Pacific Region CHP Application Center for California, Nevada, and Hawaii

Task 1.3 - Case Studies - Draft

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The Pacific Region CHP Application Center

The Pacific Region Combined Heat and Power (CHP) Application Center was established in 2004 and features a collaborative structure among UC Berkeley (UCB), UC Irvine (UCI), and San Diego State University (SDSU). Each university provides some unique capabilities and resources to the center, including the Energy and Resources Group at UCB, the Advanced Power and Energy Program at UCI, and the Industrial Assessment Center at SDSU. The Pacific CHP Application Center has established strategic alliances with key partners in the region, including the San Diego Regional Energy Office, Sempra Energy, and Lawrence Berkeley National Laboratory. Due to the warm climate associated with the region and the presence of relatively restrictive emission regulation, the emphasis of the Center is on low emissions technologies and applications involving cooling for commercial buildings. The states in the region continue to offer attractive incentives for self-generation, and on average, has a significant "spark spread" that can make small and medium-scale CHP projects attractive. The region features the greatest population densities along coastal regions, though it also has large populations in the high desert areas.

One key activity of the Pacific Region CHP Application Center is to disperse information about small scale CHP demonstration projects. In course of these outreach activities we have been performing case studies for sites in California, Hawaii, and Nevada.

This document will provide you with a summary of the most recent case studies performed at the Pacific Region CHP Application Center.

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PACIFIC REGION CHP APPLICATION CENTER

combined heat & power in an administration building

East Bay Municipal Utility District

600 kW microturbine CHP/chiller system

Project Profile

Quick Facts

Location:
Oakland, California

Capacity:
600 kW (ten Capstone C60 microturbines)

Fuel: Natural gas

Noise Level: 70dB at 30 feet

Planning and Construction Time:
23 months

System Online: July 2003

Total Project Cost:
$2,510,000 (administration building only)

Energy Cost Savings:
$200,000 – $300,000/year

Expected Payback Time:
6 to 8 years (with SGIP rebate)

Maximum On-Site Plant Efficiency with Heat Utilization: 74%

Funding Sources:
California Public Utilities Commission/Pacific Gas & Electric
California Energy Commission

Project Overview

The East Bay Municipal Utility District (EBMUD) is a publicly owned utility that provides water service to portions of two counties in the San Francisco Bay Area. Its water supply system covers 325 square miles (841 km^2) and serves some 1.3 million customers. One of EBMUD's largest electrical demands is its own headquarters. In 2001 EBMUD decided to install a distributed generation (DG) system at its downtown Oakland administration building.

The motivation for the project was to reduce energy costs and ultimately increase reliability while the electric utility industry experienced financial and technical turbulence.

The DG system consists of ten 60-kW Capstone microturbines and a ~180 refrigeration ton (RT) (~633-kW) York absorption chiller. EBMUD has also installed two 60-kW microturbines at its Adeline Maintenance Center, along with a 30 kW solar PV system. The selection of microturbines was driven by the air quality restrictions in downtown Oakland.

Fuel cells were also considered. Apart from their higher capital costs they were rejected because they proved to be too heavy for the roof.

It is estimated that the DER system will produce enough residual heat to power the adsorption chiller to meet 60% of the existing cooling load that is currently met by two 880-kW (250 RT) centrifugal chillers.

Costs & Financial Incentives for the Administration Building

- System design: $125,000
- 10 Capstone microturbines: $1,100,000
- Installation of turbines: $410,000
- Absorption chiller: $360,000
- Electrical and gas connections: $130,000
- Service contract: $100,000
- Air permit: $30,000
- Other costs: $255,000

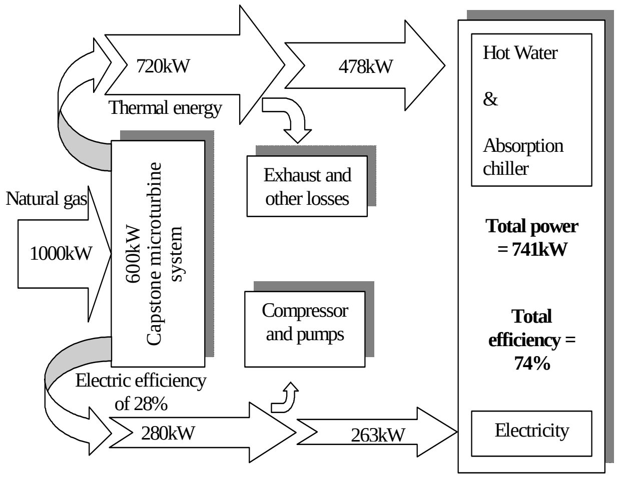
Total cost: $2,510,000

To assist with project costs EBMUD has received a $2,000,000 low interest (3%) loan (payable within 11 years) from the California Energy Commission (CEC) and a $900,000 rebate from the California Public Utilities Commission (CPUC) and Pacific Gas and Electric Co. (PG&E) under California's Self-Generation program (SGIP).

