COMBINED HEAT AND POWER POTENTIAL AT CALIFORNIA'S WASTEWATER TREATMENT PLANTS

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Abstract

To meet energy efficiency and greenhouse gas reduction goals, the California Energy Commission and other state agencies support the installation of combined heat and power systems. This paper assesses combined heat and power potential using sludge from wastewater treatment plants. It estimates additional combined heat and power capacity at wastewater treatment plants from co-digesting biodegradable wastes from the dairy and food industries. The paper reviews technology, economic, and regulatory issues helping or hindering development of combined heat and power potential at wastewater treatment plants in California. Conclusions and suggestions to overcome the barriers are presented at the end of the paper.

Keywords: AB 32, AB 1969, air quality management district, biodegradable waste, carbon dioxide emissions, CHP, cogeneration, combined heat and power, CH_4, dairy waste, feed-in-tariff, flaring, food processing waste, generation technology, FOG, GHG, greenhouse gas, methane, NO_x emissions, restaurant grease and oil, sludge, Self-Generation Incentive Program, sludge, SGIP, net metering, wastewater treatment plant

Executive Summary

The California Energy Commission has long supported policies that encourage clean and efficient combined heat and power[1] generation in California's portfolio of energy resources. The California Air Resources Board's *Climate Change Scoping Plan* for implementing Assembly Bill 32 (Núñez, Chapter 488, Statutes of 2006) includes 4,000 megawatts (MW) of combined heat and power as a strategy to reduce greenhouse gas emissions. Understanding the full potential for combined heat and power in California and assessing barriers to its development are necessary for developing policies that foster combined heat and power development. Combined heat and power potential at wastewater treatment plants in California is a small yet necessary step to meet combined heat and power development goals. Developing combined heat and power from wastewater sludge is also important since it helps reduce methane generated by these plants while adding to the amount of renewable-based electric generation in California.

This paper assesses the combined heat and power potential at the wastewater treatment plants in California. Based on the work done by the Energy Commission's Public Interest Energy Research Program, there is a market potential to develop approximately 100 MW of combined heat and power from sludge at the wastewater plants. The market potential could be increased to as much as 450 MW by adding biodegradable waste from California dairies, food processing plants, and restaurants' oil and grease to the sludge in the anaerobic digesters.

Realizing the market potential often depends on the three major factors — technology, economic considerations, and regulatory regime. The technologies commonly used by the combined heat and power systems are microturbines, small turbines, internal combustion engines, and fuel cells. Other critical technologies that are important in realizing the market potential are waste-mixing technologies, digester technologies, and gas-cleaning technologies. Availability of emission-reducing equipment and instruments for accurate measurement of emissions plays a vital role in selecting one type of combined heat and power system over another.

Among the economic factors that could help or hinder attaining the market potential, availability of various financing incentives plays a crucial role. Self-generation incentive programs, feed-in-tariffs, net metering, and tax credits are all evaluated for their merits when deciding to invest in combined heat and power systems. Both public sector and private sector financing are used, and benefits and drawbacks of each are discussed in the paper.

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[1] Combined heat and power, also known as *cogeneration*, is the concurrent production of electricity and useful thermal energy from a single source of energy and is usually located at or near the point of consumption.

Prevailing and pending emission regulations have a major impact on the operation of existing and planned combined heat and power systems. The regulations affect the technology selection, economic viability, and overall feasibility of a combined heat and power project at a wastewater treatment plant. Some existing combined heat and power plants at such facilities have reverted back to flaring[2] the methane as they are unable to or unwilling to meet newer regulation. While impending carbon reduction goals along with the possibility of participating in a carbon cap and trade market may create opportunities for combined heat and power systems at wastewater treatment facilities, they also create some uncertainties until the rules are clear.

The following conclusions and suggested actions, based on the report's findings, may help reduce some of the barriers to attaining the 450 MW of combined heat and power potential from California-based biodegradable wastes:

- Reinstate combined heat and power eligibility for the California Public Utilities Commission's Self-Generation Incentive Program.
- Fund development and demonstrations of technologies that improve gas yields.
- Eliminate development barriers.
- Develop methods to accurately measure carbon reduction for these technologies.
- Provide incentives for on-site use of sludge to reduce long-distance waste transport.
- Develop a database or bulletin board listing available biodegradable materials.
- Finance new digesters and expand existing digester capacity to accommodate co-digestion opportunities.
- Include low-interest financing for private sector financiers willing to develop municipal systems using California energy efficiency and infrastructure financing programs.
- Encourage California agencies disbursing federal stimulus dollars to develop program rules that foster development of biogas combined heat and power systems at wastewater treatment plants.
- Inform the U.S. Congress about the public benefits of biogas combined heat and power projects so that the tax credits and production credits for eligible technologies continue without interruption.
- Evaluate the multiple public benefits delivered by these systems and develop feed-in tariffs that reflect their value to the electric grid and environment.
- Differentiate feed-in tariffs by each technology's contribution to meeting the state's renewable energy and environmental goals.
- Base emission limits on net benefits to a region from avoided pollution from site-specific reduction in electricity use and criteria pollutants.

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[2] A flare is a flame atop a tall pipe burning a gas without any recovery of heat for any use. The sole purpose of a flare is to get rid of a gas that generally as no economic value.

Develop state-level carbon reduction measures that credit co-digestion of biowastes such as manure and food wastes.

Adopt control rules for oxides of nitrogen that eliminate the discrepancy in emission limits between flaring gas and burning it for electricity generation at landfill and wastewater treatment plant sites to increase development of cost-effective, renewable electric generation capacity.

Introduction

The California Energy Commission has long supported and recommended policies that encourage the inclusion of clean and efficient combined heat and power (CHP) generation in California's portfolio of energy resources.[3] In spite of this support, market and regulatory barriers continue to make developing CHP in California difficult. On December 11, 2008, the California Air Resources Board (ARB) approved the *Climate Change Scoping Plan* as directed by Assembly Bill 32 (Núñez, Chapter 488, Statutes of 2006), which includes emission reductions specific to CHP. The preliminary recommendations to reduce greenhouse gas (GHG) emissions in California by 2020 include a target of 4,000 megawatts (MW) of installed CHP capacity, enough to displace approximately 30,000 gigawatt-hours (GWh) of demand from other power generation sources. Slow development of new CHP in California makes it important to revisit the potential for new CHP and determine whether the current CHP target is realistic. Understanding the full range of opportunities for CHP across industrial, commercial, and residential sectors will help determine where the opportunities for new facilities are the greatest. This information will be used to develop policies and regulations that encourage CHP and support the state's GHG emissions reduction goals. This staff paper will not attempt to look at the full range of CHP applications and sizes, but instead will focus on the opportunities for developing CHP at wastewater treatment plants.

The paper starts by assessing the technical and market potential for CHP systems at California wastewater treatment plants. It extends the inquiry for technical and market potential by including the use of other biodegradable waste streams for co-digestion at wastewater treatment plants. Co-digestion is a strategy that creates economic efficiency by producing more energy from the same or expanded infrastructure. The paper enumerates and analyzes the technical, regulatory, economic, and environmental issues that inhibit development of CHP potential at wastewater treatment plants and, finally, suggests steps to remove the identified barriers.

The paper is based on communications with wastewater treatment plant industry stakeholders, a survey of owners and operators of wastewater treatment plants,[4] and data from several state and federal government organizations. This paper is part of the larger effort at the Energy Commission to assess the CHP potential from all energy sources and sectors in California.

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[3] Specific recommendations with regard to distributed generation and combined heat and power resources can be found in the California Energy Commission's *2003, 2005*, and *2007 Integrated Energy Policy Reports*.

[4] The survey was conducted during April—May 2009. A copy of the survey is included in Appendix A.

Overview of Wastewater Treatment Plants and Operations in California

Wastewater treatment plants are an essential and integral part of all urban and many rural communities. These plants routinely process residential, commercial, and industrial wastes for conversion into benign liquid and solid waste streams. As energy users, wastewater treatment plants are in a class by themselves because, besides being high energy users, they also generate sludge, which can be used as a renewable energy resource. In addition, they often generate methane, a greenhouse gas that will need to be reduced under new regulations being developed by the ARB. One option is to flare the methane, and this is routinely done at wastewater treatment plants throughout the state. Another more efficient option is to burn the methane to generate electricity and then recover and use the waste heat to meet digester and space heating loads. By making use of the waste heat from onsite electricity production, CHP increases fuel efficiency and decreases energy costs.

There are about 268 wastewater treatment plants in California that have a discharge capacity of one million gallons per day or more.[5] The wastewater treatment plants are owned mostly by cities and counties, although some are owned and operated by federal and state institutions, such as military bases and prisons. All of these wastewater treatment plants use waste treatment processes that are somewhat similar and invariably energy intensive. Moreover, wastewater treatment service is critical to modern living, requiring reliable power supply to the plants. Many treatment plants have backup generation to ensure continued operation in an emergency. Using CHP would limit the need for backup generators, which are usually diesel-fired. However, a preferred alternative is to generate electricity and steam from sludge, a renewable resource produced by the wastewater treatment plant. Sludge is the material left over after the incoming sewage is treated. According to the U.S. Environmental Protection Agency (U.S. EPA):

> Sewage contains 10 times the energy needed to treat it, and it is technically feasible to recover energy from sludge. As renewable energy, it can be directly used in wastewater treatment, reducing the facility's dependency on conventional electricity. The greater the quantity of energy produced by the industry, the more the industry can help reduce emissions of greenhouse gases. Using solids as a resource rather than a waste may help stressed public budgets as well. Wastewater solids must be processed prior to disposal, and solids handling accounts for as much as 30 percent of a wastewater treatment facility's costs.[6]

[5] EPA Database for Waste Treatment Plants, 2008, data sent by the U.S. Environmental Protection Agency staff.

