.89	13.4	22.2	2.09	0.848	0.222	25,007	0.076	0.0032	1.57	26.2	5.2	135	166,094	36.1	21.6	24.7
2054	931	436	22.4	3.54	137	21,752	16.9	8.06	13.7	22.7	2.09	0.848	0.222	25,007	0.076	0.0032	1.57	26.7	5.3	137	169,072	36.9	22.0	25.2
2055	950	446	22.8	3.61	140	22,209	17.3	8.23	13.9	23.1	2.09	0.848	0.222	25,007	0.076	0.0032	1.57	27.2	5.4	140	172,098	37.7	22.5	25.7
2056	971	455	23.3	3.69	143	22,688	17.7	8.41	14.2	23.6	2.09	0.848	0.222	25,007	0.076	0.0032	1.57	27.8	5.5	143	175,272	38.5	23.0	26.2
2057	992	465	23.8	3.77	146	23,182	18.1	8.59	14.6	24.2	2.09	0.848	0.222	25,007	0.076	0.0032	1.57	28.3	5.6	147	178,543	39.3	23.5	26.7
2058	1,013	475	24.3	3.85	149	23,683	18.4	8.77	14.9	24.7	2.09	0.848	0.222	25,007	0.076	0.0032	1.57	28.9	5.7	150	181,862	40.1	24.0	27.2
2059	1,036	486	24.9	3.94	152	24,206	18.9	8.97	15.2	25.2	2.09	0.848	0.222	25,007	0.076	0.0032	1.57	29.5	5.8	153	185,328	41.0	24.5	27.8
2060	1,058	496	25.4	4.02	156	24,737	19.3	9.17	15.5	25.8	2.09	0.848	0.222	25,007	0.076	0.0032	1.57	30.1	5.9	156	188,843	41.9	25.1	28.4
2061	1,082	507	26.0	4.11	159	25,290	19.7	9.37	15.9	26.3	2.09	0.848	0.222	25,007	0.076	0.0032	1.57	30.7	6.0	160	192,505	42.9	25.6	29.0

Appendix H Anaerobic Digestion Scenario using Fuel Cell

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Western Placer Waste Management Authority
Alternate Energy Feasibility Study
Pollutant Profile - AD Biogas to Fuel Cell

Assumptions		Units	
LFG Collection Efficiency:	75%	%	
LFG Methane Content:	46.9%	%	Average of 1 minute minimum and maximum values from "June 2010.xlsx".
LFG CO_2 Content:	53.1%	%	Calculated from the average methane content and the assumption that CO2 is the remainder of the landfill gas.
Collected LFG to IC Engines:	80%	%	Assumed.
Collected LFG to Flare:	20%	%	All LFG not directed to IC engines assumed to flare.
Cover Oxidation Factor:	10%	%	40 CFR Part 98, Subpart HH, Table HH-1.
LFG Heat Content:	433	Btu/cf	Stack Test Results
Flare and IC Engine Destruction Efficiency:	99.81%	%	Stack Test Results
LFG CO2 Content Emission Factor:	29.8	ton/MM cf LFG	Based on average of 1 minute minimum and maximum values from "June 2010.xlsx".