A main reason for the installation of micro-turbines is their small footprint and weight. Each turbine is placed in a space only 30 in. (76 cm) wide and 77 in. (196 cm) long.

Natural gas compressors located on the roof of the EBMUD admin. building.

Maximum On-Site Plant Efficiency



The efficiency of serving the entire heating and cooling loads was critical to obtaining the required 42.5% overall FERC energy efficiency rating. This energy efficiency level is necessary to receive state funding as part of the California Public Utilities Commission SGIP program. EBMUD operates the individual microturbines only when there is sufficient heating or cooling load to meet this level of efficiency on an annual basis.

The microturbines will occasionally be shut down if there is insufficient thermal load, regardless of electrical load requirements.

EBMUD does not sell electricity back to the grid. Under agreement with the local utility it uses the system for onsite cogeneration only.

The system operation is controlled by waste heat needs and not by electrical demand. It is designed to first meet the building thermal load and then to contribute to electricity supply.

The system produces NO_X emissions of $0.2 lb/MWh_{elec}$, which is roughly 7% of the NO_X emissions released by conventional US electricity production.

Further information can be found at

EBMUD: www.ebmud.com
Microturbines: www.capstoneturbine.com
Self-Generation Incentive program (SGIP): www.pge.com/suppliers_purchasing/new_generator/incentive/index.html
PRAC: www.chpcenterpr.org

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PACIFIC REGION CHP APPLICATION CENTER

combined heat & power in a pharmaceutical research facility

Johnson & Johnson

2.2 MW reciprocating CHP system

Project Profile

Quick Facts

Location:
La Jolla (near San Diego), CA

Capacity:
2.2MW (two 1,100 kWe 16-cylinder reciprocating engines from Cummins)

Fuel: Natural gas

CHP system:
Hot water and absorption cooling

Grid Interconnection:
The system can be operated in grid-independent mode to provide high-reliability power

System Online:
March 2004

Total Project Cost:
Approximately $4,000,000

Energy Cost Savings:
Approximately $1,000,000/year

Estimated Payback Time:
4 to 5 years

Funding Sources:
Johnson & Johnson, San Diego Regional Energy Office (SDREO) refund of $800,000 (from the CA Self-Generation Incentive Program)

Project Overview

Johnson & Johnson operates eleven research laboratories worldwide (Pharmaceutical Research & Development - J&JPRD) and is a leading maker of personal care products, diabetes medications, and other pharmaceuticals. Three years ago J&JPRD planned to double the size of its La Jolla, California facility space from 120,000 sq. ft. to 300,000 sq. ft.

This project was conceived in 2003, when the California energy crisis made J&JPRD reluctant to sign long term electricity contracts. J&JPRD sought to find an integrated holistic approach to its energy needs

For the particular research facility in La Jolla electrical loads are high during the business hours 7am and 6pm (the maximum peak load is around 2.5GW), when power peak rates in California also climb. These circumstances make the facility to an ideal absorption chiller candidate. Almost all recovered heat can be utilized by the cooling system. However, because there also are cold days at this seaside location J&JPRD has to heat the facility during some periods and the need for recovered heat is well distributed over the whole year.

Originally, fuel cells and microturbines were also considered, but were rejected reasons including better maintenance agreements for reciprocating engines and a smaller system footprint. The installed 2,200 kW internal combustion system produces around 15,000,000 KWh/yr of electricity plus 10,548,040 kWh/yr (= 360,000therms) of heat and 1,120,000 kWh/yr (= 1,600,000 ton-hr/yr) of chilled water, providing more than 90% of the facility's electric power and much of its heating and cooling needs. The current overall exhaust heat utilization is about 75%.

The installation was done in two phases. Unit one, which is powering the old J&JPRD building, came online 2003 and unit two was switched on in February 2004.

As part of the agreement for this project, J&JPRD is required to buy 5% of its electricity needs from the grid (San Diego Gas & Electric). Furthermore, to obtain the permit, J&JPRD had to demonstrate that the system does not back-feed electricity to the grid.

It is estimated that the CHP system at J&JPRD saves around 3,200,000 lb CO2/yr. This is equivalent to the operation of about 285 automobiles.

Picture by Johnson&Johnson

Left hand side: 500 RT (refrigeration ton) absorption chiller.

Picture below: 16-cylinder 1,100 kW reciprocating engine from Cummins.

Picture by Johnson&Johnson

The system runs without any operator and is fully monitored by DSL line. Sensors automatically page and dispatch a technician when needed.

Costs & Financial Incentives

The total costs of the CHP project are estimated at $4,000,000. It is difficult to exactly determine the total project cost because a complete new building with HVAC system was erected and some of the CHP and HVAC components are not clearly dissoluble. Some of the HVAC aspects were rolled into the larger construction budget and new elements were married up to existing elements. However to mitigate the high costs J&JPRD received a $800,000 rebate from the San Diego Regional Energy Office (SDREO) under the Self-Generation Incentive program.

