5 MILLION GALLON/DAY NET ZERO ENERGY AND REDUCED GREENHOUSE GAS EMISSION WASTEWATER RECLAMATION PLANT

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Abstract: Re-commissioning and upgrading the San Pasqual Aqua III wastewater reclamation facility in San Diego, CA from a 1 MGD to a 5 MGD capacity could reduce life-cycle costs and provide an opportunity for a net zero energy reclamation plant using bio-solids-to energy plus Solar PV and low GHG emissions.

Introduction:
Figure 1 shows an aerial view of the San Pasqual Aqua III site 2.5 miles east of Lake Hodges.

Fig 1. San Pasqual Aqua III site

Aqua III includes 2-acres of sewage reclamation facilities and ~ 0.6 acre of hardscape to the Southwest plus 24 primary treatment ponds with 6.5-acres of surface area plus 1.5-acres of hardscape to the Northeast.

San Pasqual Aqua III system limitations:
Treatment capacity is only 1.1 MGD vs. the 3 to 5 MGD capacity required to eliminate $ 2.1 million/year for treatment of 2.5 to 4 MGD of San Diego sewage at the City of Escondido Hale Ave. TTP and the $ 0.36 million/year cost of sewage pumping from PS 77A 7 miles/450 ft. uphill to Hale Ave. vs. 4 miles/20 ft. to Aqua III.

Continued use of the Hale Ave. treatment option is not sustainable! A 4-million gallon surge tank at Lake Hodges (Pump Station 77A) filled in January 2011 in rainy weather when Escondido the Hale Ave. facility reached its 30 MGD maximum capacity and could not accept additional sewage. The surge tank at PS 77A filled to within 6 inches of its overflowing.

San Pasqual Aqua IV Upgrade Objectives
1. Produce up to 5 MGD of recycled water from north San Diego City sewage that is currently being treated at the Escondido Hale Ave Tertiary Treatment Plant (TTP). *This could reduce San Diego O&M expense by $ 2,460 K/year by*:
a. Eliminating treatment of north San Diego City sewage by the Hale Ave. TTP saving $ 2,100 K/year payment to Escondido for sewage treatment, and
b. Reducing Pump Station 77A electricity costs for pumping 2.5 MGD 450 ft. uphill to the Hale Ave TTP, saving ~ $ 360 K/year.

2. Proposed upgrades can be accomplished within the existing San Pasqual Aqua III facility 15-acre “footprint”. Figure 2 shows a diagram of the system.

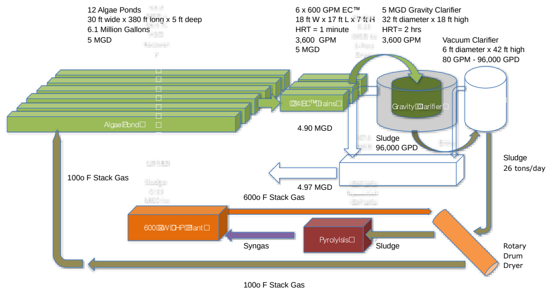


Fig 2. 5-MGD Reclamation System Diagram.

The following upgrades are required for 5 MGD:
a. Primary Treatment: Install greenhouse with algae incubation tanks and fine bubble aeration systems in 24 Aqua III ponds (6 million gallons) to introduce algae and air to maximize microbe and algae growth.

b. Secondary Treatment - Install:
1) Six 600 GPM Powell Electrocoagulation (EC™) trains to allow treatment of up to 5 MGD of sewage and brackish groundwater,
2) Gravity and Vacuum Clarifiers,
3) Sand Filters, and
4) Sterilization

c. Waste-to-Energy Converter (WEC) with:
1) Triple-pass rotary drum dryer for bio-esolids,
2) Pyrolyzer changing bio-solids to Syngas, and
3) A Combined Heat and Power (CHP) system.

d. Sequester CO_2 from CHP stack gas
1) Dry bio-solids with CHP stack gas
2) Sequester in sewage treatment pond algae.