[6] U.S. Environmental Protection Agency, http://www.epa.gov/waterinfrastructure/pdfs/guidebook_si_energymanagement.pdf

Wastewater Plants: A Source of Renewable Energy

At all wastewater treatment plants, the process of treating wastewater begins with a primary level of treatment, but many plants also do secondary and tertiary treatments of the waste stream. Disposal of the residual waste stream (effluent) left after processing waste to the required level of cleanliness must comply with local, state, and federal regulations. The effluent is dried using mechanical means to the extent economically possible for the volume and site. The resulting sludge can then be disposed of in one of several ways as it biodegrades and produces methane gas and other materials. In urban areas, sludge can be spread in drying beds and then transported to composting sites or landfills, and in rural areas, it can be spread on agricultural fields.

An alternative method of disposal is to collect waste materials in a digester where it is subject to controlled biodegradation, followed by combusting the resulting methane (biogas) through various means. **Figure 1** shows the process for producing methane at a wastewater treatment plant.

Digester-generated methane has almost the same chemical composition as natural gas used at home for cooking and water heating. The only difference is that digester gas has contaminants and contains about 40 to 60 percent of the caloric value of pipeline quality natural gas.[7] Nonetheless, digester methane can be used just the same in boilers, turbines, and fuel cells. However, digester methane must be treated further to reduce moisture, hydrogen sulfide, and other harmful materials before it can be used for turbines or fuel cells. Combusted properly for heat and possibly electric generation, the sludge from a wastewater treatment plant becomes a valuable renewable resource rather than a liability.

Of the 268 wastewater treatment plants with more than 1 million gallons per day of capacity in California, only 117 have digesters. Generally, it is not cost-effective to install CHP systems at plants with less than 3 million or 4 million gallons per day of capacity. Consequently, the total biogas-based renewable electricity capacity at wastewater treatment plants is currently 35 MW; the generation capacity at individual wastewater treatment plants ranges from 250 kilowatts to 3 MW. However, it is now possible to cost-effectively install CHP at wastewater treatment plants with low flows by adding biodegradable waste from elsewhere to increase biogas production. The following sections of this report explore these possibilities and their impact on technical and market potential for wastewater treatment plant-based cogeneration capacity.

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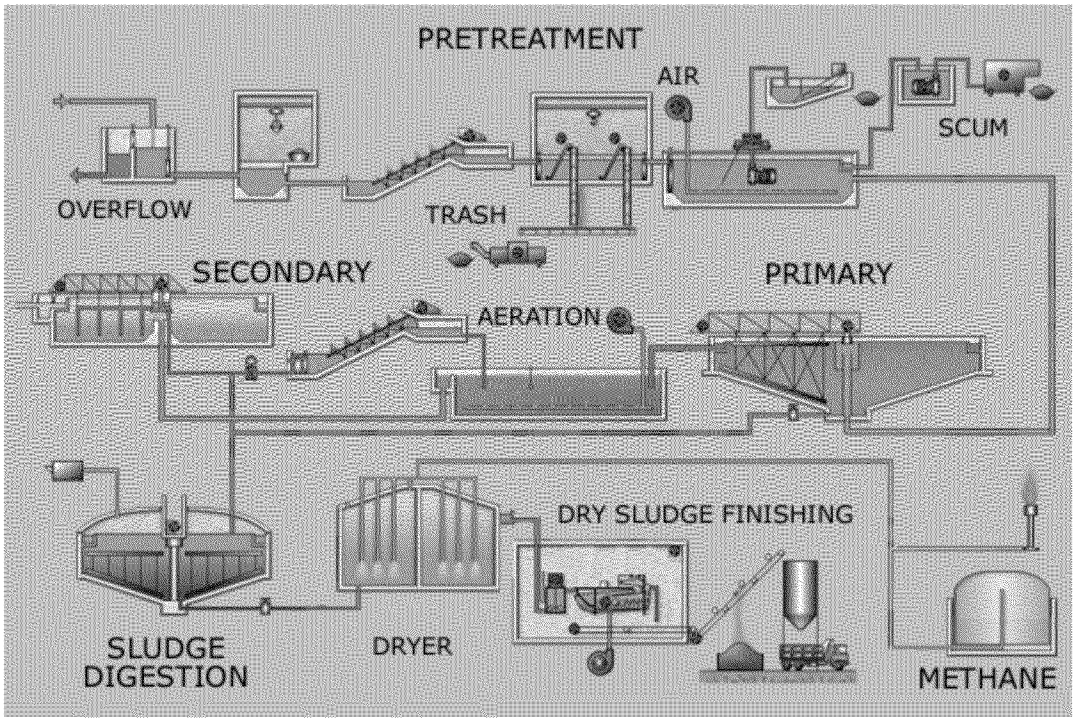
[7] Natural gas has approximately 1,020 British thermal unit (Btu) per standard cubic feet while digester-based methane generally has 400 to 600???.

Figure 1: Schematic Showing Production of Methane at a Wastewater Treatment Plant



Source: http://en.wikipedia.org/wiki/Sewage_treatment

Wastewater Plants: Source of Greenhouse Gases

Since the adoption of the ARB's AB 32 *Climate Change Scoping Plan,* which details strategies for reducing the production of GHG in California by 2020, wastewater treatment plants have made it a priority to investigate options for containing the production of GHG at their facilities. According to a U.S. EPA report on climate change,[8] wastewater treatment plants accounted for 29.3 million metric tons of CO_2 equivalent in 2007, approximately 4 percent of total U.S. carbon dioxide emissions. In California, centralized wastewater treatment plants, with or without digesters, contributed 2.24 million tons of CO_2 equivalent.[9]

[8] *Report on the Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2006.* Published April 15, 2008, by the U.S. Environmental Protection Agency. GHG emissions include methane and nitrous oxide.

[9] California Air Resources Board. *California Greenhouse Gas Inventory for 2000–2006—by IPCC Category.*

Resource Assessment: CHP Potential from Existing and New Biowastes

For several years, many of California's wastewater treatment plants with digesters have been producing on-site energy using CHP systems. Many more have the potential to do so but have not, thus missing opportunities to both reduce on-site energy use and add to California's electricity generating capacity. As of 2005, only 23 wastewater treatment plants were producing power using CHP.[10]

The following section assesses the technical and market potential for CHP capacity from the incoming sewage (influent) at wastewater treatment plants. It also assesses additional CHP capacity at existing wastewater treatment plants if biowastes such as dairy manure, waste from food processing plants, and restaurant waste oil and grease are combined with the influents.

Potential for Electric Generation Using Existing Sludge

According to EPA Region 9's 2008 database,[11] there are about 268 wastewater treatment plants in California that have digesters with an average dry weather flow of at least 1 million gallons per day or more. An average aggregate daily wastewater flow of these wastewater treatment plants is 3,000 million gallons per day. These WWTPs range in size from 1 million gallons per day to 400 million gallons per day and are mostly city- or county-owned treatment facilities, with a few at military bases and state and federal prisons. The associated digesters can produce approximately 17 billion standard cubic feet (scf) of gas per day. Reciprocating engines, also called internal combustion engines, are the most common technology for electric generation at these wastewater treatment plants. Using this technology, the 17 billion scf of gas has the potential to generate approximately 125 MW of baseload power in California. In addition, this electric production also can produce 64 million therms[12] of waste heat, most of which can be used on-site to keep the digesters at the optimum temperature for biogas production. Based on the prevailing economics of producing biogas, CHP system costs, and applicable electric and gas rates, only a small portion of this potential is realized. Approximately 35 MW of the projected capacity is in place, leaving 90 MW of unmet CHP potential.

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[10] Shahid Chaudhry, PowerPoint presentation, Water–Energy Program, California Energy Commission, August 2005.

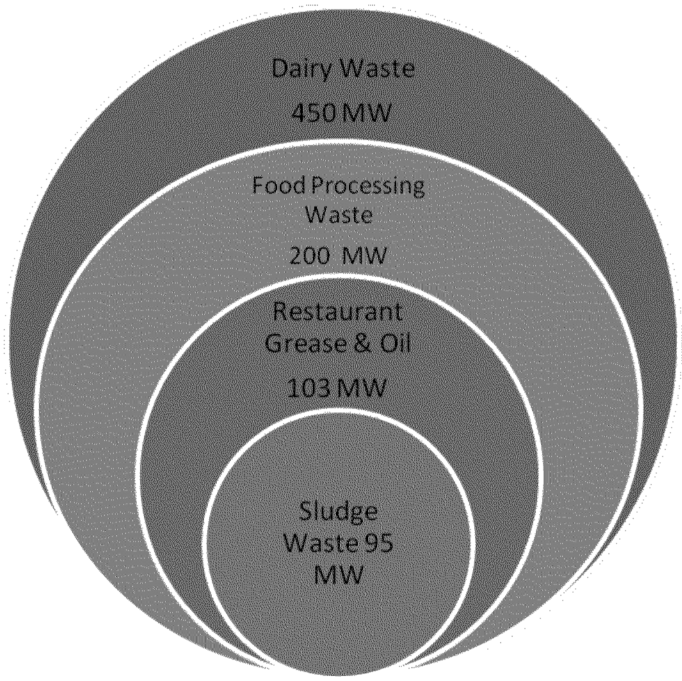
[11] EPA Database for Waste Treatment Plants With and Without Digsters. 2008. Data sent by the U.S. EPA staff.

[12] A therm is equal to 100,000 Btu. It is the measurement unit in which gas prices are quoted.

Potential for CHP From New Resources

Figure 2 shows the cumulative CHP market potential[13] if digesters use other biodegradable feedstocks in addition to the sludge produced by the wastewater treatment plants. A study by the Energy Commission's Public Interest Energy Research (PIER) Program concluded that co-digesting dairy manure and food processing waste in addition to sludge in digesters, substantially increased biogas production.[14]

Figure 2: Expanding Market Potential for Wastewater Treatment Plant CHP Through Sludge Co-Digestion of Multiple Biowaste Streams in California



Source: *Co-Digestion of Dairy Manure/Food Processing Waste and BioSolids/Food Processing Wastes to Energy,* California Energy Commission Report, 500-2007-015. March 2008.