SDREO is an independent, public-benefit, non-profit corporation that provides objective information, research, analysis and long-term planning on energy issues for the San Diego region.

IC engines and large gas turbines (with waste heat utilization)	Incentives ($/W)
with renewable fuel	1.00
with non-renewable fuel	0.60

Incentives from the Self-Generation program for qualifying equipment for the year 2006 are shown in the table on the left hand side.

Future Tasks

At the La Jolla site five heat exchangers are currently in place. There is enough waste heat for a sixth heat exchanger, which is planned to be added to maximize heat utilization. When this sixth heat exchanger comes online, two old remaining boilers can be decommissioned and this will result in an overall exhaust heat utilization of nearly 100%. Furthermore, J&JPRD is exploring the possibility of adding a 200 kW photovoltaic system for additional peak power shaving. Moreover, other J&J sites are possible CHP candidates. Plans are being discussed to install a CHP system at an East Coast location, as well as at a Puerto Rico site.

Further information can be found at

Johnson & Johnson (La Jolla):
www.jnjpharmarnd.com/locations/ca.html
San Diego Regional Energy Office (SDREO):
http://www.sdenergy.org/ *and*
Self-Generation Incentive Program:
http://www.sdenergy.org/ContentPage.asp?ContentID=35&SectionID=24
PRAC: www.chpcenterpr.org

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"There are so many benefits to cogeneration. Innovation is at the core of our R&D efforts, and so we're pleased to be using this cutting-edge cogeneration technology to power, heat and cool our new laboratories."
J&JPRD Senior Vice President of Drug Discovery, Michael Jackson

"Self-generation reduces electricity consumption from the grid, reduces the need for new infrastructure and helps the environment. This project is great for the San Diego region."
SDREO Executive Director, Irene M. Stillings

PACIFIC REGION CHP APPLICATION CENTER

combined heat & power in a brewery

Sierra Nevada Brewery

1MW direct fuel cell/CHP system

Project Profile

Quick Facts

Location:
Chico, California

Capacity:
1MW (four molten carbonate fuel cells)

System Online:
2005

Hydrogen Production Method:
Digester gas from brewing process

H_2- Production Capacity:
Currently fuel for one 250 kW fuel cell

Total Project Cost:
$7 million over five years

Expected Electricity Cost Savings:
$400,000/year

Expected Payback Time:
5 years (with incentives)

Funding Sources:
Sierra Nevada Brewery
California Energy Commission,
U.S. Department of Defense

Project Overview

The Sierra Nevada Brewery in Chico, California is producing hydrogen from byproducts of the company's beer brewing process. Founded in Chico in 1980, Sierra Nevada applies resource conservation and reusing/recycling raw materials as guiding operating principles.

Beer brewing uses a two-step anaerobic and aerobic digester process that produces methane, which is then captured and directly reformed into hydrogen.

The brewery has installed four 250 kW molten carbonate fuel cells that run off a combination of the renewable hydrogen and natural gas.

The four 250 kW fuel cells are high-temperature molten carbonate fuel cells from FuelCell Energy Inc. They will provide almost 100 percent of the facility's baseload power, and the waste heat will be collected as steam and used for the brewing process as well as other heating needs onsite. The fuel cells initially ran off of natural gas, but the brewery hopes to displace 25-40% of the natural gas use with the digester gas, depending on what type of beer is being brewed.

The fuel cell system was installed by Alliance Power, a distribution partner of FuelCell Energy. Alliance Power performs all aspects of project implementation including siting, planning, permitting, designing, constructing, financing, and operating.

Sierra Nevada is purchasing electricity from the fuel cells through a power purchase agreement established between Alliance Power and FuelCell Energy. Sierra Nevada has the option to purchase the fuel cell power plant from Alliance and FuelCell Energy after 12 months in operation.

Financial Incentives

The total project cost for the first five years is approximately $7 million, including installation costs and operation and maintenance for the hydrogen production system and the fuel cells.
The Sierra Nevada Brewery received $2.4 million in funding through the California Public Utility Commission (CPUC) Self Generation Incentive Program (PG&E is part of this program) and the U.S. Department of Defense Climate Change Fuel Cell Program. Given these initial subsidies, project managers expect a payback of less than five years, which reflects an electricity cost savings of about $400,000 per year.

Self Generation Incentives Program

CPUC/PG&E's self-generation incentive program provides financial incentives, to help pay the costs of on-site electric generating systems utilizing either solar, wind, fuel cell, micro turbine or internal combustion engine cogeneration systems. Program participants are eligible to receive incentives under this program for installing self-generation technologies based on system type, size, fuel source and out-of-pocket costs. Only commercially available and factory new equipment is eligible for incentives. Rebuilt or refurbished equipment is not eligible to receive incentives under this program. The maximum system size is 5 MW (the incentive payment remains capped at 1 MW).

Eligible fuel cells by September 11, 2003.