Proposed San Pasqual Aqua IV system capabilities:

1. 3 to 5 MGD wastewater reclamation to CA Title 22 non-potable standards.
2. Upgrade with modular systems having minimum footprint, and energy use.
3. Incorporate Waste-to-Energy Conversion (WEC) to reduce purchase of electric power and maximize use of Combined Heat and Power waste heat.
4. Minimize carbon footprint of facilities.
5. Minimize life cycle costs.

Algae Ponds: Figure 3 shows the algae growth cycle and algae production of O_2. This O_2 in turn accelerates the growth of microbes that feed on sewage. Figure 4 shows algae incubation tanks in a greenhouse, and Figure 5, a fine bubble diffuser that inserts algae and air into the ponds. Microbe growth generates CO_2 that, in turn, accelerates the growth of algae.

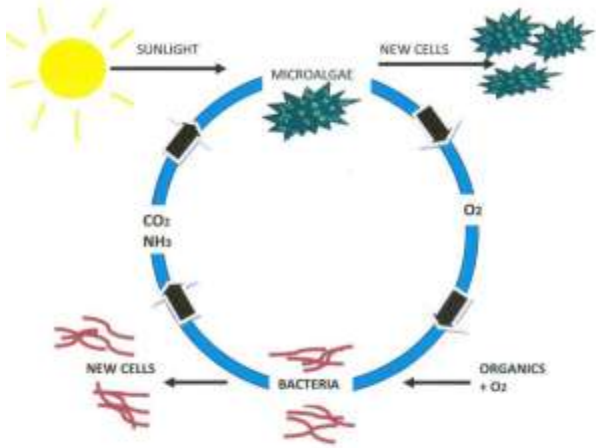


Fig 3. Biological Oxygen Generation

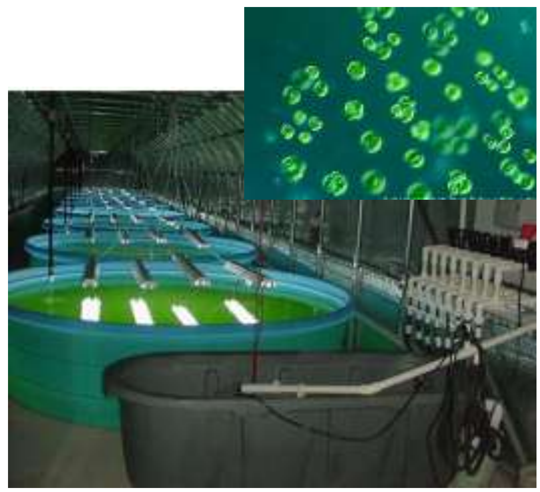


Fig. 4. Algae incubator tanks in greenhouse

Fig 5. Fine bubble diffuser

•San Pasqual Aqua IV: The Aqua III Water Hyacinth ponds would be converted to algae ponds and fitted with blowers and diffusers to aerate the pond to stimulate microbe growth with O_2 and algae growth with incubator algae and CO_2 from CHP stack gas and microbe growth.

BiO_2 sewage treatment ponds installed at Wray, Colorado and Hydro, Oklahoma eliminate sewage odors.

Hydraulic Retention Time: Normally 10 - 12 days are required for the BiO_2 process to completely treat sewage in the ponds. However, @ 5 MGD, the 6.1 Million gallon pond capacity would allow only 30 hours for algae pond treatment prior to EC™ treatment. Since microbes preferentially feed on short carbon chain (sugars), the BiO_2 process is expected to be adequate to remove most of the 25% of short carbon-chain constituents from 8-tons/day of bio-solids in 5 MGD of raw sewage during a 30-hour HRT. However, normal sewage flows are smaller, averaging 2.5 MGD allowing a 60-hour HRT. This could:

–Remove short Carbon-chain compounds with anaerobic microbes
–Use minimum energy for fractional HP aeration blowers and diffusers
–Facilitate algae growth with:
    Pond Biological O_2 Generation –
    Microbial growth and
    Algae sequestration of CHP CO_2