LFG Methane Content Emission Factor:	9.58	ton/MM cf LFG	Based on methane content and the assumption that CO2 is the remainder of the landfill gas
LFG Combustion SO2 Emission Factor:	0.0038	ton/MM cf LFG	AP-42 Default Value
LFG Uncontrolled NMOC Content Emission Factor:	148	lb/MM cf LFG	Stack Test Results
LFG Uncontrolled Organic HAP Content Emission Factor:	0.0128	ton/MM cf LFG	AP-42 Default Value
LFG Mercury Content Emission Factor:	7.53E-08	ton/MM cf LFG	AP-42 Default Value
LFG Combustion HCl Emission Factor:	0.0020	ton/MM cf LFG	AP-42 Default Value
Flare NOx Emission Factor:	0.045	lb/MMBtu	Stack Test Results
Flare CO Emission Factor:	0.0050	lb/MMBtu	Stack Test Results
Flare VOC Emission Factor:	0.0010	lb/MMBtu	Stack Test Results
Flare PM10 Emission Factor:	17.0	lb/MM cf CH4	AP-42, Table 2.4-5
IC Engine NOx Emission Factor:	0.111	lb/MMBtu	Stack Test Results
IC Engine CO Emission Factor:	0.680	lb/MMBtu	Stack Test Results
IC Engine VOC Emission Factor:	0.040	lb/MMBtu	Stack Test Results
IC Engine PM10 Emission Factor:	48.7	lb/MM cf LFG	Based on engine quarterly permit limits
CT MSW Throughput:	182,500	tons per year	Based on 500 tpd, 365 days per year
AD Biogas Production:	477	MM cf/yr	Based on assumed 2615 scf/ton MSW AD biogas production rate
AD Biogas Heat Content:	261,049	MMBtu/yr	Based on assumed AD biogas methane content of 60% and methane LHV heat content of 912 Btu/cf
AD Biogas Combustion CO2 Emission Factor:	52.4	lb/MM cf AD Biogas	HDR Library. Assumes all of the methane in the AD biogas is oxidized to CO2 and the CO2 in the biogas passes through the device.
AD Biogas Fuel Cell HAP Emission Factor:	0	lb/MMBtu	HDR Library. Assumes syngas is cleaned to gas quality required by the fuel cell for proper operation.
AD Biogas Fuel Cell SO2 Emission Factor:	1.38E-05	lb/MMBtu	HDR Library. Assumes AD Biogas is cleaned to gas quality required by the fuel cell for proper operation.
AD Biogas Fuel Cell NOx Emission Factor:	1.38E-03	lb/MMBtu	HDR Library.
AD Biogas Fuel Cell CO Emission Factor:	0	lb/MMBtu	Assumes the fuel cell produces negligible levels of CO.
AD Biogas Fuel Cell PM10 Emission Factor:	2.75E-06	lb/MMBtu	HDR Library. Assumes AD Biogas is cleaned to gas quality required by the fuel cell for proper operation.
AD Biogas Fuel Cell VOC Emission Factor:	0	lb/MMBtu	HDR Library. Assumes AD Biogas is cleaned to gas quality required by the fuel cell for proper operation.

	Calculated Uncontrolled LFG			Uncollected LFG					Collected LFG – Flare									