Disposing of these waste streams is a serious challenge for both the dairy and food processing industry. If left untended, both waste streams generate 3 million metric tons of CO_2 equivalent emissions annually.[15] When added to anaerobic digesters at wastewater treatment plants, these liabilities can be turned into assets, significantly boosting gas and

[13] Technical and market potential for each of the biodegradable feedstock in this figure is shown in **Table 1** of this report.

[14] *Project 3.1 Co-Digestion of Dairy Manure/Food Processing Waste and BioSolids/Food Processing Wastes to Energy*, California Energy Commission, CEC-500-2007-015. March 2008.

[15] California Air Resources Board Web page: California Greenhouse Gas Inventory for 2000-2006—by IPCC Category. http://www.arb.ca.gov/cc/inventory/data/tables/ghg_inventory_ipcc_00-06_all_2009-03-13.pdf

electricity production. Finally, fat, oil, and grease wastes from restaurants and institutions can also be added to digesters at wastewater treatment plants to increase generation. Fat, oil, and grease wastes, although not as abundant as dairy manure, are still quite potent in their ability to generate additional gas and deliver collateral benefits by reducing wastewater treatment plant operating costs.[16]

The technology for mixing these waste streams has been demonstrated in commercial settings in several locations. These demonstrations show that, by using co-digestion, biogas production at a wastewater treatment plant can increase by 10 to 40 percent.

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Manure from dairies is a biodegradable resource that can also be co-digested in wastewater treatment plant digesters. After a successful demonstration at a wastewater treatment plant digester in eastern Los Angeles County, a PIER study estimated that the long-term technical potential for co-digesting dairy manure with food waste in California yields 334 MW of electric generation capacity.[17] After applying the financial models used to evaluate capital investment decisions, the PIER report found the long-term market potential to be 250 MW.

The dairies themselves could possibly digest all the manure on-site for electric generation, but they do not have enough on-site electrical load to use all the electricity generated on-site. There are currently less than 10 dairy-based digesters operating in California, and the prospect of adding more at this time is discouraging. Water discharge and air emissions restrictions preclude additional digester deployment. Consequently, currently enough dairy manure is available in proximity to wastewater treatment plants that have sufficient existing digester capacity or could be expanded in short order. Obtaining additional permits for dairy manure treatment and sludge disposal may not be as formidable for a wastewater treatment plant as it is for a dairy.

The potential for cogeneration requires the food and dairy processing sites and the wastewater treatment plants to be located within logistically manageable distances. The PIER study assessed this parameter and found that a sufficient number of dairies, food processing plants, and wastewater treatment plants located near each other.

Figure B-1 in Appendix B shows the locations of dairies, food processing plants, and wastewater treatment plants in California. The 250 MW CHP market potential using dairy waste considers the proximity analysis.

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[16] Information brochure from Kennedy/Jenks on the Millbrae Project. The brochure mentions reduction in undigested sludge volume by 30 percent that needs transportation to the landfill and reduction in chemicals use.

[17] Source: *Co-Digestion of Dairy Manure/Food Processing Waste and BioSolids/Food Processing Wastes to Energy,* California Energy Commission, CEC-500-2007-015. March 2008.

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The food processing industry is a major part of California's economy. It consists of vegetable and food processors and manufacturers of dairy products and beverages. A byproduct of these operations is a waste stream that needs to be disposed properly. The solid waste is generally landfilled, and the liquids are neutralized and discharged according to strict regulations. Both these operations add to the food processor's operating expenses. There are more than 4,600 food and beverage manufacturers[18] and 121 dairy processors in the state who collectively produce a renewable resource that could be co-digested with sludge.

The PIER study discussed above-assessed the technical and market potential for added CHP capacity at wastewater treatment plant locations using food processing waste. The study concluded that co-digestion of the food processing waste stream in the long run can increase CHP technical and market potential by 129 MW and 97 MW, respectively. This conclusion was also based on the economics and logistic viability of transporting the food processing waste to nearby digesters.

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Approximately 20 pounds of restaurant fat, oil, and grease waste is generated per person per year in metropolitan areas.[19] Assuming that 28 million Californians live in metropolitan areas, some 275,000 tons of restaurant waste oils/grease are produced per year. This has a potential to yield 1.2 billion scf of gas, enough to supply about 10 MW of base load generation capacity. Tipping fees[20] and the additional available gas could be sufficient to improve the economics for small wastewater treatment plants, which otherwise may not consider developing CHP projects. The Kennedy/Jenks analysis for the Millbrae project cited earlier demonstrated that adding grease/oil digestion to an otherwise uneconomical small project can result in a cost-effective CHP system.[21]

Collectively, oil and grease waste, food processing plant waste, and dairy manure have the technical ability to add 473 MW of capacity to California's renewable electric generation. This technical potential is based solely on the availability of biodegradable material. Many factors can prevent the realization of full technical potential, including site economics, transaction costs, organizational priorities, and regulations that encourage or impede project development. Considering these factors yields an estimated market potential of 335 MW of capacity from biodegradable waste other than sludge.

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[18] *2002 Economic Census, State Manufacturing by Industry*. Statistics based on North American Industry Classification System codes 311 (food manufacturing) and 3121 (beverage manufacturing).

[19] Robert B. Williams *Biofuels From Municipal Wastes — Background Discussion Paper.* California Air Resources Board Workshop, March 2007.

[20] A tipping fee is paid by the generator of waste to someone who accepts the waste. The waste hauling companies pay a fee to the local landfills for accepting the municipal waste.

[21] Information brochure from Kennedy/Jenks on the Millbrae Project.

Table 1 summarizes the technical and market potential of co-digesting the three categories of biowastes described above. Using the existing digester capacity and incoming waste stream, the technical resource potential is presently 125 MW. Adding fat, oil, and grease waste, food process industry waste, and dairy waste for co-digestion increases the cumulative technical CHP potential to 598 MW. After applying the financial criteria normally used to evaluate capital investment decisions, the cumulative market potential from sludge and other biowaste streams is 450 MW of electric generation in the next 15 years. A rudimentary infrastructure for collecting and diverting food waste already exists. However, a study is needed to estimate additional investments necessary to augment the existing waste handling equipment and digester capacity.

Table 1: Resource and Market Potential for Combined Heat and Power From Wastewater and Co-Digestion From Other Biowastes in Megawatts

Resource Type	Technical Resource Potential	Market Potential
Wastewater	125	95
Restaurant Fat, Oil, and Grease	10	8
Food Processing Waste	129	97
Dairy Waste Manure	334	250
Combined Total	**598**	**450**

Note: The 95 MW of market potential from the wastewater plants includes the existing CHP capacity of 35 MW in California.

Source: Energy Commission.

Attaining Combined Heat and Power Market Potential

Technically, most of the waste coming into a treatment plant can be converted into biogas and used for a CHP project. Yet the decision to install a CHP system using sludge or another biowaste at a wastewater treatment plant depends on the interplay of three major factors: technology, economics, and regulations. Only some of these factors can be influenced by policy changes to make CHP more attractive. Table 2 lists the three factors and the various components of those factors that affect the decision to install CHP at a wastewater treatment plant. The next section of this paper discusses how these factors influence the decision to install CHP at a wastewater treatment plant.

Technology

A CHP system consists of many parts that include the electric generator, equipment to spin the generator (except for a fuel cell), waste-heat recovery systems, anaerobic digester to generate gas, equipment to clean the gas, mixers, waste heat recovery equipment, pollution control equipment, and instruments to monitor and measure pollution. Many of the CHP system subcomponents are selected based on the quality and quantity of gas available, the regulatory regime in effect, and cost considerations. Following is a discussion of major technologies that affect the performance, economics, and decision to install CHP.

Electric Generation Technologies

Technology choice for electric generation and waste heat recovery influence a CHP project's economic viability. Two major factors in selecting technologies are the ability to convert biogas into electricity efficiently and cost-effective recovery of heat. Waste-heat recovery is critical at a wastewater treatment plant because it displaces the thermal energy derived from the natural gas purchased from the local utility. The cost of applicable emission controls and monitoring are also critical factors in a selecting one technology over another.

There are many CHP technologies, and each has its own benefits and drawbacks. Their deployment is determined by site-specific conditions. The four main technology types are:

Reciprocating engines (commonly referred to as internal combustion engines or ICE)

Microturbines

Gas turbines

Fuel cells

Table 2: Factors and Components Affecting Combined Heat and Power Viability at Wastewater Treatment Plants

Technology	Economic Considerations	Environmental Regulations
Digester Chemistry	Electricity Rates	Limits On Criteria Pollution
Digester Yield	Natural Gas Rates	Limits On GHG Emissions
Feedstock	Biosolids Disposal Cost To Land Fill	Limit On Biosolids Disposal
Generator Technology	Transporting Waste For Disposal	Limits On Water Discharge
Waste Heat Recovery	Financing Cost	Limits On Biogas-To-Natural Gas Ratio
Combustion Efficiency	Capital Cost for Digesters, Scrubbing & Generators, Etc.	Flaring Permits
Gas Scrubbing Technology	Tipping Fee For Imported Biomass/Fat, oil, and grease	
Monitoring , Measurement & Validation Equipment	Utility Rebates	
Emission Control Technologies	Tax Credits	
	Carbon Trading Price	
	Price Of Renewable Energy Credits	
	Permitting Cost	
	Interconnection Cost	
	Feed-In Tariff	
	Maintenance Cost	

Source: California Energy Commission

Selection of a specific technology for the CHP system is done by optimizing the system efficiency, emissions, and cost of the technology. Table 3 shows the comparative efficiencies and emissions from each technology type.

The size of the CHP system is also determined by the amount of gas that is available from each digester site. The current installations in California range from a 30 kW to 2 MW of different configurations of microturbines, fuel cell modules, small turbines, or internal combustion engines. All of these technologies could be deployed as one large unit or multiple units of smaller size, depending on the certainty and timing of biogas availability. Internal combustion engines are the most common equipment used for CHP systems at wastewater treatment plants. Microturbines and small turbines are also common but are installed less frequently. Fuel cells are the least common. The general characteristics of each of these technologies are discussed in Appendix D, along with their advantages and disadvantages as wastewater treatment plant CHP systems.

