CALIFORNIA
ENERGY
COMMISSION

An Assessment of Biomass Power Generation in California: Status and Survey Results

DRAFT

CONSULTANT REPORT

January 2005
Contract 500-01-016

Arnold Schwarzenegger, *Governor*

CALIFORNIA ENERGY COMMISSION

Prepared By:

R.E. Aldas
M.C. Gildart
California Biomass Collaborative
University of California
Davis, CA   95616

Contract No. 500-01-016

Prepared For:
Valentino Tiangco
Contract Manager

George Simons
PIER Renewables Program Manager

Marwan Masri
Deputy Director

Robert L. Therkelsen
Executive Director

LEGAL NOTICE

An Assessment of Biomass Power Generation in California
(DRAFT)

Abstract

This report details efforts to obtain performance information from existing biomass-to-energy facilities in California and to assess industry status and to help quantify benefits to the state. Four general categories of facilities currently predominate in the industry, namely, direct combustion or steam cycle facilities, landfill gas-to-energy (LFGTE) plants, sewage digester gas-to-energy plants or wastewater treatment facilities, and animal and food waste digester gas-to-energy plants. Information regarding technical performance, environmental, socio-economic and other key indicators was gathered and compiled from cooperating facilities through survey and from indirect sources such as literatures and available databases. Attempts were also made to analyze the state programs and incentives concerning these biomass-to-energy facilities. This assessment has identified a total of 229 facilities covering 29 biomass direct combustion facilities, 3 municipal solid wastes-to-energy combustion facilities, 59 LFGTE facilities, 115 wastewater treatment plants, and 23 animal and food waste digester facilities. These facilities have a gross generating capacity of at least 1087 MWe, about 69% of which are from direct combustion plants. The net to grid capacity is at least 869 MWe. The estimated annual gross and net energy production is 8100 GWh and 6475 GWh, respectively. Power and energy production will increase substantially once data from all 229 facilities have been obtained. So far, these facilities have a low response rate to the survey; retuned surveys were around 22% of the total industry. Thus there is a need to continue the efforts in gathering reliable data directly from each facility. The information can be used to appraise the current operating condition of the industry as well as issues and concerns associated with continued operation and growth of the bioenergy sector.

Acknowledgements

Thanks go out to the many facility operators and other industry representatives who responded to the Collaborative survey, staff at the California Energy Commission, California Integrated Waste Management Board, and California Environmental Protection Agency, the Energy Information Administration of the U.S. Department of Energy, and the US Environmental Protection Agency.

Executive Summary

In an effort to update information regarding the status of the biomass-to-energy (bioenergy) sector in the state, the California Biomass Collaborative (Collaborative) conducted surveys of known California biomass-conversion facilities. The initial effort was undertaken by Bates Consulting under contract to the Collaborative with follow-up work performed by the Collaborative staff. This report presents information from the returned surveys describing the operational, financial, environmental, and other key indicators of industry performance.

Most of the facilities fit into one of four different groups. They are direct combustion/steam cycle power plants, landfill-gas-to-energy plants, animal-waste-digester-gas-to-energy plants, and sewage-digester-gas-to-energy plants. A survey form was developed to gather information from individual facilities. Three different versions of the survey forms were generated to match the different types of energy conversion technologies: thermochemical, biochemical, and physicochemical. Copies of the forms are included in the Appendices. The forms were matched to facility type and mailed to the biomass-to-energy facilities throughout the state. During the time that surveys were being returned, mailing lists were refined and additional surveys were sent both by surface mail and electronically. The compilation of received data is presented later in this report. Telephone calls and offers of assistance followed the mailing. A total of 229 facilities across all categories were identified. To date, 56% of these facilities were able to be contacted regarding the survey, 42% were sent survey questionnaires (14% are either pending response to communication or formally declined to respond to the survey), and 52% of the surveys sent have been returned (Table ES1). All (100%) of identified biomass direct combustion and landfill gas-to-energy facilities have been contacted. In the case of wastewater treatment facilities and animal and food digesters, contact rate is still below 50% as contact information are being verified but efforts are continuing to reach all the other facilities. Efforts are also continuing to increase survey response rate.

Table ES1

Summary of facility communication and survey

Facility Type	Total Number Identified	Contacted for Survey		Sent survey		Responded to survey			Declined survey	
		(Number)	(%)	(Number)	(%)	(Number)	(% of total)	(% of sent)	(Number)	(% of total)
Direct combustion	32	29	91	20	62.5	8	25	40.0	2	6.2
Landfill gas to energy	59	59	100	44	74.6	18	30.5	40.9	2	3.4
Wastewater treatment plant	115	30	26.1	22	19.1	16	13.9	72.7	0	0
Animal and food waste digester	23	11	47.8	11	47.8	7	34.8	72.7	0	0
All	229	129	56.3	97	42.4	49	21.4	51.5	4	1.7

The summary of technical performance of four facility categories is given in Table ES2. Current information from existing facilities indicate gross generating capacity of at least 1 GW which could potentially increase further once all facilities, for instance all wastewater treatment plants, have been accounted for and all facilities currently under-development become operational. The net energy being exported to the grid is estimated at 869 MW which is at about 1.4% of total generating capacity in the State from all fuel sources. Further results from the surveys and other sources of information are described in detail in Section 3 – Results and Discussion.

Table ES2

Summary of technical performance of four facility categories

Type of facility	Direct Combustion	Landfill gas to energy	Wastewater treatment plant	Animal & food waste digesters	Total
Number of facilities	32	59	115	23	229
Number of facilities operating	32	59	For verification	7	
Total gross generating capacity—existing and planned (MWe)	760.9	257.6	63 (from 18 plants)	5.6	1,087.1
Total net (to grid) generating capacity (MW)	641.5	227.2	0.96 (from 2 plants	For verification	869.6
Annualized capacity factor (%)	46-100 (ave = 77)	93-97 (ave = 94)	55-97 (ave = 70)	99 (from 1 facility)	81.1[b]
Availability (%)	76-98 (ave = 93)	23-98 (ave = 80)	64-100 (ave = 84)	96 (from 3 facilities)	89.2[b]
Gross efficiency (%)	25-30.1 (ave = 28)	28-36 (ave = 34)	23-32 (ave = 29)	na*	30.4[b]
Net efficiency (%)	22-26.7 (ave = 24)	26-33 (ave = 30)	21-28 (ave = 26)	55[a] (from 1 facility)	26.0[b]
Estimated annual gross energy production (GWh)	5,665	1,918	475 (from 18 plants)	41.6	8,099.6
Estimated annual net energy production (GWh)	4,776	1,692	7.2 (from 2 plants)	na*	6,475.2

* na = not available

[a]Reported high efficiencies were from combined heat power (CHP) facilities; data on electrical efficiencies as separate from CHP are not available from these facilities.

[b]Calculated as capacity weighted average.

Table of Contents

List of Tables

List of Figures

Nomenclature

BDT	– bone dry ton
CO	– Carbon Monoxide
CBC	- California Biomass Collaborative
CEC	– California Energy Commission
CIWMB	– California Integrated Management Board
CF	– cubic foot
EIA	- Energy Information Administration
HHV	- higher heating value
kW	– kilowatts of electricity (power)
kWe	--kilowatts of electricity
kWh	– Kilowatt-hour (energy)
lb	– pound
LHV	– Lower heating value
LFGTE	– Landfill gas to energy
MGD	- Million gallons per day.
MMBtu	– million British Thermal Units
MW	- Megawatt
MWe	– Megawatts of electricity
MWt	--Megawatt thermal (or fuel)
NO_X	– Nitrous oxide – NO_2 or NO_3
NMHC	– Non-methane hydrocarbons
NR	-- Not Reported
PM	– Particulate Matter
SCF	– Standard cubic foot
SO_2	– Sulfur Dioxide
ROC	– Reactive Organic Compounds

Unit Conversions

1 acre	= 4046.9 m^2
1 square inch (in^2)	= 6.4516 x 10^{-4} m^2
1 pound per cubic foot (lb/ft^3)	= 16.018 kg/m^3
1 Btu	= 1054.4 J
1 Calorie (cal)	= 4.184 J
1 ft-lbf	= 1.3558 J
1 kilowatt-hour (kWh_	= 3.6 x 10^6 J
1 therm	= 1.0551 x 10^8 J
1 quad	= 10^{15} Btu
1 pound-force (lbf)	= 4.4482 N
1 inch	= 0.0254 m
1 foot (ft)	= 0.3048 m
1 mile (mi)	= 1609.3 m
1 Watt (W)	= 1 J/sec
1 Btu/sec	= 1055.1 W
1 GW	= 10^9 W
1 pound (lb)	= 0.45359 kg
1 ton (long, 2240 lb)	= 1016.0 kg
1 ton (short, 2000 lb)	= 907.18 kg
1 ton (metric ton)	= 1000 kg
1 Btu/h	= 0.29307 W
1 cal/s	= 4.184 W
1 ft-lbf/h	= 3.7662 x 10^{-4} W
1 horsepower (550 ft-lbf/s)	= 745.7 W
1 horsepower (boiler)	= 9809.5 W
1 horsepower (electric)	= 746 W
1 atmosphere	= 101325 Pa
1 bar	= 100 000 Pa
1 lbf/in^2 (psi)	= 6894.8 Pa
1 lbf/ft^2	= 47.880 Pa
1 inch of water (39.2 °F)	= 249.08 Pa
1 ft/s	= 0.3048 m/s
1 km/h	= 0.27778 m/s
1 mile/h	= 1.6093 km/h
1 cubic feet	= 28.32 liters
1 cubic meter	= 1000 liters

1. Introduction

The California Biomass Collaborative, operating under contract to the California Energy Commission, is developing a database and reporting system for biomass-to-energy facilities in California. The database is structured to provide public access to information on biomass power technologies, feedstocks, environmental impacts and benefits, economics, and other features of the industry. The California Biomass Collaborative (Collaborative) is a consortium of industry, government, academia, and environmental representatives working together on issues surrounding the sustainable management and use of biomass of all types in the state.

Information on biomass energy facilities has been compiled by various agencies, companies, and institutions. Initial survey contact information was compiled from databases maintained by the California Energy Commission (CEC) and the California Biomass Energy Alliance (CBEA). The latter is an industry organization representing all but one of the direct combustion biomass power plants in the state. The facility database was later expanded using information from the US Environmental Protection Agency (EPA) Region IX, California Integrated Waste Management Board (CIWMB), California Air Resources Board (CARB), Energy Information Administration (EIA), and separate identifications by the Collaborative. The CEC 2004 power plants database in particular, which included plant type, size, location, and fuel use, contained 28 direct combustion facilities, 51 landfill-gas, 3 animal waste digester, and 10 sewage digester plants (CEC, 2004c). This assessment now identifies 29 active direct combustion facilities, 59 landfill gas-to-energy facilities, 23 animal and food waste digesters, and 115 biogas producing wastewater treatment plants.

Identified facilities were surveyed to obtain information on current operating status, management, technical performance, permitting requirements, emissions and environmental controls, financing, costs, and overall economic performance. Information from the surveys was compiled into a database and is accessible through the Collaborative website. A principal objective of creating a centralized database of information was to improve understanding of benefits derived from biopower in the state and the potential for increasing the future amount of renewable energy from this source. The survey process also identified a number of discrepancies in existing databases and other information sources, pointing to the need for improved reporting standards and quality assurance. This is likely to emerge as an important issue for renewable facility reporting in association with the state's renewable portfolio standard (RPS).

Survey Goals:

The survey effort had two principal goals:

1. Characterize the existing biomass power industry throughout California by identifying particular strengths and weaknesses, quantifying benefits and costs, and providing information useful to stakeholders and policymakers in examining ways of strengthening the industry and improving the management of biomass resources.
2. Establish a baseline against which future progress could be measured.

Survey Scope:

The survey solicited information in the following categories:

- Resources, fuel, or feedstock types, quantities, and characteristics,
- Processing and conversion technology design and performance,
- Environmental controls and emissions
- Economic performance
- Social impacts

Initial surveys were comprehensive in scope. Concerns expressed by industry participants, especially regarding reporting of environmental and economic information considered to be proprietary, led to subsequent modifications in the survey design in an effort to increase response rate.

2. Survey of biomass power generation in California

2.1 Biomass energy conversion pathways

Separate surveys were prepared for facilities within each of the three major biomass conversion pathways, including:

Thermochemical conversion: Combustion, thermal gasification, and pyrolysis are classified as thermochemical conversion techniques which generally occur at elevated temperatures. Products include heat, fuel gases, synthesis gases, ammonia, hydrogen, alcohols, other liquids, and solids. Thermochemical techniques tend to be higher rate than biochemical processes, but have different selectivity for products. Byproducts include ash, chars, and liquid effluents for disposal or recovery as new products. Biomass direct combustion facilities are included under this category. No commercially operating biomass gasification or pyrolysis facilities were identified in the state.

Biochemical conversion: Conversion systems using biological processes include fermentation to produce alcohols, fuel gases (such as biomethane by anaerobic digestion), acids and other chemicals, and aerobic processes used for waste stabilization and composting. Byproducts include organic solids and liquid effluents. Where feedstocks are uncontaminated by heavy metals or other toxic compounds not degraded by the process, byproducts can be recovered as commercial products for uses including animal feeds, fertilizers, and soil amendments. Animal waste and municipal waste water digestion facilities fall under this category, as do landfill gas to energy (LFGTE) facilities.

Physicochemical conversion: Among the physicochemical methods are alkaline and acid processes, esterification, steam and ammonia freeze explosion and other explosive decompression processes, and pressing and extrusion, many times in combination with a biochemical or thermochemical reaction process. A major new industry is developing around vegetable and waste oils to manufacture biodiesel as a substitute diesel engine fuel. Although biodiesel facilities exist in the state, they are not included in this report because they do not generally produce power directly.

2.2 Bioenergy facilities databases

A number of biomass-to-energy conversion facility databases provided reference points in the current assessment of biomass power generation in California. These databases are briefly described below.

CEC 2004 Power Plant Database

The power plant database contains information on all 100 kW (0.1 MW) or larger power plants in California, including both renewable (such as biomass) and non-renewable (fossil fueled) energy generation. The database information includes plant name, facility type, fuel categories, conversion technology, equipment power rating, online megawatt, county, owner, and operator. The current database (as of July 1, 2004) contains 964 power plants where about 10% are classified in the biomass category (direct combustion, landfill gas, animal waste digester, and sewage digester plants).

Website: http://www.energy.ca.gov/database/index.html#powerplants

EIA - 767 Annual Steam-Electric Plant Data Files

The data in the EIA-767 database are obtained from Form EIA-767 "Steam-Electric Plant Operation Design Report" which is required for power plant operators. The data file includes the annual data from organic-fueled or combustible renewable steam-electric plants with a generator nameplate rating of 10 or more megawatts located nationwide. It contains data on plant operations and equipment design including boilers, generators, cooling systems, flue gas desulfurization, flue gas particulate collectors, and stacks. Not all of these data, however, are available for all plants in the database. Steam-electric plants with capacity of 10 to less than 100 MW, which is the range for most large-scale biomass power plants, are not obligated to provide certain data such as annual byproduct disposition and thermal output, financial information, air emission standards, design parameters, generator information, cooling system information, and stack and flue information. The set of data available for less than 100 MW power plants include the plant identification and configuration, fuel consumption and quality including fuel heating value, nitrogen oxide emission controls, mercury emission controls, flue gas particulate collector information, and flue gas desulfurization unit information.

Website: http://www.eia.doe.gov/cneaf/electricity/page/eia767.html

LMOP Landfill Database

The US EPA website described the Landfill Methane Outreach Program (LMOP) as a "voluntary assistance and partnership program that promotes the use of landfill gas as a renewable, green energy source." The program supports the development of landfill gas energy projects to mitigate emissions of methane and help protect the environment. The LMOP database lists the operational, under construction, and planned landfill gas utilization projects. The data file contains the landfill name, location (City, County, and State), landfill status (wastes in place and closures), project operation status, landfill gas energy utilization type, and MW capacity among other information.

Website of EPA LMOP: http://www.epa.gov/lmop/

Website of LMOP Landfill Database: http://www.epa.gov/lmop/proj/index.htm

CEC Database for Landfill Gas to Energy in California

The California Energy Commission maintains a landfill gas database associated with the Solid Wastes Information System (SWIS) which will be described below. The CEC landfill gas database provides information on total landfills in California, existing landfill gas to energy projects, and landfills with flaring, venting or without control on landfill gas. The database website also provides maps for landfill gas to energy in California.

Website: http://www.energy.ca.gov/pier/renewable/biomass/landfill/data.html

Solid Waste Information System (SWIS)

The Solid Waste Information System (SWIS) is maintained by the California Integrated Waste Management Board (CIWMB). It contains information on solid waste facilities, operations, and disposal sites throughout California. Information includes the name, location, owner, operator, facility type, operational status, authorized waste type and local enforcement agency for each facility that covers landfills, transfer stations, material recovery facilities, composting sites, transformation facilities, waste tire sites, and closed disposal sites.

Website: http://www.ciwmb.ca.gov/SWIS/

CEC Data for Anaerobic Digestion

The renewables program area of the Public Interest Energy Research (PIER) program of CEC maintains accessible data on anaerobic digestion in its website. Available data files include the biogas potential from animal wastes in California, which is a listing of California dairies by county as provided by the California Department of Food and Agriculture. Another data file provides the biogas potential from sewage wastewater treatment plants which includes the total sewage wastewater treatment plants in California given by the US EPA Region IX. Maps of these biogas plants are also available.

Website:
http://www.energy.ca.gov/pier/renewable/biomass/anaerobic_digestion/data.html

There are other state programs and databases from various sources that were reviewed and used in the current assessment. Some of these are mentioned in the discussion section and some are described in Section 3.7.

2.3 Survey methodology

All those identified facilities were requested to provide information on location, facility contacts, business operations, facility operations, and economic performance. For facilities that convert biomass directly into heat using direct-fire or boiler type technology, a thermochemical survey form was designed as noted above. Along with the operating information requested of all types of facilities, specific thermochemical information on the burner/grate design, manufacturers, air pollution controls and emissions, and supplemental fuels was also requested. A biochemical survey form was sent to bioconversion facilities. All these identified use anaerobic digestion to produce biogas or landfill gas that is subsequently used to power an engine- or turbine-generator set. Facilities in this class were all of the landfill-gas-to-energy, animal-waste-digester-gas-to-energy, and sewage-digester-gas-to-energy types. The survey requested information on digester or fermentation system design and other information similar to that addressed in the thermochemical facility survey. A third survey form, physicochemical, was created for facilities that convert biomass directly into biodiesel or pretreat biomass for ethanol fermentation and other types of fuel oils or liquids.

Surveys were initially sent to known facilities during November 2003. Accompanying the surveys were letters of introduction and postage-paid, self-addressed envelopes for the return of the surveys. Follow-up letters and e-mails were sent to many of the facilities during December, 2003 offering assistance in survey completion and return. As additional facilities were identified, surveys were sent and phone calls made.

