CAL POP

SOLAR-POWERED CIRCULATOR TECHNOLOGY ENERGY ASSESSMENT PROJECT

Emerging Technologies Program

Application Assessment Report
No. 0810

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P1172

Contract: CWA 08CEE-T-2500051205

December 31, 2008

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Table of Contents

EXECUTIVE SUMMARY

Pacific Gas and Electric Company (PG&E) funded this Solar Powered Circulator Technology (SPCT) Evaluation Project to assess the technology in terms of power and energy reduction potential when applied in wastewater treatment facilities (WWTF) that deploy pond-based systems for municipal and industrial wastewater treatment. SPCT units are solar-powered circulation devices that employ a near-laminar radial flow technology that provides high-flow, long-distance circulation in open wastewater lagoons. The SPCT can be deployed in facultative ponds without aeration, partial mix ponds with aeration and total mix ponds with intense levels of aeration. SPCT units can reduce or avoid aeration run times. In facultative ponds, aeration can be avoided altogether

The market potential for SPCT across raw water storage reservoirs, freshwater recreational lakes, wastewater, stormwater basins and potable water systems is promising. One manufacturer of SPCT units projects that the technical potential for energy savings in the PG&E service territory to be as great as 877 MW and 7.7 billion kWh annually. By the end of 2010, more than 600 SPCT units are expected to be installed yielding energy savings of 12 MW and more than 280,000 MWhrs annually.

The primary objective of this study is to evaluate and document energy savings and the range of wastewater treatment improvements that SPCT technology has provided in a recent, large-scale field application at one host wastewater treatment facility. Energy savings of eight prior SBCT projects, implemented with assistance from the California Wastewater Process Optimization Program (CalPOP) since 2004, have already been well documented and are summarized in Table E-1. All of these projects used one type of SPCT, known by the trade name "SolarBee".

Table E-1
Installed CalPOP SPCT Projects Since 2004

Facility	Utility	Annual Savings (kWh)	Project Cost
Site 1	PG&E	747,228	$ 121,706
Site 2	PG&E	48,478	$ 26,000
Site 3	PG&E	768,886	$ 156,420
Site 4	PG&E	959,529	$ 884,289
Site 5	PG&E	649,116	$ 164,000
Site 6	PG&E	1,647,392	$ 427,912
Site 7	PG&E	855,722	$ 273,407
Site 8	PG&E	472,711	$ 261,399
Total		**6,149,062**	**2,315,133**

The average (simple) payback period of these eight projects is 3.77 years, (not including the PG&E (CalPOP) incentive), and the average incremental cost of these eight projects is $0.369 per annual (gross) kWh savings. However, the true average incremental cost and simple payback period of SBCT units may be considerably lower if one considers the capital, operation and maintenance costs of the alternative mechanical, grid-connected equipment to the SBCT system.

Particularly when SPCT units are introduced at a time when equipment replacement of conventional equipment is needed, the incremental cost of SPCT is considerably lower than the $0.369 incremental cost and 3.77 average simple payback figures given here.

Past projects typically involved the replacement of standard mechanical mixing and aeration systems with SPCT units whereas the project featured in this case study report involves the introduction of SPCT as an alternative to introducing standard mechanical mixing and aeration systems to a large-scale facultative lagoon treatment system. The introduction of aeration and mixing systems is needed at the host facility to accommodate increased plant capacity, both in terms of plant flow and loadings. Table E-2 shows the calculated energy savings of this project provided in a Facility Audit report by the CalPOP program.

Table E-2
Energy Savings Summary

Description	Impacts
Demand Savings (kW)	109.5
Annual Energy Savings (kWh)	959,529
Demand Savings	$ 22,082
Annual Energy Savings	$ 86,704
Total Annual Savings	$ 108,786
Project Cost *	$ 884,289
Rebate Estimate @ $0.11/(kW-hr)	$ 105,548
Net Project Cost	$ 778,741
Simple Pay Back (yrs) *	7.2 *

* NOTE: The payback figure in Table E-2, merely divides project costs by energy savings; It does not indicate the capital and O & M costs of the mechanical, grid-connected alternative to the SPCT system. To include these costs in this analysis would identify the true incremental cost of the SPCT project, which would be much lower than the total project costs stated here, thereby also significantly reducing the payback period.

This project focused on the existing operating parameters of an facility with an annual average 3.5 MGD flow and a peak BOD_5 (biological oxygen demand) of about 600 mg/l. Additional analysis will be required to validated the anticipated performance for this facility at an expanded capacity of 4.9 MGD with a peak BOD_5 of 800 mg/l. The analysis of wastewater treatment improvements at the host facility showed promising results in terms of meeting the pilot project objectives: Twenty (20) SPCT units, manufactured by SPCT, were installed in two of the seven ponds in April 2008. The units have proven to operate reliably and continuously in the large ponds at the project site. Significant testing showed that the SPCT ponds were better mixed, the sludge and slurry levels have been reduced, and short-circuiting has been prevented. Overall, the plant performance has improved, with $CBOD_5$ (carbonaceuos biochemical oxygen demand) levels sometimes at non-detect. More specifically, the water column characteristics of temperature, DO (dissolved oxygen), pH, and conductivity for the Ponds with SPCT units show that these ponds are better mixed, less stratified, cooler, and show significantly better oxygen profiles than the control ponds. All of these are enhancements over the existing natural pond system and should help to control odors and make for a more reliable treatment process.

The water quality analysis was somewhat complicated by the process of constant effluent recycling and redistribution to ponds, as well as differences in pond depths, internal loadings, and detention times. Findings indicate that that the ponds with SPCT units are better mixed and are addressing what amounts to a backlog of biological loadings (in the form of stored sludge). Once this backlog is eliminated, the effluent of the SPCT ponds may eventually show longer-term improvements in DO and BOD_5 parameters. More detailed testing and a longer test period will likely be required to evaluate the SPCT performance under higher BOD_5 loading rates.

The analysis of water treatment improvements at the host facility was complicated by the process of constant effluent recycling and redistribution to ponds, as well as differences in pond depths, pond internal loadings, and detention times. However, results of the Project analysis indicate that the are operating according to their design parameters and meeting their specifications and overall project objectives. Specifically, the water column characteristics of temperature, DO, pH, and conductivity for the Ponds with SPCT units show that these ponds are better mixed, less stratified, cooler, and show significantly better oxygen profiles than the control ponds. All of these are enhancements over the existing natural pond system and should help to control odors and make for a more reliable treatment process. To this end, the SPCT units appear to be functioning as a reasonable alternative to the mechanical aeration previously proposed for this purpose.

Additional findings also suggest that better mixing in that the ponds with SPCT units are addressing what amounts to a backlog of biological loadings (in the form of stored sludge). Once this backlog is eliminated, the effluent of the SPCT ponds may eventually show longer-term improvements in DO and BOD_5 test parameters. More detailed testing and a longer test period will likely be required to evaluate the SPCT performance under higher BOD loading rates.

PROJECT BACKGROUND

Description of the Solar-Powered Circulator Technology

Solar-Powered Circulator Technology (SBCT) is an emerging technology that uses solar-powered equipment to drive mixing in water supply and wastewater treatment systems. One manufacturer, SolarBee, utilizes a patented near-laminar radial flow process that provides high-flow, long-distance circulation™ (LDC). SBCT has been implemented in water treatment processes in potable water tanks and reservoirs, in wastewater ponds and lagoons; it also has been used to improve water quality in freshwater lakes, reservoirs and estuarine environments. SPCT utilization is scalable in project size and provides energy efficiency and renewable energy benefits as well as a range of water quality and treatment process benefits.