Secondary and Tertiary Treatment

•Powell Water Electrocoagulation (EC™)
Chemical coagulation has been used for decades to destabilize suspensions and effect precipitation of soluble metal species, as well as other inorganic species from aqueous streams, permitting their removal through sedimentation or filtration. Alum, lime, and/or polymers are the chemical coagulants used. These processes, *generate large volumes of sludge with high bound water content that can be slow to filter and difficult to dewater.* Chemical coagulation treatment processes increase the total dissolved solids content of the effluent. The HRT for chemical coagulation is typically several hours – lading to large treatment tanks.

Electrocoagulation neutralizes ion and particle charges, precipitating contaminants reducing their concentration below that possible with chemical precipitation and eliminates use of expensive chemical agents used in conventional treatment. HRTs are short (1 to 2 minutes) allowing relatively small treatment systems (18 ft. x 17 ft. x 7 ft. = 600 GPM that can be installed in and operated from 20 ft. and 40 ft. ISO containers significantly reducing sag reclamation plant footprint and cost.

Figure 6 shows a 500 GPM EC™ chamber with floc in front and an empty EC chamber with electrodes the top.

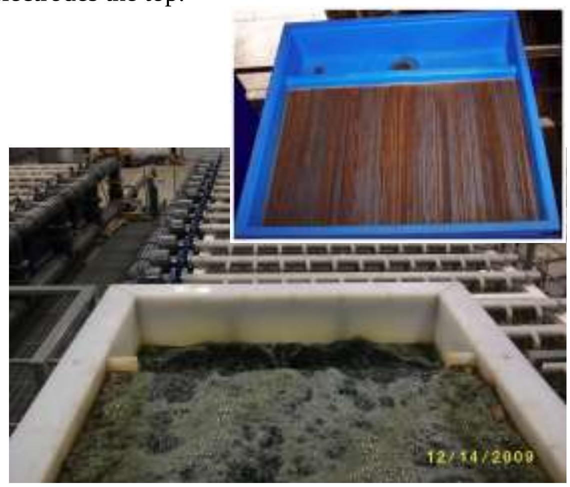


Fig 6. 500 GPM Electrocoagulation train

HRT = 2-minutes @ 5 MGD
–Removes 75% of BOD_5 (long carbon-chain)
–Removes 98% of Calcium and Magnesium
–Kills 99.999% of pathogens
–Energy use: 2-kWh/1,000 gallons.

EC™ Electrodes: Figure 7 shows new and depleted EC electrodes. These are fabricated from 1/8 in steel and can be manufactured by most sheet metal fabricators. Electrodes would be replaced at 8-month intervals.

Fig 7. New and Depleted EC™ Electrodes

The Powell Water EC™ Process

•The Powell Water EC™ chamber is fitted with 0.125” thick steel electrodes placed parallel to each other in vertical slots in the chamber walls on 0.250” centers.

•Untreated water is introduced into the bottom of the chamber and is dispersed evenly as it moves upward through the electrodes.

•Direct current is applied to the first and last electrode.

•The water becomes a conductor, allowing a current to pass freely through electrodes and water the EC ™ chamber.

•Flooding of electrons into the water neutralizes charged colloidal particles causing them to coalesce into *floc*.

•Metal ions form metal oxides that electro-mechanically attract water contaminants that have been destabilized causing them to coalesce into ***floc***.

•EC™ creates gas bubbles at the electrode surfaces that couple with coalesced carry the ***floc*** to the surface.

•Electricity consumption: 4-kWh/1,000 gallons for Aqua III sewage - < 3-kW/1,000 gallons for brackish groundwater

•Air-purge system keeps debris from accumulating.

•Polarity reversing:

–Extends electrode life,

–Prevents contaminants from coating tank and electrodes.