Year	LFG cfm	LFG MM cf/yr	CO2 tpy	LFG MMcf/yr	Methane tpy	Methane From Cover tpy	VOC (NMOC) tpy	Total HAP tpy	LFG MMcf/yr	Methane MMcf/yr	NOx tpy	SO2 tpy	CO tpy	CO2 Combustion tpy	Methane tpy	VOC tpy	Total HAP tpy	PM10 tpy
2020	1,997	1,050	31,279	262	2,514	2,262	19.4	3.36	157	73.8	1.53	0.598	0.170	3,680	2.87	0.034	2.31	0.628
2021	2,028	1,066	31,764	266	2,553	2,298	19.7	3.41	160	75.0	1.56	0.608	0.173	3,737	2.91	0.035	2.35	0.637
2022	2,017	1,060	31,592	265	2,539	2,285	19.6	3.39	159	74.6	1.55	0.604	0.172	3,717	2.89	0.034	2.33	0.634
2023	2,010	1,056	31,482	264	2,530	2,277	19.5	3.38	158	74.3	1.54	0.602	0.172	3,704	2.88	0.034	2.33	0.632
2024	2,005	1,054	31,404	263	2,524	2,272	19.5	3.37	158	74.1	1.54	0.601	0.171	3,695	2.88	0.034	2.32	0.630
2025	2,003	1,053	31,373	263	2,521	2,269	19.5	3.37	158	74.1	1.54	0.600	0.171	3,691	2.87	0.034	2.32	0.630
2026	2,004	1,053	31,388	263	2,523	2,270	19.5	3.37	158	74.1	1.54	0.600	0.171	3,693	2.88	0.034	2.32	0.630
2027	2,008	1,055	31,451	264	2,528	2,275	19.5	3.38	158	74.2	1.54	0.602	0.171	3,700	2.88	0.034	2.32	0.631
2028	2,015	1,059	31,561	265	2,537	2,283	19.6	3.39	159	74.5	1.55	0.604	0.172	3,713	2.89	0.034	2.33	0.633
2029	2,024	1,064	31,702	266	2,548	2,293	19.7	3.40	160	74.8	1.55	0.606	0.173	3,730	2.90	0.035	2.34	0.636
2030	2,037	1,071	31,905	268	2,564	2,308	19.8	3.43	161	75.3	1.56	0.610	0.174	3,754	2.92	0.035	2.36	0.640
2031	2,051	1,078	32,125	270	2,582	2,324	19.9	3.45	162	75.8	1.58	0.614	0.175	3,779	2.94	0.035	2.37	0.645
2032	2,068	1,087	32,391	272	2,603	2,343	20.1	3.48	163	76.5	1.59	0.620	0.176	3,811	2.97	0.035	2.39	0.650
2033	2,087	1,097	32,688	274	2,627	2,364	20.3	3.51	165	77.2	1.60	0.625	0.178	3,846	2.99	0.036	2.41	0.656
2034	2,108	1,108	33,017	277	2,654	2,388	20.5	3.55	166	77.9	1.62	0.632	0.180	3,885	3.03	0.036	2.44	0.663
2035	2,131	1,120	33,378	280	2,683	2,414	20.7	3.58	168	78.8	1.64	0.638	0.182	3,927	3.06	0.036	2.47	0.670
2036	2,157	1,134	33,785	283	2,715	2,444	21.0	3.63	170	79.8	1.66	0.646	0.184	3,975	3.10	0.037	2.50	0.678
2037	2,184	1,148	34,208	287	2,749	2,474	21.2	3.67	172	80.8	1.68	0.654	0.186	4,025	3.13	0.037	2.53	0.686
2038	2,213	1,163	34,662	291	2,786	2,507	21.5	3.72	174	81.8	1.70	0.663	0.189	4,078	3.18	0.038	2.56	0.696
2039	2,245	1,180	35,163	295	2,826	2,543	21.8	3.78	177	83.0	1.72	0.673	0.192	4,137	3.22	0.038	2.60	0.706
2040	2,278	1,197	35,680	299	2,868	2,581	22.2	3.83	180	84.2	1.75	0.682	0.194	4,198	3.27	0.039	2.64	0.716
2041	2,314	1,216	36,244	304	2,913	2,622	22.5	3.89	182	85.6	1.78	0.693	0.197	4,264	3.32	0.039	2.68	0.727
2042	2,351	1,236	36,823	309	2,959	2,664	22.9	3.95	185	86.9	1.81	0.704	0.201	4,332	3.37	0.040	2.72	0.739