The SolarBee SPCT technology was originally developed in 1998 and has evolved over the last 10 years. SolarBee units are the exclusive manufacturer of SPCT units evaluated in this technology report, as additional information of other types of SPCT was difficult to obtain. Each SolarBee unit is typically equipped with three floatation pontoons, three 80-watt solar PV panels which charge onboard batteries and (SCADA compatible) Control systems, and a brushless motor. The battery system that allows for continuous day/night operation is driven entirely by solar power. The drive motor is a direct drive, direct current motor with no gear box so in some critical applications (notably primary cells in wastewater applications), the SolarBee can be connected to the grid for added redundancy and insurance. SolarBee units have a 25 year life, with a need to replace the battery every 5 to 15 years. There are five different models, with flow rates ranging from 950 to 10,000 gallons per minute (gpm). Four units are self-adjusting to widely varying water levels ranging from 3 ft to 100 ft. Near laminar flow and a proprietary distribution mechanism allows one SolarBee to circulate up to 35 surface acres in a lake. The SolarBee systems are patented both nationally and internationally, and a recent decision from the California Public Utility Commission (CPUC) allows "stand-alone solar powered water circulators" to be eligible as an energy efficiency measure. Figure 1 shows a SolarBee unit in operation.

The solar-driven mechanical output from a SolarBee unit is much lower than the 30 horsepower that is typically displaced by the mixing energy of conventional grid-connected mixing equipment in wastewater treatment ponds. The range of displacement goes from 5 hp up to 75 hp per SolarBee in wastewater applications depending upon the pond's organic loading. SPCT units have also been found to displace high horsepower aeration/mixing equipment in freshwater reservoirs and other water bodies. Using an average of one SolarBee per 30 hp, the energy savings from a large SolarBee displacing 25 kW, and running 24 hours per day, 365 days per year, is typically about 220,000 kWh per annum.

The price of SolarBee units ranges from $25,000 to $60,000 on an installed cost basis. On a life cycle basis, SPCT units typically provide a favorable payback when compared to alternatives. The capital costs may be higher initially, but over time the energy savings, and operations and maintenance savings, yield cost savings to the customer.

Figure 1

An Operating SolarBee Unit

SBCT Market Segments and Market Potential

Market segments in which SBCT is applicable include:

- *Wastewater Treatment Plants:* including facultative ponds, partial mix cells, total mix cells, effluent storage basins, sludge storage basins, and stormwater ponds. In some cases the SPCT provides only the mixing horsepower that is required, and in other cases, they provide both oxygen and mixing hp.

- *Freshwater Lakes:* including raw water reservoirs for drinking water, and recreational lakes.

- *Potable Water Tanks and Reservoirs:* including finished drinking water and recycled water stored in above-ground, below ground and elevated tanks (solar panels are placed on the roof and a power cord is run to the floating SPCT in the tank).

There are about 1,600 SolarBee installations total in the US and Canada; there are another 50 SolarBee installations internationally (International efforts have just begun). The current number of installations in California is over 500 sites; about two-thirds of those sites are in PG&E territory. In summary, the total potential market for SPCT across all market segments in the PG&E service territory is about 56,000 units. The total potential energy displacement or conservation with SBCT in the PG&E service area is 875 MW of demand, and 7.7 billion kWh/year

Freshwater is the biggest market segment for SBCT. In the freshwater market, one manufacturer, SolarBee, estimates that between 60 and 80 percent of the lakes and reservoirs, and 50 percent of the estuaries would require SBCT. This translates to nearly 100,000 freshwater lakes and reservoirs in California that are impaired and in need of circulation to improve water quality. An energy savings analysis would have to be performed on a "Savings By Design" basis because most of these lakes are not currently aerated or mixed. Our analysis in freshwater applications researched energy rates by aeration vendors, and it is believed that it is reasonable to use 1 hp/acre of aeration that would otherwise be required to circulate these lakes that suffer from impaired water quality. Using 35,000 freshwater lakes, ponds and reservoirs, it is estimated that about 35,000 SPCT units would be required in the PG&E service area. Using an average of 25 hp/SolarBee, 875,000 hp would be required to circulate these 35,000 lakes and ponds to improve impaired water quality. The total calculates to be 875,000 hp x (0.746 KW/hp/90 percent efficiency) x 24 hours/day x 365 days/year equals 725 MW demand and 6.4 billion kWh/year that would be otherwise required.

In the potable water market segment, SolarBee estimates that 80 percent of all potable tanks and reservoirs require mixing to maintain water quality. The market size for SPCT units in the PG&E service area is about 16,800 tanks and reservoirs. Using an average of 3 MG/tank, and 1 HP/Million Gallons, these tanks would otherwise require 50,400 hp, or about 41.8 MW of demand, 366 million kWh annually.

For the wastewater market, SolarBee estimates that 80 percent of all systems would have a need for SPCT units somewhere in their systems. In the wastewater sector, the market size in the PG&E service area is estimated to be about 4,400 SPCT units, displacing about 110 MW of energy, and about 1 billion kWh/year of existing aeration run time. Table 1 presents recent and estimated wastewater market penetration of SPCT units in the PG&E Service area:

Table 1
Estimated Market Penetration

Year	2006	2007	2008	2009	2010	Total (5 Yr.)
Sales ($ in PG&E territory)	$1.4 m	$2.1 m	$3.7 m	$6.9 m	$12 m	26.1 m
# units in PG&E	35	45	75	125	200	605
Energy Savings (MWh/yr)	7,665	9,855	16,425	27,375	219,000	280,320
Demand Savings (MW)	0.875	1.125	1.875	3.125	5	12

Despite this potential in the wastewater market, the engineering community has been slow to adopt SPCT as an alternative to conventional aeration. SPCT does not have a deemed Oxygen Transfer Rate (OTR), nor can engineers readily design to the Ten States Standard (EPA) with SolarBees. In addition, SPCT units are typically a low cost, low impact, low input solution that have the potential to reduce the need for capital intensive, energy intensive improvements. The potential savings may reduce engineering fees; there are cases where employing SPCT units at a cost of $217,000 allowed a community to avoid having to build a capital intensive, energy intensive $10 million plant.

The remainder of this Technology assessment focuses on SPCT as applied in the Wastewater Sector in general, and at one large-scale host wastewater facility that recently installed 20 SolarBee units (referred to as the Host Wastewater Facility).

Description and Results of Prior SolarBee Applications in Wastewater Facilities

This section offers a brief review of SolarBee Applications that have been served by a PG&E Third Party Program. Since 2004, PG&E has funded a Third Party Implementer, Quantum Energy Services and technologies, Inc. (QuEST), to operate the California Wastewater Process Optimization Program (CalPOP). CalPOP has helped with the project identification and engineering analyses for various SolarBee projects that implemented as a part of the PY 2004-2005 and the PY 2006-2008 programs. In total, QuEST was able to implement and provide rebate incentives for eight (8) projects within the PG&E service territory.