2.4 Modifications and Second Survey

Concerns over the proprietary nature of some of the data requested resulted in a rejection of the survey by the direct combustion sector. In consultation with the industry, the survey was redesigned and issued through the California Biomass Energy Alliance. Eight direct-combustion facilities responded directly and remaining facilities were contacted by phone with additional surveys mailed or sent electronically in November, 2004. Results to-date is shown in Table 1.

Table 1

Response rates of surveys

Facility Type	Total Number Identified	Number of responses to **initial** survey	Follow-up after initial survey			Survey Response Rates		
			Facilities contacted	Surveys Sent	Surveys Declined	Number	Fraction of sent (%)	Fraction of Total Industry (%)
Direct combustion	32	0	29	20	2	8	40	25
Landfill gas to energy	59	7	59	44	2	18	40.9	30.5
Wastewater treatment plant	115	7	30	22	0	16	72.7	13.9
Animal waste digester	23	7	11	11	0	8	72.7	34.8
Total	229	21	129	97	4	50	51.5	21.8

Contact data for the mailing of the surveys were obtained from the sources mentioned in Section 2.2. By contacting many of the facilities the contact lists were updated and expanded. Follow-up contacts continue to yield more current plant data and contact information. A summary from the database of currently identified biomass facilities is included in the appendix.

3. Results: Current Status of Biomass Power Generation Technologies in California

3.1 Current status across facility categories

Within the thermochemical category, only direct-combustion power plants are known to be operating on a commercial basis. These facilities use a variety of combustion technologies including bubbling fluidized beds, circulating fluidized beds, fixed or traveling grates, and suspension fired technology. Biomass fuel energy inputs range from 46 to 460 MMBtu/h (13.5 – 135 MWt). The net electric power production of individual facilities ranges from 5 MW_e to 50 MW_e. Maximum capacity is so-far limited by additional licensing requirements for 50 MW_e and beyond.

Landfill-gas-to-energy plants, animal-waste-digester-gas-to-energy plants, and sewage-digester-gas-to-energy plants, for the most part, generate electricity by burning the gas produced from an anaerobic process. Landfills produce gas (40-60% methane) through the anaerobic decomposition of the organic component of wastes placed in the landfill. Wastewater treatment plants process sewage sludge in anaerobic digesters, and confined-animal-facilities such as dairies collect manure for processing in anaerobic digesters to produce biogas.

Biogas and landfill gas are mostly used in internal-combustion engine and generator-sets for conversion into mechanical and electrical energy. Gas turbines and boilers are also used. Some plants use additional biogas for on-site process heating and others send the gas to off-site users. Many of the facilities supplement their electrical generation by using natural gas, but only in small percentages and on an as-needed basis. Fifty nine landfill gas to energy plants range in size from 0.3 to 52 MW with an average size of 5.1 MW. The seven facilities reporting as animal-waste-gas-to-energy plants are ranging from 85 kW to 1850 kW. The 17 sewage-gas-to-energy plants range in size from 75 kW to 13 MW, with an average of 3.6 MW. A number of dairy waste digesters have recently started up under the CEC dairy power production program, with the list detailed in Section 3.4.

The number of each facility category and the relative distribution with respect to total is shown in Figure 1. Figure 2 shows the relative proportion of gross generating capacity of these facilities.

Figure 3 is a similar plot of biobased power generation in California with data obtained from 2004 CEC database for comparison purposes.

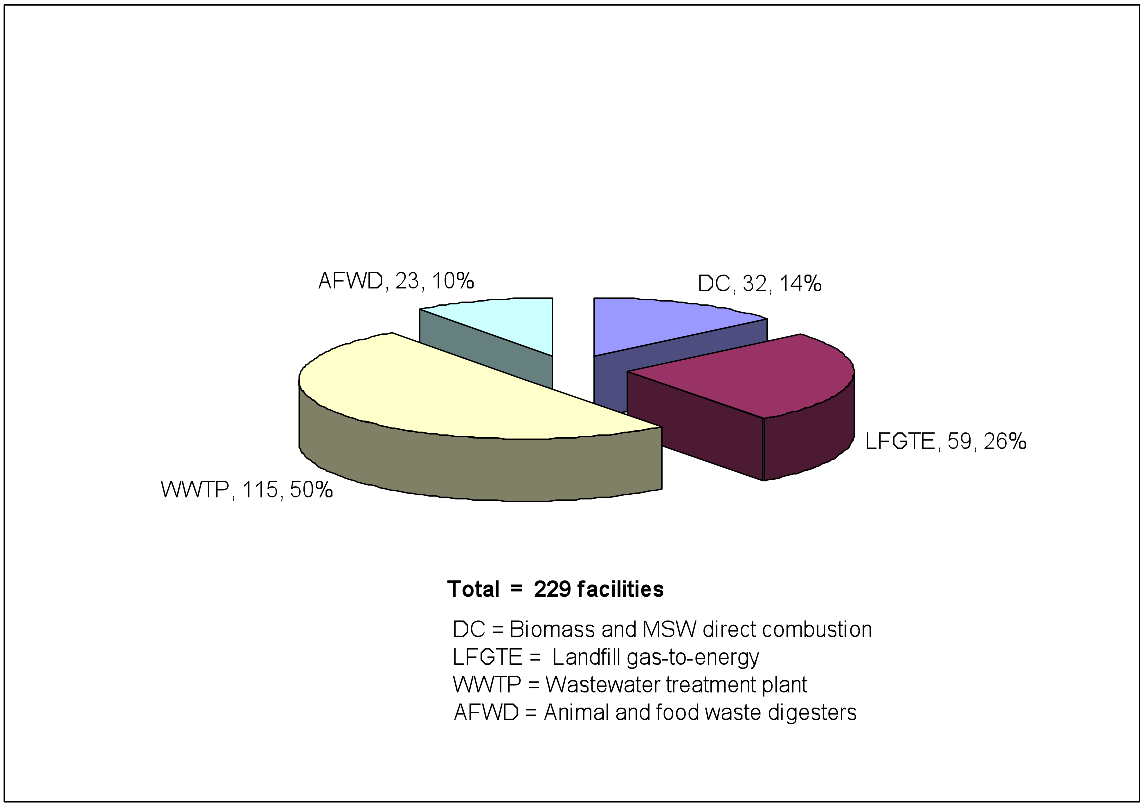

Figure 1. Number and proportion of biomass to energy facilities

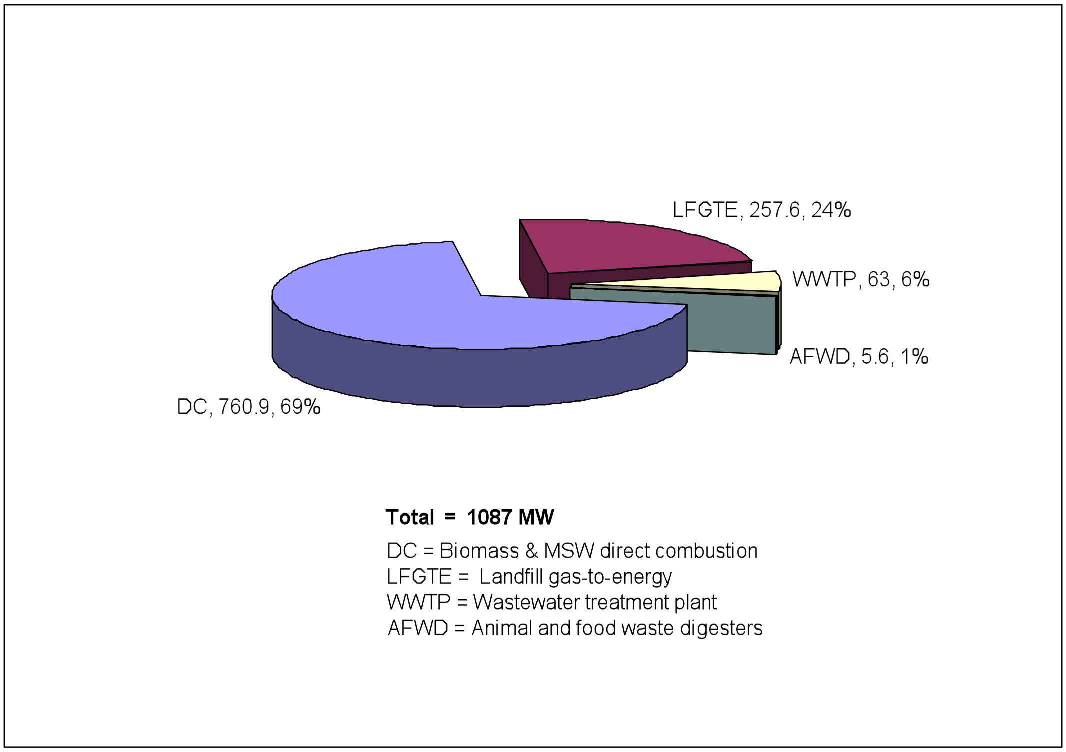

Figure 2. Aggregate generating capacity of identified biomass facilities.

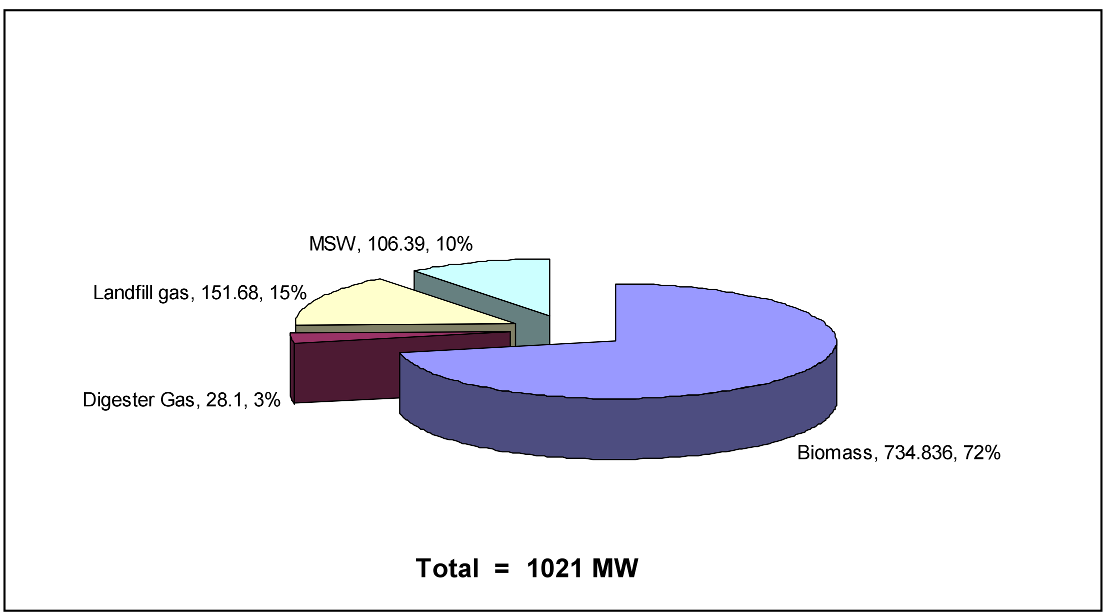

Figure 3. Biobased power generation in California from CEC 2004 power plant database.

3.2 Direct Combustion Facilities

Biomass and municipal solid wastes are two accepted terms for general fuel classifications in the direct combustion industry. Biomass direct combustion facilities generally refer to a power generation group that uses urban, mill and forest woodwastes, agricultural wastes such as orchard pruning and fruit and nut shells, and other woody industrial byproducts. Municipal solid wastes or MSW combustion facilities, on the other hand, use materials commonly known as garbage and defined by the US EPA as durable goods such as appliances, tires, batteries, nondurable goods, containers and packaging, food wastes, yard trimmings, and miscellaneous organic wastes from residential, commercial, and industrial non-process sources. The 2004 CEC power plants database used the term biomass as a general fuel category for facilities that use agricultural, wood, and animal wastes for high temperature thermochemical waste to energy conversion. The same database used MSW as a general category for facilities that use municipal solid wastes for steam turbine, landfill gas, or digester gas for electricity generation. The rest of the discussion in this section will follow these distinctions when referring to biomass direct combustion and MSW combustion.

3.2.1 Units, capacity, and technology and equipment.

The number of operating biomass direct combustion power plants has been declining in recent years and currently stands at 28, although at the time of the initial survey 29 were active. These 28 active power plants were identified through the CBEA (Reese, 2004). Two more power plants, which were identified by CBEA as inactive, were added in the list for analysis and comparison purposes (as will be shown in Section 3.2.3) since their data were available from the EIA database. In comparison, CEC's (2004) power plants database listed 34 biomass direct combustion facilities while Morris (2002 and 2003 reports) reported 35 operating power plants. The number peaked at 60 facilities in the early 1990s but for mostly economic reasons many of the plants have been dismantled, converted to fossil fuel, or are now idle. The gross generating capacity ranges from 5 to 55 MW_e with total generating capacity of around 691 MW and exporting approximately 579 MWe to the grid. This capacity is higher than the latest (July 2004) CBEA estimate due to differences in values between CBEA data and the survey responses. Actual generation data from the California ISO has been requested for facilities providing authorization in order to further evaluate delivered capacity. All respondents reported higher capacity than listed in the CBEA database. The capacity figure is also slightly lower than the total online capacity listed in the CEC's 2004 database due to variations in recorded capacity and identification of active plants.

Direct combustion facilities generate electricity based on the Rankine cycle utilizing steam boilers, combustors of different designs, and steam turbines with options to operate in combined heat and power mode (cogeneration). For the 8 returned surveys, 2 are fluidized bed, 1 is a traveling grate type, and the rest use fixed grates. Five plants operate in combined heat and power mode. In comparison, the 2004 CEC power plants database showed that 82 % (28 out of 34) of biomass direct combustion power plants reported using steam turbine technology. Out of 28, 2 indicated using circulating fluidized bed (cfb), 3 using fixed grate, and 1 traveling grate. One out of 34 reported operating fuel cell gasification. Furthermore, about 62% of 34 biomass facilities were identified as a cogen (CEC, 2004c).

Combustion of municipal solid wastes reduces the amount of waste by up to 90% by volume and 75% by weight (EPA, 2005) and provides the opportunity of recovering the energy products such as steam or electricity. MSW combustion with energy recovery is also referred to as waste-to-energy (WTE) combustion facilities. In California, there are three identified WTE combustion facilities with total gross generating capacity of 70 MWe and export approximately 62 MWe to the grid. All three facilities use moving grates in waterwall furnaces. In these systems, wastes are dropped from the feed chute and pushed by hydraulic rams into the combustion area. Moving grates push the burning refuse through the boiler. One facility uses two 400-ton/day waterwall furnaces with Martin reverse-reciprocating grates and ash handling system.

Combining the biomass and municipal solid wastes direct combustion facilities results to total number of active facilities to 31 and total generating capacity of approximately 761 MWe. The locations of biomass and municipal solid wastes direct combustion power plants are shown in Figure 4.

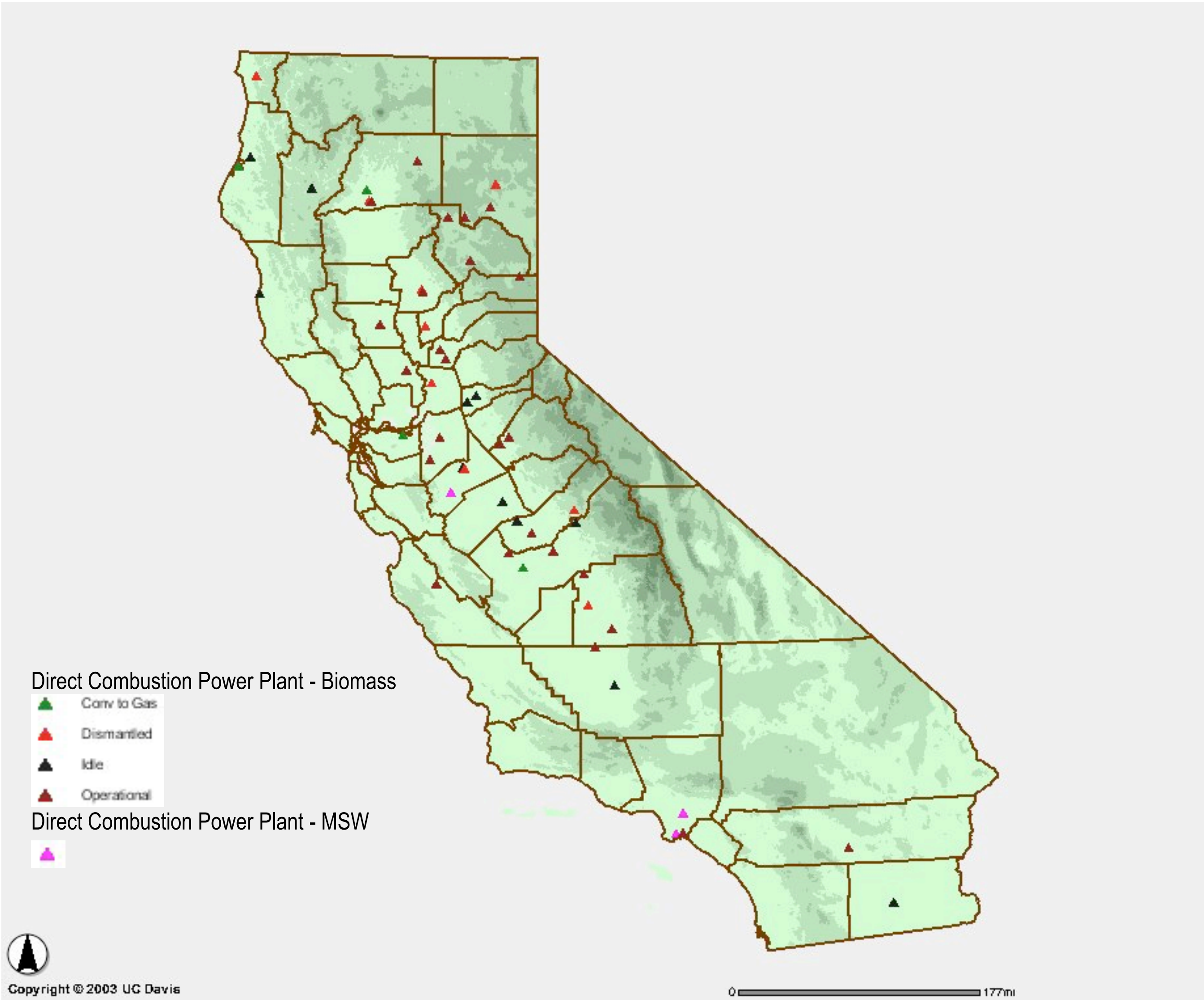

Figure 4. Distribution of direct combustion facilities in California.

