Preliminary Building Energy Audit

--------- facility address ---------

---------- city ----------

Final Report

October 6, 2003

----- auditor logo -----

Preliminary Building Energy Audit

--------- facility address ---------
------- city, state, zip code -------

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October 6, 2003

Report No. -- #### --

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1.0 EXECUTIVE SUMMARY

This report presents the results of a preliminary facility audit and energy evaluation of potential improvements to reduce energy consumption and related operating costs at the commercial office building at ---------- facility address ---------- . This study was completed by -- auditor -- for ----- client ----- under sponsorship by PG&E's 2003 Commercial/Industrial Audit Program. Questions or comments about the results or conclusions herein can be directed to ---------- PG&E contact name, title, phone number ---------- or ---------- PG&E contact name, title, phone number ---------- .

A Facility Audit was undertaken by -auditor- in June and July of 2003. Subsequent on-site monitoring of energy usage and equipment trending through the building automation system, facilitated by -auditor- and implemented by building staff, confirmed the energy performance of specific building equipment. Audit and monitored data were used to develop and calibrate a DOE-2 computer model of the building. After calibration results showed reasonable comparison with utility data, the model was used to estimate energy savings from energy efficiency opportunities. As the building is supplied with steam from a source other than PG&E, gas energy measures were not the focus of this work and are discussed separately.

The results of the audit and monitored data suggest the potential for up to thirteen electrical energy saving measures. These were evaluated separately for electrical usage and peak-period demand savings using DOE-2 modeling or spreadsheet analysis. Capital costs were estimated and combined with annual energy savings to calculate a simple payback, forming the basis of recommendations.

A summary of recommended energy retrofit measures are shown below. Of the thirteen total measures identified for potential electric savings, seven are recommended with an additional two requiring further detailed analysis. Four measures cannot be recommended as their payback periods exceed 10 years. All measures summarized below require either moderate or significant capital investment. No no-cost or low-cost energy efficiency measures were identified.

Table E.1
Recommended Cost-Effective Measures and Estimated Savings

Measure Description	Implementation Cost ($)	Annual Savings (kWh)	Annual Savings (kW)	Cost Savings ($)	Simple Payback (years)
Measures Requiring Modest Investment					
Repack/Overhaul lead cooling tower	$15,700	12,800	1	$1,900	8.3
Install VFD on open loop condenser water pump	$10,100	28,000	0	$2,200	4.6
Measures Requiring Significant Capital					
Install occupancy sensors in enclosed spaces	$17,900	20,800	7	$3,100	5.8
High efficiency motors	$37,500	25,000	8	$4,300	8.8
Insulate roof	$84,400	48,800	0	$8,800	9.6
Lighting upgrade. Complete replacement of T-12 fixtures with T-8 Fixtures	$124,600	103,500	33	$15,600	8.0
Tinted Window Film	$114,100	127,400	20	$12,900	8.8
New cooling tower for lead chiller and auxiliary condenser water loop	$117,500	67,300	30	$12,800	9.2
Air handler conversion to variable air volume zones	$1,368,200	821,700	122	$145,600	9.4

2.0 BUILDING DESCRIPTION

2.1 Overview and Operation

The ---------- facility ---------- building was constructed in 1955 and has a total of twenty-five rentable floors, three penthouses and a basement, totaling 475,000 gross square feet. The total rentable space is approximately 422,000 square feet.

The building has been owned by ---------- client ---------- for approximately 2 years. Building occupancy has averaged about 75% over the past few years. Space types consist primarily of office space with some retail tenants and an empty bank on the first floor.

The building is occupied primarily on a weekday only basis. It is accessible from 6 AM till 6 PM Monday through Friday, with limited hours on weekends and holiday.

2.2 Building Envelope

The building, configured in a low-rise and high-rise floor plates, is of concrete-wrapped steel frame construction with uninsulated stone veneer, aluminum spandrel panels, and no insulation at the original built-up asphalt roof over concrete deck. The windows are predominantly metal frame single pane clear glass with operable units at the lower floors. Interior shades are Levelor miniblinds.

At the time of this audit, -client- is considering a building envelope retrofit package consisting of granite or metal exterior cladding and weatherproofing of the windows as the existing building skin is experiencing weathering failure. A roofing retrofit is also being planned that may include an exterior insulation system.

2.3 Lighting Systems

Building interior lighting consists of predominantly recessed 2x4 and surface-mounted 2x2 fluorescent fixtures with a mix of 2, 3 or 4-lamp T-12s with core/coil ballasts and 2, 3 or 4-lamp T-8s with high efficiency electronic ballasts. The majority of the “back-of-house” fixtures are T-12s with core/coil ballasts. Audit results show that approximately 25% of the lighting has not yet been converted to efficient T-8s.

Elevator and private lobbies and similar spaces have dual PL-13 compact fluorescent fixtures. There are a few 50-watt MR-16 incandescent low voltage fixtures added in private lobbies and conference rooms.

There is no central lighting control in the building. All lighting fixtures are controlled by wall-mounted switches or motion sensors. Approximately 60% of new tenants have motion sensors installed with *Novitas SuperSwitch Mini* as the building standard, however there are few sensors installed in restrooms.

The building maintenance plan calls for older T-12 lamps and ballasts to be replaced with T-8 lamps and high efficiency ballasts only upon failure.

2.4 HVAC, Controls and Domestic Hot Water Systems

This section describes the installed HVAC equipment and building automation system.