The extent of the SPCT projects, their host facilities, and the equipment used were highly diversified. These projects have typically involved the partial or complete replacement of mechanical, grid-connected brush aeration and pond mixing equipment. As SPCT units are typically stand-alone units, the energy savings of these projects are generally measured against the prior energy use of aeration and mixing systems equipment that are removed, or by the reduced amount of energy for aeration / mixing systems that are left in place. The level of service of installed SPCT units is generally equivalent to or greater than the equipment that they replace. In addition to energy savings, SPCT technology often provides elegant solutions to chronic problems with the wastewater treatment processes at the sites where they are installed. All of the SPCT projects evaluated in this report utilized SolarBee technology.

Table 2 shows the annual savings and project costs of the eight projects installed since 2004 as a part of the CalPOP program. The average project cost of these eight projects is $289,392, and the average annual savings of these projects is 768,633 kWH. Assuming a bended average PG&E rate of $0.10 / kWh for these sites, the average (simple) payback period is 3.7 years, not including the PG&E (CalPOP) incentive. Assuming that the project incremental costs are equal to the total project costs for these projects, the average incremental cost of these eight projects on is $0.369 per annual (gross) kWh savings. However, the true average incremental cost of SPCT units may be considerably lower if one considers the capital and O&M costs of the alternative mechanical, grid-connected equipment to the SPCT system. Particularly when SPCTs are introduced at a time when equipment replacement of conventional equipment is needed, the incremental cost of SPCT technology is considerably lower than the $0.369 figure given here.

Table 2
Installed CalPOP SPCT Projects Since 2004

Facility	Utility	Annual Savings (kWh)	Project Cost
Site 1	PG&E	747,228	$ 121,706
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Total		**6,149,062**	**2,315,133**

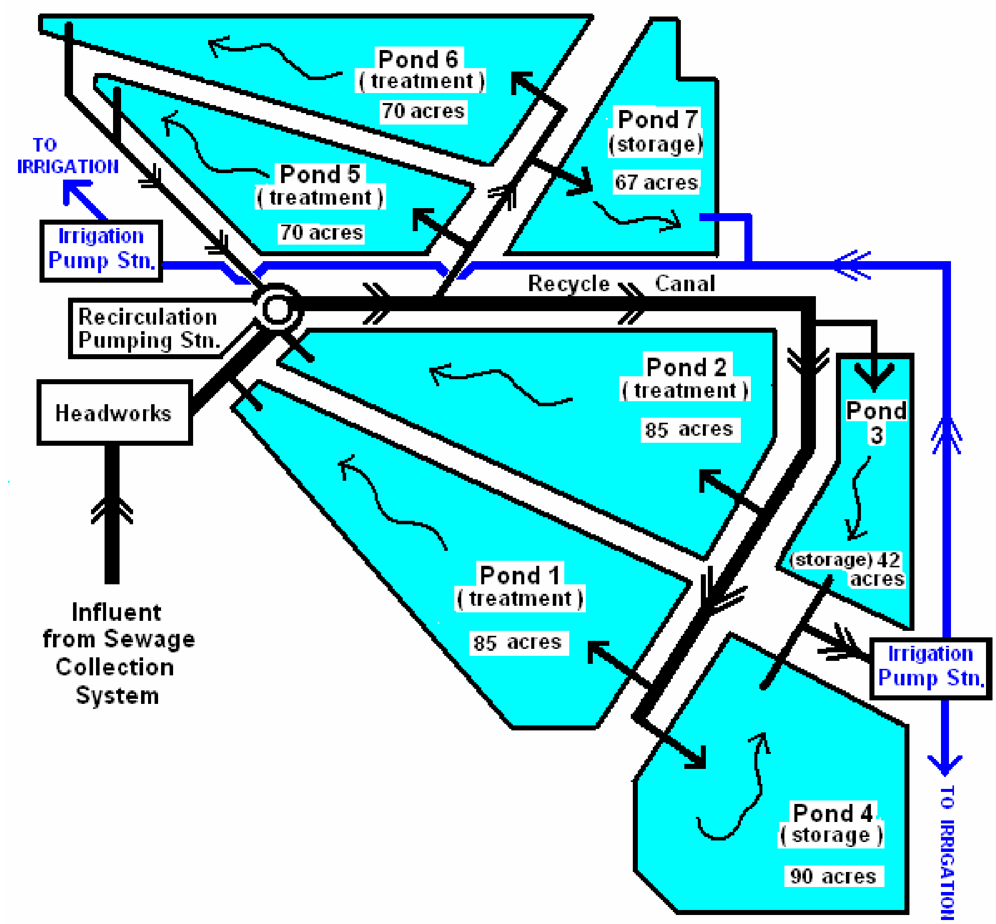
Description of the Host Wastewater Facility

Facility Operations Overview:

The host wastewater treatment facility that is the focus of this study currently utilizes more than 500 acres of facultative lagoons and effluent storage basins that do not presently have equipment for mixing and aeration. However, the existing facultative pond system is currently running at close to its permitted capacity at a time when plant influent flows and loads continue to increase. The host facility currently has a dual need to expand plant capacity without adding lagoon acreage, and to address potential problems in treating effluent to levels required by regulatory standards.

The remainder of this section provides a summary of the pre-project operations of the host WWTF. The review of pre-project operations along with a discussion of the nuances of the application of SBCT (vis-à-vis the foregone mechanical aeration alternative) is necessary to understanding the performance results of the SPCT as applied at the host WWTF. Figure 2 provides a simplified diagram of the prep-project host WWTF.

Figure 2
Host Wastewater Treatment Facility



This wastewater treatment system includes over 500 acres of facultative lagoons including four parallel treatment ponds and three storage ponds. Influent wastewater is a combination of domestic wastewater flows from the host City and industrial flows from food processors in the treatment area.

The plant operation consists of mixing the influent raw wastewater from the plant headworks with the effluent flow from the four treatment ponds (Ponds 1, 2, 5, & 6). This combined flow is sent through a recycling canal where flows are allocated back to the treatment ponds (Ponds 1, 2, 5, & 6) and to the storage ponds (Ponds 3, 4 & 7). The effluent from the four treatment ponds (Ponds 1, 2, 5, & 6). is recycled, while the flow to the storage ponds undergoes further treatment within the storage ponds and is then stored until the growing season when it is discharged for irrigation on adjacent fields. Depending on storage and treatment requirements, storage ponds (1, 3 & 7) can be used as a treatment ponds (with treated effluent), or as storage ponds with no effluent flow until irrigation discharges begin. In order to provide effective treatment, the plant periodically used Storage Pond 7 for treatment as well as storage. Using Pond 7 as a treatment pond had limited flexibility in terms of balancing storage and treatment requirements.

It is noted that this WWTF system has a recirculation channel that thoroughly mixes incoming raw sewage with effluent from all ponds, at about a 1:5 ratio, and then distributes the mixture to the influent of all ponds, which are all essentially operated in parallel. The recirculation channel also effectively "seeds" all ponds with feedback nutrients from the de-composing wastewater in the channel. This hydraulic design continuously homogenizes the water in all ponds and minimizes differences in influent wastewater concentrations between ponds. It has been noted that there is considerable volume of accumulated sludge in the recirculation channels that is not diminished by flows in the channel.

Table 3 provides a facility process summary that presents applicable information collected as part of the pre-project analysis for the treatment facility. Based on influent data from January 2007 to December 2007, the current plant influent loading is 3.5 mgd flow with a yearly average BOD_5 (biological oxygen demand) concentration is 535 mg/l. However, as is common in plants with food processing influent flows, there is a sustained peak of 600 mg/l influent BOD_5 for two months during the year.