3.2.2 Survey Response Rate

No response was received to the first survey effort from the direct combustion facilities. Discussions with industry representatives indicated that operators felt the survey was too detailed, requested proprietary information that if published would jeopardize their competitive status or lead to unfair public opposition, and duplicated existing reports filed with EIA. Although several questions of the survey did request information redundant to EIA reports, the majority of the requested detail is not available from that source. A second survey was designed in consultation with the industry and sent under the auspices of the industry association (CBEA). The CBEA effort resulted in only eight surveys returned. Phone contact was made with each facility that had not yet returned a survey form. Two facilities declined to respond. Responses remain pending from the rest. Information on all non-responsive facilities was extracted from various published databases and web-sites and is therefore subject to greater uncertainty, especially since a number of discrepancies can be identified in existing records. Efforts are continuing to identify a survey instrument to which the industry feels comfortable responding. There is no current state reporting requirement for biomass power facilities except for those participating through the RPS. EIA data for California biomass power plants, all of which are under 100 MWe, are insufficient to fully characterize facility performance and benefits.

3.2.3 Technical Performance

Direct combustion facilities contribute the largest fraction of electrical energy generated from biomass. The maximum achievable annual electrical generation from the operating biomass combustion power plants is 6,052 GWh assuming 100% capacity factor. This energy production is 75% of the total calculated energy generated from all biomass sectors. These power plants, however, do not operate 100% of the time at full capacity (there may also be occasions in which actual generation exceeds rated capacity for individual plants) due to scheduled and unscheduled maintenance that require shutdown, and curtailment when peak output is not required or not economic to generate. The availability values reported by survey respondents ranged from 75 to 97%. Availability factor is the ratio of the total number of hours that the plant is actually generating electricity in a year to the number of hours in one year. Using the average availability of 92% and total net generating capacity, these power plants should supply close to 4,700 GWh of electricity to the grid, or 78% of maximum achievable. Actual data are so far not available. The annualized capacity factor can also be used to assess the technical performance of power plants. It is defined as the amount of energy produced in a year divided by the potential amount of energy that could be produced if the plant ran the entire year at the rated power capacity. The facilities that responded to the survey reported annualized capacity factors ranging from 46 to 100%. These values can be checked against the power rating of the generation equipment and the reported gross capacity and number of hours of operation in a year.

Table 2 lists the generating capacity, annual fuel consumption, and delivered energy of individual biomass direct combustion facilities. The Table compares the fuel consumption from survey responses and data available from EIA databases 906 and F767 steam-electric plant database (EIA, 2004). It should be mentioned that attempts were made to contact all facilities but were able to send surveys to only 20 facilities due to non-response or formally declining the survey. Reported data on generating capacity and fuel usage from eight responding facilities are included in this Table. Table 2 also compares the energy delivered data, which refers to the estimated net energy exported to the grid, from estimated value using CBEA net MW estimate and 85% availability and those from EIA and EPA eGrid2000 databases. Further, this Table includes two other facilities which were identified by CBEA as idle but are included in the most recent EIA database.

Table 2
Operating biomass combustion power plants in California.

Plant Name	County	CBEA Estimate		Survey Response		Annual Fuel Usage (BDT)**				Electrical Energy Delivered (GWh/year)		
		Gross MW	Net MW	Gross MW	Net MW	Survey Response	EIA 767 (2002)	EIA 767 (2003)	EIA-906 (2002)	Estimated*	Source: EIA-906 (2002)	US EPA eGRID (2000)
Delano Energy	Kern	56	50	-	-	NR	292,400	371,400	295,864	372.3	354.5	255.9
Wheelabrator Shasta	Shasta	55	50	-	-	NR	826,800	730,500	478,820	372.3	429.9	338.6
Colmac Energy	Riverside	52	47	53	47	312500	258,000	292,000	91,479	350.0	304.1	381.3
Burney Forest Power	Shasta	35	31	-	-	NR	235,000	124,000	220,937	230.8	215.5	222.1
Honey Lale Power Plant	Lassen	33	30	-	-	NR	160,700	199,000	157,810	223.4	197.8	161.8
Woodland Biomass	Yolo	28	25	29	25	190000	171,900	135,900	171,758	186.2	167.7	171.5
Madera	Madera	28	25	-	-	NR	-	-	-	186.2	-	-
Mendota Biomass	Fresno	28	25	-	-	NR	157,000	187,100	-	186.2	-	168
Rio Bravo Fresno	Fresno	28	25	-	-	NR	201,000	192,500	200,020	186.2	179.0	140.2
Rio Bravo Rocklin	Placer	28	25	-	-	NR	177,000	182,000	175,971	186.2	170.7	163.4
Chinese Station	Tuolumne	27.5	25	-	-	NR	150,400	153,700	150,409	186.2	126.7	122.6
Pacific Lumber	Humboldt	27.5	19	-	-	NR	550,100	375,000	441,296	141.5	185.5	156.5
SPI Quincy	Plumas	14	12.5	27.5	20	237048	250,000	237,000	145,495	93.1	192.5	191.6
Wadham Energy (Williams)	Colusa	27.5	25	-	-	NR	201,000	181,000	200,973	186.2	175.0	174.7
Fairhaven Power	Humboldt	21	17.5	-	-	NR	248,300	220,900	248,224	130.3	95.2	118
Tracy Biomass	San Joaquin	20.3	18.5	-	-	NR	151,000	163,500	150,456	137.8	131.6	157.3
SPI Burney	Shasta	11	9.5	20	14	144000	145,000	150,000	81,829	70.7	116.5	95.9
SPI Loyalton	Sierra	11	10	20	10	88941	98,000	94,000	-	74.5	-	124.3
Pacific Oroville Power	Butte	20	18	-	-	NR	143,200	147,600	148,217	134.0	119.4	76.9
Soledad	Monterey	15	13.5	-	-	NR	-	-	-	100.5	-	-
Collins Pine	Plumas	13.3	12	-	-	NR	37,100	-	-	89.4	-	48.6
Mt. Lassen Power (Westwood)	Lassen	13.3	12	-	-	NR	84,600	92,600	84,478	89.4	73.5	49.3
Dinuba	Tulare	13	11.5	-	-	NR	-	-	-	85.6	-	-
SPI Lincoln	Placer	6	5	13	3	240000	120,000	134,000	45,364	37.2	60.3	52
Burney Mt. Power	Shasta	11	10	-	-	NR	92,900	92,100	92,877	74.5	80.8	51.8
Sierra Power	Tulare	11	9.5	-	-	NR	-	-	75,001	70.7	65.5	-
SPI Sonora	Tuolumne	4	3.5	6.5	2	76751	-	-	29,092	26.1	46.2	10.2
SPI Anderson	Shasta			5.5	1	59193	-	-	12,430	7.4	39.3	37.8
Diamond Walnut	San Joaquin	5	4.5	-	-	NR	-	-	28,674	33.5	42.0	26.4
Stockton Pacific Cellulose	Humboldt	1	0	-	-	Not Sent	-	349300 (BL)	24,427	0.0	8.9	-
TOTAL										4247.9	3578.1	3497.0

NR=No Response
* Calculation based on 0.85 capacity factor, and Net MW (CBEA estimate)
BL is Black Liquor; see Stockton Pacific Cellulose (don't know what physical unit this is)
** Assumed BDT (is not clear in EIA reporting instructions).

Table 3 lists the three operating municipal solid waste-to-energy combustion facilities in California. The three facilities, which generate approximately 70 MWe, produce an estimated annual electrical energy of 521 GWh and supply to the grid about 465 GWh of electrical energy. However, not all of the energy contained in the fuel is from biomass as plastics and rubber also contribute. The annual energy generation was calculated from the generating capacities and availability factor of 85%.

Table 3

Operating municipal solid wastes-to-energy combustion facilities in California

Facility Name	County	Generating capacity (MW)		Estimated Annual electrical energy production (GWh)	
		Gross	Net	Gross	net to grid
Commerce Refuse-to-Energy Facility	Los Angeles	11.5	10	85.6	74.5
Southeast Resource Recovery Facility (SERRF)	Los Angeles	36	30	268.1	223.4
Stanislaus Resource Recovery Facility	Stanislaus	22.5	22.5	167.5	167.5
TOTAL		70	62.5	521.2	465.4

A summary of aggregated technical performance is given in Table 4. The estimated annual gross and net energy production from biomass direct combustion facilities are 5144 GWh and 4311 GWh, respectively, which were calculated using an availability factor of 85% and reported generating capacity where available, otherwise the CBEA estimate was used. The total estimated annual gross and net energy production from all biomass and municipal solid wastes combustion facilities are 5,665 GWh and 4,776 GWh, respectively. The availability factor used was slightly more conservative than the average from responses to the survey (92%), since not all facilities reported their availability factor. Only two facilities reported gross and net efficiencies. The values are 25% and 32.1% gross, and 22% - 26.7% net. For non-reporting facilities, gross and net efficiencies were calculated for different assumptions of capacity factor using the fuel supply information from the EIA database and the reported gross and net electricity generating capacity of each power plant. In comparison, Morris (2003) reported that in 2002, 35 biomass direct combustion power plants have a combined generating capacity of 635 MW with an annual energy generation of 4,400 GWh per year.

Table 4

Summary of capacity and annual energy production for direct combustion facilities.

Number of facilities	31
Total gross generating capacity (MW)	760.9
Total net (to grid) generating capacity (MW)	641.5
Annualized capacity factor (%, from 8 facilities)	46-100 (ave = 77)
Availability factor (%, from 7 facilities)	76-98 (ave = 93)
Gross efficiency (%, from 2facilities)	25-30.1 (ave = 28)
Net efficiency (%, from 2 facilities)	22-26.7 (ave = 24)
Estimated annual gross energy production (GWh)	5,665
Estimated annual net energy production (GWh)	4,777

Fuel supply radius for individual biomass direct combustion facilities was in some cases reported to be more than 120 miles. There is seasonality in the availability of some fuels such as agricultural prunings and wastes. Biomass materials used as fuels include clean urban woodwaste, sawmill residues and wastes, forest residues and thinings, orchard prunings and renewals, fruit and nut shells, pits, and seeds, land clearing materials, and woody industrial byproducts. In the survey, operators could respond by reporting tonnages of either specific fuel types or aggregate into in-forest, mill residue, agricultural, urban wood, and others. Seven out of eight respondents chose to report aggregated fuel use data. For the eight surveys received from direct combustion facilities, mill residue accounted for 40% of all biomass fuels used for power generation while agricultural biomass contributed 6% (Figure 5).

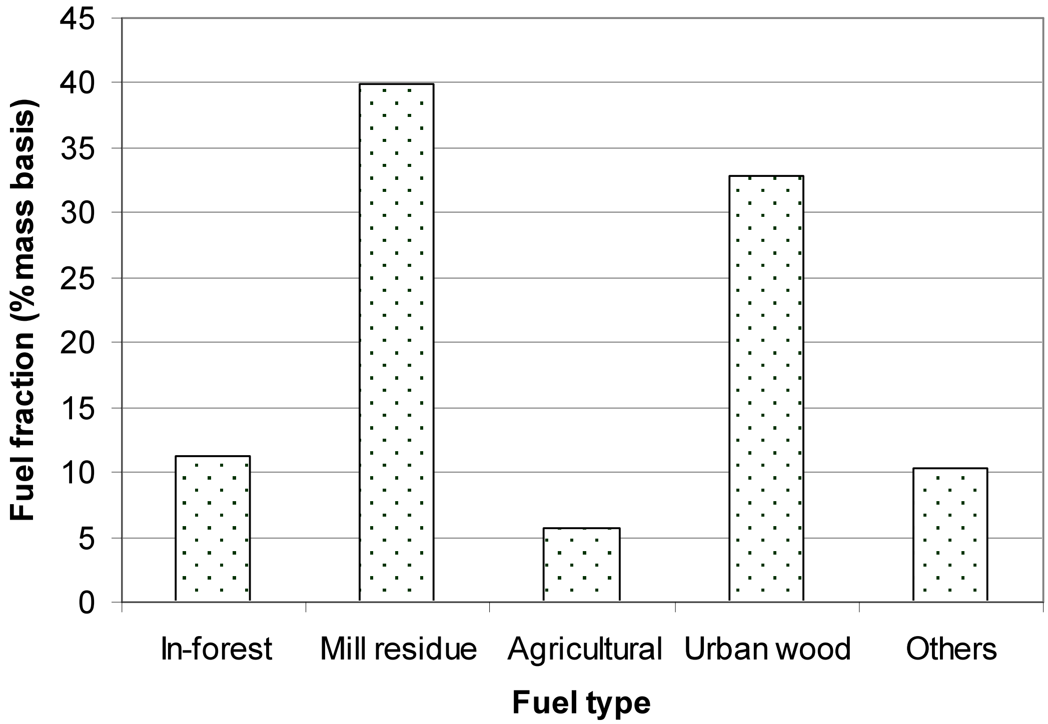

Figure 5. Types and relative quantity of biomass fuels used in power generation (n=8 facilities).

The seasonality of fuel use is depicted in Figure 6 which plots the monthly fuel mass and energy from biomass facilities in 2003. The data used to generate the graphs were from 25 biomass direct combustion facilities with available data from the EIA-767 database. The equivalent energy from the fuel was calculated using the monthly fuel consumption and the monthly heating values which were reported in the database as “as-burned” higher heating value in Btu per pound. In the database, fuel data are reported as consumption. However, still to be verified is whether the values reported are fuel received, in which case the low fuel amounts in the winter months are expected, or fuel burned. A number of facilities typically do not receive fuel during winter, instead building up supply on site during the summer and fall. Many facilities also typically shut down in November for maintenance.

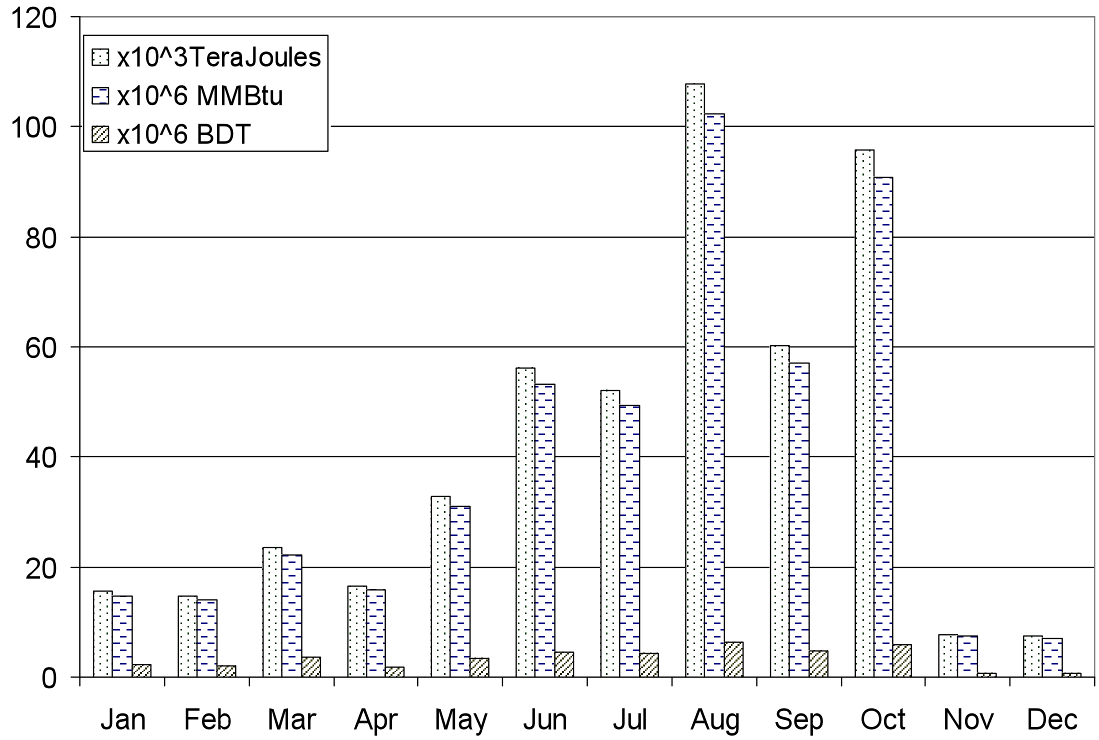

Figure 6. Monthly total fuel consumption of 25 direct combustion facilities (source: EIA F-767 2003 data).

3.2.4 Economic Performance

Power plant operators viewed questions of economic status as confidential. Only two out of eight responded to selected questions in the economic section of the survey, and then only to report the number of full time equivalent employees (FTE). One facility has 28 FTE and also reported generating about 500 jobs additional from selling byproducts such as flyash, sand, and gravel, but this numbers is still unverified. The other facility has 50 FTE. Considering the plants' generating capacities, 28 and 50 FTE generates about 1 job/MW. Contract type was provided for all facilities by CBEA. Economic performance is difficult to evaluate without actual data and can only be broadly estimated.

3.2.5 Environmental Performance

Seven out of eight facilities responding indicated they have local air permits and EPA/title V permits, 75% have wastewater permits and none has a solid waste permit (Table 5). A majority of respondents do no have mitigation controls for noise, odor and other public nuisance since they deem it not necessary, “we do not create any therefore do not need to mitigate” is a verbatim from one of the responses. One of the eight facilities responding are able to use flyash and bottom ash for beneficial uses such as soil amendments, road building products, composting additives, and soil stabilization products.

Table 5

Fraction of responding facilities with environmental permits (n=8)

	With	Without
Local air permits	88%	12%
EPA/Title V air permits	88%	12%
Wastewater permits	75%	25%
Solid waste permit	0%	100%
Noise mitigation controls	0%	100%
Odor mitigation controls	0%	100%
Other public nuisance mitigation controls	12%	88%

.

Data gathered from CARB and SCAQMD by subcontractor (DR Bates) in the initial survey phase showed that all facilities, including those that did not respond to the survey have one or more local air pollution control permits establishing emissions limits for criteria, and in some cases non-criteria, pollutants. The percentage of plants that have air pollution control equipment to control NOx, VOC, CO and SOx below permit levels and those that have permitted levels for certain criteria pollutants were obtained from these supplemental data and are shown in Table 6. Most are able to operate without specific SOx control due to the low sulfur content of the fuels used.

Table 6

Fraction of facilities (n=24) having pollutant controls and specified permit levels, by species

Category	Fraction of facilities (%)
Control NOx	93
Control VOC	2
Control CO	4
Control SOx	17
ROC permitted	59
CO permitted	85
NOx permitted	80
SOx permitted	54
PM permitted	91
Ammonia slip permitted	28

3.3 Landfill gas to energy

3.3.1 Units, capacity, and technology and equipment

Limited data on a number of landfill facilities in the State can be found from the EPA Landfill Methane Outreach Program (LMOP) database and the Solid Waste Inventory System (SWIS) database supported by CIWMB and CEC. The most recent and comprehensive published survey of LFGTE facilities in the state was completed by the CEC in 2001 (CEC, 2002). Landfills produce methane-rich gas from biomass waste decomposition. The gas naturally vents to the atmosphere if not specifically recovered for flaring or use. Landfill gas control is now required for most landfills. The SWIS database (CIWMB, 2004) identifies a total of 3505 landfills in California. The CEC's 2004 power plant database lists 28 active landfill- gas-to-energy (LFGTE) facilities from the overall list, although the CEC 2001 survey records 311 active landfills and identifies 51 landfill gas-to-energy facilities. The Collaborative initially listed 46 LFGTE facilities, a number later expanded to 59 based on updates from USEPA and SCS Engineers (Sullivan, 2004). Figure 7 shows the location of both active and planned landfill facilities converting gas to electricity or heat throughout the State of California. Forty-seven facilities have known electrical generating capacity, based on survey response and LMOP, which ranged from 0.3 MW to 52 MW. The total generating capacity using LMOP and survey data where available was 257 MWe. In comparison, the 2001 CEC survey listed a total generating capacity of 211

MWe from 51 landfill gas-to-energy facilities (CEC, 2002). The technology used to convert the energy from landfill gas into energy is still dominated by reciprocating engines. The types of conversion technology and the fraction of facilities using a particular technology, based on received responses, are shown in Figure 8. The conversion technology and capacity reported in the CEC 2001 database is shown in Figure 9.