2.4.1 Equipment Description

The building is supplied with medium pressure steam from the ---------- name ---------- Steam Plant. The steam tie-in is located in the basement utility room and the cooling plant is located in the mechanical penthouse on the roof. Chilled water is supplied by two 350 ton HFC-134a Carrier centrifugal chillers that replaced a single 700 ton absorption chiller in 1998. The lead Carrier chiller has VSD control of the compressor for more efficient part-load operation. There are two smaller reciprocating chillers: one 30 ton Carrier R-22 unit located in the mezzanine, and one 60-ton York water-cooled R-22 unit located in the basement. This equipment, installed in 1993 and 1994, serves the basement, mezzanine and first floors only.

The chilled water distribution system is constant flow primary and variable flow secondary. The two primary pumps are 15 HP each, one dedicated to each chiller. The two secondary pumps are 50 HP and have VFDs.

The building condenser water loop is supplied by two Marley induced draft cooling towers (CT-1 & CT-2) located on the upper roof. These original towers feature redwood fill. CT-1 provides condenser water to the lead chiller and has two 15 HP single speed propeller fans with on off control. CT-2 provides condenser water to the lag chiller and an auxiliary condenser water loop. CT-2 features one fan with 2-speed control and is able to run at 40 HP or 10 HP. Each chiller has a dedicated 15 HP condenser water pump.

The auxiliary condenser water circuit serves the basement chiller and the building's heat pumps via a plate and frame heat exchanger. Two 15 HP pumps serve the open loop side and two 25 HP pumps serve the closed loop side; only one pump is needed for each loop and the other is used as a backup.

Air distribution to the building is provided by built up single duct constant volume air handlers. Each air handler has: cooling coils with 2-way control valves, (heating coils have been removed), economizer dampers, supply air and return air temperature sensors, filters and separate supply and return fans. Table 2.1 shows the areas served by specific air handlers.

Table 2.1
Air Handler Summary

Air Handler	Area Served	Supply Fan Size	Return Fan Size
AHU-1	Basement	7.5	N/A
AHU-2	Mezzanine & 1st Floor	10	7.5
AHU-3	Floors: 2, 3 & 4	40	25
AHU-4	Floors: 5, 6 & 7	40	25
AHU-5	Floors: 8, 9 & 10	40	25
AHU-6	Floors: 11, 12 & 13	25	25
AHU-7	Floors: 14 & 15	15	15
AHU-8	Floors: 16, 17, 18 & 19	40	75
AHU-9	Floors: 19, 20, 21 & 22	40	N/A
AHU-10	Floors: 22, 23, 24 & 25	40	N/A

The perimeter zones feature floor-mounted constant volume induction terminal units with low pressure steam reheat coils. The perimeter terminal units have finned tubes housed in a box located against the exterior walls directly under the windows with a grill on top. An estimated 60% of terminal units are controlled by automatic thermostats with remaining terminals employing manual dials. Each floor has between two and four hot water reheat coils that serve interior zones; these re-heat coils have been disabled to save energy. The re-heat coils were also causing comfort problems with some spaces being over-heated.

There are approximately 20 packaged heat pump units and computer room air conditioning (CRAC) units sized between 2 to 5 tons and totaling about 60 tons. Many of these heat pumps operate 24/7.

Building domestic hot water is provided by a heat exchanger connected to the district steam loop. A 7.5 HP pump circulates DHW to the building. The heat exchanger also supplied hot water to the now-disabled interior hot water coils via a 7.5 HP hot water reheat pump. An additional AO Smith 95 gallon water heater with a heat input of 60,000 Btu/hr has a small 1/3 HP circulation pump. Building domestic cold water is stored in two tanks located on the roof which are refilled as needed by two 40 HP pumps located in the basement.

There are five toilet exhaust fans each approximately 3 HP and various smaller exhaust fans serving the lobby, mezzanine and elevator equipment rooms. Make-up air is provided by the main air handlers.

Two GE 10 Hp air compressors located in the mechanical penthouse provide control air to pneumatic valves and actuators.

2.4.2 Building Controls and Sequence of Operation

The building's HVAC systems are controlled by a MCC Powers 600 Direct Digital Control (DDC) building automation system (BAS) system installed in 1992 and upgraded to a windows interface in 1996. The BAS provides full control and monitoring of the building's air handler systems, condenser water systems, but is limited to monitoring of the chillers. Pneumatic transducers interface the DDC system with HVAC pneumatic valves and dampers. The BAS has no control over the steam coil perimeter induction units.

The BAS operates the air handlers between 6:00 AM and 6:00 PM Monday through Friday, and they are generally disabled on weekends unless a tenant specifically requests comfort conditioning. The supply and return fans on the air handlers are enabled and disabled through the BAS using this schedule. Current switches monitor the status of the supply and return fans.

Table 2.2
HVAC Operating Schedule

Day	Equipment Operating Time
Mon thru Fri	6:00 AM to 6.00 PM
Sat & Sun	Off

The air handlers have differential temperature integrated economizer control. The economizer dampers modulate as the first stage of cooling to maintain the supply air temperature setpoint. When the outside air temperature exceeds the return air temperature the outside air damper goes to the minimum position, the return air damper opens to 100% and the exhaust air damper closes. The cooling coil valves modulate as the second stage of cooling to maintain the supply air setpoint

The supply air setpoint is reset based on the schedule provided in Table 2.3 below. This table was current at the time of the survey but it changes to maintain comfort conditions in the building.

Table 2.3
Supply Air Temperature Reset Schedule

OSA Temperature (deg F)	SA Temperature (deg F)
58 or below	64
59-60	61
67 or above	58
Override	
RA Temperature (deg F)	
77 or above	55
70 or below	64

The chillers are enabled and disabled manually by the building engineers based on an observed demand in the building for mechanical cooling. The chillers operate under their own controls to maintain a chilled water supply temperature setpoint of 45 deg. F. When the building engineers send a start signal to the chillers the primary pump for the lead chiller and the dedicated lead chiller condenser water pump are enabled. The lead secondary chilled water pump is also enabled. On proof of condenser water and chilled water flow through the chiller, the lead chiller is enabled. The lead secondary chilled water pump speed modulates through its VFD to maintain the chilled water loop differential pressure (DP) setpoint. If the lead pump cannot maintain the DP setpoint, the lag secondary chilled water pump is enabled.