Table 3: Sizes, Efficiencies, and Emissions for Combined Heat and Power Technologies Commonly Used for Biogas Combustion

Technology Types	Size Available	Electric Conversion Efficiency With Higher Heating Value	CO_2 Emissions Lbs Per MWh	NO_x Emissions Lbs Per MWh Without SCR*
Microturbines	30kW–400 kW	23%–28%	1,780–1,440	0.08–0.25
Gas Turbines	1–5.5 MW	21%–28%	1,920–1,440	0.17–0.20
Internal Combustion Engines	100 kW–5 MW	28%–39%	1,440-1,030	0.06 Rich Burn , 3-way catalyst to 0.8 Lean Burn
Fuel Cells	250 kW modules	25%–55%	1,660-730	0.03

* Selective catalytic reduction.

Source: Arthur Soinski, Ph.D. California Energy Commission. Table derived from the U.S. EPA *Catalogue of CHP Technologies"* 2008 for natural gas as the fuel.

Gas Scrubbing Technology

In designing a CHP system, the costs of purchasing and maintaining equipment to clean the digester methane are important. Digester methane often contains moisture, siloxane,[22] and other trace elements that impact the performance of the generation technologies. Microturbines and fuel cells are more susceptible to these contaminants than internal combustion engines. Early installations of microturbines were seriously hampered by failure of the gas scrubbing equipment. A developer who has constructed 12 wastewater treatment plant-based CHP projects in California found that initially microturbines were not robust enough to withstand variations in gas quality, resulting in expensive maintenance, interruptions, and underperformance.[23] According to this developer, for systems less than 400 kW, the cost of the gas-scrubbing equipment represented almost 50 percent of the

[22] Any of a class of compounds, varying from liquids to hard resins, whose molecules are composed of chains of alternate silicon and oxygen atoms.

[23] Telephone conversation with Lou Lagomarisino of US Energy Services, Inc., Scottsdale, Arizona. US Energy Service develops and finances WWTP CHP projects.

system costs above the cost of digester itself. Facility developers generally avoid the use of CHP technologies that are sensitive to the quality of methane for systems smaller than 300 or 400 kW unless there are other compelling reasons to use CHP. However, the use of gas scrubbing equipment for large systems may still be cost-effective. Although gas-scrubbing technology is well-proven and widely used, ongoing research[24] is underway to reduce the cost and improve performance of gas-cleaning technologies. There are some alternative options being explored to improve the technology.

Digester Technology

Although anaerobic digesters are quite common and have been used for decades, the ease of operation and maintenance can differ among digester types. Some researchers and operators of digester systems believe that certain European digesters have relatively better output of biogas and lower maintenance costs.[25] Although there is a lot of interest in these improved technologies, they need to be tested under California conditions.

Policies that encourage development and demonstration of new digester technologies have been effective in bringing new technologies to the market, but there is a need for additional investment in technology transfer and commercialization of the newer, more efficient, and cost-effective digester technologies. The Energy Commission has funded many digester technologies in the past through its PIER Program; this research should be continued and expanded.

Co-Digesting Biowastes

As discussed in the earlier section on CHP potential from existing and new biowastes, recent research into the feasibility of co-digesting different bio-waste in wastewater treatment plant digesters has opened up opportunities to expand the potential of this technology. However, this work is ongoing, and additional study is needed on mixing of different types of food wastes in different volumes to digesters. Once these studies are completed, evaluated, and translated into engineering specifications, the use of multiple biowastes could become a common practice.

The availability of excess capacity at existing wastewater treatment plants is another factor affecting the use of biowaste. Analysis of U.S. EPA and the California State Water Resources Control Board databases shows that that there is approximately 15 percent excess capacity in the 268 wastewater treatment plants with digesters. Reaching the market and technical

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[24] *Commerce Energy Biogas/PV Mini-Grid Renewable Resources Program*. California Energy Commission, CEC-500-2007-029, 2007. Page 3-27.

[25] Communications with Dr. Zhiqin (Jessica) Zang of California Energy Commission and Ms. Martha Davis of Inland Empire Utility Agency, May-June 2009.

potential for co-digestion at wastewater treatment plants once this excess capacity is used up will make it necessary to augment digester capacity. Suggestions in this regard are presented in the "Conclusions" section at the end of this report.

An accessible database on volume and location of available restaurant oil and grease, cow manure, and food processing waste that can be economically transported would minimize the cost and time required to identify viable sources of waste for co-digestion.

Monitoring, Measuring, and Validation Equipment

Monitoring, measuring, and controlling emissions are critical for obtaining permits and operating within permit requirements. As regulations controlling criteria pollutants change and become more stringent, it becomes imperative that technologies for monitoring, measuring, and validating (MMV) emission reductions be accurate and inexpensive. A recent rule change by several air quality management districts requires wastewater treatment plants prevent mixing more than 10 percent use of natural gas with digester methane for electric generation. The rule also requires stringent monitoring to ensure compliance. According to the spokesperson[26] for the Southern California Alliance for Publically Owned Treatment Works, the need to comply with the 10/90 rule requires the installation of MMV equipment, which adds to the cost of operation. More importantly, currently available MMV technology is not reliable enough. Incorrect monitoring leads to non-compliance and the threat of heavy fines; consequently, the wastewater treatment plant-based CHP operators shut the plants down and resort to flaring the gas.

The need for inexpensive and well-calibrated MMV technologies becomes more critical as requirements for GHG reduction are implemented and marketable carbon credits are created. Measurement according to acceptable and established protocols becomes critical to participate in the carbon market. The nascent industry needs automated, well-calibrated, and inexpensive MMV technologies to validate carbon reductions to the standards acceptable to those trading in and certifying carbon reductions. Again, this is an arena where calibrating equipment standards need to be developed with funding support from programs such as PIER.

State agencies need to actively support protocols for assessing GHG reductions and their validation, standardization, and eventual acceptance. In the past, the PIER Program has supported development of such protocols, and this support needs to be continued. A California wastewater treatment plant operator[27] responsible for multiple CHP installations believes that there should be flexibility to use any of the accepted and validated protocols. This is essential because some protocols are more difficult or expensive to use. When a small

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[26] Phone conversation with Mr. John Pastore, Execuive Director of Southern California Alliance for Publically Owned Treatment Works (SCAP), June 2009.

[27] Conversation with Ms. Martha Davis, Inland Empire Utility Agency, June 1, 2009.

amount of GHG control is required, it may not be cost-effective to allow the use of only one particular protocol. This institutional barrier needs to be removed; a dialogue and collaboration between government agencies and wastewater treatment plant stakeholders would help remove this barrier.

Economic Considerations

There are many public benefits to installing and operating wastewater treatment plant-based CHP systems, yet decisions to develop such systems hinge on the on-site operating economics. The primary business of a wastewater treatment plant is to quickly and cost-effectively treat the incoming waste stream in accordance with regulations of the California Environmental Protection Agency and U.S. EPA, regional water quality control boards, and local entities. In this context, the use of digesters and the development of CHP systems to reduce methane are based on assessing energy savings and the relative costs of compliance verses cost of non-compliance (penalties). Sometimes the decision hinges on the potential and benefits of exporting the electricity to a local utility. The transaction costs of entering into a contract to sell power figure prominently in the economic calculations. Many of the components considered in developing a business case for installing a CHP system are listed in Table 2. Descriptions of salient components and their effect on the economics of CHP installation are presented below. The following sections discuss the costs for disposing waste byproducts, energy, emission mitigation, and financing. The discussion also focuses on how the dynamics of energy costs, emissions, and regulations affect the financial viability of CHP installations at the wastewater treatment plants.

Transporting Waste to Off-Site Disposal

Treated waste or sludge has to be disposed at landfills, spread on nearby fields, or transported to remote facilities that accept such waste material. Of the 268 sewage treatment plants in California with capacity of more than 1 million gallons per day, 104 send their sludge outside the county of origin. Most of these exporters are urban plants that truck their sludge to a composter or landfill as far as 100 miles away. Increased diesel prices, other transportation costs, and a need to reduce transportation-based GHG emissions are affecting the economics of this practice. The result is increased interest in possibly reducing the quantity of waste material through use of anaerobic digesters.

According to U.S. EPA staff, digesters typically reduce the volume of incoming waste by 40 to 50 percent. Large plants that want to reduce shipments of sludge to distant locations normally have digesters on site, yet many choose to flare the gas into the atmosphere rather than generate electricity on site. Until the recent past, due to the low cost of energy and little concern about GHG emissions and other pollution, it made economic sense to transport the waste to a far-off location. The rising cost of energy and refusal by localities to accept waste from other cities or counties is changing the economics in favor of expanding digester capacities or building new ones. Desire to reduce energy and transportation costs, especially in light of co-digestion possibilities, will go a long way toward reducing the long-distance hauling of dried sludge. Adding more digesters will create new opportunities for CHP installation to displace on-site electrical load and garner added public benefits.[28] Reducing long-distance transportation of wastes should be encouraged by providing incentives for developing infrastructure and technologies for on-site use of sludge. Such initiatives would complement existing state policies that support intelligent and sustainable land use planning.

Energy Cost for Processing Wastewater

The wastewater treatment process is inherently energy-intensive, requiring pumps, motors, and aeration equipment day and night. Approximately 35 percent of the operating costs of wastewater treatment plants are energy costs. Depending on the utility, the electricity prices range from the low of $0.08 per kWh during off-peak periods to a high of $0.30 during the summer peak. In 2008 and 2009, the average electricity rates in California's major urban centers have ranged from $0.135 per kWh and $0.165 per kWh, respectively. The on-site energy use is also increasing as many wastewater treatment plants are using more energy-intensive technologies to meet increasingly stringent water discharge rules. Often there are high demand charges that are added. The rising cost of electricity, especially during peak hours, has led wastewater treatment plant operators to explore energy efficiency and self-generation options on their own. Often wastewater plants also buy natural gas from the local utility to use in boilers that provide heat to the digesters.