2043	2,390	1,256	37,434	314	3,009	2,708	23.2	4.02	188	88.4	1.84	0.716	0.204	4,404	3.43	0.041	2.76	0.751
2044	2,431	1,278	38,076	319	3,060	2,754	23.6	4.09	192	89.9	1.87	0.728	0.207	4,480	3.49	0.041	2.81	0.764
2045	2,475	1,301	38,766	325	3,116	2,804	24.1	4.16	195	91.5	1.90	0.741	0.211	4,561	3.55	0.042	2.86	0.778
2046	2,520	1,325	39,470	331	3,172	2,855	24.5	4.24	199	93.2	1.94	0.755	0.215	4,644	3.62	0.043	2.92	0.792
2047	2,567	1,349	40,207	337	3,231	2,908	25.0	4.32	202	94.9	1.97	0.769	0.219	4,730	3.68	0.044	2.97	0.807
2048	2,616	1,375	40,974	344	3,293	2,964	25.4	4.40	206	96.7	2.01	0.784	0.223	4,821	3.75	0.045	3.03	0.822
2049	2,667	1,402	41,773	350	3,357	3,022	25.9	4.49	210	98.6	2.05	0.799	0.228	4,915	3.83	0.046	3.09	0.838
2050	2,720	1,430	42,603	357	3,424	3,082	26.4	4.57	214	101	2.09	0.815	0.232	5,012	3.90	0.046	3.15	0.855
2051	2,775	1,459	43,464	365	3,493	3,144	27.0	4.67	219	103	2.13	0.831	0.237	5,114	3.98	0.047	3.21	0.872
2052	2,831	1,488	44,342	372	3,564	3,207	27.5	4.76	223	105	2.17	0.848	0.242	5,217	4.06	0.048	3.27	0.890
2053	2,890	1,519	45,266	380	3,638	3,274	28.1	4.86	228	107	2.22	0.866	0.247	5,326	4.15	0.049	3.34	0.908
2054	2,951	1,551	46,221	388	3,715	3,343	28.7	4.96	233	109	2.27	0.884	0.252	5,438	4.23	0.050	3.41	0.927
2055	3,013	1,584	47,192	396	3,793	3,414	29.3	5.07	238	111	2.31	0.903	0.257	5,552	4.32	0.051	3.49	0.947
2056	3,078	1,618	48,210	404	3,875	3,487	29.9	5.18	243	114	2.36	0.922	0.263	5,672	4.42	0.053	3.56	0.967
2057	3,145	1,653	49,260	413	3,959	3,563	30.6	5.29	248	116	2.42	0.942	0.268	5,795	4.51	0.054	3.64	0.988
2058	3,213	1,689	50,325	422	4,045	3,640	31.2	5.40	253	119	2.47	0.963	0.274	5,921	4.61	0.055	3.72	1.010
2059	3,284	1,726	51,437	432	4,134	3,721	31.9	5.52	259	121	2.52	0.984	0.280	6,052	4.71	0.056	3.80	1.032
2060	3,356	1,764	52,565	441	4,225	3,802	32.6	5.64	265	124	2.58	1.01	0.286	6,184	4.82	0.057	3.88	1.055
2061	3,431	1,803	53,739	451	4,319	3,887	33.4	5.77	271	127	2.64	1.03	0.293	6,322	4.92	0.059	3.97	1.078

	Collected LFG – IC Engines										AD Biogas to Fuel Cell							Total Emissions						
Year	LFG MMcf/yr	Methane MMcf/yr	NOx tpy	SO2 tpy	CO tpy	CO2 Combustion tpy	Methane tpy	VOC tpy	Total HAP tpy	PM10 tpy	NOx tpy	SO2 tpy	CO tpy	CO2e tpy	VOC tpy	Total HAP tpy	PM10 tpy	NOx tpy	SO2 tpy	CO tpy	CO2e tpy	VOC tpy	Total HAP tpy	PM10 tpy
2020	630	295	15.1	2.39	92.7	14,720	11.5	5.45	9.24	15.3	0.180	0.0018	0	25,007	0	0	0.0004	16.8	2.99	92.9	122,498	24.9	14.9	16.0
2021	640	300	15.4	2.43	94.2	14,948	11.6	5.54	9.38	15.6	0.180	0.0018	0	25,007	0	0	0.0004	17.1	3.04	94.3	124,012	25.3	15.1	16.2