2.5 Comfort & Operational Issues

The main operational issue and cause of comfort complaints is inadequate zone control. When the building is in cooling mode, the system has limited zone control beyond the air handler level. The building engineers have to make a compromise on the supply air temperature so that perimeter zones do not get too warm and the interior zones do not get too cold.

2.6 Building Loads and HVAC Equipment Sizing

The central plant and HVAC systems appear to be reasonably sized for the building's load, based on modeled results and discussions with building operators. It is rare for the building to require a second chiller. Table 2.4 shows how building heating and cooling loads compare to HVAC equipment sizing.

Table 2.4
Equipment Size Compared to Load

Equipment	Cooling Capacity (tons)	Peak Cooling Load (tons)	Heating Capacity (kBtu/hr)	Peak Heating Load (kBtu/hr)
Basement Chillers	90	63.5	-	-
Heat Pump Loop	59.1	49.6	-	-
Main Building Chillers	700	650	-	-
Steam Heating System	-	-	7800	6890

3.0 UTILITY BILL ANALYSIS AND RESULTS OF ENERGY MODELING

This section provides a summary of the utility rate structure and a review of the electric utility use for the building. The results of energy modeling of baseline building energy use are also shown.

3.1 Utility Bill Analysis

This section provides a summary of the utility rate structure and a review of the electricity usage and demand, (kWh and kW) for the building. Pacific Gas and Electric Company supplies electricity to the site under the large commercial E-20S rate. Medium pressure steam is provided directly from the ---------- name ---------- steam plant. Electric bills were obtained for January 2001 through December 2002.

A summary of the utility bill data and building energy use is given in Table 3.1. The bill data used in the analysis is for 2002; this data better reflects the current usage as the interior hot water coils were disabled in 2001. The table shows that the building consumes 4,699,851 kWh/yr, which corresponds to an average of 10.15 kWh/sq.ft. The annual electricity cost is $756,324, which corresponds to an average of $0.16 per kWh.

Table 3.1
Utility Bill Data (Summary)

	Equity Office			
Cond. Floor Area (sq.ft)	463,000			
Energy Type	**Annual Consumption**	**Peak Demand**	**Annual Cost**	**Average Rate**
Electricity	**(kWh)**	**(kW)**	**($)**	
	4,699,851	1,484	$756,324	
	(kWh/sq.ft)	**(W/sq.ft)**	**($/sq.ft)**	**($/kWh)**
	10.15	3.21	$1.63	0.16
Steam	**(pounds)**	**(therms)**	**($)**	
	9,439,100	94,391	222,535	
	(lbs/sq.ft)	**(therms/sq.ft)**	**($/sq.ft)**	**($/lb)**
	20	0.20	$0.48	0.02

3.2 Modeling Results and End-Use Allocation

A DOE-2 computer simulation energy model was used to calculate energy savings for the recommendations discussed in Section 5 and to compare the installed equipment capacity against the building's heating and cooling loads. A baseline building energy simulation model was developed using audit data and record documents and compared (calibrated) against actual utility data. Figures 3.2.1 and 3.2.2 compare the modeled simulation results with the metered and billed electricity and electric demand data. The results of the baseline model compare favorably with the utility data for both usage and demand. Modeled electricity varied less than 1 percent on an annual basis and not more than 11 percent for any month. Modeled demand varied less than 1 percent annually and no more than about 10 percent for any month.