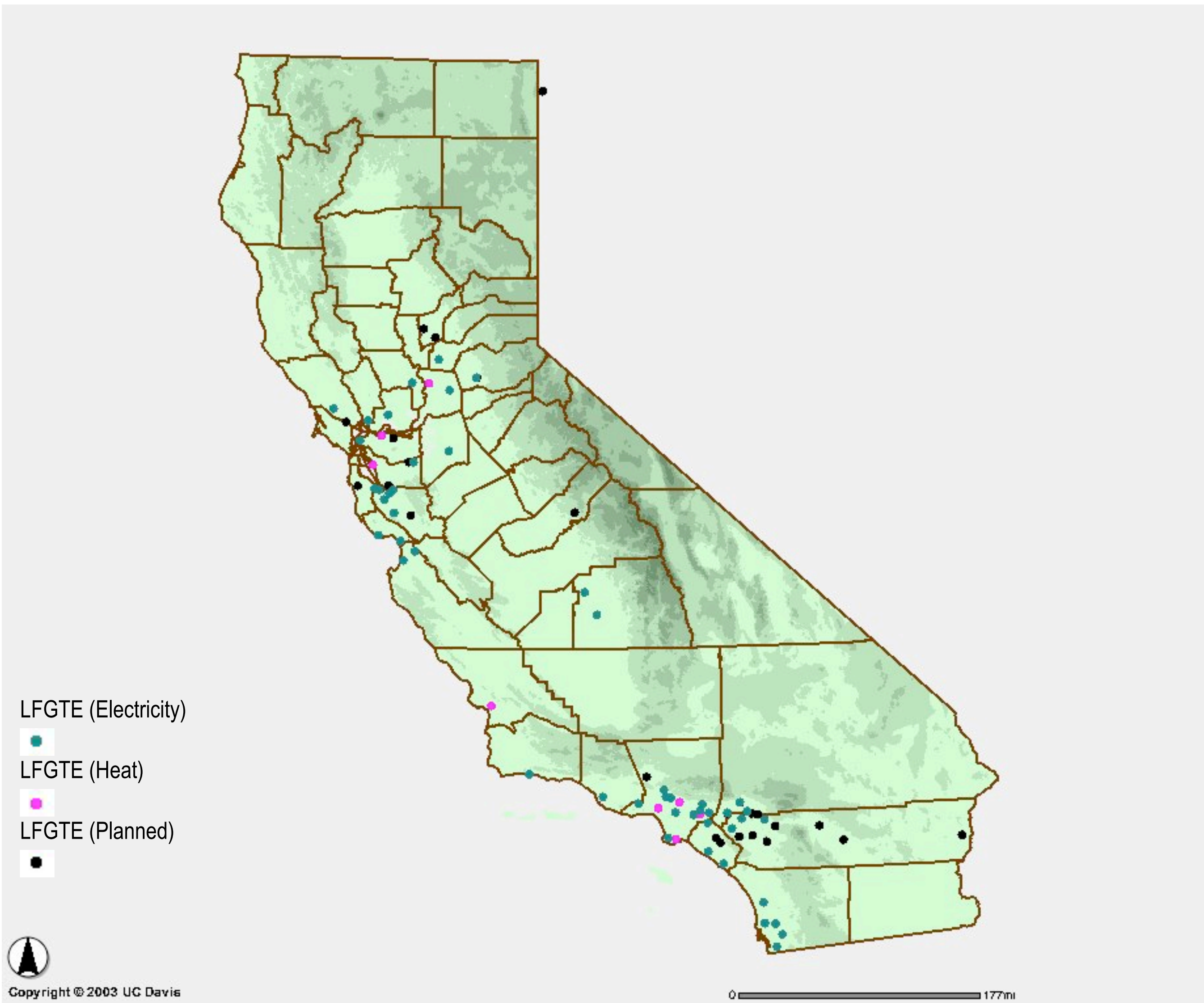

Figure 7. Distribution of LFGTE in California.

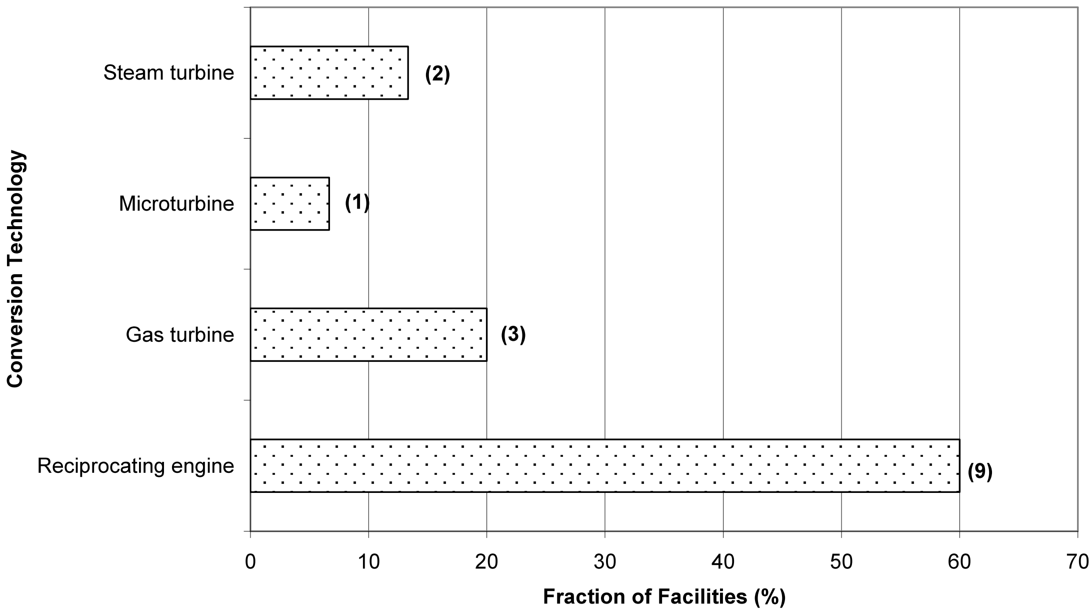

Figure 8. Landfill gas to energy facilities by conversion technology (number at end of bars indicate number of facilities; n=15).

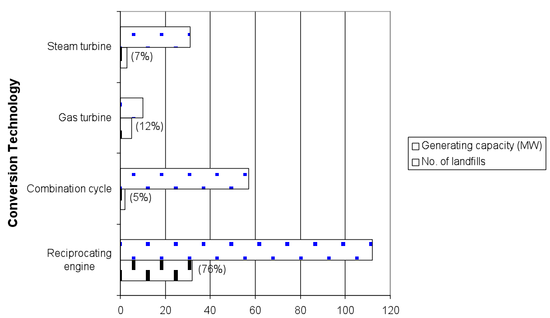

Figure 9. Landfill gas to energy facilities by conversion technology and generating capacity (data from CEC 2001 landfill survey).

3.3.2 Survey response rate

Seven out of the initial 46 facilities (15%) completed and returned the survey after the first mailing. After the initial mailing, the number of facilities was expanded to 59 as stated above. Follow-up phone calls were made to the other 52 facilities, and a modified survey was distributed based on feedback from operators. Overall (including the initial effort), attempts were made to contact all 59 facilities, 44 were sent the survey, 13 did not respond (did not return calls or could not be reached), while two facilities formally declined to participate in the survey. A total of 18 responses were received which is about 31% with respect to the total number of LFGTE facilities and 41% with respect to the number of surveys sent. Efforts are continuing to obtain survey responses from all remaining facilities.

3.3.3 Technical Performance

The current LMOP landfill database available from the EPA contained 80 operational LFGTE facilities generating electricity, 4 under construction, 14 have shutdown, 27 candidate and 212 potential LFGTE, for a total of 357 facilities in California. The combined generating capacity of operational LFGTE based on the same database is 288 MW. In the latest list prepared by USEPA and SCS Engineers (Sullivan, 2004), the number of operating LFGTE facilities in California was reduced to 59. Forty six out of 59 facilities have known quantity of generating capacity from survey and LMOP which totaled 258 MW. In comparison, the CEC 2004 power plant web-database contains 29 operating units with a generating capacity of 152 MW, fewer than included in the CEC 2001 survey (CEC, 2002). Availability, based on survey responses, ranged from 23% to 98%. The reported annualized capacity factor, on the other hand, ranged from 90% to 97% except from one facility that reported 1.11%. The calculated capacity factor for this facility is around 85% using the self-reported availability and generation equipment rated capacity. The availability and capacity factors as reported are inconsistent with each other and need further verification. Six facilities provided information on gross efficiency, five have a range of 28% to 36% and one reported 92%. The net efficiency from three responding facilities ranged from 26% to 33% in addition to one that reported net efficiency of 83%. These extreme values of reported efficiencies warrant further verification since the two responding facilities do not operate in combined heat and power mode. Facilities at the higher end of the gross efficiency range use reciprocating engines while the facility with 28% gross efficiency uses both a gas turbine and steam turbine for generation. The gross aggregate annual energy production from landfill facilities is estimated at 1805 GWh using the total generating capacity from the survey and LMOP data (for those without survey response) and availability of 80% averaged from five respondents, however this value is entirely speculative due to the limited response from this sector. The estimated annual energy generation from these facilities can increase to around 1918 GWh using the same total generating capacity and assumed average availability of 85% from all facilities. The estimated annual energy generation from each facility is shown in Table 7 while the summary of technical performance for all facilities is listed in Table 8. Net generating capacity and net annual energy were estimated using the average gross and net efficiencies and the total gross generating capacity.

Table 7

Generating capacity and energy for Landfill gas to Energy Plants

Facility Name	County of Facility	Gross generating capacity, from survey (MW)	Gross generating capacity, from LMOP (MW)	Estimated annual energy generation (GWh)
Acme Landfill	Contra Costa		2.2	16.4
All Purpose (aka Santa Clara)	Santa Clara	0.9	9	6.7
Altamont Landfill & Resource Recv`ry	Alameda	6	6	44.7
American Canyon Sanitary Landfill	Napa		1.5	11.2
Ascon Sanitary Landfill	Los Angeles			
Austin Road & Forward Lamdfills	San Joaquin			
Azusa Land Reclamation Co. Landfill	Los Angeles		3.2	23.8
Badlands Disposal Site	Riverside	1.2	1.1	8.9
Bailard Landfill	Ventura		1.7	12.7
Bradley East Landfill	Los Angeles		5.3	39.5
Buena Vista Drive Sanitary Landfill	Santa Cruz			
Burbank Landfill Site No. 3	Los Angeles		0.3	2.2
Calabasas Sanitary Landfill	Los Angeles		10.3	76.7
Central Disposal Site - Sonoma County Landfill	Sonoma	8	8	59.6
City of Palo Alto Refuse Disposal Site	Santa Clara		1	7.4
City Of Santa Cruz Sanitary Landfill	Santa Cruz	0.8	0.7	6.0
City Of Sunnyvale Landfill	Santa Clara	1.6	1.6	11.9
Cold Canyon Landfill Solid Waste DS	San Luis Obispo			
Colton Sanitary Landfill	San Bernardino		1.2	8.9
Corona Disposal Site	Riverside			
Coyote Canyon Sanitary Landfill	Orange		20	148.9
Crazy Horse Sanitary Landfill	Monterey	1.5	1.4	11.2
Davis Street Sanitary Landfill	Alameda			
Guadalupe Sanitary Landfill	Santa Clara		2.5	18.6
Industry Hills	Los Angeles		0.5	3.7
Jamacha Sanitary Landfill	San Diego		0.3	2.2
Kiefer Landfill Energy Plant	Sacramento	9	9.1	67.0
Lopez Canyon Sanitary Landfill	Los Angeles	7.6	6	56.6
Marsh Road Sanitary Landfill	San Mateo	2	2	14.9
Mid-Valley Sanitary Landfill	San Bernardino		2.5	18.6
Milliken Sanitary Landfill	San Bernardino		2.5	18.6
Miramar Sanitary Landfill	San Diego		10.3	76.7
Mission Canyon 4-8/Mt. Gate	Los Angeles			
MM West Covina LLC	Los Angeles	11		81.9
Monterey Regional Wst Mgmt DSt/Marina LF	Monterey		11.3	84.1
Newby Island Sanitary Landfill	Santa Clara		5.3	39.5
Olinda Alpha Sanitary Landfill	Orange	5.625	5.6	41.9
Otay Landfill	San Diego		3.7	27.6
Palos Verdes Landfill	Los Angeles		6	44.7
Penrose Pit	Los Angeles		4.5	33.5
Potrero Hills Landfill	Solano			
Prima Deshecha Sanitary Landfill	Orange	6	6	44.7
Puente Hills Landfill #6	Los Angeles		52.8	393.1
Sacramento City Landfill	Sacramento			
San Marcos Landfill	San Diego		1.5	11.2
Scholl Canyon Sanitary Landfill	Los Angeles			
Sheldon - Arleta Landfill	Los Angeles	2.3	2.3	17.1
Spadra Sanitary Landfill #2	Los Angeles		8.5	63.3
Sycamore Sanitary Landfill	San Diego		1.5	11.2
Tajiguas Sanitary Landfill	Santa Barbara		3	22.3
Tequesquite/Riverside	Riverside			
Toyon Canyon Park Reclamation Project	Los Angeles	4	4	29.8
Union Mine	El Dorado			0.0
Visalia Disposal Site	Tulare		19	141.5
West Contra Costa Landfill	Contra Costa		3	22.3
West Miramar Sanitary Landfill	San Diego			
Western Regional Landfill	Placer	1.6		11.9
Woodville Disposal Site	Tulare		0.6	4.5
Yolo County Central Landfill	Yolo		2.5	18.6
TOTAL		69.1	251.3	1918.3

Table 8
Capacity and annual energy production for landfill gas to energy facilities

Number of facilities	59
Total gross generating capacity (MW)	257.6
Estimated net (to grid) generating capacity (MW)	227.2
Annualized capacity factor (%, from 7 facilities)	93-97 (ave = 94)
Availability (%, from 9 facilities)	23-98 (ave = 80)
Gross efficiency (%, from 5 facilities)	28-36 (ave = 34)
Net efficiency (%, from 3 facilities)	26-33 (ave = 30)
Estimated annual gross energy production (GWh)	1918.3
Estimated annual net energy production (GWh)	1692.4

3.3.4 Economic Performance

Eight facilities, representing 53% of survey respondents and 21% of the total number of facilities that were contacted, provided information on selected economic questions. Out of eight, two provided cost information, six on current basis for sale of electricity although only two provided dollar figures, and six on number of full time equivalent employees. A majority of facility owners and operators view economic information as confidential. Both two facilities with cost data reported capital investments of $12 million in current dollars, which is about $1300/kW and $1500/kW considering their gross generating capacity. One facility reported the total generation cost at $0.03/kWh while the other at $2.9 million per year which is equivalent to around $0.05/kWh if divided by the estimated annual energy production. Facility operators recover the cost from long-term negotiated contracts with utilities. Two respondents listed the current negotiated price for the sale of electricity at $0.0537/kWh. One facility reported getting $54/MWh ($0.054/kWh) from the City office and claiming reimbursement of $14.70/MWh ($0.0147/kWh) from CEC as part of cost recovery.

3.3.5 Environmental Performance

Thirteen responding facilities reported having air pollution control permits from the local district. Ten out of 14 responding facilities indicated they also had USEPA Title V operating permit for air pollutants. Operating permits are required under Title V of the Clean Air Act Amendments of 1990 (40 CFR 70). Six out of 13 had local wastewater permits. Five out of six had waste discharge requirement permits and four out of seven had solid waste permits. The rest of the respondents did not provide complete responses to environmental information questions.

3.4 Animal and food waste digesters

3.4.1 Units, capacity, and technology and equipment

Confined animal feeding operations (CAFO) produce large amounts of manure which can be collected and treated in anaerobic digesters. Bacteria, operating in the absence of oxygen, break down a portion of the organic fraction of the manure and produce a biogas high in methane. The biogas can be used to generate electricity. Table 8 lists the 23 animal and food waste digesters considered in this assessment. The list includes the 14 dairy facilities which are involved in CEC's Dairy Power Production Program (DPPP), the Inland Empire Utility Agency project funded separately by CEC, and a food processing waste digester project which also received a CEC grant. Details about the DPPP and the grant recipients are available in literature (CEC, 2003; CEC, 2004a; Western United Resources Development, Inc, 2003). Five dairy facilities started up in 2004 under the DPPP and the remaining nine are scheduled to start in 2005, as is the food processing waste digester. The list also includes four swine facilities, Royal Farms 1 & 2, Sharp Enterprises, and Sharp Ranch. The latter two facilities are now closed but are included because they responded and provided data in the initial survey conducted in 2003. Royal Farms 1 and 2, on the other hand, still operate but on a limited scale. Based on the response from the operator, they can still generate around 20 kW of electricity out of 100 kW capacity. The initial survey sent questionnaires to 11 facilities. The effort identified five CAFO as having manure digesters with electrical production ranging from 85 to 1850 kW and a total generating capacity of 2.3 MW. By including the data obtained from other sources such as the DPPP, facility websites and survey, the capacity shown in Table 9 ranged from 30 to 1500 kW or a total capacity of at least 5.6 MW from all facilities. This capacity will increase to around 6.8 MW once Phase II of IEUA-RP5 becomes fully operational. In terms of biogas to energy conversion technology, survey respondents reported using reciprocating engines. However, there are also at least two facilities that are being developed to use microturbines for power generation. Locations of animal and food waste digesters are shown in Figure 10.

