Appendix E
Potential Water and Energy Savings

An estimate on the potential water and energy savings were calculated using the following assumptions and equations:

Water Savings Assumptions and Calculations:

Assumptions and Conversion Factors Used:

Gallon per year = gallon per minute * (60 minutes per hour) * (24 hours per day) * (365 days per year)

Conversion factor for cooling load to gallons per minute (gpm):

3 gpm/100 ton cooling load (Source: North Carolina Department of the Environment and Natural Resources Division of Pollution Prevention and Environmental Assistance, *Water Efficiency-Water Management Options-Cooling and Heating* fact sheet, no date)

Cycles of Concentration (COC):

The average COC based on chloride and TDS were used to estimate the amount of bleed water added at each demonstration location.

The average cycles of concentration for a chemical treatment tower was assumed to be 4 COC (Source: City of San Jose, San Jose/Santa Clara Water Pollution Control Plant, *Guidelines for Managing Water in Cooling Systems for Owners, Operators, and Environmental Managers*, July 2002).

Energy Efficiency Reduction Due to Fouling:

Efficiency Reduction = 5% due to biofilm build-up on chiller surfaces (Source: Draft *Independent Evaluation of the Energy Savings, Environmental Improvements and Water Conservation of Emerging Non-Chemical Water Treatment Technologies* for the CEC PIERS program)

Electric rate is estimated from information in the PG&E January 2008 Bill inserts for a typical bundled customer: $150.90/850 kWh = $0.18/kWh (see http://www.pge.com/mybusiness/myaccount/explanationofbill/billinserts/previous/2008/jan.shtml)

Chemical Cooling Tower Assumptions:

The direct chemical cost was based on the estimate listed in the 2006 ASHRAE GreenGuide. ASHRAE Green Tip #14 lists an estimated annual cost of $8 to $20 per ton of cooling. An average annual cost of $14 per ton of cooling was used in estimating the annual chemical costs.

Estimated Chemical cost = $14 per ton of cooling per year*cooling load (tons)

The O&M cost from Equinix was scaled based on the cooling load for all sites except LBNL.

Estimated O&M cost = $2,500 / (2,500 ton)*cooling load
= $$1.00/ton * cooling load

Evaporation Loss (gpm) Calculation:

= (Total cooling load [tons]) * (Conversion factor for cooling load to gpm) * (Average Annual Load Factor)

= (Total cooling load [tons]) * 3 gpm/100 tons * (Average Annual Load Factor)

Bleed water calculation:

Bleed water added (gpm) = Evaporation Loss / (Cycles of Concentration-1)

Bleed water fee ($/year) = (Sewer Discharge Fee) / (0.748 gallons per cubic foot) * (bleed water discharged in gallons per minute) * (60 minutes per hour) * (24 hours per day) * (365 days per year)

Make-up water calculation:

Make-up water discharged (gpm) = Evaporation Loss (gpm) + Bleed Water Added (gpm)

Make-up water discharged (gallons per year [gpy]) = (Make-up water discharged in gallons per minute) * (60 minutes per hour) * (8760 hours per year)

Make-up water fee ($/year) = (Water Use Fee in $ per 100 cubic feet) / (0.748 gallons per cubic foot) * (make-up water discharged in gallons per year)

Energy Savings Assumptions and Calculations:

Calculations for VRTX System:

Fouling Factor Savings:

= Total Cooling Load (ton) * (0.76 KWH per ton) * (Hours operated per year) * (cost per kilowatt hour ($/KWH)) * Efficiency * (average annual load factor)

= Total Cooling tower tonnage * (0.76 KWH per ton) * (8760 hours) * (cost per kilowatt hour ($/KWH)) * 0.05 * (load factor)

Operating Cost:

= (Total pump HP) * (0.76 KW per HP) * (cost per kilowatt hour [$ / KWH]) * (Hours operated per year)

Calculation for the Dolphin System:

Fouling Factor Savings:

= Total Cooling Load (ton) * (0.76 KWH per ton) * (Hours operated per year) * (cost per kilowatt hour ($/KWH)) * Efficiency * (average annual load factor)

= Total Cooling tower tonnage * (0.76 KWH per ton) * (8760 hours) * (cost per kilowatt hour ($/KWH)) * 0.05 * (load factor)