Manufacturer Name	Model Number	Description	Rated Output (kW)
FuelCell Energy	DFC300A	Direct FuelCell DFC300A Standard Power Plant	250kW
FuelCell Energy	DFC1500	Direct FuelCell DFC1500 Power Plant	100kW
ONSI	PC-25	200 kW Phosphoric Acid Fuel Cell	200kW

The paid incentive is 4,500$/kW for renewable fuel cells and 2,500$/kW for non-renewable fuel cells.

Further information can be found at

Sierra Nevada Brewery: www.sierranevada.com
Alliance Power, Inc: www.alliancepower.com
FuelCell Energy, Inc: www.fuelcellenergy.com
Self-Generation Incentive program: www.pge.com/suppliers_purchasing/new_generator/incentive/index.html
PRAC: www.chpcenterpr.org

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"Like any business, Sierra Nevada was looking for stable, affordable, reliable power, and they wanted to limit the environmental impact of their operation. They found the answer in a hydrogen fuel cell that generates power on site."
Arnold Schwarzenegger Governor of California

Air quality improvement is equal to an elimination of 500 gasoline cars.

The overall energy efficiency of the installation is double compared to grid-supplied power.

PACIFIC REGION CHP APPLICATION CENTER

combined heat & power in a luxury hotel

The Ritz-Carlton in San Francisco

240 kW microturbine/abs. chiller system

Project Profile

Quick Facts

Location:
San Francisco, CA

Capacity:
PureComfort™ system from UTC Power with 240-kW (four 60-kW Capstone C-60 microturbines)

Fuel: Natural gas

CHP system:
120 RT double-effect absorption chiller from Carrier Corp.

Chiller performance: >1.3 COP

Noise: <65dBa at 30 feet with sound suppression system

System Online: October 2005

Total Project Cost: $1,012,640

Energy Cost Savings:
Approximately $120,000/year

Estimated Payback Time:
8 years (without incentives), under 3 years with incentives

Funding Sources:
Host Hotels and Resorts, CA Self-Generation Incentive Program, and U.S. Department of Energy

Project Overview

The Ritz-Carlton San Francisco is the city's highest-rated hotel, located in the upscale Nob Hill area. This luxury hotel, which is owned by the Host Hotels and Resorts, accommodates 336 guest rooms, Fitness Center, indoor pool, whirlpool, and steam rooms.

A plan to lower energy consumption and reduce energy expenses for the hotel resulted in the purchase of the PureComfort™ 240 Combined Cooling, Heating and Power (CCHP) package from UTC Power Company. This system includes four 60-kW Capstone microturbines, running on natural gas, with the exhaust collected in a manifold and used to drive a 120 refrigeration tons (RT) double-effect chiller from Carrier Corporation (a sister company from UTC Power). The peak electricity demand at the Ritz-Carlton is 1 MW and chilling requirements can reach almost 300 RT. The PureComfort™ solution provides 240 kW of power and 120 RT of chilling and is therefore able to run base-loaded for the entire year, resulting in near maximum overall efficiency for this type of system. The system is designed to satisfy the base-load chiller demand for the whole year and run the chiller in the most efficient mode. The PureComfort™ solution is able to achieve an overall fuel utilization of greater than 80%.

Originally, the hotel used a 300 RT electric chiller. This was relatively inefficient because it had to run 24 hours a day year-round, even though typical chilling needs were well below its capacity – only about 100 RT for eight months of the year. Operated in this way, the chiller accounted for about 20% of the hotel's total electricity use. The new configuration - using the absorption chiller - allows for shutting off the 300 RT chiller for eight months of the year. The overall net energy cost saving is estimated at $120,000 per year.

Costs & Financial Incentives

- Turbines: $224,640
- CHP unit: $141,000
- Mechanical and electrical: $502,000
- Consulting: $16,000
- Project management: $77,000
- Other costs: $52,000, **Total: $1,012,640**

To mitigate these costs the Ritz-Carlton has received a $150,000 rebate from California's Self Generation Incentive Program (SGIP) as well as a $500,000 grant from the U.S. Department of Energy for installing an advanced CHP demonstration project.

The picture to the left shows the four C-60 Capstone microturbines. The absorption chiller is oversized to 300 RT and currently delivers a maximum of 120 RT, giving the Ritz-Carlton the possibility of adding additional microturbines without the need to change the chiller.

To ensure the luxurious ambiance for guests of the five-star hotel, CHP system noise and visibility was a major issue. The picture to the right shows the view from the cocktail lounge towards the microturbine system. The system is placed behind the white wall and does not affect the guests' view.

The 240 kW "Pure Comfort" microturbine system at the Ritz-Carlton saves enough electricity to power 200 average American households.