2022	636	298	15.3	2.42	93.6	14,867	11.6	5.51	9.33	15.5	0.180	0.0018	0	25,007	0	0	0.0004	17.0	3.02	93.8	123,475	25.2	15.1	16.1
2023	634	297	15.2	2.41	93.3	14,816	11.5	5.49	9.30	15.4	0.180	0.0018	0	25,007	0	0	0.0004	17.0	3.01	93.5	123,133	25.1	15.0	16.1
2024	632	297	15.2	2.40	93.1	14,779	11.5	5.48	9.28	15.4	0.180	0.0018	0	25,007	0	0	0.0004	16.9	3.01	93.3	122,889	25.0	15.0	16.0
2025	632	296	15.2	2.40	93.0	14,764	11.5	5.47	9.27	15.4	0.180	0.0018	0	25,007	0	0	0.0004	16.9	3.00	93.2	122,791	25.0	15.0	16.0
2026	632	296	15.2	2.40	93.0	14,771	11.5	5.47	9.27	15.4	0.180	0.0018	0	25,007	0	0	0.0004	16.9	3.00	93.2	122,840	25.0	15.0	16.0
2027	633	297	15.2	2.41	93.2	14,801	11.5	5.48	9.29	15.4	0.180	0.0018	0	25,007	0	0	0.0004	16.9	3.01	93.4	123,036	25.0	15.0	16.1
2028	635	298	15.3	2.41	93.6	14,853	11.6	5.50	9.32	15.5	0.180	0.0018	0	25,007	0	0	0.0004	17.0	3.02	93.7	123,377	25.1	15.0	16.1
2029	638	299	15.3	2.43	94.0	14,919	11.6	5.53	9.37	15.5	0.180	0.0018	0	25,007	0	0	0.0004	17.1	3.03	94.1	123,817	25.2	15.1	16.2
2030	642	301	15.4	2.44	94.6	15,015	11.7	5.56	9.43	15.6	0.180	0.0018	0	25,007	0	0	0.0004	17.2	3.05	94.7	124,451	25.4	15.2	16.3
2031	647	303	15.5	2.46	95.2	15,118	11.8	5.60	9.49	15.7	0.180	0.0018	0	25,007	0	0	0.0004	17.3	3.07	95.4	125,135	25.6	15.3	16.4
2032	652	306	15.7	2.48	96.0	15,243	11.9	5.65	9.57	15.9	0.180	0.0018	0	25,007	0	0	0.0004	17.4	3.10	96.2	125,965	25.8	15.4	16.5
2033	658	309	15.8	2.50	96.9	15,383	12.0	5.70	9.66	16.0	0.180	0.0018	0	25,007	0	0	0.0004	17.6	3.13	97.1	126,892	26.0	15.6	16.7
2034	665	312	16.0	2.53	97.9	15,538	12.1	5.76	9.75	16.2	0.180	0.0018	0	25,007	0	0	0.0004	17.8	3.16	98.0	127,917	26.3	15.7	16.9
2035	672	315	16.1	2.55	98.9	15,708	12.2	5.82	9.86	16.4	0.180	0.0018	0	25,007	0	0	0.0004	18.0	3.19	99.1	129,040	26.6	15.9	17.0
2036	680	319	16.3	2.58	100	15,899	12.4	5.89	9.98	16.6	0.180	0.0018	0	25,007	0	0	0.0004	18.2	3.23	100	130,310	26.9	16.1	17.2
2037	689	323	16.6	2.62	101	16,098	12.5	5.96	10.1	16.8	0.180	0.0018	0	25,007	0	0	0.0004	18.4	3.27	102	131,628	27.2	16.3	17.5
2038	698	327	16.8	2.65	103	16,312	12.7	6.04	10.2	17.0	0.180	0.0018	0	25,007	0	0	0.0004	18.7	3.32	103	133,043	27.6	16.5	17.7
2039	708	332	17.0	2.69	104	16,548	12.9	6.13	10.4	17.2	0.180	0.0018	0	25,007	0	0	0.0004	18.9	3.36	104	134,606	28.0	16.8	17.9
2040	718	337	17.3	2.73	106	16,791	13.1	6.22	10.5	17.5	0.180	0.0018	0	25,007	0	0	0.0004	19.2	3.41	106	136,217	28.4	17.0	18.2
2041	730	342	17.5	2.77	107	17,056	13.3	6.32	10.7	17.8	0.180	0.0018	0	25,007	0	0	0.0004	19.5	3.47	108	137,974	28.9	17.3	18.5