•Kills 99.999% of pathogens, and

•Removes 75% of solids in sewage and > 95% of the solids in brackish groundwater

Each of the twelve (12) 600 GPM @ 4 kW/1,000 gallon - 300 GPM @ 2 kW/1,000 gallon EC™ trains would be housed in a 40 ft. ISO container. This modular configuration allows installation of the 12 EC™ trains in increments.

Gravity Clarification: The existing 16 ft. high x 32 ft. diameter (96,200 gallon) Aqua III contact clarifier can be used as the 1st-stage of a 2-stage clarification process. Gravity clarification produces 98% clarified effluent and 2% sludge in 2-hours and would be followed by vacuum clarification of the 2% sludge drained from the gravity clarifier.

Vacuum Clarification:

Figure 8 shows the 34 ft. high x 12 ft. diameter 1.4 MGD Vacuum Clarifier at the El Paso Electric Company. Vacuum clarification of EC™ solids from the gravity clarifier reduces their water content to 75%. This uses less energy, is less expensive (no polymer required) and is more effective than dewatering of bio-solids with a centrifugal separator.

Treatment of 100,000 GPD of gravity clarifier sludge would require a x 6 ft. diameter x 34 ft. high vacuum clarifier. This would need ~ 200 kWh/day to pump sludge to the top of the clarifiers and power a vacuum pump.

Fig 8. Vacuum Clarifier

Sand/Dual Media Filters:

The 1 MGD Aqua III design uses four 10 ft. x 10 ft. dual media (sand + carbon) filters requiring 400 ft^2. Filter requirements would be 5 x greater for the 5.0 MGD Aqua IV facility that would need a 2,000 ft^2 cross sectional area.

Sterilization:

Chlorination or other sterilization is needed to produce Title 22 non-potable water. However, since EC kills 99.999% of the pathogens, only supplementary sterilization is required.

Algae Pond and EC™ Hybrid Performance

In the initial 30-hour pond treatment microbes are expected to preferentially feed on short carbon-chain constituents - reducing their concentration to ½ of that in 120 hours of Aqua III Water Hyacinth remediation. Table 1 refers.

Table 1. Algae Pond - EC™ Hybrid Remediation

Constituent	RAW PPM	Aqua III PPM	50% of Aqua III PPM	Removal 60 sec EC Percent	30 sec EC PPM	60 sec EC PPM	Recommended PPM
BOD	186	6	96	99%	94	2.4	
TSS	218	4	111.00	100%	109	0.9	
TDS	1262	6	634	43%	990	716	< 1000
Ammonia	22	9.3	9.3	60%	6	3.7	
Sulfate	312	368	340	34%	262	223	< 250
TKN (nitrogen)	31.5	14.2	22.85	95%	12	1.2	< 10
Calcium	74.4	70	67.8	96%	35	2.4	20 -100
Magnesium	36.5	6.4	21.45	99%	11	0.1	
Chloride	240		240		240	240	< 250
Sodium	106		106		106	106	< 115

Green shows less than recommended PPM.

Energy Use: If this plant operates at full 5 MGD capacity year round an estimated 5,872,450 kWh/year of electricity would be required (3.22-kWh/1,000 gallons). 68% of this energy would be the 2.0-kWh/1,000 gallons for EC operation. This assumes that EC trains use a 2-minute HRT at ¼ power that equals the 60-sec. performance values in Table 1.

Table 1 values for 30-sec. performance imply that 1-minute treatment at ¼ power may also provide acceptable reclaimed water. If this is found to be the case, either energy use can be reduced and/or the EC train capacity can be reduced with a significant reduction in capital expense.

•Waste-to-Energy Converter – 600 kW
–Sludge Dryer
–Pyrolysis – 5-8 tons/day
–CHP Plant – Capacity ~ 600 kW
(3 Capstone C200 micro-turbines)

Dryer, pyrolysis, CHP and solar-PV O&M expenses plus debt service would be ~ 15% less than $ 704,698 SDG&E in electricity costs @ $ 0.12/kWh. SDG&E costs are expected to increase by 5.5%/year vs. 3% Aqua IV O&M increases resulting in:
$ 13.4 million savings over 20-years and
$ 21.3 million savings over 25-years.