Figure 3.2.1
Building Electricity (kWh)
Billed vs. Modeled Comparison

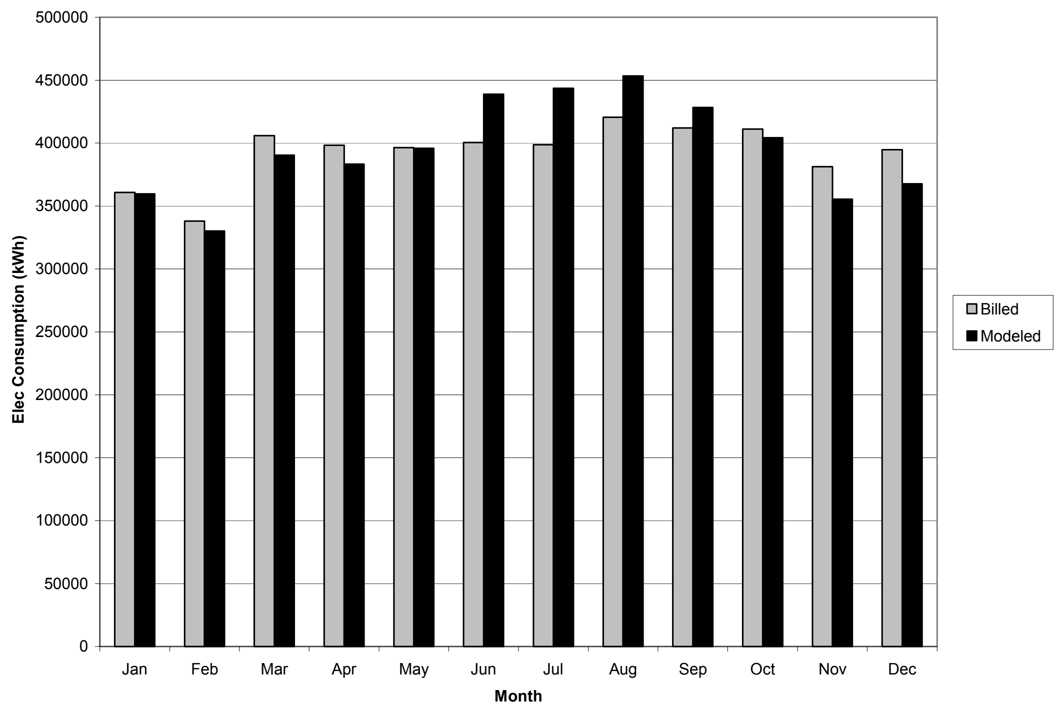


Figure 3.2.2
Building Electric Demand (kW)
Billed vs. Modeled Comparison

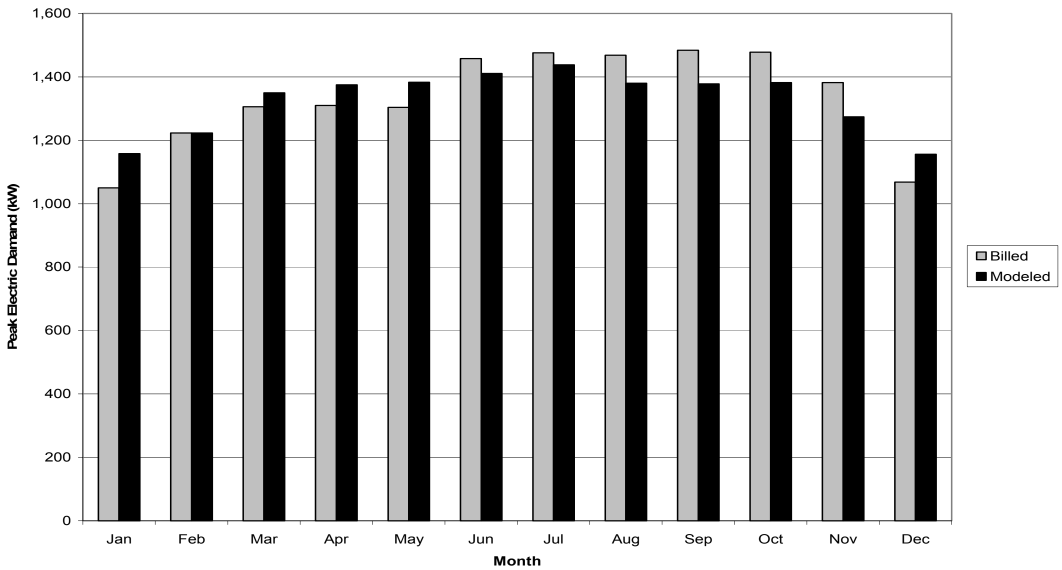


Figure 3.2.3 shows annual metered and modeled steam usage on an equivalent energy basis. Modeled usage varied about 2 percent annually and calibrated reasonably well for most months.

Figure 3.2.3
Building Heating (Steam)
Billed vs. Modeled Comparison (Equivalent Therms)

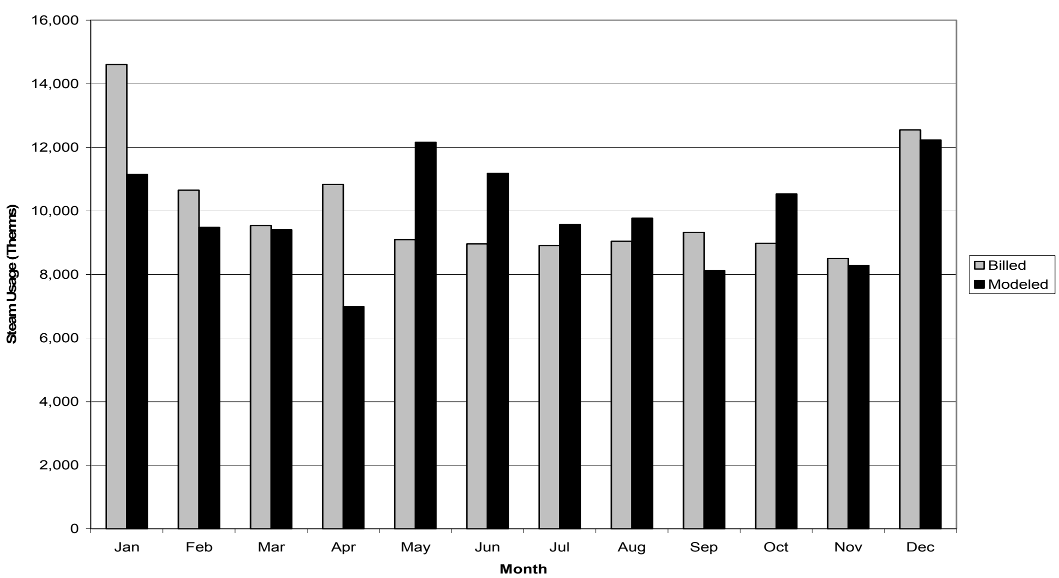
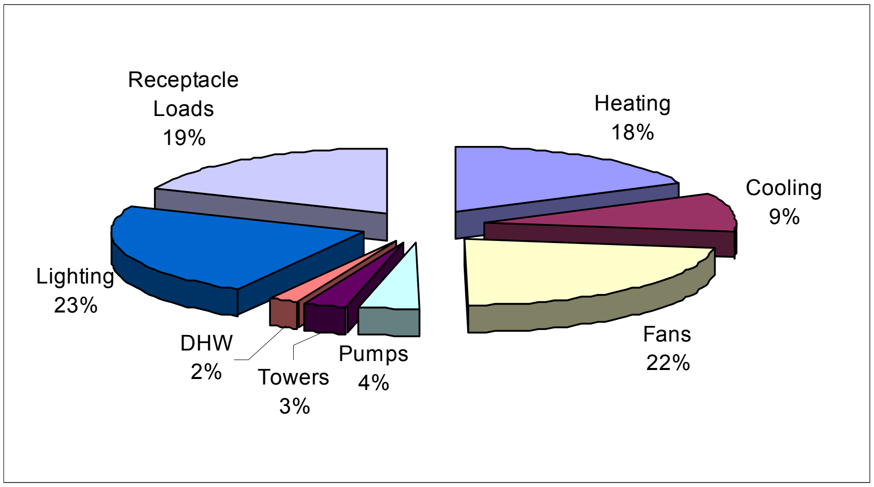