Table 9

Animal and food waste digester gas to energy plants

Facility Name	County	Bio-waste fuel Type	Status	Digester Type	Energy Generation equipment	Generating capacity (kW)
Van Ommering Dairy	San Diego	Dairy manure	In development	Plug flow		130[a]
Cottonwood Dairy (Gallo Cattle Company)	Merced	Dairy manure	Operational	Covered lagoon	Caterpillar ICE	300[a]
Blakes Landing Dairy (Straus Family Creamery)	Marin	Dairy manure	Operational	Covered lagoon		75[a]
Button Willow	Kern	Dairy manure		Covered lagoon		
Calif Polytechnic State University Dairy	San Luis Obispo	Dairy manure	In development	Covered lagoon	Capstone Microturbine	30[a]
Meadowbrook Dairy	San Bernardino	Dairy manure	Operational	Plug flow		160[a]
Koetsier Dairy	Tulare	Dairy manure	Operational	Plug flow	Caterpillar G342 engine	260[a]
Langerwerf Dairy	Butte	Dairy manure	Operational	Plug flow	Franklin generator	85
Laurenco Dairy	Tulare	Dairy manure	In development	Covered lagoon		150[a]
Castelanelli Bros. Dairy	San Joaquin	Dairy manure	Operational	Covered lagoon	Caterpillar G3406 ICE	160[a]
Royal Farms #1	Tulare	Swine manure	Limited Operation	Covered lagoon	Waukesha engine/Marathon generator	100
Royal Farms # 2	Tulare	Swine manure	Limited operation	Covered lagoon		100
Inland Empire Utilities Agency RP-1	San Bernardino	Dairy manure	Operational?? Idle?			250
Inland Empire Utilities Agency RP5 / Chino Desalter	San Bernardino	Dairy manure	Operational?? Idle??	Plug flow	Waukesha/VHP engine/Kato generator	500 (1250 in second phase)
Sharp Enterprises	Fresno	Swine manure	Closed	Covered lagoon	Waukesha engine/Marathon generator	100
Sharp Ranch	Tulare	Swine manure	Closed	Covered lagoon	Waukesha engine/Marathon generator	
Hilarides Dairy (Sierra Cattle Company)	Tulare	Dairy manure	In development	Covered lagoon		250[a]
Harmony Farms	Tulare	Dairy manure	In development	Covered lagoon		120[a]
Plane View Dairy	San Bernardino	Dairy manure	In development	Mixed		100[a]
Eden-Vale Dairy	Kings	Dairy manure	In development	Plug flow		150[a]
Bidart Dairy II	Kern	Dairy manure	In development	2-stage plug flow		1000[a]
Inland Empire Utilities Agency Phase II	San Bernardino	Manure & Food wastes	In development			1500
Valley Fig Growers	Fresno	Food processing wastes	In development	Heated-mixed	IngersollRand microturbine	70

[a] Data from Dairy Power Production Program (DPPP).

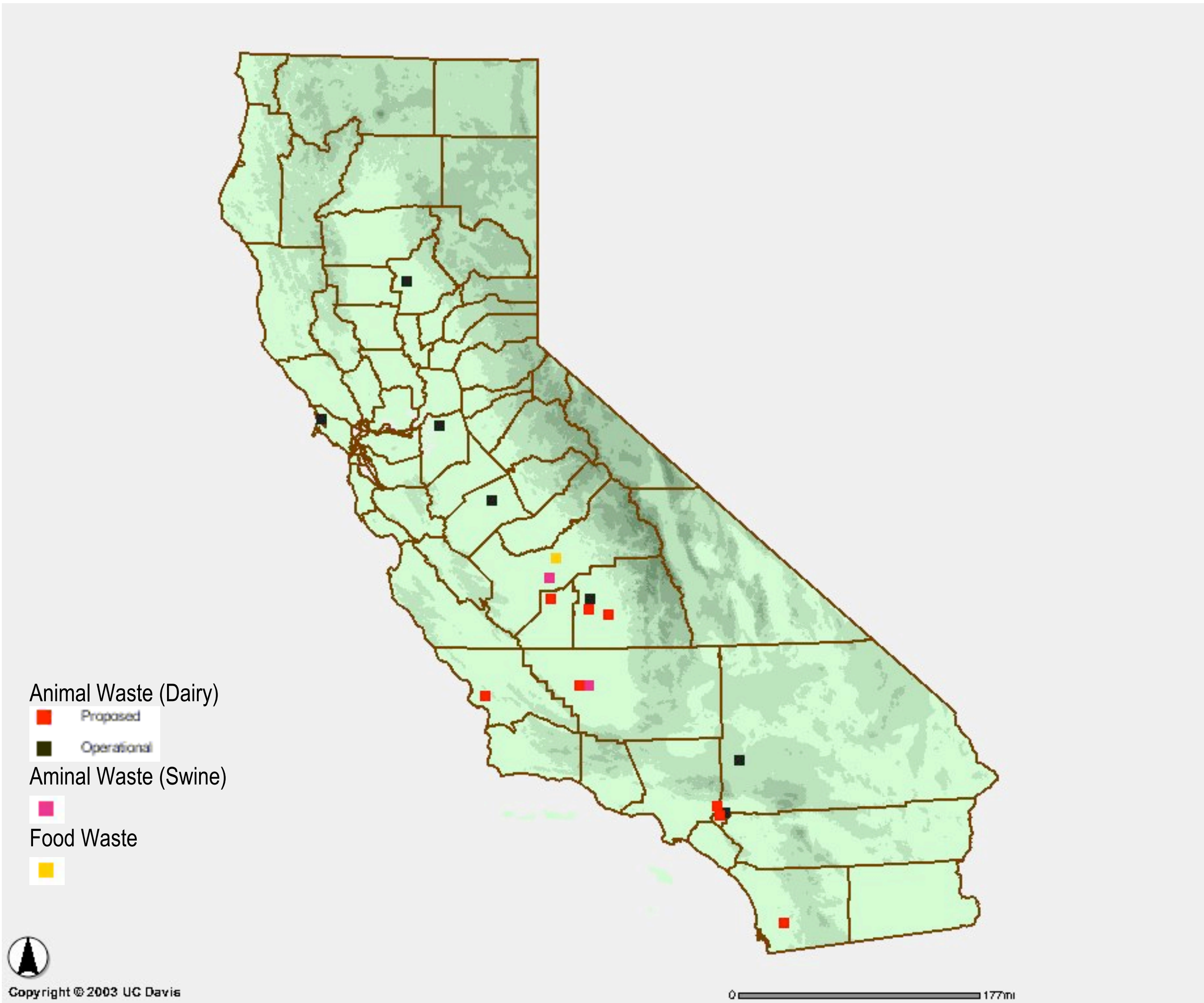

Figure 10. Locations of animal waste digesters in California.

3.4.2 Survey Response Rate

Ten out of the 23 facilities in the list are operational although only eight may be operating currently. The others are idle, under construction, or in development. So far, 11 facilities (48%) have been sent survey questionnaires. Efforts are continuing to establish communication and encourage the remaining facilities to participate in the survey. Eight of the eleven facilities, or

73% of surveys sent and 35% of total facilities, responded to the survey. Two of these responses are for facilities that are no longer operational.

3.4.3 Technical Performance

Data on annual electricity generation for each animal and food waste digester facility are given in Table 10, which provides both the annual electricity data as available from DPPP and the calculated annual energy generation based on 85% availability factor. A column in Table 10 shows the result of calculating for the availability factors of each facility using the generating capacity and annual electricity data from DPPP. The results of this calculation showed three facilities with availability of more than 100%, indicating a problem in some of the data. This result and the use of 85% availability factor make some data and estimates highly uncertain. Facilities are being contacted to confirm.

The total annual electricity generation as summed from all facilities is 28.2 GWh/y using the DPPP values and at an estimated value of 41.6 GWh/y if all facilities operate at least 7446 hours a year (85%). Excluding swine facilities that are either closed or in limited operation, the annual energy generation estimate declines to 39.4 GWh/y. These data on annual generation can be considered gross energy production estimates. There are no current data on net energy being exported by each facility to the grid which may happen only when the facility generates more electricity than they can consume. Examination of DPPP data showed that 8 out of 14 facilities (57%) can produce more electricity than they consume. However the total electricity consumption of all facilities is greater than the total generation capacity resulting in no surplus energy coming out of this sector, although there is substantial offset of demand. Net metering is available under AB 2228 (2002) for biogas facilities, adding to the economic benefit. The survey respondents provided only limited information on the annualized capacity factor, availability factor, and gross and net efficiencies. Two facilities reported operating at 96% availability, one reported 99% capacity factor, and one reported a net efficiency of 55% (Table 11). Additional follow-up is necessary to assess these values.

Table 10

Technical performance of animal and food waste digesters power generation.

Facility Name	County	Generating capacity (kW)[1]	Annual Electricity Generation, from DPPP (kWh/y)[2]	Annual energy generation, estimated (kWh)[3]	Availability (%)[4]
Van Ommering Dairy	San Diego	130	850,745	967980	74.7
Cottonwood Dairy (Gallo Cattle Company)	Merced	300	4456230	2,233,800	169.6[a]
Blakes Landing Dairy (Straus Family Creamery)	Marin	75	300,000	558,450	45.7
Button Willow	Kern			0	
Calif Polytechnic State University Dairy	San Luis Obispo	30	186,000	223,380	70.8
Meadowbrook Dairy	San Bernardino	160	1,163,647	1,191,360	83.0
Koetsier Dairy	Tulare	260	1,964,278	1,935,960	86.2
Langerwerf Dairy	Butte	85		632,910	
Laurenco Dairy	Tulare	150	1,176,000	1,116,900	89.5
Castelanelli Bros. Dairy	San Joaquin	160	1,077,338	1,191,360	76.9
Royal Farms #1	Tulare	100		744,600	96.0[b]
Royal Farms # 2	Tulare	100		744,600	96.0 [b]
Inland Empire Utilities Agency RP-1	San Bernardino	250		1,861,500	
Inland Empire Utilities Agency RP5 / Chino Desalter	San Bernardino	500		3,723,000	
Sharp Enterprises	Fresno	100		744,600	96.0 [b]
Sharp Ranch	Tulare			0	96.0 [b]
Hilarides Dairy (Sierra Cattle Company)	Tulare	250	5,319,072	1,861,500	242.9[a]
Harmony Farms	Tulare	120	800,000	893,520	76.1
Plane View Dairy	San Bernardino	100	889,200	744,600	101.5[a]
Eden-Vale Dairy	Kings	150	1,304,551	1,116,900	99.3
Bidart Dairy II	Kern	1000	8,760,000	7446,000	100.0
Inland Empire Utilities Agency Phase II	San Bernardino	1500		11,169,000	
Valley Fig Growers	Fresno	70		521,220	
Total		5,590	28,247,061	41,623,140	

[1]Data from Dairy Power Production Program (DPPP) except for Langerwerf Dairy, Royal Farms, Inland Empire Utilities Agency RP1 & RP5, and Sharp Enterprises.
[2]Data from California Energy Commission – DPPP
[3]Estimated/calculated using the generating capacity and availability factor of 85%
[4]Calculated based on DPPP annual electricity generation and generating capacity, except for Royal Farms, Sharp Enterprises, and Sharp Ranch
[a]Indicate need to correct and verify data
[b]Value provided by survey respondent

Table 11

Summary of technical performance

Type of facility	Animal & food waste digesters
Number of facilities	23
Total gross generating capacity (MW)	5.3
Total net generating capacity (MW)	na*
Annualized capacity factor (%)	99 (from 1 facility)
Availability (%,)	96 (from 3 facilities)
Gross efficiency (%)	na
Net efficiency (%)	55 (from 1 facility)
Estimated annual gross energy production (GWh)	41.6
Estimated annual net energy production (GWh)	na

*na – not available

3.4.4 Economic Performance

Survey responses on economic indicators are very limited, 4 out of 8 facilities provided few economic data. One respondent indicated capital investment for the construction of the power plant which includes the anaerobic digester and power generation equipment at $900/kWh, operating cost of $0.0075/kWh, and total generation cost of $131,000/year. This respondent applied the same economic values to all four facilities that his company operates. The facilities are now either closed or at limited operation and the data may not necessarily reflect well with the cost requirements of other animal waste digester facilities. In comparison, the estimated capital cost for dairy manure digesters and power generation facilities for participants in the Dairy Power Production Program ranged from about $1500 to $6000 per kW. Response from an actively operating dairy manure digester (which is not a participant in the present DPPP) showed an operations/maintenance cost of $5000/year or equivalent to $.008/kWh considering the estimated annual gross energy production. The same facility reported an annual capacity payment of $3600 and net of use sale of electricity at $0.05/kWh. Survey respondents indicated benefits from sale of electricity through Standard Offer (SO) #4, power purchase agreement and net metering.

3.4.5 Environmental Performance

With one exception, respondents do not have local air and wastewater permits. None of the respondents has an EPA/Title V permit or performs groundwater quality monitoring. No controls were reported for noise, odor, and other public nuisances, although the digesters are installed partly to control odor and environmental discharges. Air emissions from biogas fueled engines have been an issue of discussion and research is currently underway to quantify these. Environmental permitting and management practices for animal and food waste facilities in this assessment are governed by SJVAPCD proposed rules and SCAQMD rules as briefly noted in the following paragraphs.

San Joaquin Valley Air Pollution Control District (SJVAPCD)
SB 700 created new air pollution permit requirements for dairies. As of January 1, 2004, permits are required for dairies with emissions of volatile organic compounds (VOC) or oxides of nitrogen (NOx) greater than 12.5 tons per year. In addition, New Source Review Rule 2201 requires new or modified dairy operations to obtain an authority to construct (A/C) and apply best available control technology (BACT) if they will emit over 12.5 tons per year of VOC or NOx.

South Coast Air Quality Management District (SCAQMD)
Rule 1127 requires best management practices for livestock wastes to achieve emission reductions of VOC and ammonia (NH3). Dairy operations with more than 50 cows (defined) must remove the manure and take it to a manure processing operation. The manure can be processed in an anaerobic digester, windrow composting or in-vessel composting.

Both districts' actions are driven by a new state law (SB 700, 2003) which deleted the exemption for agricultural operations and equipment from local air pollution control authority.

3.5 Wastewater Treatment Facilities

3.5.1 Units, capacity, technology and equipment

Municipal wastewater treatment facilities often employ anaerobic digesters to stabilize a portion of the sewage sludge. The latest list from USEPA (Fondahl, 2004) contains 246 wastewater treatment facilities in California, 115 are known to use anaerobic digesters and generate biogas.

Eighteen out of 22 facilities that have been directly contacted and were identified as using the biogas for electricity generation are listed in Table 12. The generating capacity of these plants ranges in size from 120 kW to 13 MW. Total generating capacity is 63 MW. The majority of the responding facilities use reciprocating engines. Out of 13 responding facilities that indicated their prime mover, two were using microturbines, one with gas turbine, and the rest were using reciprocating engine. Locations of wastewater treatment facilities with biogas generation are shown in Figure 11.

Table 12

Sewage Digester gas to Energy Plants

Facility Name	MWe (Gross)	Prime Mover*	County
East Bay MUD Special District 1	4.3	Enterprise ICE	Alameda
Bakersfield Plant 3	0.25	Caterpillar G398	Kern
Bakersfield Plant 2	0.61	Waukasha 400 kW	Kern
Hyperion TP	13.37		Los Angeles
LACSD-JWPCP	22	Solar Mars GT	Los Angeles
Orange County Sanitation Dist. Plant 2	6.98		Orange
Riverside Regional WQCP	3.33	Caterpillar ICE	Riverside
Sacramento Regional WTP	2.83		Sacramento
San Francisco Oceanside WPCP	1	Waukesha F3521GL	San Francisco
City of Watsonville WWTP	0.6	Cooper ICE	Santa Cruz
IEUA Regional Recycling Plant No. 1	3.67	Waukesha ICE	San Bernardino
IEUA Regional Recycling Plant No. 2	0.58	Waukesha ICE	San Bernardino
Monterey Regional WPCA	1.16	WhiteSpence6 GTLB	Monterey
Santa Rosa, City of	2.4	Wankesha 7042 GL	Sonoma
Carmel Area WTP	0.12	Capstone MT	Monterey
Davis WWTP	0.075		Yolo
Hayward	0.298		Alameda
Yuba WTF	0.29	Capstone MT	Sutter
Total	63.863		

*ICE = internal combustion reciprocating engine; MT = microturbine; GT = gas turbine

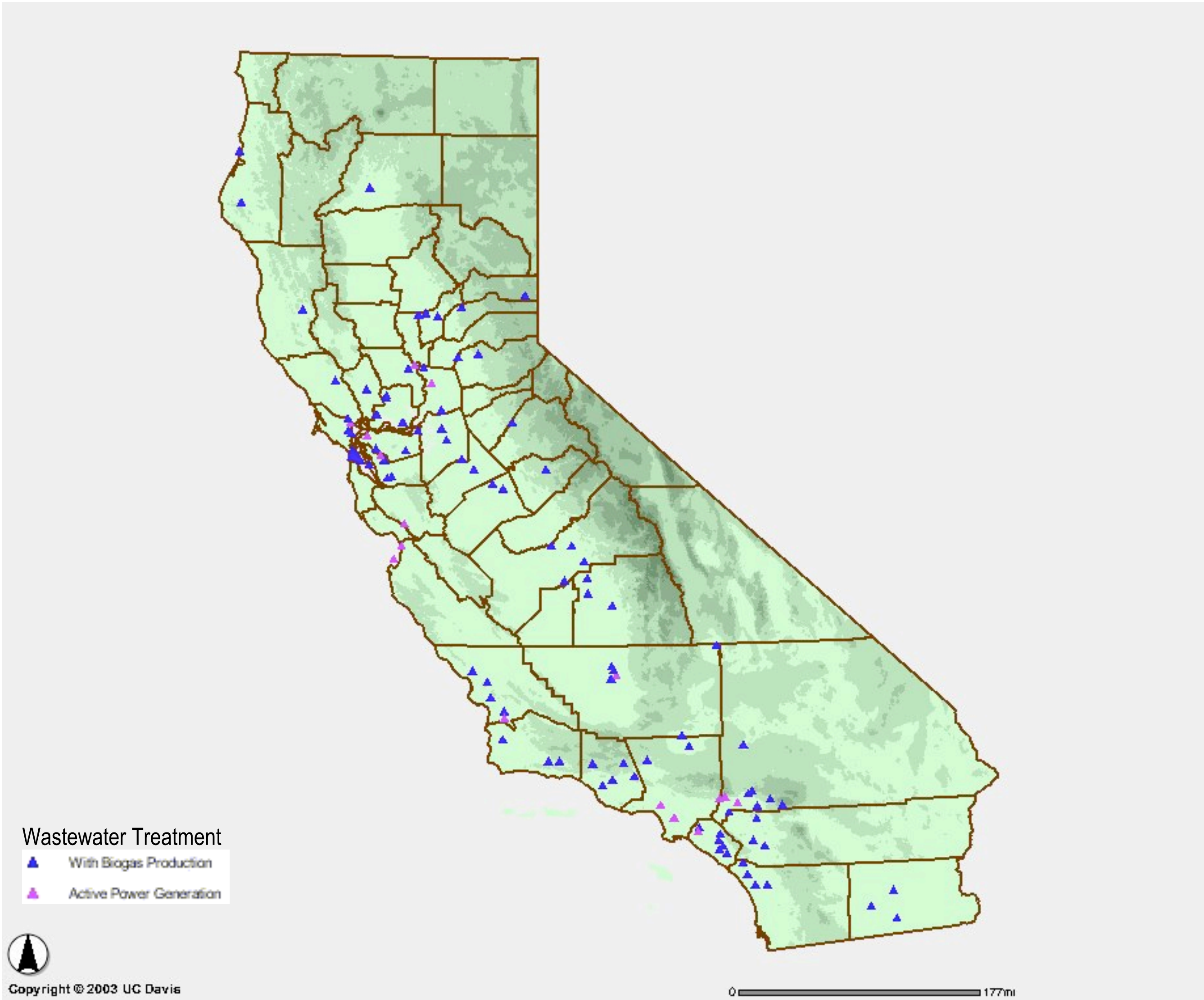

Figure 11. Locations of wastewater treatment facilities with biogas generation and active power generation

3.5.2 Survey Response Rate

The initial survey of 12 wastewater treatment plant operators gathered six responses, with one sanitation district submitting a report with information on a seventh plant. The number of facilities was increased to 115 based on an update from EPA (personal communication with Ms. Fondahl of EPA Region IX). After the follow-up survey so far, 22 surveys were sent gathering 16 responses or a rate of 73% with respect to the surveys sent (Table 13). Table 13 also indicates that contact rate is still below 50% as contact information of remaining facilities are being verified but efforts are continuing to reach all the other facilities. Efforts are also continuing to increase survey response.