Waste-to-Energy Converter (WEC):
5 - 8 tons sludge/day 400 kW – 600 kW
The WEC would be comprised of a Triple-Pass Sludge/Algae dryer, a pyrolyzer, a CHP (Combined Heat and Power) plant, plumbing/ducting and pumps/blowers required to transport stack gas to the dryer, remove contaminants, condense moisture from dryer exhaust and provide stack gas cooled to100º F. rich in CO_2 to the algae ponds where the CO_2 is sequestered by pond algae and promotes algae growth.

Bio-solids to Syngas and Electricity:
The 3 to 5 MGD of sewage processed by Aqua IV is expected to produce 6 to 8 tons of bio-solids and sufficient Syngas to generate 400 to 600 kW of electric power ~ 77% of the projected demand shown in Table 1 – leaving ~1,980 kWh/day of additional power required. Additional bio-solids from septic system pump outs, port-a-potty effluent and/or municipal solid waste could be used to increase biofuel to provide the 1,980 kWh/day of additional power required.

Alternatively Solar PV could be used provide sufficient electric power for operation of the reclamation plant with net zero energy.

Triple-Pass Sludge Dryer:
A triple-pass sludge/algae dryer is capable of drying up to 2,000 lb. of (dry) sludge and algae/hour using 7,000 lb. of feedstock with 75% moisture content. The initial analysis of feedstock indicates that 5 to 8-tons/day of dry sludge will be available from North City sewage pumped from PS 77A.

The triple-pass dryer is expected to require 1,415 BTU/lb. of dried sludge (3 MMBTU/hr. for 8 tons/day). This requirement is within the thermal energy capacity of 900 $kW_{thermal}$ (3.07 MMBTU) stack gas from the 600 kW CHP system discussed below.

Waste-to-Energy Converter (WEC):
Figure 9 shows a 10-ton/day pyrolyzer and an 800-kW power module housed in two 40 ft. ISO containers. An 800 KW micro-turbine CHP plant is located in the 40 ft. container behind the pyrolyzer. Pyroyzers ranging in size from 10 to 100 tons/day are commercially available.

Fig 9. 10-ton/day Pyrolyzer and 800 kW CHP Modules in 40 ft. ISO Containers

Figure 10 shows an operational sequence diagram of the pyrolysis process. Bio-solids dried to less than 30% water are inserted into the pyrolysis chamber by auger and is heated to 1,100 F. in an atmosphere that contains almost no oxygen. Pyrolysis transforms the bio-solids into 96% syngas and 4% carbon char. Syngas passes through a cyclone separator with ~ 10% bled off as fuel to heat the pyrolysis chamber(s). The remaining 90% fuels CHP micro-turbines.

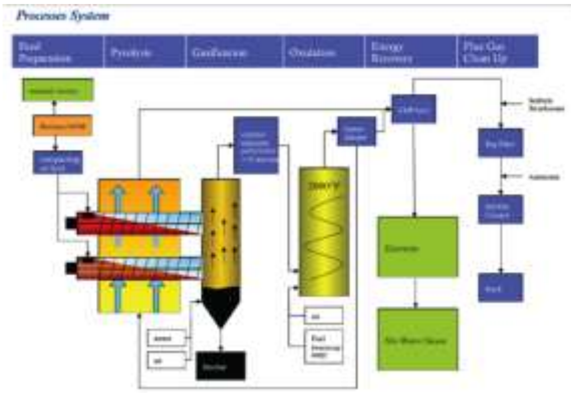
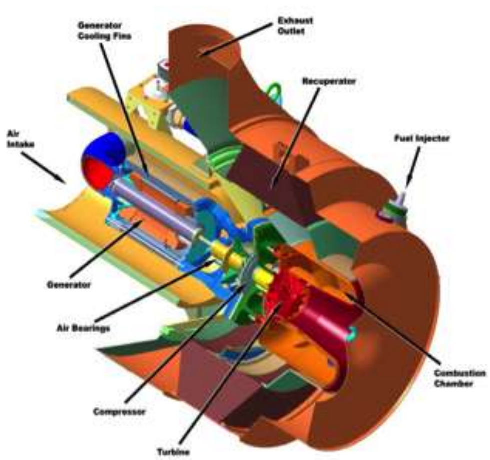