Figure 3.2.4 shows the relative percentages of annual energy usage in the building by end use, normalized on a BTU basis, from the baseline model. The largest usage is lighting, accounting for 23%, followed by ventilation fans at 22%, and receptacle loads at 19%.

Figure 3.2.4
Energy End-Use Allocation
Modeled Results



4.0 Monitoring Plan and Results

- Auditor - developed a short-term monitoring plan that was executed by building operations personnel. The monitoring plan relied on lighting loggers to determine the correlation between occupancy and lighting function. BAS trends were also initiated to investigate equipment operating hours and economizer and reset sequences.

4.1 Lighting Monitoring

The lighting monitoring plan was carried out from June 11 through June 18. The light loggers used were the *InteliTimer Pro 211*, installed at five locations throughout the building.

Figure 4.1.1 below shows the percentage of time the room was lit and occupied for a copy/stationery room without an occupancy sensor installed, averaged over one week. The yellow shows the composite time the lights were on and the green shows when the room was occupied. As the yellow does not indicate 100%, it is clear that some occupants turn off the lights as they leave. However, the monitoring shows that the lights were on and the room vacant for 37% of normal hours of occupancy.

Figure 4.1.1
Copy/Stationary Room Average Usage

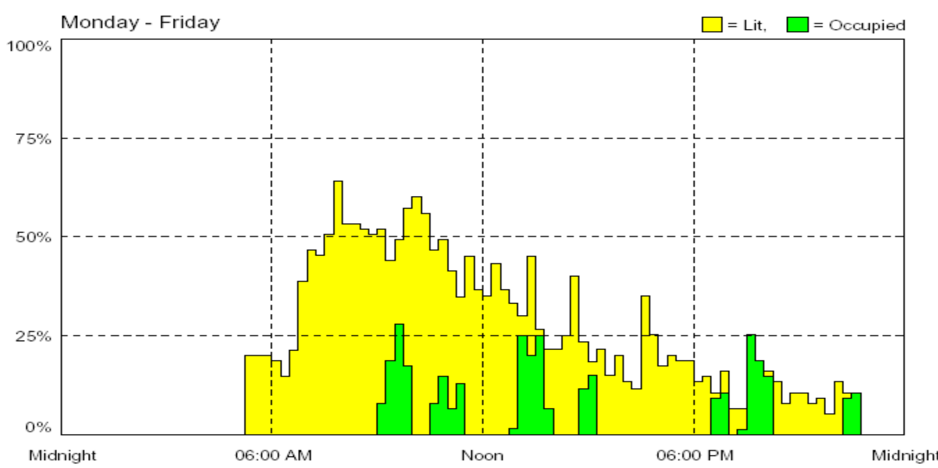
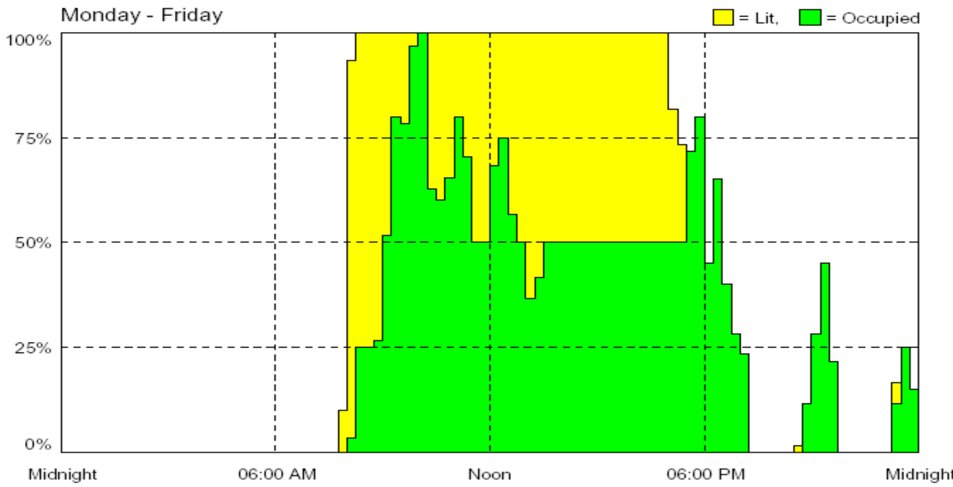


Figure 4.1.2 below shows the average percentage of time the room was lit and occupied for an enclosed office without a sensor installed. These show clearly that the night-time cleaning crew turns off the lights as they vacate a space. The analysis showed that the lights were on and the office vacant for 30% of normal hours of occupancy.

Figure 4.1.2
Enclosed Office Average Usage



4.2 Building Automation System Trending

BAS trend logs of outside air economizers, auxiliary condenser water (CW) loop and basement chillers are discussed in this section.