Financial Incentives

Despite the high cost of energy, the availability of financial incentives most frequently motivates actual installations. Financial incentives have taken many forms over the years and are often the result of policy initiatives at the federal or state level. In early 1980s, it was the Public Utility Regulatory Policy Act of 1978 (PURPA) and resulting standard offer contracts that prompted cogeneration in California. In recent years, it has been the state's Self-Generation Incentive Program (SGIP) and Net Metering Program that have influenced CHP decisions. Generous federal tax credits and production credits have also improved the economics, leading to several CHP installations at wastewater treatment plants. The need for such incentives becomes more urgent as the recent economic slowdown diminishes municipal revenues and ability to raise capital by issuing debt.

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[28] Public benefits in this context means reducing air and water pollution, use of fossil fuel, increasing grid stability, and increasing the use of renewable fuel. Societal benefits thus delivered may be monetized or non-monetized.

Financial incentive programs vary substantially in their ability to encourage a CHP installation at a wastewater treatment plant. The value of a kWh saved or exported varies by the local utilities, and generation technologies are treated differently. Some incentive programs place limits on the size of individual generation units and on aggregate generation capacity installed in each utility's service territory. The rules regarding the ownership of the renewable energy credits associated with the kWh generated also differ. These differences favor some renewable technologies over others. The disparity in valuing kWh from different technologies puts wastewater treatment plant-based CHP at a disadvantage. Consequently, some financial incentives programs are rarely used for funding CHP systems at wastewater treatment plants.

Self-Generation Incentive Program (SGIP)

Since its inception, the SGIP program has funded more than 1,200 facilities representing 300 MW of electricity generation capacity. Of this capacity, 160 MW are from 330 CHP facilities. Although most are fueled by natural gas, 30 MW from 60 facilities is generated using biogas from wastewater treatment plants, landfills, and dairies.[29] While wastewater treatment plant-based CHP constitutes a small number of these installations, the SGIP has played a significant role in the installations that have occurred at wastewater treatment plants in the last few years.

The SGIP has some clear advantages for wastewater treatment plant-based CHP over other incentive programs. The motivation for on-site generation by wastewater treatment plants is often displacing on-site use, not exporting power. Consequently, incentive programs that involve the complications of interconnection and contract negotiations with a utility are found less attractive. A recent survey by Energy Commission staff showed that most wastewater treatment plant-based CHP projects operate to displace a substantial amount of their native load. The SGIP incentives also permit third-party financing, thus increasing the number of available financing options. A private financier who has built more than 10 wastewater treatment plant-based CHP projects in California has used the SGIP in all but one of those projects.

In the last few years, the SGIP has been the most effective program for motivating CHP installations, especially for small plants. Beginning in 2008, natural gas-based generation ceased to be eligible for the SGIP incentives. This has had an adverse impact on wastewater treatment plant-based CHP installations. Reinstatement of CHP eligibility under the SGIP would encourage wastewater treatment plant-based CHP.

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[29] George Simons, "Lessons Learned From Decade of CHP in California," *Cogeneration and On-Site Power Production*. March-April 2009.

Net Metering

Net metering enables customers to use their own generation to offset their consumption over a billing period when they generate more than they use. Customers avoid paying full retail rates for their consumption by selling the excess electricity they generate to the utility. Full rate includes generation, transmission, distribution, and utility overheads. A second meter is usually installed to measure the electricity that flows back to the utility.

The suitability of this program for wastewater treatment plants is quite limited. High, around-the-clock electrical load at the site makes opportunities for selling the power to the utilities minimal. Moreover, the eligible projects are limited in size to 1 MW, meaning almost all the generation is likely to be used on site, leaving very little, if any, to be sent to the utility. This program can at best negate or reduce the electricity bill for a wastewater treatment plant, but it cannot provide a net increase in payments received, even though the plant may have exported more power than it consumed. Under net metering, the renewable energy credits are normally retained by the site owner, but not all electricity generated is valued equally. Solar and wind technologies are credited against the full retail value. On the other hand, biogas and fuel cells avoid paying just the cost of generation and still pay transmission, distribution, and other applicable charges. This discrepancy makes net metering less economically attractive for biogas digesters compared to other technologies.

Clearly, net metering is not the best option for a wastewater treatment plant-based CHP program. The only benefit is that the wastewater treatment plant can keep its renewable energy credits, but that benefit is not enough to outweigh the disadvantages.

Feed-In Tariff Under AB 1969

In 2006, Assembly Bill 1969 (Yee, Chapter 731, Statutes of 2006) was passed requiring California's investor-owned utilities to file a standard tariff with the California Public Utilities Commission (CPUC) for renewable energy output produced by public water or wastewater agencies that purchase power from the utility. A subsequent CPUC decision (D.07-07-027), issued in July 2007, authorized expanding the tariffs to include other customer classes. Pacific Gas and Electric Company (PG&E) and Southern California Edison (SCE) were required to submit separate tariffs for the purchase of eligible renewable generation from entities other than public water and wastewater agencies. The proceeding resulted in an effective feed-in tariff to encourage small, customer-owned renewable energy projects.

The feed-in tariff allows eligible customer-generators to enter into 10-, 15-, or 20-year standard contracts with their utilities to sell the electricity produced by small renewable energy systems up to 1.5 MW in size at time-differentiated, market-based prices. As of April 2009, this expansion has led to a total of 9 MW and 15 MW of capacity from PG&E and SCE, respectively. Almost all of these projects are solar, wind, hydroelectric, or landfill gas projects. In spite of its intent, AB 1969 did not result in a single biogas-based CHP project.

Inquiry into this failure led to the following explanations from industry analysts[30] routinely reviewing incentive programs:

> For CHP plants generating up to 1.5 MW of power, there is often sufficient on-site energy need. This situation takes away the option for exporting power unless the feed-in tariff is very high.
>
> The feed-in tariff price for exported power is differentiated by the time of delivery, and the range varies from $0.31 per kWh to a low of $0.06 per kWh, depending on the time and the utility.[31] The average prices across utilities range from $0.09 per kWh to $0.11 per kWh. Unlike solar, the majority of biogas generation is not on the system peak, so the prices that can be received by CHP wastewater treatment plant under the feed-in tariff are generally low and not sufficient to justify export.

Advocates for the wastewater industry believe that the feed-in tariff should be differentiated by specific technology type, and the tariff for wastewater treatment plant-based CHP should be high enough to reward the unique public benefits those plants deliver, which currently are undervalued. They contend that the value of kWh delivered under a feed-in tariff is undervalued since many other public benefits are not included in that tariff.

The *2009 IEPR* proceeding has had other forums where the limitations of existing feed-in tariff program were analyzed. A consultant report on the topic of feed-in tariffs, *California Feed-In Tariff Design and Policy Options,*[32] was discussed at a May 2009 workshop and outlined various ways in which the feed-in tariff program could be made more effective. The actions and policies for making feed-in tariffs more conducive to wastewater treatment plant-based CHP should be in concert with the recommendations in that report.

Utility Contracts

Some of the initial CHP power sales from wastewater treatment plants to utilities were enabled by PURPA-inspired contracts with qualifying facilities (QF). These were multi-year contracts with very lucrative rates; the generous payments, combined with tax credits, made the economics of these projects quite attractive and financing easy. Today, QF contracts available from utilities offer short-term avoided costs for those projects that cannot provide firm power. Uncertainty of gas production and fluctuating power needs at the wastewater treatment plant site lead the receiving utility to declare biogas-based CHP as an "intermittent" resource, thus ineligible to receive the prices offered to a "firm" resource.

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[30] Communications with Dan Guis, The Dolphin Group, Sacramento, California, June 2009.

[31] Market Referent Price Tables 2008, paper presented Dan Guis, The Dolphin Group at the Association of California Water Association Conference, Sacramento, California, May 2009.

[32] KEMA, *California Feed-In Tariff Design and Policy Options.* California Energy Commission, CEC-300-2008-009F, May 2008

Absent better rates, some wastewater treatment plant owners have resorted to flaring the gas, thus squandering an opportunity to provide renewable power in support of California's Renewables Portfolio Standard and GHG emission reduction goals. A possible solution may be making the tariff for wastewater plant-based CHP high enough to justify exporting of electricity rather than flaring gas.

Tax Credits

Federal tax credits have played a major role in improving the economics and financing options for many renewable projects. Wastewater treatment plant-based CHP projects are no exception. The tax credits have been instrumental, especially in fuel cell CHP systems installations. Fuel cells are expensive, but the 30 percent federal tax credit combined with the SGIP incentives has improved the economics and financing options for fuel cell installation. Fuel cells are very clean but remain expensive even after accounting for the savings from avoiding the pollution control equipment needed for other CHP technologies. Financial incentives, such as the SGIP, augmented by tax credits undoubtedly are responsible for the installation of many wastewater treatment plant-based fuel cell CHP facilities. For example, the city of Tulare received $4 million from the SGIP program.[33] By installing fuel cells, the city avoided purchasing $600,000 worth of state emission reduction credits that would have been required with alternative combustion equipment.

With the equipment and production-based tax credits, wastewater treatment plant-based CHP projects can be financially attractive to third-party investors. These investors use the tax credits towards the upfront costs of the project and then contract with a wastewater treatment plant to provide electricity for a fixed price. Many wastewater treatment plant-based CHP projects in California are built with such an arrangement. Absent the tax credits, it is doubtful that private or third-party developers would be willing to enter into these arrangements with wastewater treatment plants. One drawback of tax credits is that wastewater treatment plants are often municipally owned and thus tax-exempt and cannot benefit if they purchase tax credit-eligible equipment themselves. There is a need for ingenious, legally sound business models where private financiers can pass on the tax benefits to the wastewater treatment plant installing CHP systems.