Fig 10. Pyrolysis Operational Sequence

600 kW CHP Plant:
Figure 11 shows a diagram of the C1000 Power Package. The package is comprised of five Capstone C200 micro-turbines installed in an ISO container.

Fig 11. C1000 1 MW Power Package

The C200 micro-turbine shown in Figure 12 is the basic building block for these packages.



- 200 kWe
- 33% electrical efficiency
- 50% thermal efficiency
- 98,000 RPM
- Air bearings
- Integral electric generator
- Heat Recovery Unit (HRU)
- 40,000 hr. between overhauls
- Installed cost $ 2,213/kW
- SGIP incentive $ 1,500/kW - 68%
- O&M cost $ 0.018/kWh

Fig 12. C200 Micro-turbine

The use of multiple micro-turbines allows variation of output power in 200 kW steps while operating those micro-turbines that are on-line at their peak efficiency.

Electricity Use and Generation from Dried Bio-Solids:

Powell EC™ energy requirements dominate the reclamation process. EC™ energy is reduced 50% to 2 kWh/1,000 gallons by operating at ¼ power and doubling the EC™ train treatment time - as shown in Table 1. This EC™ train would operate at ¼ power for a 2-minute EC™ HRT rather than a 1-minute HRT. This would reduce the reclamation plant energy budget from 5.22 kW/1,000 gallons to 3.22 kW/1,000 gallons allowing a combination of bio-solids-to-energy and solar PV to power the plant allowing it to operate with net zero energy use.

Table 2 shows energy demand and generation for a 5 MGD reclamation system using 8-tons of bio-solids/day for Syngas.

Table 2. Energy Demand and Production

Subsystem	Flow/day	8-tons sludge		
Pump 77A to Aqua IV	5 MGD	240	kWh/day	1.5%
Algae Pond Pumps/Aeration	5 MGD	1,274	kWh/day	7.9%
Powell Water EC™	5 MGD	10,000	kWh/day	62%
Vacuum Clarification (VC):	0.1 MGD	200	kWh/day	1.2%
Triple-Pass Sludge Dryer		1,495	kWh/day	9.3%
Pyrolyzer		2,880	kWh/day	18%
TOTAL		16,089	kWh/day	
600 kW CHP x 22 hours/day		(13,200)	kWh/day	82%
Solar PV		$ (2,889)	kWh/day	18%
Net Power		$ (0)		

The 13,200 kWh/day provided by the waste-to-energy system would be 72% of the 16,089 kWh/day required. The remaining 2,889 kWh/day could be provided by adding 2 - 3 tons/day of additional biomass to the waste-to-energy converter or the installation of solar-PV.

Capital and O&M Expenses for Water Reclamation and Renewable Energy:

Table 3 shows projected Capital and O&M expense, debt service on CAPEX at 4% interest over 20-years, a yield of 5,602 AFY, and $ 620/ acre-foot costs for reclamation of 8-tons of bio-solids and 5 MGD of sewage at net zero energy.