Operating Cost:

= (KW rating for Dolphin unit) * (Hours operated per year) * (cost per kilowatt hour [$ / KWH])

= (KW rating for Dolphin unit) * (8760 hours) * (cost per kilowatt hour [$ / KWH])

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The following assumptions from the report cited above were used to calculate potential water and energy savings:

Parameter	Value
Total Cooling Tower/Condenser Cooling Load (tons)[a]	400
Average Annual Load Factor (LF)	75%
Water Charge/100 Cubic Feet	$2.60
Sewage Charge/100 Cubic Feet	$2.65
Delta T (temperature)	10
Cost per kilowatt hour ($ / KWh)	0.18
HP for VRTX (hp)	10.0
Usage of VRTX (hours)	8760
[a]Cooling load for one cooling tower = 400 tons	

Parameter	Cooling tower treatment method		
	Chemical	VRTX	
Cycle of Concentration (COC)	4.0[a]	6.6[b]	4.4[c]
Evaporation Loss (gpm)	9.0	9.0	9.0
Bleed water added (gpm)	3.0	1.6	2.6
Make-up water discharged (gpm)	12.0	10.6	11.6
[a]Assumption on the average COC for a chemically treated cooling tower [b]Used average COC concentration based on chloride concentration for the demonstration. [c]Used average COC concentration based on TDS concentration for the demonstration.			

Water Use Type	Amount (gpy)			Fee ($/year)		
	Chemical	VRTX		Chemical	VRTX	
		Chloride based	TDS Based		Chloride based	TDS Based
Make-up	6307200	5571360	6096960	$70,766.78	$62,510.66	$68,407.89
Bleed	1576800	840960	1366560	$14,743.08	$7,862.98	$12,777.34
Total				$85,509.86	$70,373.64	$81,185.23
gpy = gallons per year						

Energy Savings/Costs	Results ($/yr)
Energy Cost Due to Fouling	$17,975.52
VRTX Operating Costs	$11,983.68
Note: Cooling load for one cooling tower = 400 tons.	

Treatment System	Cost ($/yr)				
	Water Fees	Chemicals	O&M	Fouling Cost	Total
Chemical	$85,509.86	$5,600.00	$ 400.00	$17,975.52	**$109,485.38**
VRTX (Based on chloride COC)	$70,373.64	$ 0.00	$11,983.68	$ 0.00	**$82,357.32**
VRTX (Based on TDS COC)	$81,185.23	$ 0.00	$11,983.68	$ 0.00	**$93,168.91**

Net Annual Savings for a Cooling Tower Which Uses the VRTX treatment technology versus chemicals treatment

Net Annual Saving = Total cost of chemical system – Total cost of VRTX system
= $(109,485.38 – 82,357.32)
= $27,128.06 based on the chloride COC

Or = $(109,485.38 – 93,168.91)
= $16,316.47 based on TDS COC

Headway Technologies

The following assumptions from the report cited above were used to calculate potential water and energy savings:

Parameter	Value
Total Cooling Tower/Condenser Cooling Load (tons)[a]	1600
Average Annual Load Factor (LF)	50%
Water Charge/100 Cubic Feet	$3.40
Sewage Charge/100 Cubic Feet	$2.61
Delta T (temperature)	10
Cost per kilowatt hour ($ / KWh)	0.18
HP for VRTX (hp)	15.0
Usage of VRTX (hours)	8760
[a]Cooling load for one cooling tower = 800 tons Two (2) cooling towers are served by the VRTX unit at this site with a total cooling load of 1,600 tons	

Parameter	Cooling tower treatment method		
	Chemical	VRTX	
Cycle of Concentration (COC)	4.0[a]	11.2[b]	7.5[c]
Evaporation Loss (gpm)	24.0	24.0	24.0
Bleed water added (gpm)	8.0	2.4	3.7
Make-up water discharged (gpm)	32.0	26.4	27.7
[a]Assumption on the average COC for a chemically treated cooling tower [b]Used average COC concentration based on chloride concentration for the demonstration. [c]Used average COC concentration based on TDS concentration for the demonstration.			