Table 3
Wastewater Treatment Process Characteristics

	Value
Average Influent Flow (mgd)	3.5
Average Influent BOD (mg/l)	535
Assumed Influent Ammonia (mg/l) (Conservative Estimate)	25(1)
Average Recycled Flow (treatment pond effluent) to Plant Headworks (mgd)	19.2
Average Recycled BOD (treatment pond effluent) to Plant Headworks (mg/l)	70
Combined (Influent + recycled) BOD to Ponds	140
Volume/Surface Area of Treatment Pond 1 (MG / Acres)	124.5 / 85
Volume/Surface Area of Treatment Pond 2 (MG / Acres)	124.5 / 85
Volume/Surface Area of Treatment Pond 5 (MG / Acres)	172 / 70
Volume/Surface Area of Treatment Pond 6 (MG / Acres)	195 /70
Volume/Surface Area of Storage Pond 3 (MG / Acres)	81 / 42
Volume/Surface Area of Storage Pond 4 (MG / Acres)	161 / 90
Volume/Surface Area of Storage Pond 7 (MG / Acres)	190.5 / 67

SPCT Project Overview:

Prior to the introduction of SPCT, the host WWTF facultative pond system was operating at close to its permitted capacity. At the same time, plant influent flows and loads continue to increase. The host facility currently had a dual need to expand plant treatment capacity without adding lagoon acreage, and to address potential problems in treating effluent to levels required by regulatory standards. One option to address these issues was to abandon the lagoon treatment system and build a very expensive, industrial, activated sludge treatment plant that the host municipality simply could not afford.

The only alternative to solve this dual need was to introduce equipment for pond mixing and aeration in selected cells of their lagoon system to deliver higher levels of Dissolved Oxygen (DO) to treat the increasing Biological Oxygen Demand (BOD) of the plant's influent. BOD_5 is the primary measure of required treatment capacity, and is the central measurement in tracking the performance of the SPCT project. In general, aeration reduces BOD levels in lagoon-based wastewater treatment systems. However, biological processes occurring in lagoon-based treatment systems are complex and need to be balanced to favor beneficial algal cycles and prevent disruptive algal blooms.

A 2006 engineering study conducted by Boyle Engineering of Fresno, CA, has indicated that a minimum of 500 hp of surface aeration equipment (twenty 25-hp surface aerators) was needed at the host facility to help reduce effluent BOD_5. A 500 hp aeration system operating 24 hours a day, 7 days a week would use more than 3.2 million kWh annually, and would represent a considerable cost burden to the host WWTF.

A subsequent 2007 Engineering Strategic Plan by ECO:Logic proposed a innovative approach for introducing twenty solar powered mixing units, as a possible alternative to (or in conjunction with) standard mechanical aeration systems. The ECO:Logic approach included the phased installation and testing of solar mixers to determine if they are an effective alternative to brush aerators. The advantage of the SPCT solar circulators is that they supply the required increase in aeration for BOD reduction without the surface turbulence which disrupts the algal cycle. In addition, the solar circulators supply adequate movement of the water to allow the oxygen to be distributed throughout the pond.

The installed aeration capacity to serve the expanded capacity would also need to be capable of treating the peak loading periods. Table 4 shows the anticipated oxygen demand and horsepower requirements for the average and peak loading periods, and the plants next proposed expansion to treat 4.9 MGD. The horsepower requirements listed in Table 4 are for required aeration only and do not include the likely need for supplemental pond mixing.

The SolarBee regional representative (SPCT equipment vendor) prepared a proposal for phased development of SPCT applications in the host facility in accordance with the ECO:Logic proposal. The first phase of this proposal entailed the installation of 20 SolarBee units to address the host facility's immediate needs in addressing problems of potential wastewater discharge permit violations, and to examine the outcome of the SPCT in addressing expanding treatment capacity needs of the host facility.

With the help of an independent engineering analysis and incentives provided by the California Wastewater Process Optimization Program (CalPOP) the first 20 SPCT units were installed in April, 2008, as the first stage in a phased project to eliminate the need for 500 hp of new aeration load to meet expanding capacity needs.

Table 4
Aeration Requirements

Parameter	Units	3.5 mgd Case Yearly Average	3.5 mgd Case Peak Months	4.9 mgd Case Peak Month
Influent Q, mgd	mgd	3.5	3.5	4.9
Influent BOD_5, mg/l	mg/l	535	600	800
Influent BOD5, lb/d	lb/d	15,617	17,514	32,693
Influent Ammonia, mg/l	mg/l	25	25	25
Influent Ammonia, lb/d	lb/d	730	730	1,022
lb O_2 Req'd by BOD_5 @ 1.5 lbO_2/lb BOD_5	lb/d	23,425	26,271	49,039
lb O_2 Req'd by NH_3 @ 4.6 lbO_2/lb NH_3	lb/d	3,357	3,357	4,700
Total Req'd lb O_2 per day	lb/d	26,782	29,628	53,739
Total hp Req'd @ 1.9 lb O2 / hp	hp	587	650	1,178

In evaluating the treatment system, the CalPOP Facility Audit Report recommended that SPCT be installed in one treatment pond and one storage pond (Ponds 1 & 4, respectively). While this would not allow the entire influent flow to be treated, it was intended to give plant staff the ability to pilot test the units as an alternative to the installation of mechanical aerators. In theory, by changing the feed rates to the ponds, it may be possible to "stress test" Ponds 1 & 4 to verify their capacity with the solar circulators, although the host facility was not receptive to conducting this test. The facility operator at the host facility chose to install eleven SPCT units, manufactured by SolarBee, in Pond 1 and nine units in Pond 7, as shown in Figure 3.