2042	741	348	17.8	2.82	109	17,329	13.5	6.42	10.9	18.1	0.180	0.0018	0	25,007	0	0	0.0004	19.8	3.52	109	139,780	29.3	17.6	18.8
2043	754	353	18.1	2.86	111	17,617	13.7	6.53	11.1	18.4	0.180	0.0018	0	25,007	0	0	0.0004	20.1	3.58	111	141,684	29.8	17.8	19.1
2044	767	360	18.4	2.91	113	17,919	14.0	6.64	11.2	18.7	0.180	0.0018	0	25,007	0	0	0.0004	20.5	3.64	113	143,686	30.3	18.1	19.4
2045	781	366	18.8	2.97	115	18,243	14.2	6.76	11.5	19.0	0.180	0.0018	0	25,007	0	0	0.0004	20.8	3.71	115	145,834	30.9	18.5	19.8
2046	795	373	19.1	3.02	117	18,575	14.5	6.88	11.7	19.4	0.180	0.0018	0	25,007	0	0	0.0004	21.2	3.78	117	148,031	31.4	18.8	20.1
2047	810	380	19.5	3.08	119	18,921	14.7	7.01	11.9	19.7	0.180	0.0018	0	25,007	0	0	0.0004	21.6	3.85	119	150,325	32.0	19.2	20.5
2048	825	387	19.8	3.13	121	19,283	15.0	7.14	12.1	20.1	0.180	0.0018	0	25,007	0	0	0.0004	22.0	3.92	122	152,717	32.6	19.5	20.9
2049	841	394	20.2	3.20	124	19,658	15.3	7.28	12.3	20.5	0.180	0.0018	0	25,007	0	0	0.0004	22.4	4.00	124	155,207	33.3	19.9	21.3
2050	858	402	20.6	3.26	126	20,049	15.6	7.43	12.6	20.9	0.180	0.0018	0	25,007	0	0	0.0004	22.9	4.08	127	157,795	33.9	20.3	21.7
2051	875	410	21.0	3.33	129	20,455	15.9	7.58	12.8	21.3	0.180	0.0018	0	25,007	0	0	0.0004	23.3	4.16	129	160,480	34.6	20.7	22.2
2052	893	419	21.5	3.39	131	20,867	16.3	7.73	13.1	21.7	0.180	0.0018	0	25,007	0	0	0.0004	23.8	4.2	132	163,213	35.3	21.1	22.6
2053	911	427	21.9	3.46	134	21,302	16.6	7.89	13.4	22.2	0.180	0.0018	0	25,007	0	0	0.0004	24.3	4.3	134	166,094	36.0	21.6	23.1
2054	931	436	22.4	3.54	137	21,752	16.9	8.06	13.7	22.7	0.180	0.0018	0	25,007	0	0	0.0004	24.8	4.4	137	169,072	36.8	22.0	23.6
2055	950	446	22.8	3.61	140	22,209	17.3	8.23	13.9	23.1	0.180	0.0018	0	25,007	0	0	0.0004	25.3	4.5	140	172,098	37.6	22.5	24.1
2056	971	455	23.3	3.69	143	22,688	17.7	8.41	14.2	23.6	0.180	0.0018	0	25,007	0	0	0.0004	25.9	4.6	143	175,272	38.4	23.0	24.6
2057	992	465	23.8	3.77	146	23,182	18.1	8.59	14.6	24.2	0.180	0.0018	0	25,007	0	0	0.0004	26.4	4.7	146	178,543	39.2	23.5	25.1
2058	1,013	475	24.3	3.85	149	23,683	18.4	8.77	14.9	24.7	0.180	0.0018	0	25,007	0	0	0.0004	27.0	4.8	149	181,862	40.1	24.0	25.7
2059	1,036	486	24.9	3.94	152	24,206	18.9	8.97	15.2	25.2	0.180	0.0018	0	25,007	0	0	0.0004	27.6	4.9	153	185,328	41.0	24.5	26.3
2060	1,058	496	25.4	4.02	156	24,737	19.3	9.17	15.5	25.8	0.180	0.0018	0	25,007	0	0	0.0004	28.2	5.0	156	188,843	41.9	25.1	26.8
2061	1,082	507	26.0	4.11	159	25,290	19.7	9.37	15.9	26.3	0.180	0.0018	0	25,007	0	0	0.0004	28.8	5.1	160	192,505	42.8	25.6	27.4

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