UTC Power PureComfort™ System

The PureComfort™ 240M microturbine-based CHP solution is one of three available standard packages from UTC Power. Other available packages include the 300M and 360M systems, with 300 or 360 kW of power output rating. Each system consists of a double-effect absorption chiller/heater from Carrier Corporation and four to six 60-kW microturbines. This standardized approach reduces system costs and results in an average overall thermal efficiency of greater than 80%. The relatively quiet system (65dBa @ 30 feet with sound suppression system) consists of the core mictroturbine units with height of 83", width of 30", length of 77", and weight of 1,700 lb., as well as the chiller with a height of 82", width of 79", length of 145", and weight of 18,544 lbs. The system emits less than 0.49lb/$MWh_{electricity}$ of NOx.

PureComfort™ 240M System	Hot Day (ARI conditions*, 95°F)	ISO Day with 59°F	Cold day with 32°F
Net Power [kW]	193	227	231
Cooling Output [RT = Refrigeration ton]	124	142	
Heating output [MBh]			1,100
Net system efficiency [%] for lower heating value (LHV)	80	91	68

*ARI conditions: 44°F leaving chilled water, entering condenser water temperature of 85°F, 95°F outdoor temperature

Typical performance values for the 240M system under different conditions are shown in the table to the left.

The CHP system installed at The Ritz-Carlton reduces emissions of 800 tons of CO_2 per year. This is equivalent to removing 140 cars from California roads.

Further information can be found at

The Ritz-Carlton, San Francisco: http://www.ritzcarlton.com/hotels/san_francisco
UTC Power: http://www.utcpower.com; Tel.: (866) 900-7693;
Microturbines: www.capstoneturbine.com
Carrier Corporation (absorption chiller): http://www.corp.carrier.com
PRAC: www.chpcenterpr.org

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Joseph Gallo Farms Dairy

700 kW reciprocating CHP system

Project Profile

combined heat & power in a dairy

Quick Facts

Location: Atwater, CA

Capacity: 300 kW Caterpillar 3412 and 400 kW Caterpillar G399 reciprocating engine generators

Fuel: Digester gas (methane)

CHP system:
Process steam for cheese making

Construction Time: 25 months

System Online:
October 2004, upgrade from 300 kW to 700 kW in February 2006

Total Project Cost:
$3,200,000 (including the 400 kW upgrade in February 2006)

Energy Cost Savings:
$800,000/year (electricity and propane)

Expected Payback Time: 3 to 4 years (without incentives)

Funding Sources:
Joseph Gallo Farms,
Dairy Power Production Program (DPPP) – expired March 2004,
and CA Self-Generation Incentive Program;

Project Overview

Joseph Gallo Farms, founded in 1979, accommodates 16,000 dairy cows across five dairies in Merced Country. About 5,000 of them are at the Cottonwood Dairy. Each cow produces about 120 lbs (54 kg) of liquid and solid waste per day, which can result in serious environmental problems. Authorities are struggling with the air and water pollution consequences and are searching for solutions. One can be the installation of an anaerobic digester to produce biogas from manure and allow electricity generation. In 2004 a 44,225,000 gallon (167,400 m^3) lagoon digester with 7 acre surface area (ca. 28,000 m^2) in combination with a 300 kW Caterpillar 3412 reciprocating engine were installed at the Cottonwood site.

The digester produces up to 300,000 cubic feet/day (ca. 8,500 m^3/d), but only 130,000 cubic feet/day (ca. 3,700 m^3/d) are used by the 300 kW Caterpillar engine. To avoid flaring or releasing the remaining fuel to the atmosphere, Josephs Gallo Farms installed a second 400 kW reciprocating engine in February 2006. With these two engines the system produces 5.6 GWh electricity onsite every year. Furthermore, the Cottonwood dairy also houses a cheese plant which processes around 900,000 lbs (ca. 408,000 kg) milk per day. Methane production is accelerated by the addition of warm plant clean up water to the digester.

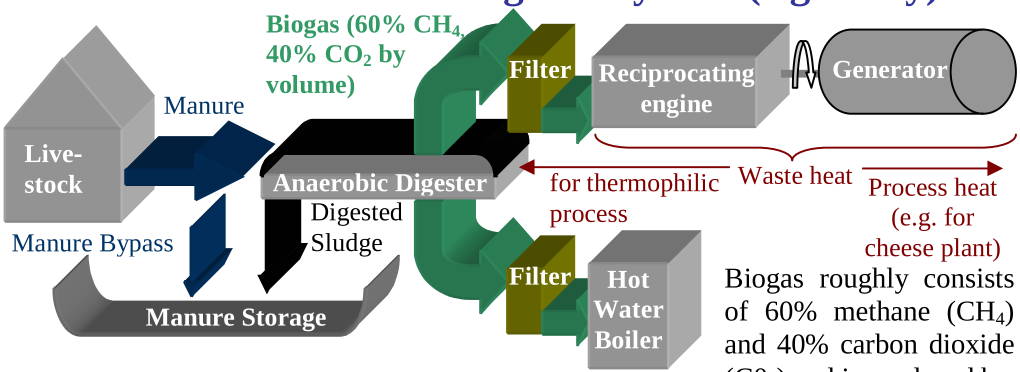
The new 700 kW CHP system which also uses waste heat for the cheese plant can offset 55% of the utility provided electricity (the peak load of the dairy is around 1.6 MW). The exhaust waste heat is used to produce steam for pasteurizing and sterilizing. Additionally, Jacket coolant heat will eventually preheat air for a whey drier.