Water Use Type	Amount (gpy)			Fee ($/year)		
	Chemical	VRTX		Chemical	VRTX	
		Chloride based	TDS Based		Chloride based	TDS Based
Make-up	16819200	13875840	14559120	$188,711.42	$155,686.92	$163,353.33
Bleed	4204800	1261440	1944720	$39,314.88	$11,794.46	$18,183.13
Total				$228,026.30	$167,481.38	$181,536.46
gpy = gallons per year						

Energy Savings/Costs	Results ($/yr)
Energy Cost Due to Fouling	$47,934.72
VRTX Operating Costs	$17,975.52
Note: Two (2) cooling towers are served by the VRTX unit at this site with a total cooling load of 1,600 tons.	

Treatment System	Cost ($/yr)				
	Water Fees	Chemicals	O&M	Fouling Cost	Total
Chemical	$228,026.30	$22,400.00	$1,600.00	$47,934.72	**$299,961.02**
VRTX (Based on chloride COC)	$167,481.38	$ 0.00	$17,975.52	$ 0.00	**$185,456.90**
VRTX (Based on TDS COC)	$181,536.46	$ 0.00	$17,975.52	$ 0.00	**$199,511.98**

Net Annual Savings for a Cooling Tower Which Uses the VRTX treatment technology versus chemicals treatment

Net Annual Saving = Total cost of chemical system – Total cost of VRTX system
= $(299,961.02 – 185,456.90)
= $114,504.12 based on the chloride COC

Or = $(299,961.02 – 199,511.98)
= $100,449.04 based on TDS COC

Equinix

(excerpt from draft *Independent Evaluation of the Energy Savings, Environmental Improvements and Water Conservation of Emerging Non-Chemical Water Treatment Technologies* for the CEC PIERS program)

The following assumptions from the report cited above were used to calculate potential water and energy savings:

Parameter	**Value**
Total Cooling Tower/Condenser Cooling Load (tons)[a]	2,500
Average Annual Load Factor (LF)	25%
Efficiency Loss Due to Fouling	5%
Water Charge/100 Cubic Feet	$1.50
Sewage Charge/100 Cubic Feet	$1.25
Delta T (temperature)	10
Cost per kilowatt hour ($ / KWh)	0.18
Flow rate (gpm)	5,000
HP for VRTX (hp)	67.5
Usage of VRTX (hours)	8760
[a]Cooling load for one cooling tower = 500 tons Five (5) cooling towers are located at the site with a total cooling load of 2,500 tons	

Parameter	**Cooling tower treatment method**		
	Chemical	**VRTX**	
Cycle of Concentration (COC)	2.2[a]	11.0[b]	6.3[c]
Evaporation Loss (gpm)[b]	18.75	18.75	18.75
Bleed water discharged (gpm)[c]	15.63	1.88	3.54
Make-up water added (gpm)[d]	34.38	20.63	22.29
[a]Used average COC for a chemically treated cooling tower given in the Draft CEC report [b]Used average COC concentration based on chloride concentration for the demonstration. [c]Used average COC concentration based on TDS concentration for the demonstration.			

Water Use Type	Amount (gpy)			Fee ($/year)		
	Chemical	VRTX		Chemical	VRTX	
		Chloride based	TDS Based		Chloride based	TDS Based
Make-up	18,070,128	10,843,128	11,715,624	$202,746.84	$121,659.90	$131,449.30
Bleed	8,215,128	988,128	1,860,624	$76,811.45	$9,239.00	$17,396.83
Total				$279,558.29	$130,898.90	$148,846.13
gpy = gallons per year						

Energy Savings/Costs	Results ($/yr)
Energy Cost Due to Fouling	$37,449.00
VRTX Operating Costs	$80,889.84
Note: Five (5) 500 ton cooling towers are used at Equinix where 2 cooling towers are in standby with a minimal amount of cooling water circulating through them.	