As of June 2009, production tax credits supporting biogas are proposed in federal legislation that would extend the existing tax credit to other technologies. Experience with renewable energy technology over the last 20 years shows that in instances where the availability of credits is extended yearly, investors have no certainty whether tax credits will be available from one year to the next. The uncertainty results in reduced investments. California may not be involved directly in developing federal polices, yet policies supporting tax credits at the federal level play an important role in promoting biogas-based CHP installations in California.

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[33] Information Pamphlet from Fuel Cell Energy, Inc., 2008.

Private and Public Financing

Wastewater treatment plants are generally infrastructure development projects funded by public entities that own the wastewater plants. These organizations have three primary funding sources: the general budget, special bond funds, and special purpose federal and state grants. For the first two categories, CHP development must compete with other municipal priorities, and the standard capital budgeting considerations apply.

Each of the first two options has its benefits and drawbacks. Municipal bonds are often tax-exempt; the lower capital costs justify a project with lower energy savings than what may be needed given higher financing costs for private capital. The municipal financing from budgets or bonds has a lower threshold for returns *and* generally has a longer payback period. This improves the project economics, but when private sector financing is used, the cost of capital is higher, and a higher threshold for financial return is applied. The current (year 2009) United States banking and financial sector problems make it difficult to obtain financing. Nor is it always easy to pass on the tax credits available to the private sector to projects built for and used by the public sector. State government should explore various business models that facilitate the passing the benefits of tax credits through to wastewater treatment plant projects. If the projects contribute substantially toward meeting public policy goals, then California energy efficiency and infrastructure financing should also look into extending low-interest financing to the private sector. Wastewater treatment plant-based biogas CHP often meets several public policy goals and, therefore, should be eligible for concessionary financing at the state level.

The American Reinvestment and Recovery Act 2009 (ARRA) is likely to provide new special purpose federal grants for investment in the wastewater treatment plant-based CHP projects. It is too early to assess how these funds will be used to encourage CHP projects, but several funding programs under ARRA target infrastructure improvements, fossil fuel displacement, and carbon reduction efforts. California agencies delegated with disbursement of ARRA funds should make concerted efforts to develop program rules to support biogas CHP development at wastewater treatment plants. Where the programs are directly administered by the federal government, California state agencies should show their support in as many ways as possible, including letters of endorsement, in-kind support, and matching funds if the budget allows.

Environmental Regulations

Impact on CHP Project Cost

Environmental regulations figure prominently in evaluating the viability of CHP projects at wastewater treatment plant. As an electric generator, CHP facilities generally are subject to a relatively stricter set of pollution control rules compared to a wastewater treatment plant that flares its methane.

Many wastewater treatment plant sites have an existing permit that allows them to burn biogas from digesters through flaring. If they decide to install CHP, they are reclassified as "electricity generation." Once this change occurs, they are subject to a different set of emission compliance rules, which add to the cost of emission containment. Although the net impact on the site emissions from criteria pollutants may change only slightly, the rules applicable to electric generation are more restrictive and require investment in new and expensive emission abatement equipment. This investment may adversely affect the decision by wastewater treatment plant to install CHP in some jurisdictions. This reclassification has become a major barrier that should be addressed.

Implementing the Global Warming Solutions Act of 2006, commonly referred to as Assembly Bill 32 (Núñez, Chapter 488, Statutes of 2006), will have yet another impact on decisions on whether to install CHP at wastewater treatment plants. AB 32 requires that a site generating more than 1 MW of power and producing more than 2,500 tons of CO_2 equivalent is subject to reporting requirements. The added reporting requirements may not be onerous, but uncertainty about the required reporting may discourage CHP installation. A wastewater treatment plant that flares the combusted biogas is treated as "industrial" and is subject to reporting requirements only if it exceeds 25,000 tons per year. Moreover, the impact of possible carbon trading rules in California and the United States is still uncertain, so the economic benefits of reducing carbon emissions are not presently known. Although CO_2 from wastewater treatment plant digesters is deemed biogenic and, therefore, exempt to some extent, this is not the case for nitrous oxide (NO_2) and methane from wastewater treatment plant digesters. The eligibility of nitrogen dioxide and methane reduction for carbon reduction credits, and their validation and tradability, are also unknown and create further uncertainty for wastewater treatment plant owners who are trying to understand what developing CHP will mean to them in the future.

As discussed earlier, collecting the necessary data to validate carbon and criteria pollutant controls would be a step toward reducing the uncertainty in evaluating the economics of installing a CHP project.

Regulating Emission Offsets

California air quality management districts have stringent rules and regulations on emitting oxides of nitrogen (NO_x) and particulate matter (PM). Currently one of the biggest hurdles for a CHP development is the availability and cost of emission reduction credits required to offset emissions of NO_x and PM. NO_x is associated with the formation of ozone, and some forms contribute to global warming. Almost all air basins in California are generally out of compliance with ozone and PM standards. In some air quality management districts, due to severity of non-compliance, emission reduction credits are either not available or prohibitively expensive, making it impossible to obtain a permit or rendering the project uneconomic. The need and cost of mitigation devices, such as selective catalytic reduction (SCR), may seriously affect economic feasibility. As discussed in previous sections, fuel cells or microturbines often become the technology of choice, provided the subsidies are available to compensate for higher fuel cell costs or the cost of scrubbing and pressurizing the gas for microturbines. If these technology options are not economic, internal combustion engines are usually chosen for CHP operations, in which case most of the air quality challenges are related to NO_x control.

Rules for Flares Versus Electric Generation

When wastewater treatment plant operators are unable to buy emission rights or find them prohibitively expensive, many opt out of CHP installation and continue flaring the methane gas produced by the plant. A few operating CHP systems have even shut down and reverted to flaring, which is governed by less stringent rules. According to many wastewater treatment plant operators and developers, the discrepancy in regulations is unwarranted since the difference in the emissions from each option is not significant (depending on the emission controls assumed). Electricity not generated at the wastewater treatment plant has to be provided from another source, which frequently involves combusting fossil fuel elsewhere and adds to pollution. The need to deliver the power from a remote source results in transmission line losses, adding to inefficiencies.

Wastewater treatment plant operators suggest that the emissions should be evaluated (and permitted) based on a broader assessment of pollution impacts than equipment-specific emissions. Current laws and regulations do not give AQMDs this flexibility. Some environmental laws and regulations create conflicting situations, where the tradeoff is between emitting NO_x and CO_2. Situations that require the selection of one over another in order to save costs are likely to proliferate. It is strongly recommended that the legislators and regulators actively explore the pros and cons of using location-specific net changes in criteria pollutants in permitting processes. These assessments should consider the net benefits to the region of avoided pollution from site-specific reductions in electricity use. Even a site-specific pollution assessment would be a step toward encouraging wastewater treatment plants to install CHP or not shut down an existing facility.

Developers who have to obtain a permit to stop flaring and begin CHP generation often use containment technologies that are expensive. Even when digester-based internal combustion engines equipped with SCR reduce emissions to a level lower than flaring, the site still has to carry permits for both the flare and the engine, doubling the permit costs. A possible solution is to allow for site-based offsets, rather than requiring purchase of offsets from elsewhere. The state agencies that influence the permitting process should weigh the benefits provided by existing rules against those of increased CHP installation: GHG emission reductions, increased efficiency in energy production, and growth in distributed generation capacity.

Change in Natural Gas/Biogas Ratio for CHP

Producing methane from digesters can be uneven and affected by irregular influent flows and other factors. To keep a CHP system functioning properly, the operator often augments biogas with natural gas from the local utility. A recent change in the rule on the proportion of natural gas that can be used to augment shortfalls in biogas production has adversely affected CHP operations. Until recently, CHP systems were allowed to use natural gas to meet up to 40 percent of their fuel needs to produce electricity. Current rules now limit natural gas use to 10 percent, with the remaining 90 percent coming from methane from the digester. [34] Strict monitoring and maintenance of this ratio are mandatory, requiring monitoring equipment that adds to costs. Moreover, according to industry sources, currently available equipment is unable to provide accurate measurement; incorrect measurement often results in fines for the wastewater treatment plant that exceed the 10 percent limit under a rule discussed below.

Recently a new wastewater treatment plant-based digester that had been permitted under the old rule—one that uses an innovative CHP technology—ceased operation once the rule changed. Many wastewater treatment plant digesters are now operating at less than the capacity of the installed generation system because they are afraid to exceed the 10 percent limit and incur fines. This newly idle capacity creates a shortfall for on-site electricity needs, requiring replacement generation from other sources. This has adverse environmental impact and suggests replacing site-specific assessments used in permitting processes with regional-or state-level evaluations of net reduction in fuel use and emissions.

GHG Emissions

Wastewater treatment plants generate methane, which is 23 times more potent than an equivalent amount of CO_2 in its contribution to global warming. Under AB 32, wastewater treatment plant-based CHP with a capacity of 1 MW or more that produces more than 2,500 tons of CO_2 will be subject to rules and reporting requirements. The economic impacts of reporting requirements and subsequent actions to control carbon emissions are still unfolding. At present, it is not clear that biogenic methane used for electric generation will be governed by rules different from those that apply to regular electricity generation. Regardless, active efforts should be undertaken to ensure that rule development includes a comprehensive assessment of the net impact on GHG reduction at a regional level, rather than at the site level.

There are some lessons from the NO_x control rules that may be applicable. When equipment-specific emission controls, rather than site-specific emission limits, are applied as

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[34] Rule 1110.12 South Coast Air Quality Management District, Reference: *http://www.aqmd.gov/rules/reg/reg11/r1110-2.pdf*

in the case of NO_x controls, some wastewater treatment plant-based CHP facilities have shut down. It is recommended that the lessons learned from the effect of disjointed NO_x control rule development be applied in developing the GHG control regulations.