Table 13.

Rate of response to survey from wastewater treatment facilities

Number of facilities	115
Number contacted	30
Number sent survey	22
Number responded to survey	16
Percent response with respect to total	14
Percent response with respect to sent	73

3.5.3 Technical Performance

The total generating capacity of 18 facilities is 63 MW_e with an estimated annual energy production of 475 GWh at an assumed availability of 85%. The gross generating capacity is totaled from the values reported in the survey and from EPA published data. Only two out of 16 responding facilities indicated net energy exported to the grid valued at 0.1 kW and 49 kW. The latter was inconsistent with regards to the energy among gross, parasitic, internal costumer and net-to-grid and was determined to 0.96 MW. The remainder either use the generated power on-site to offset purchased utility power (zero net energy) or did not provide the any quantity. The net annual energy production using the reported net generating capacity at 85% availability factor is 7 GWh. The gross and net electrical efficiencies from 5 responding facilities ranged from 23%-32% and 21%-28%, respectively. Five facilities indicated operating in combined heat and power mode with gross and net overall efficiencies ranges of 35-75% and 31-49%, respectively. The capacity weighted average of efficiencies and other technical performance indicators are summarized in Table 14.

Table 14

Capacity and energy generation estimated for wastewater treatment facilities.

Number of facilities	115
Number of facilities with known capacity	18
Total gross generating capacity (MW)	63 (from 18 plants)
Total net (to grid) generating capacity (MW, from 2 facilities)	0.96
Annualized capacity factor (%, from 7 facilities)	55-97 (ave = 70)
Availability (%, from 9 facilities)	64-100 (ave = 84)
Gross electrical efficiency (%, from 5 facilities)	23.7-32.5 (Cap.Ave=29)
Net electrical efficiency (%, from 5 facilities)	21.5-28.1 (CapAve.=26)
Gross overall CHP efficiency (%, from 5 facilities)	35-75 (Cap.Ave =38)
Net overall CHP efficiency (%, from 5 facilities)	31-49.4 (Cap.Ave =32)
Estimated annual gross energy production (GWh)	475 (from 18 plants)
Estimated annual net energy production (GWh)	7.2 (from 2 plants)

3.5.4 Economic Performance

Only 5 or 30% of the returned surveys provided information on economics. Two facilities reported capital investments of $13.3 million (in 1985 dollars) for cogeneration facilities only and $14.8 million (in 1999 dollars), the latter translate to roughly $4433/kWe using gross generating capacity. Four facilities reported operation and maintenance costs ranging from $80,000 to $993,000 per year and $83/kWe-y to $255/kWe-y using the gross generating capacity. Except for two facilities which have net power exported to the grid, the return to most of these facilities is based on the equivalent retail value of the electricity and heat where CHP is employed.

3.5.5 Environmental Performance

Eight (53%) of respondents provided information on environmental questions and all of them have local air permits and EPA title V permits. Only two out of 15 respondents confirmed having waste discharge requirement (WDR) permits, solid waste permits, and perform ground quality monitoring. None have indicated problems with noise. Odor is addressed by scrubbing, covers, and addition of chemicals such as sodium hypochlorite, ferric chloride, or sulfide .

3.6 Social impacts of biomass power generation facilities in California

Information on the social costs and benefits was solicited in the survey questionnaires. Most impacts were identified with reduced landfilling of wastes, decreased open burning, displacement of fossil fuel, and local economic support including jobs. Results and verbatim comments from surveys are noted in the following paragraphs.

<u>Comments from operators of direct combustion facilities:</u>

"Reduce material going to landfill; reduce open field burning; provide for disposal of Sudden Oak Death laden wood;"

"115 rural jobs; Contribute about 9 percentage points to area landfill diversion mandate; Eliminate open burning of ag residues; Pay $250,000 per year for clean air programs; Secondary: Displace fossil fueled generation; Pay significant property tax".

Operators of direct combustion facilities state that the plants provide many benefits. Combusting agricultural biomass materials to generate electricity reduce the burning of agricultural wastes in the open field – thereby reducing air pollution from farming operations. Use of forest slash and trimmings slows the build-up of fuels in the state's forests - thereby reducing the threat of catastrophic forest-fires - and disposes of diseased woody materials such as those infected with phytophthora ramorum – the agent in "sudden oak death". Combustion of wood and plant materials from the urban waste stream reduces the amount of waste deposited in landfills and reduces the generation of methane gas at landfills. The latter is an issue for the potential uncontrolled release of methane as a greenhouse gas, which is off-set by LFGTE facilities to some extent.

The electric power generated by the plants increases the reliability of the state's electricity supply by providing additional generation capacity in de-centralized facilities. The plants also reduce dependence on imported oil by displacing fossil-fuel power generation, and reduce emission of greenhouse gases by generating electricity from a mostly carbon-neutral process.

Unlike fossil fuels which release carbon that has been stored underground for millennia, combustion of biomass uses carbon that is part of the growth, decay, and generation cycle of living processes. Growing trees "fix" carbon from the atmosphere and soil. Combusting that carbon releases the same carbon back to the atmosphere as carbon dioxide which in turn can be taken up by growth of replacement biomass.

In rural areas, the facilities provide sorely needed jobs and can be significant contributors to local tax rolls and fee programs.

Comments from operators of landfill-gas-to-energy facilities:

"1. Produces green electricity from a source that would otherwise add to greenhouse gas emissions. 2. Provides a source of revenue to the City Refuse Fund that helps keep rates lower."

"System uses about 550 cfm of landfill gas and runs 24 hours per day."

"The landfill provided a place to manage municipal solid waste, and at the same time utilizing the produced methane for use and minimizing greenhouse gases to the atmosphere."

"Decreases reliance on fossil fuels; provide safe disposal of MSW; gas collection system minimizes release of methane to the atmosphere (greenhouse gas)"

"Gas production offsets use of natural gas in the utilities' generating plants. Utilization of gas mitigates emissions of greenhouse gas (CH4)"

"Recovery + electrical generation using gas from closed landfills; the 155 acre landfill is also operated as an open space park"

Operators of landfill-gas-to-energy plants claim many social and environmental benefits. Collecting landfill gas reduces the amount of methane, a greenhouse gas, released to the atmosphere from the decomposition of organic wastes, and combusting it provides useful energy

– either in the form of process heat or electricity. Converting the methane to carbon dioxide through combustion provides a twenty-fold reduction in the greenhouse effect of landfilling organic wastes. Use of landfill gas displaces natural gas and other fossil fuels used to generate electricity and, at the same time, it increases the reliability of the electricity supply by providing additional generation capacity at decentralized facilities. Operating the plants creates jobs and the energy sales generate revenues to offset the cost of operating the landfill.

<u>Comments from operators of animal and food waste digesters:</u>

"The direct benefit to the public and ratepayers from the project involves cost reduction, natural gas reductions, electric grid reliability improvements, odor control, and overall energy saving. Further, by environmentally disposing of animal manure, the economic importance of dairy and similar operations to California's economy, and [this] area in particular will be sustained."

"Less flies, less smell, and environmentally acceptable."

"We have found that this project is an excellent means of converting a waste product into a valuable by-product for our dairy. We produce power, have hot water for dairy equipment clean-up, as well as hot water & heat for the home. In addition, the digestion process allows for a more valuable liquid end product (nitrogen is more readily available to corn plants when applied during summer irrigation), and solids are used as bedding, humus, and sold as garden mulch to local gardeners."

"Reduces odor by over 80%; Reduces BOD from 6000 to 35 ppm; Eliminates dust; Eliminates pathogens; Remove methane from air, thus reducing global warming; Provides water and fertilizer for crops; Produces renewable energy ".

"Reducing the electrical requirements on the grid and reducing the amount of methane gas released into the atmosphere".

Installing animal-manure digesters to process the collected manure and generate electricity from combusting the produced gases provides many benefits. Processing the manure reduces the odors, flies, and dust generated by confined animal facilities making them more acceptable neighbors. Solid waste is reduced as the digester residues can be safely used as soil amendment, liquid fertilizers, and garden mulch rather than disposed and contaminating lakes and streams from run-off. Greenhouse gas emissions impacts are reduced as the methane generated by the manure is converted to carbon dioxide by combustion. Animal waste digester facilities produce electric power and process heat for use in dairy operations or for sale to utilities or industry, offsetting the cost of milk production and supporting California's dairy industry.

<u>Comments from operators of wastewater treatment facilities:</u>

"We are using existing plant waste products (treatment plant gases plus landfill gases) in a more efficient manner. Instead of flare use for the gases we are able to produce electricity, helping to control the overall cost of operating the treatment plant."

"The direct benefit to the public and ratepayers from the project include cost reduction, natural gas reductions, electric grid reliability improvements, odor control, and overall energy saving. Furthermore, on site power generation by treatment plant facilities will reduce demand on the utility companies. Ratepayers will also benefit from savings for sewage treatment."

Wastewater treatment plants protect public health and the aquatic environment by removing contaminants and infectious organisms from wastewater. Recovering the methane gas that is generated by the digesters reduces the emission of greenhouse gases and generates electric power and process heat that can be used for operating the treatment plant. Producing electricity from the gas rather than merely flaring it provides reliable, decentralized power, reduces the use of natural gas to generate electricity, and lowers costs of plant operation. Biosolids remaining after treatment can in many cases be used as soil amendment or landfill cover material.

<u>Economic Benefit</u>

A further benefit from biomass utilization is the creation of new jobs, often in rural communities with normally slow job growth. Jobs can be created in the collection, processing, and transport of biomass materials, as well as the in the operation and maintenance of the power plant. Fourteen of the plant operators that responded to the survey provided data on jobs created specifically at the power plant, combining these with the gross power produced yields an average of 0.93 jobs per MW of biomass power. (Four additional plants gave employment figures that appeared to include non-power operations, i.e. department-wide employment such as the 270 staff for an entire water quality department. These data were not included in the average.)

Table 15
Number of jobs in terms of fulltime equivalent employees (FTE) as reported by facilities.

No.	Combustion Plants		Landfill Gas Plants		Digester Gas Plants	
	Jobs	MW	Jobs	MW	Jobs	MW
1	50	53	4.5	1.6	24	22
2	28	29	(2)*	1.6	1	0.2
3			1	1.2	3+(1)	3.3
4			5	7.6		
5			7+(2)	11		
6			4	1.5		
7			3+(5)	9		
8			(1)	0.8		
9			3	8		

*numbers in parenthesis are jobs under contract or supported FTE

For comparison, based on data from two European reports, full-time employees to MW ratios range from 1.4[1] to 2.0[2]. A study cited by CBEA gives 4.9[3] employees per MW.

[1] Renewable Energy and It's Impact on Rural Development and Sustainability in the UK, 2003 *K/BD/00291/REP URN 03/886*

[2]World Wildlife Fund pamphlet: *A Biomass Blueprint to Meet 15% of OECD Electricity Demand by 2020,* cites EC [2000] "Biocosts" study

[3]California Biomass Energy Alliance (CBEA), *Biomass Energy in California: Valuation of External Benefits*, Report prepared for the California Environmental Protection Agency, December 2, 1996.

3.7 State programs and incentives

Several state agencies administer programs that provide financial support for alternative energy, energy-efficiency improvements and renewable energy. These programs offer grants, loans or direct subsidies for research into new and emerging technologies, purchase of renewable power, installation of energy efficient devices and renewable-power generating systems, and the consumption of biomass wastes. Some of the programs are listed below.

California Energy Commission

The Agricultural Biomass to Energy Program was established by Senate Bill 704-Florez, 2003, to award grants for one year at a level of $10 per ton of qualified agricultural biomass converted to energy by biomass facilities that were operational as of July, 2003. $6,000,000 was allocated from the Renewable Resource Trust Fund (RRTF) to fund the program. When the $1,480,000 encumbered in the third quarter of 2004 is paid out, the allocation will be fully expended. {See: H&SC §41606}
http://www.energy.ca.gov/renewables/overview.html

The Renewables Portfolio Standard Program requires utilities to increase their purchases of electricity from eligible renewable energy technologies (including biomass, digester gas, landfill gas, and municipal solid waste conversion) by at least one-percent a year to reach 20% of their retail sales by 2017. The utilities are required to hold competitive solicitations to procure eligible renewable energy. A utility may limit its procurement if the cost is not covered by the supplemental energy payments. Enacted by SB 1078-Sher, 2002. {See: PUC §383-399.25 (Formerly PUC §383, 383.5, moved to PRC by SB183, 2003.)}
http://www.energy.ca.gov/portfolio/index.html

The Renewable Energy Program provided supplemental energy payments to foster development of new renewable generation technologies (excluding MSW combustion) at 51.5% of collected funds; allocated 20% to improve competitiveness of existing

renewable facilities, 17.5% to foster emerging renewable technologies in distributed generation (DG) applications; and 10% for customer credits for purchases of renewable energy. The Customer Credit payments were suspended and redistributed to the other accounts in 2001. Goal was set to increase the share of electrical generation by renewable technologies to 17% by 2006. As of July 2004, the Commission had awarded over $690,000,000 to renewable projects from the RRTF (CEC, 2004f). For individual program elements, see paragraphs following. {First established by AB 1890-Brulte, 1996, PRC ∫25740 (Formerly PUC ∫∫383, 383.5, moved to PRC by SB183, 2003.)}
http://www.energy.ca.gov/renewables/index.html

The Emerging Renewables Program (a subset of the Renewable Energy Program) provides rebates to all grid-connected utility (PG&E, SDG&E, SCE) customers for the purchase of renewable energy generating systems under 30 kW. Systems using photovoltaic, wind, and solar thermal-electric technologies, and fuel cells operating on renewable fuels, including landfill gas and digester gas, are eligible for funding. Rebates vary with size and technology from $1.10 to $3.60/watt. Between 2002 and 2006, over $118,125,000 was allocated to the program (CEC, 2005). As of June, 2004, payments of $154.1 million had been made to 9700 installed systems totaling 39 MW of distributed capacity (CEC, 2005; Brasil, 2003).
http://www.consumerenergycenter.org/erprebate/

New Renewable Facilities Program (a subset of the Renewable Energy Program) provides financial incentives to encourage new electricity generation projects most likely to become competitive with conventional technologies. As of July, 2004, payments of $39.2 million had been made to 43 on-line projects. An additional $88 million has been conditionally awarded[4]. Successful projects include 2 biomass, 1 digester gas and 14 landfill gas projects totaling 50.5 MW (CEC, 2004f).
http://www.energy.ca.gov/renewables/new_renewables.html

Public Interest Energy Research (PIER) program, funds research into a wide variety of energy technologies. One component focuses on renewable energy applications and renewable applications combined with fossil fuel-fired energy. Objectives include

making improvements at existing renewable energy facilities to help provide peak capacity and increased reliability to California's electricity system; expanding renewable distributed generation technologies to help provide electricity generation in high-demand, high-congestion areas; developing renewable energy technologies, products, and services that provide electricity customers with more affordable electricity, improved reliability, and a selection of choices; and, conducting longer term research on advanced renewable technologies that will help meet tomorrow's electricity needs. One grant program that is also open to biomass technologies is the Energy Innovations Small Grant (EISG) Program which provides up to $75,000 to small businesses, non-profits, individuals and academic institutions to conduct research that establishes the feasibility of new, innovative energy concepts.
http://www.energy.ca.gov/pier/renewable/index.html

The Dairy Power Production Program was established by Senate Bill 5X – Sher (2001) to encourage the development of anaerobic digestion and gasification electricity-generation projects on dairies. The Commission awards grants for the capture and use of biogases in either digester or covered-lagoon technologies. Of the $10,000,000 program funds, $8,609,750 were available for either "buy-down" grants covering up to 50% of the capital costs of a biogas system or as electricity generation incentive payments of 5.7 cents per kWh. As of May 2004, 14 projects with potential generation of 3.5 MW had been approved for $5,792,370 (CEC, 2003).
http://www.wurdco.com/DPPPbackgrounder.htm

California Pollution Control Financing Authority

The Small Business Pollution Control Tax-Exempt Bond Financing Program provides low-interest rate loans to small businesses from a minimum $1,000,000 up to $20 M for pollution control projects including waste-to-energy, resource recovery, landfill gas and dairy manure projects through the Small Business Assistance Fund Tax-Exempt Bond Program. {H&SC §44500}
www.treasurer.ca.gov/cpcfa/smallbusiness.htm

Public Utilities Commission

Provides incentives/rebate to utility customers for self-generation and clean distributed generation projects (including some renewable combustion) at a rate of $1.50/watt in consultation with the CEC from $50,000,000. (Enacted by AB 970, moved to PUC 379.5 by SB 662 and amended by AB 1685 {PUC ∫379.5 & PRC ∫2555 })
http://www.cpuc.ca.gov/PUBLISHED/NEWS_RELEASE/7408.htm

Department of Food & Agriculture

Rice Straw Utilization Grant Program was established by AB 2514-Thomson, 2000 to provide grants of up to $20/ton of agricultural biomass or rice straw used to generate energy, products, etc. up to a maximum award of $300,000. Program funding with $2,000,000 in the Agricultural Biomass Utilization Account. {H&SC ∫39760}
http://www.cdfa.ca.gov/exec/aep/aes/rs_grant_program/

The programs described above have all been implemented with the potential to increase the amount of energy recovered from biomass materials. While the financial incentives have certainly assisted the projects, it is difficult to quantify to what extent they have increased the use of biomass as there are multiple drivers promoting that use. Bans on open-field burning of agricultural wastes, stricter controls of discharge of manure to lands and surface waters, and tighter limits on air pollutants and greenhouse gases also drive increased biomass use. The program with arguably the most measurable and direct effect – the RPS program – is still only in its infancy with limited data available. As of 2002, biomass projects were estimated as generating 6,261 gigawatt-hours of electric power out of a total renewables generation of 30,000 GWh (with total renewables equivalent to 10% of statewide generation.) By the end of 2003, total sales of renewable power were up to 32,325 GWh (CEC, 2004g).

The Existing Renewable Energy Program has supported 378 renewable energy facilities, totaling 4,400 MW of electric generation capacity and consisting of biomass, waste tire, and solar-thermal technologies, with award of over $190 million (CEC, 2004f); however, the split between generation types is not available. The New Renewable Energy Program conditionally awarded

$88 million in funding (approximately half has been paid out) to 45 renewable energy projects having a total generation capacity of 429 MW (CEC, 2004e). Of these, 17 projects, totaling 50 MW, were either biomass (2 projects), digester gas (1), or landfill gas (14). The Agricultural Biomass-to-Energy Program fully expended its $6,000,000 allocation, dispersing funds to nine facilities for the consumption of 600,000 tons of biomass between July 2003, and June 2004.