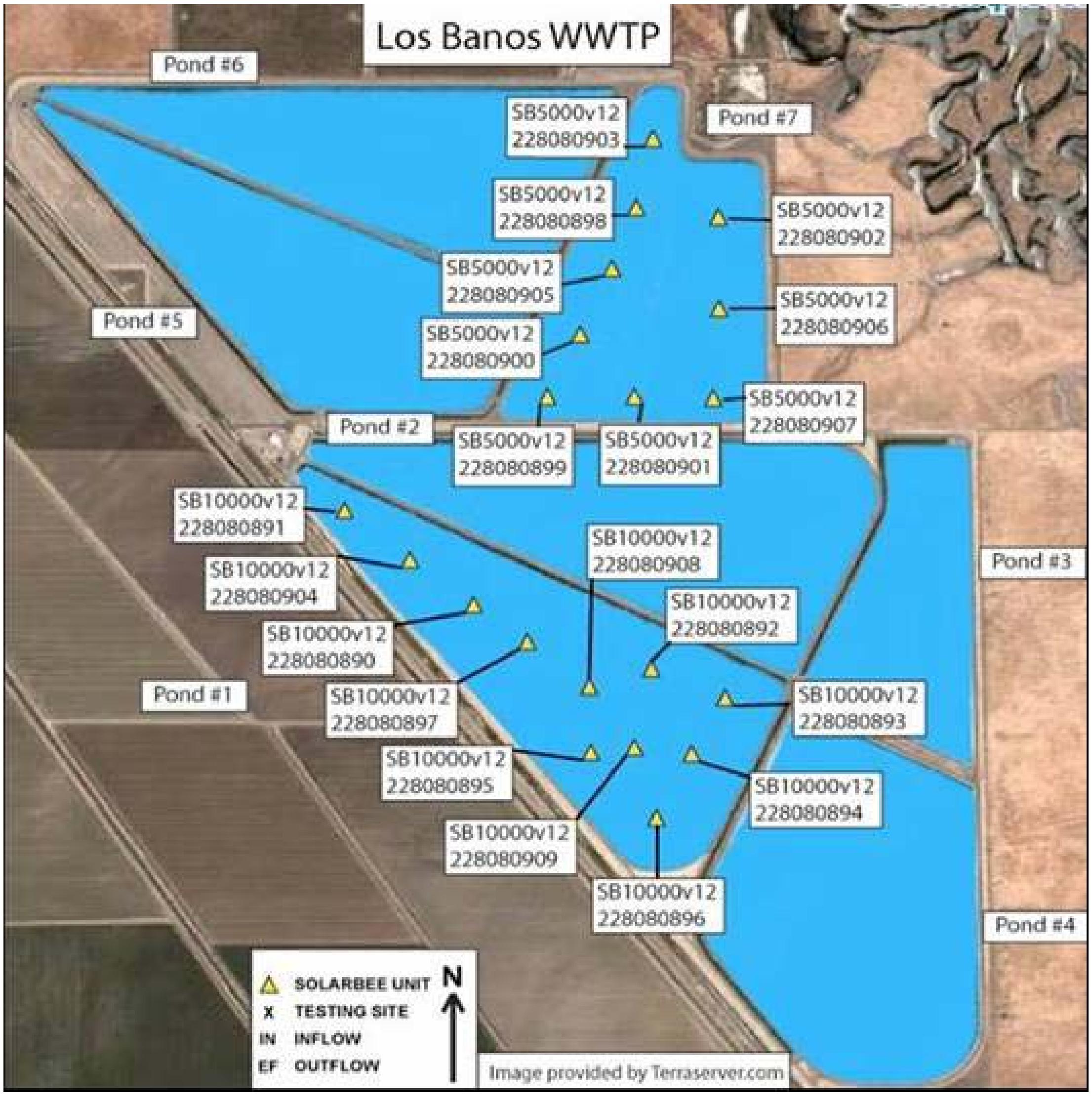
In Pond 1, eight (8) model SB10000v12 SolarBee circulators were installed with their intakes set to treat the top 3.5 ft of the lagoon. There are also three (3) model SB5000v12 machines, slightly smaller units, designed for their intakes to be set deeper in the pond to reduce the cooler influent water from short circuiting across the bottom of the pond from the inlet to the outlet. These units were designed to prevent short-circuiting. In April, these machines were set for just 3.5 ft of mixing depth, to allow the pond to adjust to long distance circulation, but on June 20-21 these intakes were lowered to 1 ft from the bottom as originally designed so as to reduce short-circuiting in the ponds.

In Pond 7, nine (9) SB5000v12 units were deployed. At installation, all of the units had their intake set high at 4.5 ft in about 8 ft of total depth of water. During the June 20-21 inspection, four (4) of the nine unit intakes were adjusted to be set deeper, to 1 ft from the bottom, in order to further reduce short-circuiting. In August, the intakes for these 4 machines were raised to 2 ft off the bottom in order to assist maintaining good DO on the surface.

At a September 27-28, 2008, inspection, all twenty (20) circulators were operating at the design parameters, including correct motor speed, motor current, and battery voltage. In addition, after some initial sliding caused by high winds, the SPCT units have since maintained their position and no longer appear affected by the high wind conditions at the host facility.

Ponds 2, 3, 4, 5 & 6 do not have circulators or mechanical aerators. Ponds 3 and 4 were off line for much of this past summer.

Figure 3
Placement of SolarBee Units in Ponds of the Host Facility



PROJECT OBJECTIVES

The Host City's 2007 Wastewater Strategic Plan recommended a phased approach to install and test solar powered circulators to determine if they could be used as an alternative to or in conjunction with previously proposed brush aerators at the existing facility. The objectives included determining if the deployment of the SPCT units could provide adequate treatment of the wastewater without the addition of mechanical aeration that would otherwise be required as recommended in previous engineering reports. From the Host City's perspective, the objective of the Phase 1 SPCT project Twenty was to demonstrate the ability of solar-powered long distance circulation at their WWTF to enhance the natural (facultative) treatment of the wastewater. The objectives of the test project were to:

1. Evaluate the performance of twenty units, including operating specifications and parameters.
2. Compare performance of the ponds with SPCT units to ponds without SPCT units.
3. Coordinate performance results with QuEST, program manager for the CalPOP program, funded by Pacific Gas & Electric, regarding potential energy efficiency, energy conservation and renewable energy incentives for the SPCT units.

The objective of this case study research is to track and verify the performance of the twenty SPCT units installed as a part of the Phase 1 project as originally outlined in the ECO:Logic study. The energy savings performance of the project is clear and is measured against a baseline of what conventional equipment would have been needed to accomplish the same results as the installed SPCT project.

Ideally, project performance would also be gauged in terms of meeting other goals of the project from the host facility's perspective, namely meeting the expanded loading and mixing requirements of the host WWTF as it seeks to expand capacity, and in terms of resolving any potential problems with meeting permit requirements for the plant effluent.

While a definitive analysis of the Phase 1 project's ability to meet additional plant capacity and effluent standards is beyond the scope of this study, this case study does seek to provide indicators that the installed SPCT project serves these objectives.

One challenge in meeting these objectives is the fact that the period of data collection for water quality parameters corresponds to a period in which plan influent flows and loadings have been dropping because of the recent, unexpected, and severe downturn in the economy. The second obstacle to definitive measurements of the capacity performance of the SPCT project is that there is insufficient water quality data, both in terms of the number of sampling points and duration of the sampling regime. The water quality sampling and analysis process outlined in the monitoring plan for this project was known to be insufficient to completely measure water quality changes in all of the host facility's treatment ponds. It was also known that the period of time in which water quality data was to be collected for this study may not show conclusive improvements in water treatment process in a way that would clearly delineate the host WWTF's ability to meet effluent standards and additional capacity projected for the plant. Given that the host WWTF has a recirculation channel that thoroughly mixes incoming raw sewage with effluent from all ponds (at about a 1:5 ratio) and then distributes the mixture to all ponds, this hydraulic design continuously homogenizes the water in all ponds and minimizes differences in influent wastewater concentrations between ponds. In addition, both the treatment ponds and the recirculation channels have been shown to contain a significant volume of accumulated sludge that represent a backlog of biological loadings. Overall the host facility's treatment system provides challenges in terms of measuring the difference in performance of treatment ponds with and without SPCT units.

Consequently, the adapted primary objective of the analysis for this case study is to explain the observed performance improvements of the Phase 1 project *as seen in the first six months of operation*. Performance will be defined based on findings drawn from observed changes in water quality parameters of the wastewater treatment process by comparing water quality conditions in treatment lagoons prior to, and following the introduction of the twenty installed SPCT units.

PROJECT DESIGN AND EVALUATION

Project Design

While the results of the prior SPCT wastewater applications are summarized in the report (above), the project design for this study focused on the energy savings as well as discerning improvements to the wastewater treatment process that lead to improvements in the water quality of facility's treated effluent, as well as improvements in the plant's ability to meet expanding capacity requirements. Potential energy savings from the project were clearly identified and estimated in a CalPOP Facility Audit prepared for the Phase 1 SPCT project at the host site, and these savings were verified in a post-installation Savings Verification Report approved by PG&E. Project energy savings results are summarized below.