Conclusions

The potential for wastewater treatment plant-based CHP is much larger than previously assumed. Expanding CHP with other biodegradable materials should provide a fresh impetus for reviewing the financing options and payments for the electricity produced. The primary function of these facilities is to provide cost-effective treatment of sewage, but the opportunity to reduce GHG emissions from other wastes and create additional CHP capacity does not have to compromise that responsibility. In fact, when properly structured and executed, these new opportunities will complement the primary functions of wastewater treatment plants. This expanded role increases the market potential of wastewater treatment plant-based CHP more than fourfold, raising it from 100 MW to 450 MW.

The complex decisions involved in investing in and operating a CHP system at a wastewater treatment plant cannot be ignored. Barriers to investment in and installation of a CHP system severely limit development of electrical capacity using sewage waste and bio-wastes. Technology choices, economic factors and regulatory issues further complicate decisions by wastewater treatment plant operators to develop CHP at their facilities. Progress has been slow in resolving issues that keep facility owners from investing in clean and efficient CHP, but resolution is essential if CHP is to play a significant role to support the environmental and efficiency goals contained in state policy directives and regulations. Besides reducing reliance on fossil fuels, reducing GHG emissions, and efficiently using waste heat, wastewater treatment plants can help reduce the impact of food processing, dairy, and restaurant grease and oil waste on California landfills and water supplies.

Specific findings and observations on issues discussed in this report are presented below. These findings pertain to streamlining or modifying existing programs, procedures, protocols, or permitting issues to support the development of wastewater treatment plant market potential. Converting some of these findings to actionable items may involve a single state agency, while others will require the active engagement of multiple agencies and industry stakeholders for implementation.

The SGIP provides a substantial and easy-to-implement incentive to install CHP at wastewater treatment plants, which almost always displace their own high electrical loads and rarely have a need to export. Most of the WWTP-based CHP systems installed in the last few years have used this program. Restoring CHP eligibility for the SGIP will provide a major impetus for expanding CHP capacity in California.

There is a need for continued funding for development and pilot demonstrations of new, advanced generation and digester technologies that improve gas yields and CHP economics.

It is necessary to actively support technology transfer and commercialization of new technologies to help eliminate institutional and economic barriers that add to transaction costs and delay CHP development.

State support is needed to validate existing and develop new protocols for data collection and analysis pertaining to carbon reductions at wastewater treatment plants.

Long-distance transport of wastes that add to cost and GHG emissions can be discouraged by providing incentives to develop infrastructure and technologies for on-site use of sludge. Such initiatives would complement state policies that encourage intelligent land use planning.

An easily accessible database or bulletin board providing location and volume of available biodegradable waste material will promote logistically and economically sound exchange of waste suitable for co-digestion at wastewater treatment plants.

CHP systems at wastewater treatment plants often meet several public policy goals and hence should be eligible for concessionary financing at the state level. There is a shortage of financing for developing new digesters and expanding existing wastewater treatment plant digester capacity to accommodate co-digestion of biodegradable waste from food processors, dairies, and restaurant grease and wastes.

California energy efficiency and infrastructure financing program packages should offer low interest loans for private sector financiers willing to develop CHP systems at municipal wastewater treatment plants. California agencies delegated with disbursement of ARRA funds should develop program rules that foster development of biogas CHP at wastewater treatment plants. In those instances where the programs are directly administered by the federal government, California state agencies should be encouraged to show their support in as many ways as possible.

On again and off again tax credits and production credits create uncertainty and slow down project development activities. The U.S. Congress should be made aware of the public benefits of biogas CHP projects so that the tax credits and production credits for eligible technologies continue without interruption.

Studies are needed to accurately and comprehensively evaluate the multiple public benefits delivered by co-digestions and CHP installations at wastewater treatment plants. Such studies are essential for developing feed-in-tariffs that capture the value of those benefits to the electric grid and environment.

Feed-in-tariffs should differentiate between various electric generating technologies and pay them in accordance with each technology's contribution to meeting the Renewables Portfolio Standard and AB 32 goals. This differentiation should monetize the public benefits delivered and need not be limited to the energy and capacity costs alone. The monetization of public benefits is essential until an efficient market for capturing carbon and other emission benefits has evolved.

Encourage emission control agencies to set emission limits based on regional-level assessments of the net effect on criteria pollutants rather than equipment-based limits alone. Pollution limits should consider the net benefits to the region from avoided pollution from site-specific reductions in electricity use and criteria pollutants.

Encourage development of state-level carbon reduction measures that would credit co-digestion of other GHG emitting biowastes, such as manure and food wastes. This will ensure that wastewater treatment plants will allow the use of their facilities to reduce GHG emissions from other feedstocks and not be penalized for doing so.

Encourage adoption of NO_x control rules that eliminate the discrepancy in emission limits between flaring and combustion for electric generation at landfill and wastewater treatment plant sites to increase development of cost-effective, renewable electric generation capacity.

Glossary of Acronyms

Acronym	Definition
AV	A44□□ □0B V%0
ACV	□□0%/&% A%C□4□H/8□4 V□□/□
ACCA	A□ □/%□& C□%D□4,□ □&, □&□ C□8□D□/B A8,
V,H	V/%41 ,1□/□ □0H&%
□* 4	S □,1□&□
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G* G	G/□□&1□H4□ 6□4
G3	G%□. □,,
G3 1	G%□. □,,-1□H/
I 3	K%□. □,,
I 3 1	K%□. □,,-1□H/
S 3	S □6□. □,,
S 3 1	S □6□. □,,-1□H/
N□x	□x%□4 □2&%□6□&
- G&A	- □8%% G□4 □&□ A0□8,/% □□□ 9□&B
- □AC - /□6/□□	- H□0% □&,□/□4, A&□/6B C□4□□/81 - /□6/□□
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APPENDIX A: Wastewater Treatment Plant CHP Potential Assessment Survey

Survey Of Cogeneration Potential at Publicly Owned Wastewater Treatment Plants

Introduction

The California Energy Commission strongly supports and encourages the utilization of waste heat through the use of cogeneration (Combined Heat & Power or CHP) technologies. The Commission staff is currently assessing the technical and economic potential of cogeneration using digested sludge at municipal wastewater treatment plants (WWTPs). The staff would also like to understand the major institutional, regulatory, environmental and financing barriers, if any, that make installing cogeneration at WWTPs difficult. The following information collected from the treatment plant operators will facilitate overcoming barriers. We thank SCAP and its members for helping us gather the necessary information. The report generated from this survey will be shared with the SCAP members. This information will also be discussed at an Energy Commission workshop on CHP in Sacramento on July 23, 2009. It should not take more than 30 minutes to respond to this questionnaire. Thank you.

Dear WWTP Operator:

Please provide responses to the following questions to the best of your ability.

1. City or County Name ______________________________

2. Name of the WWTP ______________________________

3. Location of the WWTP ______________________________

PLANT CAPACITY & ENERGY NEEDS

4. What is the Average Dry Weather Flow in million gallons per day (MGD)?___________

5. What is the plant's peak flow capacity (MGD)?________________________________

6. How much are the average and peak site electrical loads in kW or MW?

   a. Average kW/MW____________

   b. Peak kW/MW______________

7. Annual kWh consumption ____

8. Does your plant have on-site generation? Yes________ No________

9. If yes, what generation technology is being used?____________ Fuel used?__________

10. What is the on-site generation capacity in kW or MW?__________________________

11. What percent of current electricity consumed at the plant is met by site-generated electricity?____

12. What electricity rate are you currently paying ?

    Non-Peak Rate_________Peak Rate _____________Demand Charges, if any___________

13. If you do not know the rates, give the Rate Schedule for SCE or LADWP _____________

COGENERATION POTENTIAL ASSESSMENT

14. What types of sludge are produced at your treatment facility (e.g., primary, secondary)?

    ____

    a. Are these sludge thickened prior to treatment?_______________________________

15. How are these sludge treated (e.g., anaerobic digestion, dewatering)?________________

16. What is the capacity of your sludge treatment system?___________________________

17. If you employ anaerobic digestion what volume of gas is produced annually (in scf)?

    ____

18. If you produce digester gas how is it used (e.g., flaring, power generation, boiler)? If you use power generation or a boiler what is the capacity?___________________________

19. How is any waste heat from combustion of digester gas is used?____________________

____

20. How is the treated sludge (biosolids) currently handled or disposed of?______________

____

21. Was there a feasibility study done for assessing on-site electric generation using Cogeneration based on digester technology?(Yes)______(No)_____

22. If yes, when was it done? _______(year)

23. Is there an existing anærobic sludge digester on site?(Yes)_____ (No)_____

24. What is the size of the generator? ___________________(kW)

25. How much gas is being produced on site?-____________(scf or Btu)

26. Do you currently have an anaerobic digester? Yes_____ No_____

27. How old is the digester? _______(years)

28. Does it need to be repaired or need any capital expenses to be made operational? Yes_____ No_____

29. If your WWTP provides Cogeneration , please provide any details concerning electric output.____

30. Are you currently augmenting the gas production from the sludge by adding bio-wastes from other sources? Yes_____ No_____ If yes, what type of bio-waste?____________

____

31. How dependable is your bio-waste supply?_____________________________________
Are there any alternatives?____

32. Is all the digester gas produced utilized on-site by the engines/turbines/fuel cells or is there a left over gas that could allow for export of power? Yes_____ No_____

33. If there is excess gas, how is it being used?_____________________________________

34. If you could, would you export the additional electricity to the local grid? Yes_____ No_____

35. At present do you have any plans for installing Cogeneration at your site?

Yes_____ No_____

36. If yes, why are you interested? Please list the top three motivating factors for your interest in Cogeneration.

(i)____

(ii) ____

(iii) ____

BARRIERS TO COGNERATION DEVELOPMENT

37. Are there any pressing environmental issues (e.g. concern for methane or CO_2 emissions, disposals of bio-solid) that might either encourage or discourage you from exploring a Cogeneration installation at your WWTP? If so, please list them:____________________

____

____

38. If you are not interested in exporting power, what are the reasons?__________________

____

____

39. What are the major barriers that are preventing you from considering Cogeneration?

Please mark the top four or five barriers

a. Size of the plant_____

b. Not enough gas to make the project cost-effective_____

c. Lack of time and resources to do the assessment_____

d. Problems with permitting_____

e. Lack of financing/capital_____

f. Utility interconnection too difficult or cumbersome_____

g. The rates offered by the utility too low_____

h. What are they currently offering QF Contract_____SRAC___________Other_____

i. Contracts are cumbersome______

j. Little or no political support at city or county level_____

k. Any other barrier?_____

40. Is there any information that you, plant managers or City/County officials need that might help make an informed decision on assessing the CHP potential for the WWT plant?____

____

41. Are there any comments or suggestions you may have in this regards?_______________

____

____

Your information will help us immensely to assess the current potential for cogeneration at the WWTP plants in California and facilitate realization of this potential. Is there a name and phone number we could call in case there are any follow-up questions for clarification?