The dairy operates the entire digester systems on its own at a maintenance cost of roughly $150,000 per year including H_2S scrubber materials replacement, weekly electrical equipment and pump motor checks, as well as major engine overhauls every 16,000 hours. Furthermore, the dairy has to change the engine oil every 500 hours and has to perform engine tune ups every 1,000 hours.

Costs & Financial Incentives

Originally, the total project costs were projected at $1,290,000, but because of higher costs mainly of the manure collection and separation system, the gas treatment system, as well as interconnection the final costs ended up at $2,700,000 (without the 400 kW upgrade). To mitigate these costs the farm received a buydown grant of $600,000 from the Dairy Power Production Program (DPPP) as well as $238,000 from the CA Self-Generation Program. Joseph Gallo Farms has also applied for a $400,000 grant for the new 400 kW engine. The purpose of the DPPP program was to stimulate the set up of biologically based anaerobic digesters for gasification and biogas electricity generation. This program – which expired in March 2004 – contained two types of grants: a) an investment subsidy which covered up to 50% of the system capital costs and b) a production incentive in the amount of 5.7 cents per kWh of electricity produced.

Schematic of an anaerobic digester system (e.g. dairy)



Biogas roughly consists of 60% methane (CH_4) and 40% carbon dioxide ($C0_2$) and is produced by bacteria in the absence of oxygen in a covered impermeable anaerobic digester. Almost any *organic* material can be processed in this manner, e.g. leftover food, waste paper, grass, etc. Two major processes are available: a) *mesophilic*, which takes place at ambient temperatures between 68°F (20°C) and 104°F (40°C) and b) *accelerated thermophilic* process, which needs waste heat to increase the process heat up to 158°F (70°C). With such an anaerobic digester a lactating dairy cow can generate enough biogas to generate approximately 2.5 kWh electricity every day. However, very important for a well functioning system is the H_2S scrubber (filter) which reduces the corrosive hydrogen sulfide content in the biogas which could reduce the engine lifetime considerably.

Picture above: 400 kW reciprocating engine

Picture below: the 7 acre digester cover

Further information can be found at

Joseph Gallo Farms: http://www.josephfarms.com/
DPPP: http://www.wurdco.com/index.htm
Self-Generation Incentive Program:
www.pge.com/suppliers_purchasing/new_generator/incentive/index.html
Methane (Biogas) from Anaerobic Digesters:
http://web.archive.org/web/20041124201613/www.eere.energy.gov/consumerinfo/factsheets/ab5.html?print
PRAC: www.chpcenterpr.org

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Unlike traditional lagoons that emit greenhouse gases directly into the atmosphere, digesters cut down on air pollution. This is very important because of the high methane content of the released gas - *Methane is roughly 20 times more greenhouse active than $C0_2$.*

"Steep construction and maintenance costs with bureaucratic hurdles and conflicts with utility providers have prevented many interested dairies from building biogas operations"
Mike Marsh, chief executive officer of Modesto-based Western United Dairymen.

combined heat & power in waste water treatment

Chiquita Water Reclamation Plant

120 kW microturbine CHP system

Project Profile

Quick Facts

Location: Santa Margarita, CA

Capacity: Four Capstone C30 Biogas 30kW microturbines and one Microgen™ hot water generator

Fuel: Anaerobic digester gas

CHP system: Digester heating

System Online: December 2001 (Phase 1), 60 kW upgrade in October 2003 (Phase 2)

System Efficiency: Electric efficiency is around 20% to 22%

Total Project Cost: Phase 1 installation costs of $114,020 plus South Coast Air Quality Management District (SCAQMD) support; Phase 2 installation costs of $160,582

Energy Cost Savings:

Estimated $60,000/year (for Phase 1)

Expected Payback Time:

2 years for Phase 1 with the SCAQMD support

Funding Sources: Santa Margarita Water District and SCAQMD donation

Project Overview

Two Capstone 30 kW microturbines integrated with one Microgen™ hot water generator (HWG) were commissioned at the Santa Margarita Water District (SMWD) Chiquita Water Reclamation Plant in December 2001.

Two additional 30 kW microturbines were commissioned and the HWG was modified in October 2003. The original two Microturbines (Phase 1) were donated by the South Coast Air Quality Management District (SCAQMD) as part of their program to provide clean auxiliary power during periods of peak demand on the grid.

The microturbines are fueled by anaerobic digester gas from the reclamation plant. Waste heat from the microturbines is used to heat the anaerobic digesters. SMWD chose to operate their original microturbines full time, realized significant monthly cost savings and thus decided to independently acquire its second two microturbines (Phase 2).