The emphasis of the project design was to conduct water quality sampling and analysis to show water quality improvements in the host facility's treatment process that equate to an expansion in plant treatment capacity, a resolution of existing treatment problems and/or overall improvements to the quality of the plant effluent.

Measurement and Evaluation

<u>Energy Impacts of SPCT at the Project Site</u>

Energy impacts of the Phase 1 SPCT project at the host WWTF have been evaluated as a part of a CalPOP Project, and are summarized below. The installed SPCT units are solar-powered and self-contained, and did not replace any existing aeration and mixing equipment at the host WWTF. Consequently, the energy impacts of the project are expressed in terms of avoided additional kW loads that would have otherwise occurred with the introduction of new, grid-connected mixing/ aeration equipment needed to meet expanding wastewater treatment capacity and to address existing treatment process problems. The energy benefits of the project were estimated without a pre-installation or post-installation energy monitoring process for measuring energy savings, as there was never any grid-connected equipment to monitor.

Energy savings estimates from this project were based on a projected baseline of 500 hp of needed aeration (per the 2006 Boyle Report) and the CalPOP estimates that have been approved and accepted as post-installation estimates by PG&E. Approval of the CalPOP Program Incentive Payment in July, 2008, for the 20 installed SPCT units, confirmed by PG&E's approval of the pre-installation estimate of energy savings as provided in the Facility Audit Report.

Table 5 provides a summary of the estimated energy savings and the economic analysis of the SPCT project as described in the CalPOP Facility Audit Report (see appendix).

Actual energy savings were calculated to be 25 percent of 587 hp, equivalent to a total of 146.8 hp motors running 24 hours per day, every day. This yields annual energy savings of 959,529 kWh, and CalPOP paid incentives of $105,548 to the host facility based on this level of savings (at $0.11 per annual kWh). The total Project cost for the installation of twenty (20) SPCT units was $ 884,289. Based on the economic analysis of the Facility Audit Report, the payback period for installing the solar circulators is 7.2 years, when compared to the mechanical aeration option.

As indicated above, energy savings are based on 25 percent of 587 hp in required mechanical aeration, running 24 hours per day, 7 days per week. The origin of the 25 percent figure used in this calculation is explained in the following section.

Table 5
Energy Savings Summary

Description	Impacts
Demand Savings (kW)	109.5
Annual Energy Savings (kWh)	959,529
Demand Savings	$ 22,082
Annual Energy Savings	$ 86,704
Total Annual Savings	$ 108,786
Project Cost	$ 884,289
Rebate Estimate @ $0.11/(kW-hr)	$ 105,548
Net Project Cost	$ 778,741
Simple Pay Back (yrs)	7.2

* NOTE: The payback figure in Table 5, merely divides project costs by energy savings; It does not indicate the capital and O & M costs of the mechanical, grid-connected alternative to the SPCT system. To include these costs in this analysis would identify the true incremental cost of the SPCT project, which would be much lower than the total project costs stated here, thereby also significantly reducing the payback period.

Affects of Mechanical Aeration and Mixing on Algal Growth & Dissolved Oxygen

In understanding the energy and water quality impacts of the Phase 1 SPCT project at the host site, it is important to note that while it is possible to add traditional, grid-connected mechanical aeration/mixing equipment to facultative ponds, there is a problem in doing so because traditional mechanical systems tend to create turbulence which break up algae.

Algal growth is the predominant source of oxygen in an unmixed facultative process. Adding mechanical aeration reduces the effectiveness of the oxygen supplied by algal growth. In addition, given the size of the ponds, it would likely be impossible to get adequate distribution of oxygen to promote even treatment throughout the pond with the minimum horsepower required for mechanical aeration only. Therefore, as significant oxygen is added by mechanical aeration, the pond treatment process would normally be switched from a pure facultative process and designed as an aerobic partially mixed pond system so that the oxygen could be both supplied and adequately distributed. The horsepower requirements for partial mixing would normally be in the range of 8 to 15 hp per million gallons of pond volume. Table 6 shows the required horsepower in the ponds for aeration and for the partial mix range.

It is clear from Table 6 that the horsepower requirements to convert the ponds to partial mix is prohibitively high compared to the oxygenation requirements. It is likely that the pond size / layout / and plant process and flow schematic would be altered rather than add the total required horsepower for partial mixing.

The advantage of the SPCT devices is that they supply the required increase in aeration for BOD reduction without the surface turbulence that disrupts the algal cycle. In addition, the solar circulation devices supply adequate movement of the water to allow the oxygen to be distributed throughout the pond.

Table 6
Aeration versus Partial Mix hp Requirements

Parameter	Units	3.5 mgd Case Yearly Average	3.5 mgd Case Peak Months	4.9 mgd Case Peak Month(1)
Aeration Requirements from Table 2				
Total hp Req'd @ 1.9 lb O2 / hp	hp	587	650	1,178
Mixing Requirements for Treatment Ponds 1, 2, 5, & 6 (Volume 616.5 MG)				
Total hp Req'd @ 8 hp / MG Pond Volume	hp	4,932	4,932	4,932
Total hp Req'd @ 15 hp / MG Pond Volume	hp	9,248	9,248	9,248
Mixing Requirements for All Ponds 1 through 7 (Volume 1,049 MG)				
Total hp Req'd @ 8 hp / MG Pond Volume	hp	8,392	8,392	8,392
Total hp Req'd @ 15 hp / MG Pond Volume	hp	15,735	15,735	15,735

(1) Assumes pond volume does not increase for 4.9 mgd design

The percentage of the influent flow to be treated in Ponds 1 & 7 is determined by the surface area of the treatment ponds (Pond 1) and the volume of the storage pond (Pond 7). Pond 1 accounts for approximately 27.4 percent of the treatment pond surface area and Pond 7 accounts for approximately 27.5 percent of the storage volume. It is unlikely that Pond 7 would require all of the oxygen demand of Pond 1 after it is filled (assuming other storage ponds are being utilized) since it receives only a loading based on the pond volume (and does not continue to receive additional influent flows). In addition, on a yearly basis the majority of the treatment occurs in the treatment ponds (Ponds 1, 2, 5 & 6). In practice, plant staff typically splits the flow evenly to these four treatment ponds, resulting in a 25 percent loading to each pond. Therefore, a conservative figure of 25 percent of the total potential savings (based on 587 hp of needed aeration, but not mixing) is used in the calculations for Ponds 1 and 7 as the energy savings.

Measuring SPCT Performance with Biological Parameters

Data Sources:

The Analysis of the Monitoring Plan for this Case study drew upon three sources of data for tracking water quality improvements in the ponds where SPCT units have been installed (Ponds 1 & 7), and comparing these to water quality parameters at control points in Ponds 2 and 6, and at two locations in the recycle channel. The three sources of data are:

1) Water Column testing conducted by the SolarBee manufacturer prior to installation (April, 2008), at summer midpoint (June 20 & 21), and at the end of the summer (September, 2008). SolarBee provided a final water column testing report to QuEST and the host WWTF for this monitoring effort (see Appendix A-1).

2) The standard weekly testing that the host WWTF conducts for its own wastewater discharge permit reporting purposes (to the Regional Water Quality Control Board) covering both Pond influent and effluent (Ponds 1 through 7) measurements for DO, BOD_5, TSS (total suspended solids), EC and Temperature. The host WWTF has made its weekly test data available to QuEST in this monitoring effort through December, 2008 (see Appendix A-2).