Table 3. Water Reclamation Capital and O&M Expenses: 8-tons of bio-solids/day

SUBSYSTEM	8-TONS/DAY BIO-SOLIDS CAPEX	O&M Expense	
Algae Pond Upgrade	$ 4,000,000	$ 445,848	
Greenhouses @ $10/ft2	$ 114,240	$ 1,142	
Electrocoagulation - 5 MGD	$24,320,400	$ 631,961	
Gravity Clarifier Upgrade 5 MGD	$ 150,000	$ 3,000	
Vacuum Clarifier - 80 GPM	$ 1,813,500	$ 22,710	
Gravity Clarifier Upgrade 5 MGD	$ 150,000	$ 3,000	
Sand Filter - 4 MGD	$ 1,320,000	$ 13,200	
Triple-Pass Rotary Drum Dryer	$ 800,000	$ 205,461	
Pyrolyzer - 8 tons/day	$ 3,800,000	$ 166,666	
CHP - 600 kW	$ 1,000,000	$ (433,620)	
Solar-PV 1.41 kW	$ 6,345,000	$ (126,538)	
SCADA	$ 26,000		
SUB TOTAL	$43,839,140	$ 932,850	
Self Generation Incentive Program	$ (750,000)		
SDG&E Savings-by-Design	$ (150,000)		
Total Production Costs	$42,939,140		
Debt Service		$ 3,122,434	
Subtotal		$ 4,055,284	
AB32 Cap&Trade		$ (20,434)	
Surplus power			
Total O&M Costs		4,034,850	
Total Title 22 Water Produced		5,602	AFY
Cost/acre-foot		$ 720.30	/AF
MWD Reclamation Incentive		$ (100.00)	
Net Cost/acre-foot		**$ 620.30**	**/AF**

The $ 7,921,521 in capital expense for the 13,200-kWh/day waste-to-energy conversion (WEC) systems plus 2,889 kWh/day Solar PV.

The CAPEX of a WEC is $1.16/kWh/year - 53% of the $ 2.20/kWh/year CAPEX of solar-PV. However, $ 471,206/year O&M expenses + $ 417,219 debt service on WEC CAPEX are $ 0.18/kWh/year over 20-years vs. nil O&M expenses plus $ 0.16/kWh/year for debt service on solar-PV CAPEX costing $ 4.50/Watt. Since, the use of WEC avoids bio-solids disposal costs of $ 303,680/year 11,680 tons/year (25% solids + 75% water) @ $ 26/ton avoidance of disposal could reduce net WEC O&M costs from $ 0.18 to $ 0.122/kWh/year causing the O&M + debt service cost of WEC to be 3/4 that of solar-PV.

Although Solar-PV has a 30% Investment Tax Credit (ITC) vs. a 10% ITC for WEC, a WEC system could still have a small cost advantage. Solar PV would cost $ 0.112/kWh after a 30% ITC vs. WEC $ 0.1098/kWh after a 10% ITC.

The O&M cost columns in Table 3 summarize treatment costs for 8-tons of bio-solids/day. The net cost would be $ 581/acre-foot for reclamation of 5 MGD with 8-tons of bio-solids/day.

$ 620/acre-foot is significantly lower than the $ 1,012/acre-foot CY 2013 San Diego County Water Authority (SDCWA) cost for untreated imported water. Moreover, a 5.8% to 10%/year escalation in imported untreated water rates from the Metropolitan Water District (MWD) is forecast vs. Aqua IV costs that are expected to increase at only 2-3%/year.

Energy Expense Growth: Net dryer, pyrolysis. CHP and solar-PV O&M expenses plus debt service on $ 4,707,045 of Energy CAPEX and Cap & Trade rebates total $ 598,768/year - 15% less than $ 704,698 SDG&E electricity costs @ $ 0.12/kWh.

SDG&E electricity costs are expected to increase by 5.5%/year vs. projected Aqua IV O&M expense increases of 3%/year for $ 256,483/year plus fixed debt service of $ 342,285/year for 20 years resulting in:

1. $ 13.4 million in savings for Aqua IV over 20 years, and
2. $ 21.3 million in savings over 25 years.

Reduction of Greenhouse Gas Emissions

Figure 13 shows Capstone CHP NOx emissions vs. those of a NG reciprocating CHP plant and a conventional power plant.