Air Handler-7 Trends
Trends were set up for air handler AHU-7, serving floors 14 and 15, and one chiller from early June to early July; these points included outside air, return air, supply air, cooling coil valve position, and economizer damper position. The valve and damper positions are determined from control pressure; 100% open at 15 PSI, and fully closed at 1.5 PSI. Other air handlers were spot-checked through the BAS for correct operation.

Figure 4.2.1 below shows the operation of AHU-7 on June 9. The graph indicates that the supply air temperature is reset between about 61°F and 58°F based on outside air temperature, which confirms the re-set schedule shown in Table 2.3.

Figure 4.2.1 also shows that the economizer sequence is working as designed. There are three main sections of the chart that show the air handler is operating per the design sequence:

1. Hours of Operation: The fans operate between 6:00 AM – 6:00 PM as can be seen by the return air temperature rising during morning warm-up at 6:00 AM and the economizer damper returning to the closed position (1.5 PSI) at 6:00 PM.
2. Economizer Modulation as First Stage of Cooling: In the morning from 7:30 AM to 11:00 AM the outside air temperature remains below the supply air temperature and the economizer damper is modulating to maintain the supply air setpoint. This is the first stage of cooling and no mechanical cooling is required.

3. Cooling Coil Valve Operation: On this mild summer day, the building operators did not manually enable the chillers until late afternoon. Between 11:00 AM and Noon the economizer dampers are fully open (100% outside air) and the outside air temperature is cool enough (59°F) to maintain the supply air temperature setpoint. As the supply air temperature rises above the setpoint, the cooling coil valve opens to maximum position in an attempt to maintain the required supply air temperature, but the chiller is not running so there is no mechanical cooling provided. At 4:00 PM, when the chiller is enabled manually, the cooling coil modulates as the second stage of cooling to maintain the supply air setpoint. At 6:00 PM, air handlers and chillers are disabled.

Figure 4.2.1
Air Handler-7 Trend Log (June 9, 2003)

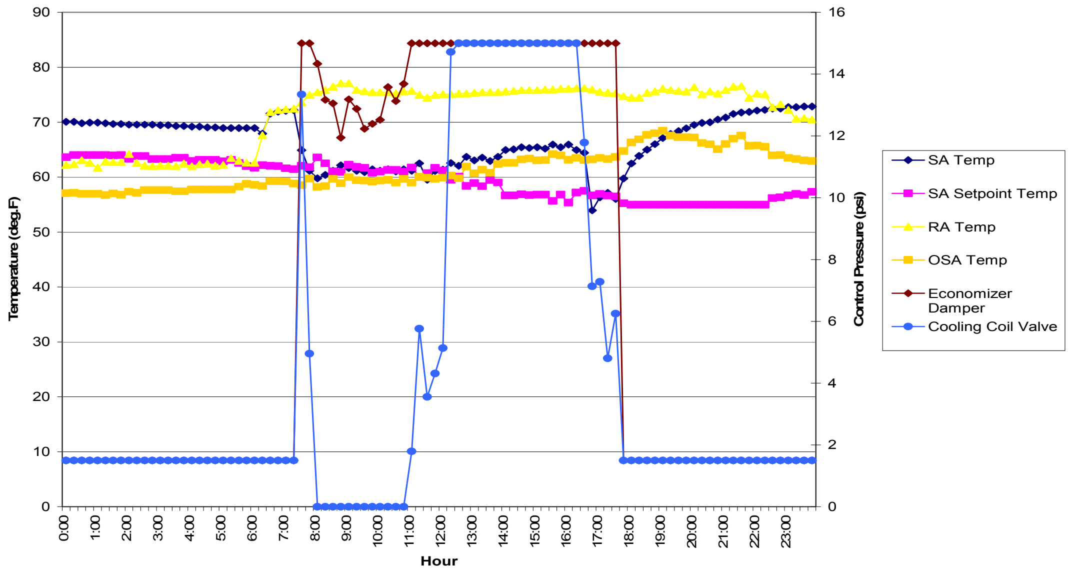


Figure 4.2.2 below shows AHU-7 on June 25, a considerably warmer day that reached 85°F when the chiller ran all day. At about 11:00 AM the outside air damper goes to its minimum position (7 PSI), when the outside air exceeds the return air temperature, thus confirming the integrated differential temperature economizer control.

Figure 4.2.2
Air Handler-7 Trend Log (June 25, 2003)

4.3 Auxiliary Condenser Water Loop Trending

Trend data were obtained for the open and closed loop condenser water system from July 7 to July 8. Figures 4.3.1 and 4.3.2 below show the operation of the CW pumps and CT-2 on July 8. The trended points include CT-2 leaving condenser water temperature, open loop CW Pump-1 and 2 enable, closed loop CW Pump-1 and 2 enable, and CT-2 Hi/Low fan speed enable.

Figure 4.3.1 below shows the operation of the CW pumps for the open and closed loops. The closed loop pump, which provides water to the building heat pumps, operates 24 hours per day and switches from Pump-2 to Pump-1 at 8:00 AM. This alternate sequencing ensures one pump doesn't receive more wear than the other and allows maintenance to be performed at regular intervals. The open loop pumps, which pump water between the CT-2 and the heat exchanger, cycles on and off throughout the night to maintain the CW supply temperature 66°F to 67°F. At 8:30 AM, as the CW temp rises, Open Loop Pump-2 runs continuously for the rest of the morning and afternoon. The fluctuations in CW temperature from 11:00 AM to 3:00 PM are due to the tower fans cycling on and off as can be seen in Figure 4.3.6.