The systems are all base loaded at full electrical power and typically deliver 26-30 kW each. Waste heat from the first two microturbines was sufficient to allow shutting down the two boilers that originally fed hot water to the digesters, although one boiler is kept in standby mode. Additional heat provided by the newer microturbines may be used to dry sludge in order to lower shipping costs and/or heat future anaerobic digesters.

Costs & Financial Incentives

The SCAQMD program supporting the original installation began in April 2001. The Chiquita Water Reclamation Plant microturbines were actually commissioned in December 2001. Phase 1 construction costs added up to $83,666, not including change order costs. Other costs included interconnection ($1,400 for four turbines), SCAQMD permits ($1,611 for two turbines) and emissions source testing ($9,520 to test one representative turbine). Total Phase 1 installation costs ultimately added up to $114,020, excluding the cost of the equipment donated by SCAQMD.

In March 2003 SMWD was granted a location specific permit exemption by SCAQMD. SMWD pointed out that burning digester gas in microturbines is more environmentally friendly than the alternatives, including fueling boilers, reciprocating internal combustion engines or simply flaring the gas. It took 16 weeks to finalize an interconnection agreement with San Diego Gas and Electric.

The Phase 2 microturbines and modified Microgen™ hot water generator were commissioned in October 2003. Total installation costs for Phase 2 were $160,582.

Picture below: Microturbines

Picture above: Microturbine disconnection switches

Performance Summary

The Phase 1 installation generated net operating cost savings of $4,000-$5,000 per month. As of May 2003, after 11 months of continuous operation, SMWD estimated total operating savings due to the microturbines to be approximately $58,300. Also as of May 2003 these two microturbines had each logged approximately 10,800 operating hours.

As of December 18th, 2003, the Phase 1 and Phase 2 microturbines had logged approximately 12,800 and 1,500 operating hours, respectively. SMWD operators estimate 99% availability for the microturbines. The most common reliability problems are centered around the fuel cleanup and delivery system.

Efficiency can be difficult to measure as anaerobic digester gas composition and heat utilization can fluctuate. However, based on a typical digester gas heating value of 60% of natural gas the electric efficiency is approximately 20-22%. Fuel compression requirements represent significant parasitic power loss. Up to 1 MMBTU/hr (293 kW) of heat is utilized. Emissions tests performed in 2002 indicated emissions levels of 1.25 ppmv NO_X and 138.5 ppmv CO, corrected to 15% O_2, from one microturbine operating at full power.

Lessons Learned

Lessons learned from both project phases include: (1) Installation costs for these systems were very significant in relation to the cost of the generators themselves; (2) Placing a robust fuel treatment system upstream of the microturbines was important (the new installation includes a refrigerated dryer and SAG™ filter system for cleaning and drying the digester gas - landfill gas can contain siloxanes and burning converts them to silica particles, which are abrasive and clog conventional combustion engines); (3) Integration of the heat exchanger with the microturbines was not trivial.

Further information can be found at

Santa Margarita Water District:
http://www.smwd.com/ , Ron Meyer (949) 459-6594
South Coast Air Quality Management District:
http://www.aqmd.gov/
Methane (Biogas) from Anaerobic Digesters:
http://web.archive.org/web/20041124201613/www.eere.energy.gov/consumerinfo/factsheets/ab5.html?print
PRAC: www.chpcenterpr.org

Contact Information

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To be able to produce digester gas from cool waste water the digester has to be heated. The necessary heat is captured from the microturbines, which increases the overall energy efficiency of the system.

Important for a well functioning system is a H_2S scrubber (filter) which reduces the corrosive hydrogen sulfide content in the biogas. Failure to scrub H_2S could reduce the engine lifetime considerably.

Alameda County Santa Rita jail

1 MW fuel cell CHP system

Project Profile

combined heat & power in a jail

Quick Facts

Location: Dublin, Alameda County, CA

Capacity: 1 MW DFC1500 molten carbonate fuel cell (single module with four internal stacks)

Fuel: Natural gas

Noise Level: <70dB @ 10 feet

CHP system:

Waste heat for hot water and space heating

Construction Time: 7 months

System Online: May 2006

Total Project Cost:

$2,200,000 (without incentives and maintenance/stack replacement contract with Chevron)

Energy Cost Savings:

$264,000/year

Expected Payback Time:

8 years (without incentives)

Overall System Efficiency: 58%

Funding Sources:

Alameda County, CA Self-Generation Incentive Program, U.S Department of Defense;

Project Overview

In 1989 the 'new' Santa Rita jail was opened which holds about 4,000 inmates on 23 acres (93,000m^2) and is considered as the third largest facility in California. This fifth largest facility in the US which produces up to 12,000 meals a day and spends roughly $500,000/month only for food has an estimated electricity peak demand of 3.2 MW and therefore a tremendous need to save tax money. As a result of all these expenses Alameda County has a long history of using innovative approaches to increase the energy efficiency and reduce public costs.