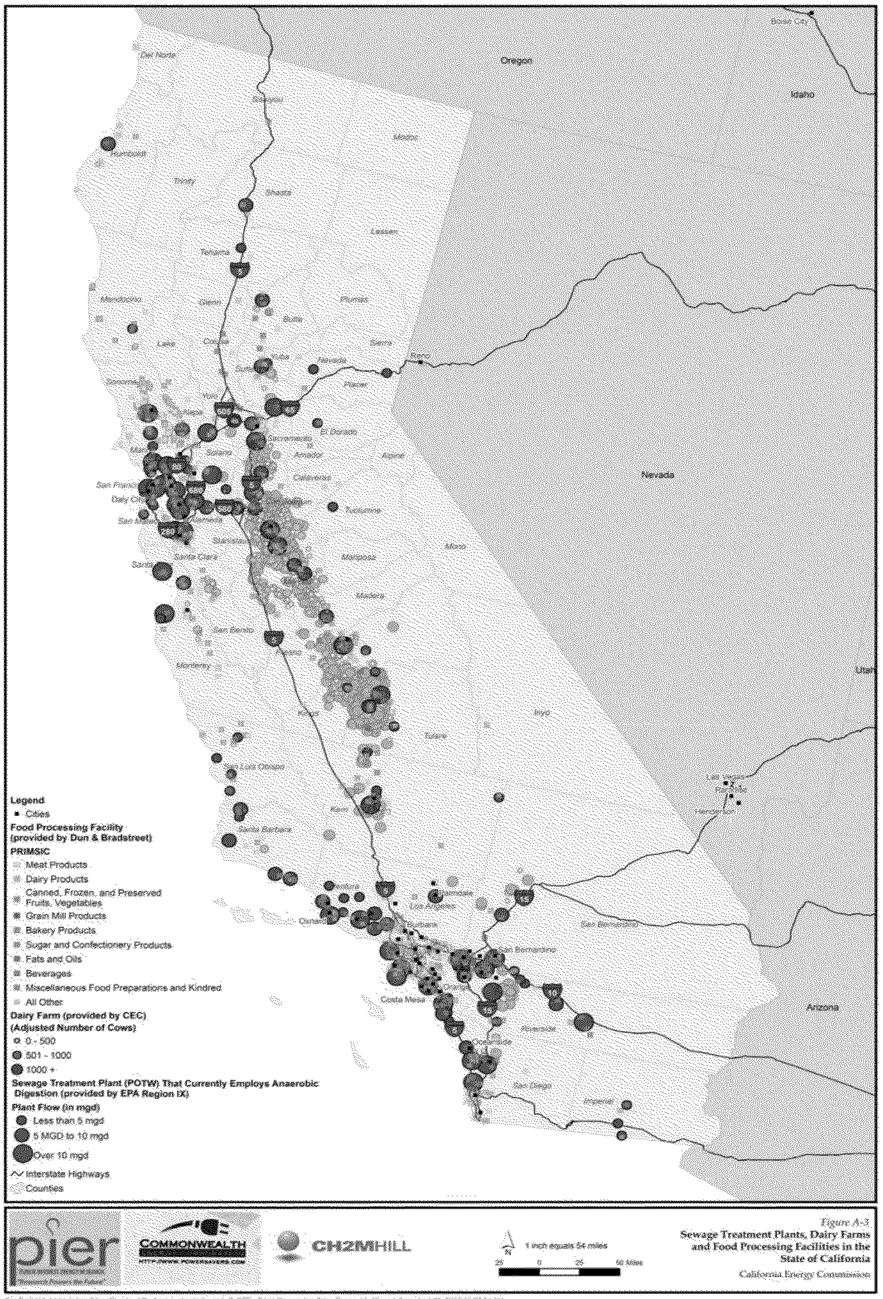
Name_____________________________________ **Phone Number**__________________

Thank you for your time and help with this survey.

In case you need any clarification on a survey question, please call Pramod Kulkarni at (916)-654-4637 at the California Energy Commission.

APPENDIX B: Resource Locations and Proximity

Figure B-1: Locations of Sewage Treatment Plants, Dairy Farms, and Food Processing Facilities in California



Source: The market potential for CHP from waste streams is based on updating data from a PIER study *Co-Digestion of Dairy Manure/Food Processing Waste and BioSolids/Food Processing Wastes to Energ y*, California Energy Commission, CEC-500-2007-015.

APPENDIX C: Addition of Waste Oil/Grease From Food Establishments

In 2007, the consulting firm of Kennedy/Jenks[35] assessed the impact of co-digesting restaurant oil/grease at the Millbrae Wastewater Treatment Plant located near the San Francisco airport. It assessed the change in gas production, electricity production and operating expenses. The project yielded increased gas production (40 percent) along with reduction in polymer dose (11 percent) for subsequent sludge dewatering process. Furthermore, the process increased the percent solids in the dewatered cake thereby lowering the sludge mass requiring disposal by nearly 30 percent. This collateral benefit of reduction in volume of leftover dried sludge (dewatered cake) saves on transportation volume and cost providing additional savings in fossil fuel use and transportation related CO_2 emission. Though the total increase in generation capacity might be limited to 10 MW, this capacity addition comes with some unexpected increase in revenue (tipping fees) and reduction in the expenses to dispose of dewatered sludge.[36] The net impact makes CHP installation at smaller wastewater treatment plants economically viable.

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[35] Information brochure from Kennedy/Jenks on the Millbrae Project.

[36] Communications with Joseph Magner, Superintendent, Public Works Department, City of Millbrae, California.

APPENDIX D: Technology Characteristics

Internal Combustion Engines

Most commonly used technology is the reciprocating engine, commonly known as an internal combustion engine or ICE. The technology is dominant in CHP applications because the maturity of the technology and industry results in competitive prices, carries low technology risk, and provides high reliability. As a drawback, internal combustion engines have generally higher emissions compared to other technologies with the exception of gas turbines. There are many suppliers of internal combustion engines, and servicing is relatively easy. They generally are robust to and tolerant of contaminants in the incoming biogas, thus negating need for scrubbing the gas to a high degree of purity. Consequently the internal combustion engines are the workhorse of the wastewater treatment plant-based CHP systems.

Gas Turbines

Gas turbines are also used, yet given that the smallest sizes are no less than 1 MW, there are not many wastewater treatment plants that have sufficient gas to justify their installations. They have the same benefits as that of internal combustion engines: mature industry, competitive prices in their size range, and reduced technology risks. Although in smaller-size turbines (1 MW to 5 MW), there are not as many vendors as in case of internal combustion engines. The turbines also require that the incoming gas be pressurized adding to the expenses. Many wastewater treatment plants with large and reliable biogas supply use turbines for cogeneration.

Microturbines

Microturbine systems have many advantages over the reciprocating (internal combustion) engine generators, such as higher power density (with respect to footprint and weight), lower emissions and few or just one moving part. Those designed with foil bearings and air cooling operate without oil, coolants, or other hazardous materials. Microturbines also have the advantage of having the majority of their waste heat contained in their relatively high temperature exhaust, whereas the waste heat of reciprocating engines is split between its exhaust and cooling system. However, reciprocating engine generators are quicker to respond to changes in output power requirement and are usually slightly more efficient, although the efficiency of microturbines is increasing. Microturbines also lose more efficiency at low power levels than reciprocating engines. Typical microturbine efficiencies are lower than that for internal combustion engines.

Microturbines are of recent vintage and have come in the market only in the last 10 years. There are few vendors, and the industry is still evolving. The early versions have had technology problems although recent products have shown consistent reliability. On the benefits side, microturbines have low emissions and have been relatively easy to site even in the most stringent air emission regulatory regime. In fact the California Air Resources Board (ARB) has certified certain microturbine brands, thus making their permitting relatively easy. But the biogas for microturbines requires a much higher degree of pretreatment to reduce moisture and other contaminants such as siloxane. The CHP system needs compressor to pressurize gas thus adding costs and parasitic electrical load resulting in lower net efficiencies and adverse economics. The size range, starting from 30 kW and going up to 250 kW, makes it easy to have various combinations of plant size and to add the generation capacity incrementally.

Fuel Cells

Fuel cells convert chemical energy contained in biogas directly into electricity and water vapor as a byproduct. This process eliminates the need to burn the gas, thus reducing the combustion byproducts needing containment to meet air quality regulations. The main advantages of fuel cells are that they can be environmentally friendly and can operate with high efficiency (for example, compared to the internal combustion engine, which operates at about 30 percent). They also operate silently. Fuel cells also give out heat during chemical conversion, thus making them suitable for cogeneration. The downside is that they are expensive, relatively new, and technologically complex. So far they have not proven commercially viable in common usage compared to the alternatives. There are several wastewater treatment plants that use fuel cells, but these installations have been subsidized through special incentive programs and generous tax credits. Absent these two factors, it is unlikely that the cost of fuel cells would come down fast enough to make a wastewater treatment plant-based fuel cell CHP cost-effective. Although the basic technology has been around for decades, the industry is still in an early stage of commercialization. Consequently the prices are likely to remain high for the near future.