All of these incentive programs have been popular; however, which of the projects were called into being solely as a result of any specific incentive program is unknown.

4. Conclusions

Significant efforts have been exerted to obtain vital information from existing biomass-to-energy facilities. Information regarding technical, socio-economic, and environmental performance and other key indicators on biomass to energy conversion facilities in the State of California has been gathered through survey and other sources. The essential information can be used to assess the long-term viability and benefits to the state. The facilities included in this assessment are categorized into direct combustion or steam cycle facilities, landfill gas to energy plants, animal and food waste digester gas to energy plants, and wastewater treatment digester gas to energy plants.

Current information from existing facilities indicate a total gross generating capacity of 1,087 MWe, a value likely to increase once all facilities, for instance all wastewater treatment plants, have been accounted. The net power being exported to the grid is estimated at 869 MW which is at about 1.4% of total generating capacity in the State from all fuel sources.

The number of active biomass direct combustion facilities had been declining since its peak in early 1990s due mostly for economic reasons. The 28 identified active biomass direct combustion facilities and 3 municipal solid wastes combustion facilities have an aggregated gross generating capacity of 761 MW with exports of power to the grid at about 641 MW using the survey and industry estimates. The annual energy generation from direct combustion facilities still represents the bulk (70%) of energy generated from all biomass categorized facilities. There are discrepancies in the power generation quantities from different sources, whether from survey response, CBEA estimates or the CEC database. There is, therefore, a need for further survey and data verification by improved means to reliably document the performance of this sector. Participation in the current survey from the direct combustion sector is low.

The currently identified landfill gas to energy facilities represent only about 1.5% of all landfill facilities in the State of California as listed in the Solid Waste Inventory Systems. There is a large opportunity for expanding the generation of electricity from these sources. The present gross capacity stands at 257 MW while the gross annual energy production is 1918 GWh. Reciprocating engines remain the dominant choice for landfill gas to energy conversion but technological changes, growing environmental concerns and changes in financial situations open up the feasibility of using other conversion technology such as microturbine, gas turbine, and boilers and steam turbines. There is a need to continue the effort in obtaining reliable data from landfill gas-to-energy facilities and improve operator response to surveys.

Out of 246 wastewater treatment facilities, 115 are generating biogas from anaerobic digesters. However remaining to be verified is the exact number of facilities that are actively generating electricity. So far, 16% (or 18 facilities) of the total industry have confirmed electricity generation with total generating capacity of 63 MW and estimated annual gross energy production of 475 GWh. In the case of animal and food waste digesters, the generating capacity of currently operational facilities represents 16% of 5.6 MW potential capacity, including those under development. The estimated annual gross energy production from animal and food waste digesters is 41 GWh. However, the status of net generating capacity and net energy needs to be determined further.

Efforts are continuing to survey remaining biomass-to-energy facilities. Responses to surveys still indicate reluctance on the part of facility owners and operators to share information. About half of the surveys sent have not been returned. Some of the information obtained from survey and other sources need further verification, particularly the efficiency values, availability and capacity factors, and economic information.

References

Bain, R.L., W.A. Amos, M. Downing, and R.L. Perlack. 2003. Highlights of biopower technical assessment: State of the industry and the technology. Technical Report. NREL/SR-510-33502. National Renewable Energy Laboratory. Golden, CO. Website: www.nrel.gov/docs/fy03osti/33502.pdf

Brasil, Tony. 2003. CEC Renewable Energy Program. Slide Presentation, August 22-24, 2003, Hopland, CA.

CEC. 2002. Landfill gas-to-energy potential in California. Staff Report. Public Interest Energy Research. California Energy Commission. Sacramento, CA.. No. 500-02-041V1. Website: http://www.energy.ca.gov/reports/2002-09-09_500-02-041V1.PDF

CEC. 2003. Dairy Power Production Program Progress Report, May 2003, California Energy Commission http://www.energy.ca.gov/process/pubs/2003-08-12_DAIRY_POWER.pdf

CEC. 2004a. Biogas potential from animal wastes in California. California Energy Commission. Sacramento, CA. Website: http://www.energy.ca.gov/pier/renewable/biomass/anaerobic_digestion/data.htm

CEC. 2004b. Biogas potential from sewage wastewater in California. California Energy Commission. Sacramento, CA. Website: http://www.energy.ca.gov/pier/renewable/biomass/anaerobic_digestion/data.htm

CEC. 2004c. 2004 Database of California Power Plants. California Energy Commission. Sacramento, CA. Website: http://www.energy.ca.gov/database/index.html#powerplants

CEC. 2004d. 2004 Database for Landfill Gas to Energy in California. California Energy Commission. Sacramento, CA. Website: http://www.energy.ca.gov/pier/renewable/biomass/landfill/data.html

CEC. 2004e. New Renewable Resources Account Projects Funded Through the Energy Commission's Renewable Energy Program. California Energy Commission. Sacramento, CA. November 15, 2004. website: http://www.energy.ca.gov/renewables/new_renewables.html

CEC. 2004f. Renewable Energy Program, Quarterly Report to the Legislature July 2004. California Energy Commission. Sacramento, CA. Committee Report 500-04-050

CEC. 2004g. Accelerated Renewable Energy Development, CEC Staff White Paper, July 2004, CEC 100-04-003D.

CEC. 2005. Emerging Renewables Program Guidebook, Final Draft. California Energy Commission. Sacramento, CA. 4th edition. Website: http://www.energy.ca.gov/renewables/emerging_update/

CIWMB. 2004. Solid Waste Information System. California Integrated Waste Management Board. Sacramento, CA. Website: http://www.ciwmb.ca.gov/SWIS/

EIA. 2004. EIA-767 data files. Annual steam-electric plant operation and design data. Energy Information Administration. Website: http://www.eia.doe.gov/cneaf/electricity/page/eia767.html

EPA. 2004. LMOP Landfill Database. Environmental Protection Agency. Website: http://www.epa.gov/lmop/proj/index.htm

EPA. Landfill Methane Outreach Program. Environmental Protection Agency. Website: http://www.epa.gov/lmop/

Fondahl, Lauren. 2004. US EPA Region IX wastewater treatment plant database. Personal communication with Lauren Fondahl, Biosolids Coordinator, US EPA Region IX.

Morris, G. 2000. Biomass energy production in California: The case for a biomass policy initiatives. Subcontractor Final Report. National Renewable Energy Laboratory. Golden, CO. NREL/SR-570-28805. Website: http://www.nrbp.org/papers/004.pdf

Morris, G. 2002. Biomass energy production in California 2002: Update of the California Biomass Database. Subcontractor Report. National Renewable Energy Laboratory. Golden, CO. NREL/SR-510-35111. Website: http://www.nrel.gov/docs/fy03osti/33111.pdf

Morris, G. 2003. The status of biomass power generation in California, July 31, 2003. Subcontractor Report. National Renewable Energy Laboratory. Golden, CO. NREL/SR-510-35114. Website: http://www.nrel.gov/docs/fy04osti/35114.pdf

Sullivan, 2004. CA LFG utilization projects database. Personal communication. November 8, 2004.

Turnbull, Jane H. 1993. Use of biomass in electropower generation: the California Experience. Biomass & Bioenergy. Pergamon Press Ltd. UK. 4(2):75-84.

Reese, P. 2004. Updated direct combustion plant data from CBEA. Personal communication from Phil Reese, president California Biomass Energy Alliance.

Western United Resources Development, Inc. 2003. Dairy Power Production Program. June 2003 Update. California Energy Commission. Agreement No. 400-001-001. Website: http://www.wurdco.com/Annual%20Report%20Aug.%202003.pdf

Wiltsee, G. 2000. Lessons learned from existing biomass power plants. Subcontractor Report. National Renewable Energy Laboratory. Golden, CO. NREL/SR-570-26946. Website: http://www.nrel.gov/docs/fy00osti/26946.pdf

Appendices

A1. Survey form for direct combustion facilities (cover letter not included)

California Biomass Collaborative
Biomass Facility Survey

Section 1. Biomass Power Plant Location

Facility Name: ____

Facility's Physical Street Address: _________________________________

Facility's City: ____

Facility's Zip Code: ____

Facility's County: ____

Facility's Phone Number: _______________________________________

Facility's Fax Number: ____

Latitude and Longitude Coordinates of Facility (if known)

Latitude ____________________Longitude________________

Section 2. Contact Information

Contact Name: ____

Contact's Position: ____

Company Name: ____

Street Address: ____

City: ____

Zip Code: ____

County: ____

State: ____

Phone: ____

Fax: ____

Cell Phone: ____

E-mail address: ____

Link/Internet Address/Web page (if any) :_____________________________

Section 3. Business Information

Ownership Structure: _____Partnership ____ Corporation

(name) ______________________________

_____Privately Held _____Other (please describe) ____________

____

____

____

____

Section 4. Facility Operator (if different from above)

Contact Name: ____

Contact's Position: ____

Company Name: ____

Street Address: ____

City: ____

Zip Code: ____

County: ____

State: ____

Phone: ____

Fax: ____

Cell Phone: ____

E-mail address: ____

Link/Internet Address/Web page (if any) :_______________________________________

Section 5. Operating Information

(if you <u>don't</u> produce electrical energy skip to Section 6)

Are you connected to the grid with the ability to export electrical energy?

___ Yes ___ No : If yes, at what voltage _________ Volts

Date of First Operation: ___ Day ___ Month ___ Year

Date of Closure (if any): ___ Day ___ Month ___ Year (or proposed)

Original Design Lifetime: _____ Years

Excluding routine or brief scheduled or non-scheduled curtailments or outages, has the plant ever been shutdown and restarted? _____ No _____ Yes. If yes, please describe,

including closure and restart dates. ______________________________________

____

System electrical generating capacity:

Gross ______ Megawatt -electrical or _____ kilowatt-electrical

Parasitic ______ Megawatt -electrical or _____ kilowatt-electrical

(parasitic power is that used to operate the power plant)

Internal Customer ______ Megawatt -electrical or _____ kilowatt-electrical

(other than parasitic)

Net to grid (if any) ______ Megawatt -electrical or _____ kilowatt-electrical

Total annual energy generated: ___________ (Megawatt-hour)

Are you a Qualifying Facility? ____ yes ____ no

Annualized Capacity Factor: _________ %

(amount of energy produced in a year divided by the potential amount of energy that could be produced if plant ran the entire year at the rated power capacity. Is this a single or multi year average?

_________ # year(s))

Annualized Availability Factor: _________ % or _______# of hours operating

(% = # hours per year operating divided by 8760 hours in a year x 100%)

Is this a single or multi year average? _________ # year(s))

Power Plant Efficiency:

Gross efficiency _____ % (gross efficiency is the gross electrical energy output divided by fuel energy input)

Net efficiency _____ % (net efficiency is the electrical energy out exclusive of parasitic load divided by fuel energy in)

Please indicate whether the efficiencies are _____annual basis or ____other basis (specify time period involved).

Facility exports electrical energy primarily to: _____________
(PG&E, SCE,SDGE, or name of other?)

Any electrical energy sold to customer(s) other than utility?) ____ yes ____ no
If yes name of customer :____________________

Do you operate as a cogenerator or in combined heat and power mode (produce thermal and electrical energy)?

Cogenerator (Qualifying Facility) ____ yes ____ no

Combined Heat and Power (CHP) ____ yes ____ no

If yes, where is the thermal energy used and/or sold?: ________________________
____If yes, how much thermal energy is used and/or sold? ______________________
____(specify units of measurement)

Section 6: Technical Information

Part A: Biomass Conversion Technology

_________ Combustion
_________ Gasification
_________ Pyrolysis
_________ Other

Please describe your conversion technology
____
____
____

What (if any) additives or catalysts are used in the process? __________________________
____

Conversion/Combustion equipment: (what kind do you have?)

____ Grate (style______________) ___________________ Manufacturer
____ Suspension/entrained ___________________ Manufacturer
____ Bubbling Fluidized Bed ___________________ Manufacturer
____ Circulating Fluidized Bed ___________________ Manufacturer
____ Other: (please describe and indicate multiple units as needed)
____ Manufacturer
____ Manufacturer

____Manufacturer

What type(s) of equipment is used to generate mechanical energy and/or electrical energy?

____Steam turbine ___________________ Manufacture/Model

type: backpressure _______ condensing _______

(turbine inlet pressure ______ psi, temperature _______ °F,

steam flow ______lbs/hr)

____Boiler ___________________ Manufacturer/Model

____Reciprocating engine ___________________ Manufacturer/Model

____Gas turbine ___________________ Manufacturer/Model

____Electrical generator ___________________ Manufacturer/Model

____Other ___________________ Manufacturer/Model

Please describe any other equipment that is a part of the conversion process (please attach facility schematic if possible) ____

____

____

Part B: Environmental Information

Does your facility have local air permits? _____ Yes _____ No

Please provide annual emission rates for the following pollutants:

	Permit value	units (tons/year or ?)
CO:	______________	____________
NOx:	______________	____________
SOx:	______________	____________
PM10:	______________	____________
NMHC:	______________	____________
(non-methane hydrocarbons)		
Ammonia:	______________	____________
Other(s)	______________	____________
	______________	____________
	______________	____________
	______________	____________

Does your facility have EPA / Title V air permits? _____ Yes _____ No

Does your facility have wastewater permits? _____ Yes _____ No

Does your facility have a stormwater permit? _____ Yes _____ No

Does your facility have solid waste permits? _____ Yes _____ No

What types of solid waste or byproducts does your facility produce?

Please describe, for each type, how it is disposed and/or any beneficial uses

____

____

Does your facility have controls to mitigate noise, odors, or public nuisance?

_____ yes _____ no. If yes, please describe for each type___________________________

____

Section 7: Fuels/Materials Information - Fuel/Feedstock Type
(check all that apply)

Fuel Type

Moisture Content (%)
Annual Amount
(bone dry tons or

⇛

(circle: wet or dry basis)

specify units)

Forest

- mill residue

- thinnings

- slash

- other _________________

Urban wood fuel

Agriculture residue

- orchard prunings

- orchard removals

- rice straw

- rice hulls

- other straw

- seeds/pits/shells/hulls

- manure

- vineyard prunings

- grape/tomato pomace

- corn stover

- cotton residues

- other ________________

Municipal waste

- paper/cardboard

- yard/green wastes

- food waste

- rubber/plastic

- other _________________

Industrial waste

- textiles

- paper/cardboard

- rubber/plastic

- restaurant food/oily waste

- food/meat processor waste

- other ________________

Total

Please indicate if green waste is commingled with urban wood fuels __________________

Fuel Supply Area: (radius of fuel supply area) ________ miles or location (city/co/region): _____________

or jurisdiction __________________

or other, please describe _____________

Average fuel heating value: ______ MJ/kg or _____ BTU/lb (circle: HHV or LHV)

(HHV=higher heating value; LHV=lower heating value)

How is fuel supplied to the facility? : ______ % commercially trucked

______ % self haul vehicles

______ % rail

______ % pipeline

______ % other – please describe __________

What supplemental fuels are used in the facility (non-biomass)?:

		Annual amount	units
______	coal	______	_____
______	pet coke	______	_____
______	waste oils	______	_____
______	natural gas	______	_____
______	propane	______	_____
______	fuel oil	______	_____
______	diesel fuel	______	_____
______	other:	______	_____

please describe _____________________________________

Section 8: Economic Information

Type of contract for the sale of electricity _________________________________

Current basis and pricing for the sale of electricity ___________________________

Annual capacity payments for the sale of electricity __________________________

Are any byproducts sold? _______ yes ______no :

Which byproducts are sold?	Annual revenue ($)
______________________	________________
______________________	________________

How many fulltime equivalent employees (FTE) including fuel processing and procurement, plant operation and maintenance, and plant management and other staff are directly employed by the plant? __________________

For contracted services (fuel procurement, maintenance, water quality, waste handling, administration, etc.), estimate the number of FTE supported? ______________

Section 9: Social Benefits

What primary social benefits does the plant provide?

____

____

____

What secondary social benefits does the plant provide?

____
____
____

Section 10: Other

Please provide any additional information or comments, attaching additional sheets as needed. Also attach any reports, schematics, or other documents you feel would be helpful.

____
____

A2. Survey form for landfill gas facilities (cover letter not included).

California Biomass Collaborative
Landfill Gas Survey

Section 1. Landfill facility Location

Facility Name: ____

Facility's Physical Street Address: __________________________________

Facility's City: ____

Facility's Zip Code: ____

Facility's County: ____

Facility's Phone Number: ____

Facility's Fax Number: ____

Latitude and Longitude Coordinates of Facility (if known)

Latitude ______________________Longitude__________________

Section 2. Business Information

Ownership Structure: _____Partnership ____ Corporation

(name) ______________________________

_____Privately Held _____Other (please describe) ____________

____

Section 3. Landfill and Landfill Gas Information

Area of landfill: _________ acres (or specify unit)

Landfill Class:___________________

Date when the landfill first opened: ___ Day ___ Month ___ Year

Date of (proposed) Closure: ___ Day ___ Month ___ Year

Landfill design Lifetime: _____ Years

Current Tons in place (2004) _________________________

Design Tons in place at end of life: _____________

Waste received from:____

____

location (city/co/region): _____________

or jurisdiction __________________

or other, please describe _____________

Waste separated or sorted prior to disposal? _______________Yes____________No

If yes, specify source separated or MRF____

Method of gas extraction (please attach schematic or map of system if possible):

________ Vertical wells

________ Horizontal collector

________ Other (please specify): ___________________________

Please provide brief description of gas extraction (such as number of wells or pipes and depth)

____

Landfill gas utilization:

_________Electricity _________Heat

_________Flaring only _________Venting (without control)

_________Other (specify)

Annual volume of landfill gas extraction: ______ m^3 or _____ standard cubic feet (or specify unit)

If monthly, daily, or hourly gas production data are available, please provide if possible.

Average gas heating value: ______ MJ/m^3 or _____ BTU/ft^3 (circle: HHV or LHV)

(HHV=higher heating value; LHV=lower heating value; Please specify unit if other than above)

Landfill gas composition:

Methane - __________ %

Non-methane compounds (please enumerate if available):

____ CO_2 _________ - ______________ %

____ H_2S __________ - ______________ %

____Others (list)____ - ______________ %

_________________ - ______________ %

Fraction of gas used for energy generation________________________%

Fraction flared____%

Fraction vented____%

Method of disposition of condensates and other materials removed from gas:

____

____

Do you employ bioreactor technology, leachate recirculation, or water addition? (if so, please provide details):

____

Section 4. Electrical Generation Information

(if you <u>don't</u> produce electrical energy skip to Section 5)

Part A: Power generation system information

Are you connected to the grid with the ability to export electrical energy?