Prior to installing the 1 MW fuel cell the County installed a 3 acres (12,100m^2) 1.2 MW solar roof on the Santa Rita jail in spring 2002. Furthermore, the jail uses also cool roof membranes and a Demand Response Smart Control System to manage the electricity demand of the facility.

In May 2006 the County added a 1 MW molten carbonate CHP fuel cell system to be able to provide also reliable onsite off-peak/base electricity and hot water pre-heating for domestic hot water needs. In this way the fuel cell provides 8,000,000 kWh/year electricity (=50% of the entire jail needs) and 1.4 MMBtu/year of heat (410 kWh/year = 18% of the entire jail needs).

Chevron Energy Solutions designed, managed the project and is responsible for maintenance. The single 1 MW DFC1500 480V AC system from FuelCell Energy was assembled on-site and is only 26.5 feet (8m) high, 43 (13.1m) feet wide, and 40 feet (12.2m) long.

This clean fuel cell power plant removes roughly 3000 tons of CO_2 emissions per year, which is equivalent to removing 520 cars from California roads or planting 830 acres (3.4km^2) of forest.

Costs & Financial Incentives

The total project costs are estimated with $6,100,000 including operating and maintenance costs. Alameda County signed a maintenance agreement with Chevron for 13 years. This agreement includes the fuel cell stack replacement and will cost roughly $200,000 - $300,000/year. In course of these replacements the rated capacity will increase at least to

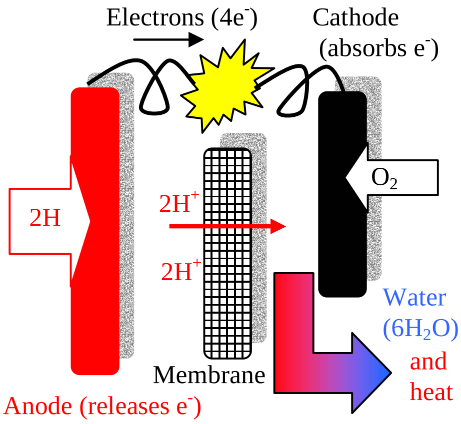
1.2 MW because of technical improvements in stack technology. However, the system lifetime is estimated with 25 years due to scheduled stack replacements and the overall net savings are estimated with $6,600,000 (=$264,000/year). To mitigate these costs Alameda County received $1,400,000 from Pacific Gas and Electric in course of the California Self-Generation Incentive Program and $1,000,000 from the U.S. Department of Defense. It is estimated that the fuel cell saves taxpayers around $264,000 per year.

How does a fuel cell work?

A fuel cell converts energy – similar to a battery – by using electrochemical processes. No combustion takes place and a fuel cell itself contains no moving parts which increases the reliability considerable. The main difference to a battery is the continuous flow of hydrogen (H_2) and oxygen (O_2) to keep the fuel cell working; fuel cells can not storage energy like batteries.

$$\text{Anode: } 2H_2 + 4H_2O \Rightarrow 4H_3O^+ + 4e^-$$

$$\text{Cathode}: O_2 + 4H_3O^+ + 4e^- \Rightarrow 6H_2O$$



On the anode H_2 diffuses to the anode catalyst (metal plate) where it dissociates into positive hydrogen (H^+) ions and electrons. The key element is the membrane (e.g. molten carbonate) which only allows the positive H^+ ions to travel to the cathode where H+, electrons and O_2 react to water – the only "waste product" of a fuel cell. The electrons have to take the "detour" through the external circuit which connects the anode and cathode. This flow of electrons constitutes a direct current. In this may a maximum voltage of 1.23V per cell can be achieved. Staking of such cells creates higher voltages. One of the major problems is the hydrogen production. Currently, most of the used H_2 is extracted from natural gas, a fossil fuel. More environmental ways are under design (e.g. using photovoltaics).

Picture above: 1 MW single direct fuel cell Module at the Santa Rita jail

Picture below: Alameda County also operates three zero emission fuel cell busses on a regular schedule

Further information can be found at

Alameda County: www.acgov.org
Chevron Energy Solutions: www.chevronenergy.com
FueCell Energy: *www.fuelcellenergy.com/*
Hydrogen, Fuel Cells and Infrastructure Techn. Program: http://www1.eere.energy.gov/hydrogenandfuelcells/
Fuel Cell bus: www.actransit.org/environment/hyroad_main.wu
PRAC: www.chpcenterpr.org

Contact Information

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Tel: (510) 486-4929 or
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Email: mstadler@berkeley.edu

The fuel cell will provide 50% of the jail's annual energy needs.

"A megawatt of power from the fuel cell covers base load electricity. And by pairing the plant with a solar array for peaking power, and utilizing waste heat for hot water, the entire system delivers the highest energy efficiency possible, while improving reliability"
R. Daniel Brdar, president and chief executive officer from FuelCell Energy.