3) Supplemental testing per the sampling regime identified in Table 7, below (see also Appendix A-2).. This supplemental monitoring effort was intended to pick up key additional sampling parameters to include: $CBOD_5$, NH_3 (ammonia) TKN (total Kjedal nitrogen), NO_2 (nitrites), & NO_3 (nitrates). Note that BOD_5 is also sampled to compare to the host WWTF's measurements of the same. This is a monthly test cycle for NH_3, TKN, NO_2 & NO_3 and an every other weekly testing cycle for $CBOD_5$. $CBOD_5$ are key test parameters to isolate the impacts of algae on overall BOD (as explained further in Appendix A-3).

Note that the supplemental testing (3) of water quality parameters was initiated on June 18, 2008, and was subcontracted to a private, certified lab (BSK). The subcontract was funded through the monitoring budget of this Emerging Technologies Case Study project. The October 1st sample was not conducted, but the host facility continued testing of the same water quality parameters beyond this date (using the same lab), and made this data available for this analysis. Appendices A-1 and A-2 show all the recorded data used in this analysis.

Table 7
Sampling Plan of the Supplemental Water Quality Testing Regime (BSK Labs)

	Pond 1 (11 Solarbees Installed)						Pond 2 (Control Pond - No Solarbees)						Pond 4 (Control Pond - No Solarbees)						Pond 5 (Control Pond - No Solarbees)					
Date of Sample:	BOD	CBOD	NH3	TKN	NO2	NO3	BOD	CBOD	NH3	TKN	NO2	NO3	BOD	CBOD	NH3	TKN	NO2	NO3	BOD	CBOD	NH3	TKN	NO2	NO3
June 18, 2008	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
June 25, 2008																								
July 2, 2008	X	X	X	X	X	X	X	X	X	X	X	X												
July 9, 2008																								
July 16, 2008		X						X																
July 23, 2008																								
July 30, 2008		X	X	X	X	X		X	X	X	X	X												
August 13, 2008																								
August 20, 2008		X						X																
August 27, 2008																								
September 3, 2008		X	X	X	X	X		X	X	X	X	X												
September 10, 2008																								
September 17, 2008		X						X																
September 24, 2008																								
October 1, 2008	X	X	X	X	X	X	X	X	X	X	X	X												

	Pond 6 (Control Pond - No Solarbees)						Pond 7 (9 Solarbees Installed)						Composite 1 - Recycle Canal @ Pond 1/4,5/7 split						Composite 2 - Recycle Canal Upstream Pond 2					
Date of Sample:	BOD	CBOD	NH3	TKN	NO2	NO3	BOD	CBOD	NH3	TKN	NO2	NO3	BOD	CBOD	NH3	TKN	NO2	NO3	BOD	CBOD	NH3	TKN	NO2	NO3
June 18, 2008	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
June 25, 2008																								
July 2, 2008	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
July 9, 2008																								
July 16, 2008		X						X						X						X				
July 23, 2008																								
July 30, 2008		X	X	X	X	X		X	X	X	X	X		X	X	X	X	X		X	X	X	X	X
August 13, 2008																								
August 20, 2008		X						X						X						X				
August 27, 2008																								
September 3, 2008		X	X	X	X	X		X	X	X	X	X		X	X	X	X	X		X	X	X	X	X
September 10, 2008																								
September 17, 2008		X						X						X						X				
September 24, 2008																								
October 1, 2008	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Data Analysis:

Analysis of the data from the above data sources was carried out upon receipt of data from all three sources. In the Monitoring Plan prepared for this project it was known that it would be difficult to set specific performance requirements for the Ponds where SPCT units are installed. In short, the approach of the analysis will be to monitor water quality changes in the lagoons with SPCT units (Ponds 1 & 7) relative to the control points using the data sources identified in Table 7. Specifically, water quality testing results of SPCT Ponds 1 and 7 will be compared against those from the "Control" Ponds 2 and 6 as well as the two additional locations in the Recirculation

Channel (referred to as the Composite sample 1 & 2 in Table 5). To compare performance differences between the ponds, $CBOD_5$, BOD_5 and TSS (total suspended solids) removal data into and out of the 7 ponds was taken and compared (See Appendix A-3 for a discussion of the relationship between BOD_5 and $CBOD_5$ Test Parameters).

An anticipated challenge in comparing the water quality test results from the ponds with SPCT units to the control ponds is that there is a very high volume of mixing and recycling of Pond effluent with influent at the facility headworks. The average influent flow of 3.5 mgd (at average BOD_5 levels of 535 mg/l), is constantly mixed with much larger treatment pond effluent flows of 19.2 mgd (and BOD_5 of 140 mg/l). This level of mixing presented challenges in the test vs. control pond analysis. To evaluate the mixing performance, water column profiling for temperature, dissolved oxygen, pH and conductivity at various water column depths between the mixed and un-mixed ponds was taken and compared.

Testing involving water column profiles was conducted at three times during the spring and summer of 2008. The first was conducted in April, 2008, the second in late June 2008 and the last was conducted at the end of September. Results of the water column testing were expected to show the following results:

1) Circulation in SPCT ponds is expected to mean that DO on the surface will be distributed move evenly and to a greater depth than the control ponds. The treatment ponds with SPCT units will have less temperature (and salinity) stratification than the control ponds. This measure will indicate that SPCT units are mixing effectively and are preventing "short circuiting" of treatment[1]. In effect, SPCT units promote a better level of mixing in the pond systems than was intended when they were designed. Eventually, overall improved mixing will result in elevated DO and reduced $CBOD_5$ test values in the SPCT ponds, and more uniform detention times.

2) SPCT ponds will have lower DO at the surface relative to control ponds. This indicates that SPCT units are mixing effectively and are promoting beneficial algae while controlling blue-green algae blooms.

REPORTING

Results and Discussion

This section provides a review of the past six months' performance of the twenty SPCT units, that were installed in April 2008 in two of the seven ponds at the Host WWTF. The 2007 Wastewater Strategic Plan for this facility recommended a phased approach to install and test solar powered circulators to determine if they could be used as an alternative to, or in conjunction with, previously proposed brush aerators at the existing facility. The objectives included determining if the deployment of the SPCT units could provide adequate treatment of the wastewater without the

[1] Short-circuiting treatment generally means that the BOD loadings of colder influent waters are retained at lower pond depths (below the thermocline) where anaerobic conditions exist. The cold influent waters generally do not mix with warmer, aerobic surface zones of the treatment ponds (above the thermocline). Improved mixing will increase the bandwidth for treated water in ponds by lowering the thermocline and increasing the volume of pond water that is subject to aerobic conditions.

addition of mechanical aeration that would otherwise be required as recommended in previous engineering reports.

Phase One Objectives: Twenty SPCT units were installed in April 2008 to demonstrate the ability of solar-powered long distance circulation at the host WWTF to enhance natural (facultative) treatment of the wastewater. The objectives of the test were to:

1. Evaluate the performance of twenty units, including operating specifications and parameters.
2. Compare performance of the ponds with SPCT units to ponds without SPCT units.
3. Coordinate performance results with QuEST, program manager for the CalPOP program, funded by Pacific Gas & Electric, regarding potential energy efficiency, energy conservation and renewable energy incentives for the SPCT units.