Figure 4.3.1
CW Pumps Trend Log (July 8, 2003)

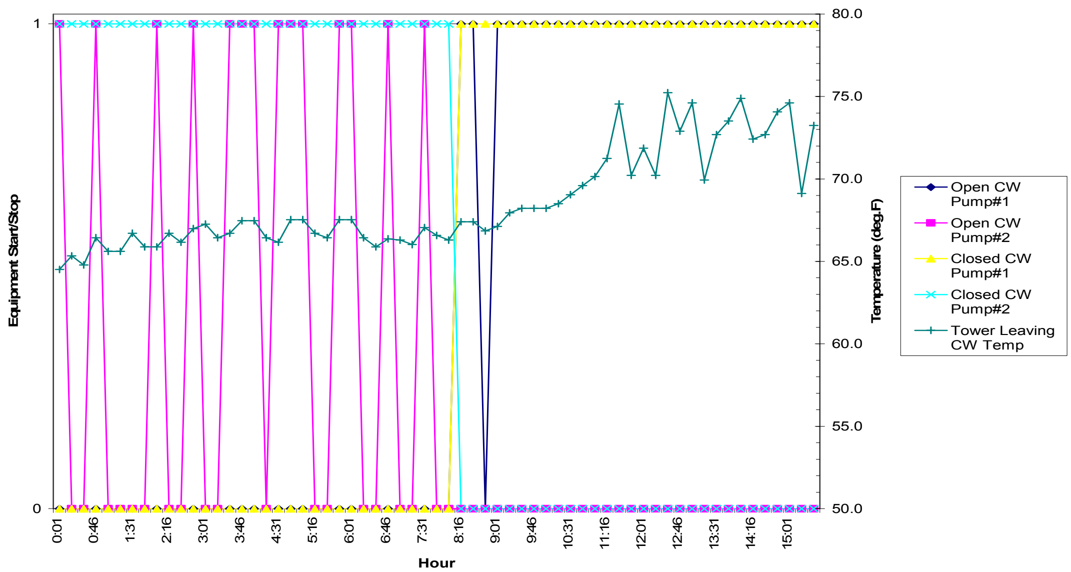
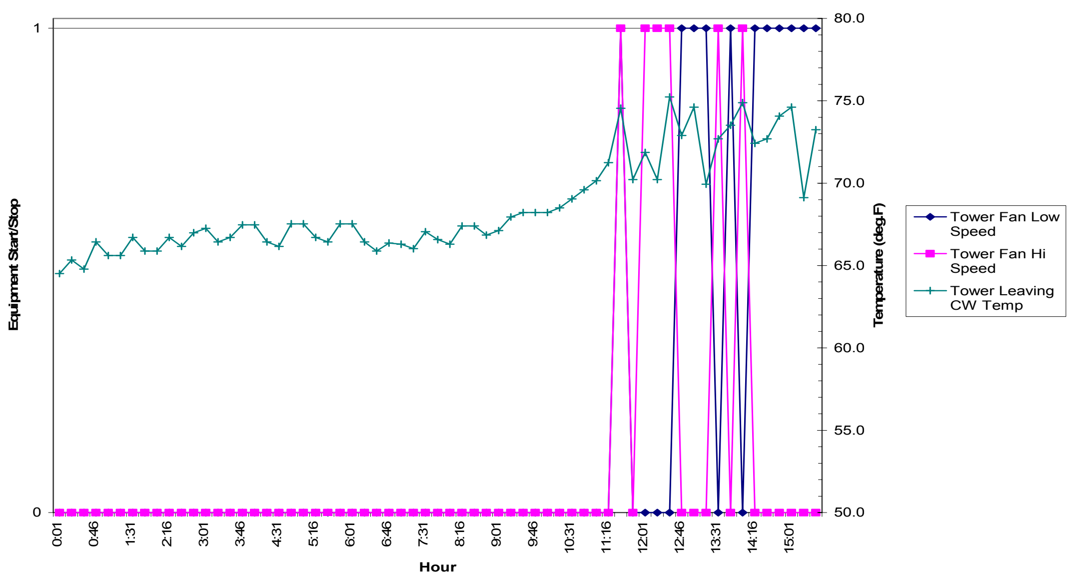


Figure 4.3.2
CW Fans Trend Log (July 8, 2003)



5.0 ENERGY SAVINGS RESULTS & RECOMMENDATIONS

Energy Efficiency Measures (EEMs) were evaluated using DOE-2 modeling and computer spreadsheet analysis for electrical consumption (kWh) and peak-period demand (kW) savings. Measures have been organized according to project cost in three tiers: no-cost/low cost, moderate cost, and high cost as summarized below and in Sections 5.1 through 5.3. As PG&E does not provide the steam to the building, measures that result in heating-only savings were identified but not evaluated; these are described in Section 5.4. Section 5.5 provides a summary of savings.

Capitol cost estimates include the following: material, labor, design where applicable (15% of materials and labor), construction/project management where applicable (10% of materials and labor), commissioning where applicable (10% of materials and labor), and contractor profit and overhead (20% of materials and labor). The capital cost estimates are based on information from suppliers and contractors, the author's experience with similar projects, and published sources including RS Means.

TIER ONE: EEM REQUIRES NONE TO MINIMAL CAPITAL (< $1.5K)
None Identified

TIER TWO: EEM REQUIRES MODERATE CAPITAL ($1.5K < EEM <$20K)
EEM 1 Repack/Overhaul lead cooling tower
EEM 2 Install VFD on open loop condenser water pump
EEM 3 New pneumatic control compressors
EEM 4 Implement a CO_2 based demand ventilation control for all air handlers

TIER Three: EEM REQUIRES SIGNIFICANT CAPITAL (EEM >$20K)
EEM 5 Connect basement and first floor air handler to main chilled water loop
EEM 6 Install occupancy sensors in enclosed spaces
EEM 7 High efficiency motors
EEM 8 Insulate roof
EEM 9 Lighting Upgrade. Complete Replacement of T-12 fixtures with T-8 Fixtures
EEM 10 Tinted window film
EEM 11 New cooling tower for lead chiller and auxiliary condenser water loop
EEM 12 Daylighting control of light fixtures in perimeter zones
EEM 13 Air handler conversion to variable air volume zones

5.1 Tier One Measures: EEMs Requiring Minimal Capital Investment

There were no no-cost or low-cost energy savings measures found for this building.