___ Yes ___ No : If yes, at what voltage _________ Volts

Date of First Operation: ___ Day ___ Month ___ Year

Date of Closure (if any): ___ Day ___ Month ___ Year (or proposed)

Original Design Lifetime: _____ Years

Excluding routine or brief scheduled or non-scheduled curtailments or outages, has the electrical generating plant ever been shutdown and restarted? ____ yes ____ no.

If yes, please describe, including closure and restart dates. ________________________

____

System electrical generating capacity:

Gross ______ Megawatt -electrical or _____ kilowatt-electrical

Parasitic ______ Megawatt -electrical or _____ kilowatt-electrical

(parasitic power is that used to operate the power plant)

Internal Customer ______ Megawatt -electrical or _____ kilowatt-electrical

(other than parasitic)

Net to grid (if any) ______ Megawatt -electrical or _____ kilowatt-electrical

Total annual energy generated: ___________ (Megawatt-hour)

Are you a Qualifying Facility? ____ yes ____ no

Annualized Capacity Factor: _________ %

(Amount of energy produced in a year divided by the potential amount of energy that could be produced if plant ran the entire year at the rated power capacity)

Is this a single or multi year average? _________ # year(s)

Annualized Availability Factor: _________ % or _______# of hours operating

(% = # hours per year operating divided by 8760 hours in a year x 100%)

Is this a single or multi year average? _________ # year(s)

Power Plant Efficiency:

Gross efficiency _____ % (gross efficiency is the gross electrical energy output divided by fuel energy input)

Net efficiency _____ % (net efficiency is the electrical energy out exclusive of parasitic load divided by fuel energy input)

Please indicate whether the efficiencies are _____annual basis or ____other basis (specify time period involved).

Are fuels (e.g. natural gas) used in addition to LFG for power generation? ___yes ___no

(if yes please specify by type in Part B)

Facility exports electrical energy primarily to: _____________

(PG&E, SCE,SDGE, or name of other?)

Any electrical energy sold to customer(s) other than utility?) ____ yes ____ no

If yes name of customer :____________________

Do you operate as a cogenerator or in combined heat and power mode (produce thermal and electrical energy)?

Cogenerator (Qualifying Facility) ____ yes ____ no

Combined Heat and Power (CHP) ____ yes ____ no

If yes, where is the thermal energy used and/or sold?: ________________________

____If yes, how much thermal energy is used and/or sold? ______________________

____(specify units of measurement)

Part B: Landfill Gas to Energy Conversion Technology

______ Reciprocating engine Mfg: _________________ Model # _____________

Number of units:__________ Catalytic Converter used?______________

______ Gas turbine Mfg: _________________ Model # _____________

Number of units:__________ Catalytic Converter used?______________

______ Microturbine Mfg: _________________ Model # _____________

Number of units:__________ Catalytic Converter used?______________

______ Boiler/steam turbine Mfg: _________________ Model # _____________

Number of units:__________ Catalytic Converter used?______________

type: backpressure _______ condensing _______

(turbine inlet pressure ______ psi, temperature _______ °F,

steam flow ______lbs/hr)

______ Other Mfg: _________________ Model # _____________

Number of units:__________ Catalytic Converter used?______________

(add additional as needed)

Please list any additional components of your landfill gas conversion technology

____

____

Moisture, condensate, particulate matter and other gas cleaning (e.g. siloxane removal) technology used:

____

____

Please describe any other equipment that is a part of the conversion process (please attach facility schematic if possible) ____

____

What other supplemental fuels are used to generate electricity?:

		Annual amount	units
______	natural gas	______	_____
______	propane	______	_____
______	fuel oil	______	_____
______	diesel fuel	______	_____
______	other:	______	_____

please describe _____________________________________

Section 5. Environmental Information

Does your facility have local air permits? _____ Yes _____ No

Please provide annual emission rates for the following pollutants:

	Permit value	units (tons/year or ?)
CO:	______________	____________
NOx:	______________	____________
SOx:	______________	____________
PM10:	______________	____________
NMHC:	______________	____________
(non-methane hydrocarbons)		
Ammonia:	______________	____________
Other(s)	______________	____________
	______________	____________
	______________	____________
	______________	____________

Does your facility have EPA / Title V air permits? _____ Yes _____ No

Does your facility have wastewater permits? _____ Yes _____ No

Does your facility have Waste Discharge Requirement? _____ Yes _____ No

Do you perform groundwater quality monitoring?_____ Yes _____ No

Does your facility have controls to mitigate noise, odors, or public nuisance?

_____ yes _____ no. If yes, please describe briefly each type________________________

____

____

Section 6: Economic Information

If generating electricity, please provide information on the following:

Type of contract for the sale of electricity _________________________________

Current basis and pricing for the sale of electricity ___________________________

Annual capacity payments for the sale of electricity __________________________

Are any products (such as recycled materials or gas) sold? _______ yes ______no :

Which products are sold?	Annual revenue ($)
______________________	________________
______________________	________________
______________________	________________
______________________	________________

How many fulltime equivalent employees (FTE) including fuel processing, plant operation and maintenance, and plant management and other staff are directly employed by the plant? __________________

For contracted services (maintenance, water quality, waste handling, administration, etc.), estimate the number of FTE supported? ______________

Section 7: Social Benefits

What primary social benefits does the landfill facility or the power generation plant provide?

____

____

____

What secondary social benefits does the landfill facility or the power generation plant provide?

____

____

____

Section 8: Other

Please provide any additional information or comments, attaching additional sheets as needed. Also attach any reports, schematics, or other documents you feel would be helpful.

____

____
____
____

Contact Information

Contact Person

Name: ____

Position: ____

Company Name: ____

Street Address: ____

City: ____

Zip Code: ____

County: ____

State: ____

Phone: ____

Fax: ____

Cell Phone: ____

E-mail address: ____

Link/Internet Address/Web page (if any) :___________________________

Facility Operator (if different from above)

Name: ____

Position: ____

Company Name: ____

Street Address: ____

City: ____

Zip Code: ____

County: ____

State: ____

Phone: ____

Fax: ____

Cell Phone: ____

E-mail address: ____

Link/Internet Address/Web page (if any) :___________________________________

A3. Survey form for digesters facilities (without the cover letter).

California Biomass Collaborative
Animal Wastes and Wastewater Treatment Facility Survey

Section 1. Digester facility Location

Facility Name: ____

Facility's Physical Street Address: __________________________________

Facility's City: ____

Facility's Zip Code: ____

Facility's County: ____

Facility's Phone Number: ____

Facility's Fax Number: ____

Latitude and Longitude Coordinates of Facility (if known)

Latitude ______________________ Longitude __________________

Section 2. Business Information

Ownership Structure: _____Partnership ____ Corporation

(name) ______________________________

_____Privately Held _____Other (please describe) ____________

____

Section 3. Digester and Biogas Information

Process equipment:

Anaerobic (fermentation):

_____ Anaerobic Digestion Manufacturer ___________________

_____ Alcohol fermentation Manufacturer ___________________

____ Other: Manufacturer ___________________

Please describe _____________________

Aerobic:

_____ Composting Manufacturer ___________________

_____ Activated (oxygenated water treatment)

Manufacturer ___________________

Type of digester (e.g. Plug-flow, CSTR, UASB, etc.): _________________________________

Date facility opened: ___ Day ___ Month ___ Year

Design Lifetime: _____ Years

Design system capacity: ______________ m^3 or kg per day (or please specify unit)

Types of wastes received: ____

Aggregated quantity of wastes received per unit time: _____________________ m^3 or kg per day (or please specify unit)

Waste received from: ____

____

location (city/co/region): _____________

or jurisdiction __________________

or other, please describe _____________

Biogas utilization:

_________Electricity _________Heat

_________Flaring only _________Venting (without control)

_________Other (specify)

Annual volume of biogas generation: ______ m^3 or _____ standard cubic feet (or specify unit)

If monthly, daily, or hourly gas production data are available, please provide if possible.

Average gas heating value: ______ MJ/m^3 or _____ BTU/ft^3 (circle: HHV or LHV)

(HHV=higher heating value; LHV=lower heating value; Please specify unit if other than above)

Biogas composition:

Methane - __________ %

Non-methane compounds (please enumerate if available):

____CO_2_________ - ______________ %

____H_2S__________ - ______________ %

____Others (list)____ - ______________ %

_________________ - ______________ %

Fraction of gas used for energy generation________________________%

Fraction flared____%

Fraction vented____%

Method of disposition of condensates and other materials removed from gas:

____

Section 4. Electrical Generation Information

(if you don't produce electrical energy skip to Section 5)

Part A: Power generation system information

Are you connected to the grid with the ability to export electrical energy?

___ Yes ___ No : If yes, at what voltage _________ Volts

Date of First Operation: ___ Day ___ Month ___ Year

Date of Closure (if any): ___ Day ___ Month ___ Year (or proposed)

Original Design Lifetime: _____ Years

Excluding routine or brief scheduled or non-scheduled curtailments or outages, has the electrical generating plant ever been shutdown and restarted? ____ yes ____ no.

If yes, please describe, including closure and restart dates. ________________________

____

System electrical generating capacity:

Gross ______ Megawatt -electrical or _____ kilowatt-electrical

Parasitic ______ Megawatt -electrical or _____ kilowatt-electrical

(parasitic power is that used to operate the power plant)

Internal Customer ______ Megawatt -electrical or _____ kilowatt-electrical

(other than parasitic)

Net to grid (if any) ______ Megawatt -electrical or _____ kilowatt-electrical

Total annual energy generated: ___________ (Megawatt-hour)

Are you a Qualifying Facility? ____ yes ____ no

Annualized Capacity Factor: _________ %

(Amount of energy produced in a year divided by the potential amount of energy that could be produced if plant ran the entire year at the rated power capacity)

Is this a single or multi year average? _________ # year(s)

Annualized Availability Factor: _________ % or _______# of hours operating

(% = # hours per year operating divided by 8760 hours in a year x 100%)

Is this a single or multi year average? _________ # year(s)

Power Plant Efficiency:

Gross efficiency _____ % (gross efficiency is the gross electrical energy output divided by fuel energy input)

Net efficiency _____ % (net efficiency is the electrical energy out exclusive of parasitic load divided by fuel energy input)

Please indicate whether the efficiencies are _____annual basis or ____other basis (specify time period involved).

Are fuels (e.g. natural gas) used in addition to biogas for power generation? ___yes ___no

(if yes please specify by type in Part B)

Facility exports electrical energy primarily to: _____________

(PG&E, SCE,SDGE, or name of other?)

Any electrical energy sold to customer(s) other than utility?) ____ yes ____ no

If yes name of customer :____________________

Do you operate as a cogenerator or in combined heat and power mode (produce thermal and electrical energy)?

Cogenerator (Qualifying Facility) ____ yes ____ no

Combined Heat and Power (CHP) ____ yes ____ no

If yes, where is the thermal energy used and/or sold?: ________________________

____If yes, how much thermal energy is used and/or sold? ______________________

____(specify units of measurement)

Part B: Biogas to Energy Conversion Technology

______ Reciprocating engine Mfg: _________________ Model # _____________

Number of units:__________ Catalytic Converter used?______________

______ Gas turbine Mfg: _________________ Model # _____________

Number of units:__________ Catalytic Converter used?______________

______ Microturbine Mfg: _________________ Model # _____________

Number of units:__________ Catalytic Converter used?______________

______ Boiler/steam turbine Mfg: _________________ Model # _____________

Number of units:__________ Catalytic Converter used?______________

type: backpressure _______ condensing _______

(turbine inlet pressure ______ psi, temperature _______ °F,

steam flow ______lbs/hr)

______ Other Mfg: _________________ Model # _____________

Number of units:__________ Catalytic Converter used?______________

(add additional as needed)

Please list any additional components of your biogas conversion technology

____

____

Moisture, condensate, particulate matter and other gas cleaning (e.g. siloxane removal) technology used:

____

____

Please describe any other equipment that is a part of the conversion process (please attach facility schematic if possible) ____

____

What other supplemental fuels are used to generate electricity?:

		Annual amount	units
______	natural gas	______	_____
______	propane	______	_____
______	fuel oil	______	_____
______	diesel fuel	______	_____
______	other:	______	_____

please describe ______________________________________

Section 5. Environmental Information

Does your facility have local air permits? _____ Yes _____ No

Please provide annual emission rates for the following pollutants:

	Permit value	units (tons/year or ?)
CO:	______________	____________
NOx:	______________	____________
SOx:	______________	____________
PM10:	______________	____________
NMHC:	______________	____________
(non-methane hydrocarbons)		
Ammonia:	______________	____________

Other(s) ______________ ____________

______________ ____________

______________ ____________

______________ ____________

Does your facility have EPA / Title V air permits? _____ Yes _____ No

Does your facility have wastewater permits? _____ Yes _____ No

Does your facility have Waste Discharge Requirement? _____ Yes _____ No

Do you perform groundwater quality monitoring?_____ Yes _____ No

Does your facility have controls to mitigate noise, odors, or public nuisance?

_____ yes _____ no. If yes, please describe briefly each type________________________

____

____

Section 6: Economic Information

If generating electricity, please provide information on the following:

Type of contract for the sale of electricity _________________________________

Current basis and pricing for the sale of electricity ___________________________

Annual capacity payments for the sale of electricity __________________________

Are any products (such as recycled materials or gas) sold? _______ yes ______no :

Which products are sold?	Annual revenue ($)
______________________	________________
______________________	________________
______________________	________________

How many fulltime equivalent employees (FTE) including fuel processing, plant operation and maintenance, and plant management and other staff are directly employed by the plant? __________________

For contracted services (maintenance, water quality, waste handling, administration, etc.), estimate the number of FTE supported? ______________

Section 7: Social Benefits

What primary social benefits does the digester facility or the power generation plant provide?

____

____

____

____

What secondary social benefits does the digester facility or the power generation plant provide?

____

____

____

Section 8: Other

Please provide any additional information or comments, attaching additional sheets as needed. Also attach any reports, schematics, or other documents you feel would be helpful.

____
____
____

Contact Information

Contact Information

Contact Name: ____

Contact's Position: ____

Company Name: ____

Street Address: ____

City: ____

Zip Code: ____

County: ____

State: ____

Phone: ____

Fax: ____

Cell Phone: ____

E-mail address: ____

Link/Internet Address/Web page (if any) :______________________________

Facility Operator (if different from above)

Contact Name: ____

Contact's Position: ____

Company Name: ____

Street Address: ____

City: ____

Zip Code: ____

County: ____

State: ____

Phone: ____

Fax: ____

Cell Phone: ____

E-mail address: ____

Link/Internet Address/Web page (if any) :_____________________________________

A4. Modified (short) version of the digesters facility survey form.

California Biomass Collaborative
Animal Wastes and Wastewater Treatment Facility Survey

1. Digester facility Location

Facility Name: ____

Facility's Physical Address: ____

____

Latitude and Longitude Coordinates of Facility (if known)

Latitude ______________________ Longitude __________________

2. Digester and Biogas Information

Process equipment:

Anaerobic/Fermentation: ___ Anaerobic Digestion ___ Alcohol fermentation

___ Other, please describe _____________________________________

Aerobic: ___ Composting ____ Activated (oxygenated water treatment)

Type of digester (e.g. Plug-flow, CSTR, UASB, egg-shaped, etc.):__________________________

Design system capacity: ______________ m^3 or kg per day (or please specify unit)

Biogas utilization: ____Electricity ____Heat ___Flaring only

____Venting (without control) ____Other (specify)__________________

Annual volume of biogas generation: ______ m^3 or _____ standard cubic feet (or specify unit)

If monthly, daily, or hourly gas production data are available, please provide if possible.

Average gas heating value: ______ MJ/m^3 or _____ BTU/ft^3 (circle: HHV or LHV)

(HHV=higher heating value; LHV=lower heating value; Please specify unit if other than above)

3. Electrical Generation Information

Are you connected to the grid with the ability to export electrical energy?

___ Yes ___ No : If yes, at what voltage _________ Volts

System electrical generating capacity:

Gross ______ Megawatt -electrical or _____ kilowatt-electrical

Parasitic ______ Megawatt -electrical or _____ kilowatt-electrical

(parasitic power is that used to operate the power plant)

Internal Customer ______ Megawatt -electrical or _____ kilowatt-electrical

(other than parasitic)

Net to grid (if any) ______ Megawatt -electrical or _____ kilowatt-electrical

Total annual energy generated: ___________ (Megawatt-hour)

Are you a Qualifying Facility? ____ yes ____ no

Rated power capacity: _______________ (MW)

Number of hours operating per year: _____________ or Annualized Availability Factor:_______

Is this a single or multi year average? _________ # year(s)

Power Plant Efficiency:

Gross efficiency _____ % (gross efficiency is the gross electrical energy output divided by fuel energy input)

Net efficiency _____ % (net efficiency is the electrical energy out exclusive of parasitic load divided by fuel energy input)

Please indicate whether the efficiencies are _____annual basis or ____other basis (specify time period involved).

Facility exports electrical energy primarily to: _______ (PG&E, SCE,SDGE, or name of other?)

Biogas to Energy Conversion Technology (Please check and/or provide data):

___ Reciprocating engine Number of units:________ Manufacturer & model no:_____________

___ Gas turbine Number of units:________ Manufacturer & model no:_____________

___ Microturbine Number of units:________ Manufacturer & model no:_____________

___ Boiler/steam turbine Number of units:________ Manufacturer & model no:_____________

type: ___ backpressure ___condensing

(turbine inlet pressure ______ psi, temperature _______ °F, steam flow ______lbs/hr)

___ Other Number of units:_______ Catalytic Converter used?__________

Please describe any other equipment that is a part of the conversion process (please attach facility schematic if possible) ____

____

Please provide type(s) and annual amount of other supplemental fuels (if any) used to generate electricity:____

4. Economic Information

If generating electricity, please provide information on the following:

Type of contract for the sale of electricity _________________________________

Current basis and pricing for the sale of electricity ___________________________

Annual capacity payments for the sale of electricity __________________________

How many fulltime equivalent employees (FTE) including fuel processing, plant operation and maintenance, and plant management and other staff are directly employed by the plant? __________________

For contracted services (maintenance, water quality, waste handling, administration, etc.), estimate the number of FTE supported? ______________

5. Environmental Information

Does your facility have local air permits? _____ Yes _____ No

Does your facility have EPA / Title V air permits? _____ Yes _____ No

Does your facility have wastewater permits? _____ Yes _____ No

Does your facility have Waste Discharge Requirements permit? _____ Yes _____ No

Do you perform groundwater quality monitoring?_____ Yes _____ No

If available, please attach a one page summary of the facility's annual emission rates for criteria pollutants (CO, NOx, Sox, PM10, NMHC, Ammonia, etc).

6. Contact Information

Contact Name: ____

Contact's Position: ____

Company Name: ____

Street Address: ____

City: ____

Zip Code: ____

County: ____

State: ____

Phone: ____

Fax: ____

Cell Phone: ____

E-mail address: ____

Link/Internet Address/Web page (if any) :_____________________________

B. Biomass Facilities and Survey Results

B1. General Information

B2. Power Generation System Information

B3. Economic information

B4. Environmental Information

B5. Other Notes

B6. Direct Combustion Fuels Info

B7. Landfill and Landfill Gas Information

B8. Waste Digesters and Biogas Information