Water Quality Monitoring of CBOD, BOD, and TSS: Data and Analysis

The raw data for $CBOD_5$, BOD_5 and TSS appear in Appendix of the attached detailed report (Appendix 1) by SolarBee (See Appendix A-3 for a discussion of the relationship between BOD_5 and $CBOD_5$ Test Parameters). The results show somewhat better performance for Pond No. 7, but slightly worse performance for Pond No. 1. In addition, the results vary widely from sample date to sample date. It is therefore difficult to draw any definitive conclusions based on this short-term test of $CBOD_5$, BOD_5 and TSS data as conducted.

This data appears to have been affected by the uncontrollable differences in hydraulic feed rates to each pond along with their different depths and resultant detention times. In addition, differences in the sludge depth between each pond also change the internal nutrient loading developed when the ponds begin mixing. For example, the addition of SPCT mixing began to stir up the sludge in the test ponds, which affected the pond total nutrient (carbon, ammonia, phosphorus) internal loading demand. In this testing these factors have combined to make it difficult to definitively compare $CBOD_5$, BOD_5 and TSS removal rates between the 7 ponds.

While the comparison of $CBOD_5$ and BOD_5 between ponds gave limited information, the ratio of BOD_5 to $CBOD_5$ was fairly consistent among all of the ponds and gives a good indication of the nitrogen and non-organic oxygen demand portion of the total BOD_5 for the host facility's specific pond system. In addition, the facility is achieving $CBOD_5$ levels that are non-detect in Ponds 6 and 7, which is very good for a large pond-based municipal system. As anticipated, the analysis of the $CBOD_5$, BOD_5 and TSS data *between* ponds is complicated by the re-circulation channel and differences between the ponds' depths, flow rates, loading rates, internal loading, and pond detention times.

Water Column Profile Data and Analysis

A final Water Column Profile Testing was conducted by a SolarBee service crew on Sept 27-28, 2008 in Ponds 1, 2, 5, 6, & 7. Ponds 3 & 4 were empty at the time of water column testing. The in-service ponds were tested for temperature, DO, pH, and conductivity as an indicator of salinity. In each pond, the water column testing was conducted at the influent end, the effluent end, and at one or more points in between the influent and effluent ends. Testing was conducted in 1 ft. depth increments, beginning at the surface and ending at the bottom, at each test point in each pond.

Figure 2 in the Appendix of the SolarBee report (Appendix A-1) shows the test points for each pond tested and the Appendix of the SolarBee report provides summary tables comparing the water column profiles for the tested ponds for each test parameter, including temperature, DO, pH and Specific Conductivity. These tests show the differences between the SPCT and control ponds by comparing the water column characteristics of temperature, DO, pH and conductivity. The comparison of BOD_5 and DO of the ponds with SPCT units (Ponds 1 and 7) and without SPCT units (Ponds 2, 5 & 6) shows that SPCT ponds are performing well but not as well as the non-SPCT ponds. While this appears to be counter-intuitive, the water column testing shows that is the result of conditions where the SPCT ponds are essentially working harder than the non-SPCT ponds. There are several findings to support the conclusion that SPCT ponds are actually mixing, which, in turn allows for the digestion of years of accumulated sludge and slurry in the ponds[2]. Comparisons of DO, pH and conductivity in SPCT and control ponds also show significant differences. The digestion of sludge in SPCT Pond 1 accounts for the higher internal loading rate and BOD. This finding is further supported by a comparison of the water column characteristics of temperature, where the data shows that the SPCT ponds are less stratified, cooler, and have cooler surface temperatures than the control ponds. These water column test findings support the conclusion that there is better mixing in the SPCT ponds, as cooler deeper water has been mixed throughout the water column. The water column analysis also shows significantly improved oxygen profiles in the SPCT Ponds and this is further evidence that the SPCT units are mixing as intended.

Overall Pond 1 (with SPCT units) had much better mixing than the control ponds with reduced stratification and more uniform values for temperature and dissolved oxygen. Higher dissolved oxygen levels were also maintained much deeper in the water column with the SPCT Ponds Nos. 1 and 7. This data shows that the SPCT ponds are significantly better mixed and less stratified than the control ponds. These findings taken together with slightly higher BOD and lower DO readings in the SPCT ponds suggest, though not conclusively, that the accumulated sludge in these ponds is being drawn down and treated through better mixing. In effect, the implementation of SPCT may be addressing a backlog of biological loadings (manifest in the form of stored sludge), and may eventually show significant, longer-term improvements in DO and BOD_5 parameters in the SPCT ponds.

It is also noteworthy that Pond 7, with 9 SPCT units installed, is now performing extremely well; the $CBOD_5$ test results are coming back as 'non-detect' from the designated independent (state certified) laboratory. All of the treatment ponds had pH in the healthy range of between 7.0 and 9.0 at the end of September.

Conclusions

In summary, the Phase 1 Project results indicate that the SPCT units are meeting the Project Objectives. The SPCT units are operating according to their design parameters and meeting their specifications. The facility is achieving $CBOD_5$ levels that are very low in Ponds 6 and 7. The water column characteristics of temperature, DO, pH and conductivity for the SPCT ponds and the control ponds show the SPCT units are mixing and working as intended. The SPCT ponds are better mixed, less stratified, cooler, and show significantly better oxygen profiles than the control ponds. All of these are enhancements over the existing natural pond system and should help to control odors and make for a more reliable treatment process. To this end, the SPCT units

[2] Pond 1 has never been desludged in 30 years; Pond 2 was desludged about 6 years ago. Pond 1 has been a 'problem' pond in the system; Pond 2 has always performed better than Pond 1.

appear to be functioning as a reasonable alternative to the mechanical aeration previously proposed for this purpose.

A definitive comparison of improved BOD_5 reduction through the SPCT ponds versus the control ponds has proven more difficult based on the $CBOD_5$, BOD_5 and TSS data obtained. The analysis of the C BOD_5, BOD_5 and TSS data between ponds is complicated by the re-circulation channel, the uncontrolled hydraulic loading to the ponds, the differences in pond depths, pond internal loadings, and detention times. However, findings of the water column test strongly suggest that accumulated sludge in the Ponds with SPCT units is being drawn down through better mixing in these ponds, and the improved mixing is treating the backlog of biological loadings as was stored in the pre-project sludge profiles. Once this backlog is addressed, it is likely that improvements in DO and BOD_5 parameters will be observed in the treatment ponds where SPCT has been applied. To confirm this anticipated result, more detailed testing over longer periods will be required to evaluate the performance of SPCT under higher BOD_5 loading rates.

Recommendations for Future Work

Based on the difficulties presented by the previously discussed recycle and sludge backlog issues, more detailed testing and a longer test period will likely be required to evaluate SPCT performance under higher BOD loading rates. This is likely true to justify both the "better treatment" and the "expanded capacity" concepts that were put forward at the inception of the SPCT Phase 1 project..

Better Treatment

Once the existing sludge volume in Pond 1 has been stabilized (i.e. on-going solids reduction), the impact from the backlog of biological loading will be reduced and it should be possible to test for improved BOD_5, $CBOD_5$, and TSS through the SPCT treatment pond (Pond 1) versus the non-SPCT (control) pond (Pond 2). This will allow a qualitative answer to whether the SPCT units are improving treatment, and increased loading rates.

Expanded Capacity

In order to achieve the secondary goal of increasing plant capacity based on the installation of the SPCT units, it will still be necessary to perform a stress test. During the stress test, the ponds can be differentially loaded to quantitatively determine design parameters for potential capacity expansion. A stress test will need a longer test period and may require physical modifications to the system to allow for a higher loading in the SPCT pond.