Treatment System	Cost ($/yr)				
	Water Fees	Chemicals	O&M	Fouling Cost	Total
Chemical	$279,558.29	$37,500.00	$2,500.00	$37,449.00	**$357,007.29**
VRTX (Based on chloride COC)	$130,898.90	$ 0.00	$80,889.84	$ 0.00	**$211,788.74**
VRTX (Based on TDS COC)	$148,846.13	$ 0.00	$80,889.84	$ 0.00	**$229,735.97**

Net Annual Savings for a Cooling Tower Which Uses the VRTX treatment technology versus chemicals treatment

Net Annual Saving = Total cost of chemical system – Total cost of VRTX system
= $(357,007.29 – 211,788.74)
= $145,218.55 based on the chloride COC

Or = $(357,007.29 – 229,735.97)
= $127,271.32 based on TDS COC

Data Center

The following assumptions from the report cited above were used to calculate potential water and energy savings:

Parameter	Value
Total Cooling Tower/Condenser Cooling Load (tons)[a]	1,000
Average Annual Load Factor (LF)	50%
Water Charge/100 Cubic Feet	$0.96
Sewage Charge/1,000 Cubic Feet	$26.85
Delta T (temperature)	10
Cost per kilowatt hour ($ / KWh)	0.18
kW usage for Dolphin (kW)	0.3
Usage of Dolphin (hours)	8760
[a]Cooling load for one cooling tower = 500 tons Two (2) cooling towers are served by the Dolphin unit at this site with a total cooling load of 1,000 tons	

Parameter	Cooling tower treatment method		
	Chemical	Dolphin	
Cycle of Concentration (COC)	4.0[a]	11.5[b]	7.9[c]
Evaporation Loss (gpm)[b]	15.0	15.0	15.0
Bleed water added (gpm)[c]	5.0	1.4	2.2
Make-up water discharged (gpm)[d]	20.0	16.4	17.2
[a]Assumption on the average COC for a chemically treated cooling tower [b]Used average COC concentration based on chloride concentration for the demonstration. [c]Used average COC concentration based on TDS concentration for the demonstration.			

Water Use Type	Amount (gpy)			Fee ($/year)		
	Chemical	Dolphin		Chemical	Dolphin	
		Chloride based	TDS Based		Chloride based	TDS Based
Make-up	10512000	8619840	9040320	$117,944.64	$96,714.60	$101,432.39
Bleed	2628000	735840	1156320	$24,571.80	$6,880.10	$10,811.59
Total				$142,516.44	$103,594.70	$112,243.98
gpy = gallons per year						

Energy Savings/Costs	Results ($/yr)
Energy Cost Due to Fouling	$29,959.20
Dolphin Operating Costs	$ 473.04
Note: Two (2) cooling towers are served by the Dolphin unit at this site with a total cooling load of 1,000 tons.	

Treatment System	Cost ($/yr)				
	Water Fees	Chemicals	O&M	Fouling Cost	Total
Chemical	$142,516.44	$14,000.00	$1,000.00	$29,959.20	**$187,475.64**
Dolphin (Based on chloride COC)	$103,594.70	$ 0.00	$ 473.04	$ 0.00	**$104,067.74**
Dolphin (Based on TDS COC)	$112,243.98	$ 0.00	$ 473.04	$ 0.00	**$112,717.02**

Net Annual Savings for a Cooling Tower Which Uses the Dolphin treatment technology versus chemicals treatment

Net Annual Saving = Total cost of chemical system – Total cost of Dolphin system
= $(187,475.64 - 104,067.74)
= $83,407.90 based on the chloride COC

Or = $(187,475.64 - 112,717.02)
= $74,758.62 based on TDS COC

LBNL Dolphin System

(excerpt from *Pulse-power Non-chemical Water Treatment Study Conducted at Lawrence Berkeley National Laboratory*, Lawrence Berkeley National Laboratory Facilities Division, Michael C. Dong, September, 2005)

Water Consumption

Water flow for the cooling tower make-up and blow-down were recorded from November 2004 to September 2005. The pulse-power system was activated on April 1, 2005.

The pulse-power system yielded significant water savings compared to the chemically treated tower. During the study period, the pulse-power system saved an estimated 1,057 gallons per week of make-up water by providing 87.1% reduction in blowdown.

	Average Blowdown (Gallons/week)	**Average Make-up Water (Gallons/week)**	**Average Weekly Cycles of Concentration**
Chemically Treated	1736	8533	3
Pulse-power System	224	12,005*	12
Water Savings per Week	1512	N/A*	--
Reduction in Water Consumption	87.1%	--	--
*Make-up water usage was higher because the Pulse-power system was activated on 4/1/05 and continued through the hot weather months. Therefore, total make-up water including evaporation and blowdown resulted in higher water usage.			