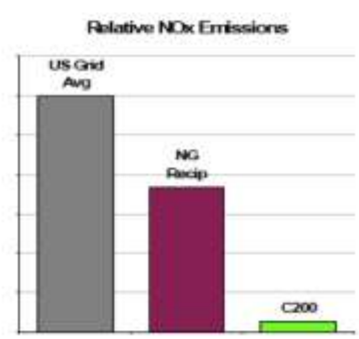


Fig 13. Capstone NOx Emissions

Use of if syngas from bio-solids to fuel Capstone micro-turbines for CHP could reduce CO_2 emissions from grid power by 24%/year.

Table 5 shows CO_2 emission reductions from use of Syngas from 8-tons of dried bio-solids/day and also shows sequestration of 1,001,268 lb. (455 tonnes) of CO_2/year in treatment pond algae.

Table 5. Reductions in CO_2 for use of Syngas derived from 8 tons of bio-solids/day

		8-tons bio-solids	
CHP Plant Offsets		3,459,003	lb CO2/year
CHP Plant Produces	76%	2,628,000	lb CO2/year
Reduces Emissions	24%	(831,003)	lb CO2/year
Algae Sequestration	58%	(2,002,536)	lb CO2/year
Total Reduction	82%	**(2,833,539)**	lb CO2/year
Electric Power		4,204,800	kWh/year

CO_2 Sequestration in Treatment Pond Algae: CHP stack gas, rich in CO_2 (~ 2.2%), would be cooled to ~100º F. by the rotary sludge dryer and introduced into the algae incubator and treatment ponds. This additional CO_2 is expected to enhance algae production.

The best results reported in the literature are 98 gm/m^2/day achieved near Phoenix, AZ by GreenFuel Technologies Corporation. This is the equivalent of 2,002,536 lb./year of CO_2 sequestration for 24 *San Pasqual Aqua IV* ponds having a total surface area of 274,360 ft^2

Total emissions reductions of 82% for 8-ton/day bio-solids CHP use and 37% for 36-ton/day bio-solids CHP use could earn $ 12,880/year and $ 26,178/year in CA AB 32 Cap & Trade credits respectively at the current rate of $ 10/metric-ton.

Greenhouse CO_2 Sequestration: Installation of greenhouses over algae treatment ponds can retain heat (facilitating microbe and algal growth) and CO_2 in the atmosphere above the ponds. This coupled with growing of plant material in greenhouses having elevated levels of atmospheric CO_2 can accelerate plant growth. However, the uptake of CO_2 in plant matter would be smaller than the CO_2 sequestration in algae ponds.

There is no reasonable scenario that would justify the $10/ft^2 capital cost of greenhouse construction based on CO2 mitigation alone. However, the combination of sequestration of CO_2 and heat from CHP stack gas in ponds would increase both algae and microbe growth and accelerate microbe removal of constituents from wastewater. This could, in turn, reduce the EC™ treatment load and electricity use.

Plant cultivation could allow cash crops to be grown in greenhouses covering the ponds and adjacent hardscape. These crops could be grown hydroponically using reclaimed water tailored by algae pond and EC™ treatment to be rich in nutrients required by the particular crops under cultivation.

These factors justify use of a greenhouse for algae incubation and may justify greenhouse use for all 24 Aqua IV algae ponds.

Summary:
Modification of existing sewage treatment plants or new construction using algae ponds, EC™, clarifiers and waste-to-energy conversion of bio-solids into syngas to fuel power modules can provide:

1. A compact, modular and low cost sewage reclamation system,
2. A renewable energy option having about 75% of the life-cycle cost of solar-PV (costing $ 4.50/watt) due to avoidance of bio-solids disposal costs,
3. Reduced GHG production from use of CHP vs. grid power and sequestration of CO_2 by algae in sewage treatment ponds, and
4. Reduced energy use (3.2 kWh/1,000 gallons), a smaller footprint, lower CAPEX and O&M expenses vs. Membrane Bioreactors (MBR) (5.6 kWh/1,000 gallons) and conventional wastewater treatment systems (5.0 kWh/1,000 gallons).