Financial Summary

When calculating savings, it is important to consider the following potential benefits:

1. Avoided chemical costs
2. Reduced water consumption discharges to the sanitary sewer system
3. Reduced maintenance (scale prevention, no chemical feed pumps to maintain or switch over)
4. Increased cooling tower and chiller efficiency (prevention and removal of existing scale)

5. Enhanced safety – no need to store, handle or use hazardous water treatment chemicals
6. More environmentally friendly than chemical treatment; may avoid costly environmental fees and penalties

The calculations presented below are based solely upon avoided chemical costs, water savings, reduced sanitary sewer fee and the cost of power required to operate the pulse-power system.

Water Treatment Cost Comparison	**Pulse Power System**	**Chemical Treatment**
Chemicals	$0	$9,400[3]
Water (Blowdown only)[1]	$26	$203
Sanitary Sewer fee	$46	$354
Energy[2]	$125	$25
Total	$197	$9982

1. Only blowdown flow rate is included. Evaporation and drift flow rates are not included
2. Chiller and tower fan not included in energy cost
3. Chemical cost includes the following on an annual cost basis:
   Biocides: Formula 315, $5,600
   Formula 314T $1,600
   Corrosion Inhibitor 222L $2,200
   Total: $9,400

Project cost = $24,000
Annual Saving = $9,785

Simple payback = 2.5 years

City of Berkeley

The following assumptions from the report cited above were used to calculate potential water and energy savings:

Parameter	Value
Total Cooling Tower/Condenser Cooling Load (tons)[a]	250
Average Annual Load Factor (LF)	75%
Water Charge/100 Cubic Feet	$2.60
Sewage Charge/100 Cubic Feet	$2.73
Delta T (temperature)	10
Cost per kilowatt hour ($ / KWh)	0.18
kW usage of Dolphin (kW)	0.3
Usage of Dolphin (hours)	8760
[a]Cooling load for one cooling tower = 250 tons Two (2) cooling towers are located at the facility but one cooling tower is not operated.	

Parameter	Cooling tower treatment method		
	Chemical	Dolphin	
Cycle of Concentration (COC)	4.0[a]	10.1[b]	6.3[c]
Evaporation Loss (gpm)[b]	5.6	5.6	5.6
Bleed water added (gpm)[c]	1.9	0.6	1.1
Make-up water discharged (gpm)[d]	7.5	6.2	6.7
[a]Assumption on the average COC for a chemically treated cooling tower [b]Used average COC concentration based on chloride concentration for the demonstration. [c]Used average COC concentration based on TDS concentration for the demonstration.			

Water Use Type	Amount (gpy)			Fee ($/year)		
	Chemical	Dolphin		Chemical	Dolphin	
		Chloride based	TDS Based		Chloride based	TDS Based
Make-up	3942000	3258720	3521520	$44,229.24	$36,562.84	$39,511.45
Bleed	998640	315360	578160	$9,337.28	$2,948.62	$5,405.80
Total				$53,566.52	$39,511.46	$44,917.25
gpy = gallons per year						

Energy Savings/Costs	Results ($/yr)
Energy Cost Due to Fouling	$11,234.70
Dolphin Operating Costs	$ 473.04
Note: Two (2) cooling towers are located at the facility but one cooling tower is not operated.	

Treatment System	Cost ($/yr)				
	Water Fees	Chemicals	O&M	Fouling Cost	Total
Chemical	$53,566.52	$3,500.00	$ 250.00	$11,234.70	**$68,551.22**
Dolphin (Based on chloride COC)	$39,511.46	$ 0.00	$ 473.04	$ 0.00	**$39,984.50**
Dolphin (Based on TDS COC)	$44,917.25	$ 0.00	$ 473.04	$ 0.00	**$45,390.29**

Net Annual Savings for a Cooling Tower Which Uses the Dolphin treatment technology versus chemicals treatment

Net Annual Saving = Total cost of chemical system – Total cost of Dolphin system
= $(68,551.22 – 39,984.50)
= $28,556.72 based on the chloride COC

Or = $(68,551.22 – 45,390.29)
= $23,160.93 based on TDS COC