5.2 Tier Two Measures: EEMs Requiring Moderate Capital Investment

EEM 1: Repack/Overhaul Lead Cooling Tower

There are two 15 HP fans operating within the lead cooling tower (No. 1) providing condenser water to the lead chiller. This measure calls for a major overhaul to be performed that would include replacing of the tower fill resulting in improved performance and a lower tower approach. For the calculations, the tower approach was estimated at 16°F and a reduction of 2°F would be expected by implementing this measure. This measure was modeled using DOE-2 and the summary energy savings modeling reports can be found in Appendix C.

The annual electricity savings are estimated at 12,800 kWh and the electrical cost savings at $1,900. There are virtually no peak-period kW demand savings. The implementation cost is estimated to be about $15,700, resulting in a simple payback of about 8.3 years. This measure is recommended.

EEM 2: Install VFD on Open Loop Condenser Water Pump

The building condenser water loop serving the heat pumps operates 24 hr/day. The load on the computer room heat pumps is assumed to be fairly constant and the closed loop pump runs at full speed for 24 hr/day. The open loop pumps cycle on and off throughout the day and night to maintain the condenser water setpoint as shown is Figure 4.3.1. This measure involves installing a VFD on the lead open loop condenser water pump so that the pump speed varies to maintain the condenser water supply setpoint. This measure was modeled using DOE-2 and the summary energy savings modeling reports can be found in Appendix C.

The annual electricity savings are estimated at 28,000 kWh with electrical cost savings of $2,200. There are virtually no peak-period kW demand savings. The implementation cost is estimated to be approximately $10,100, resulting in a simple payback of about 4.6 years. Further trending or monitoring on the closed loop side would need to be performed to verify load variation.

A preliminary analysis has shown that an SPC incentive may be available for this project.

EEM 3: New Pneumatic Control Compressors

All of the control valves and damper actuators on the HVAC system are pneumatic. The potential for air leaks in a compressed air system of this vintage are great, however the investment in time to repair leaks for this building is also significant. Alternatively, installing new efficient compressors to replace the two old 10 HP units would likely save up to 8% of compressor energy use**.** It has been assumed that the current compressor has an efficiency of 75%, and a new compressor will have an efficiency of about 83%. Thus the kW reduction associated with this measure is 8%. The operating hours of the compressor has been assumed to be 1,000 hours per year based on conversations with the building engineers. Summary calculation of this measure is shown in Table 5.2.1 below.

Table 5.2.1
New Compressor Calculation

New Pneumatic Control Compressors	
Compressor Rated Power (HP)	10
Current Efficiency	75%
Proposed Efficiency	83%
% Savings	8%
Estimated operating hours	1,000
Peak-period demand savings	0.60
kWh savings	600
Cost Savings	$160
Implementation Cost	$4,800
Simple Payback	30.0

The annual electricity savings for this measure is estimated to be 600 kWh or about $160 per year. There are virtually no peak-period kW demand savings. The implementation cost for this measure is expected to be about $4,800, resulting in a simple payback of 30 years. This measure can not be recommended based on energy savings alone. Instead, we recommend an initial inspection followed by regular maintenance of the existing compressors and believe this will enable them to be run as efficiently as is practical and is a cost effective use of resources.

EEM 4: Implement a CO_2 Based Demand Ventilation Control for all Air Handlers

The spot check of air handler readings and trend shows that the outside air damper goes to a minimum position when the return air exceeds the outside air temperature. Although not measured for this study, it is possible that the amount of outside ventilation air at minimum damper position exceeds code requirements of 15 CFM per person and occupant density varies continuously. Carbon dioxide-based demand ventilation control would minimize excessive conditioning of outside air. The savings for this measure, shown in Table 5.2.2 below, was calculated by reducing the outside air cfm/ft^2 from 0.150 to 0.125. The calculation assumes that the economizer damper returns to the minimum position when the outside air temperature goes above 72°F in the summer or below 55°F in winter. Average temperatures were calculated from -- facility city -- weather data for occupied periods outside of the lockout range and were used to calculate the load reduction.

Table 5.2.2
Demand Ventilation Control Calculation

Demand Control Ventilation	Cooling	Heating	Total
Outside Air Avg. Temp outside of lockout range* (deg F)	78	50	
Supply Air Temp (deg F)	55	55	
CFM Savings	10,550	10,550	
Chiller Efficiency (kw/ton)	0.5	-	
Hours OSA outside of lockout	208	1,203	
Load savings (Btu/hr)	266,915	58,025	
Average demand savings	11	-	**11**
Peak-period demand savings	0	-	**0**
kWh savings	2,313	-	**2,313**
Heat Savings (therms)	-	700	**700**
Cost Savings	$267	$504	**$770**
Project Cost			**$16,600**
Simple Pay Back			**21.6**

*Cooling lockout >72deg.F, Heating lockout <55deg.F

Analysis shows that this measure can save 2,300 kWh annually for cooling and heating energy savings equivalent to 700 therms. There are no peak-period kW demand savings associated with this measure since there are no changes in outside air ventilation during the peak period. The annual cost savings for this measure is determined to be $770. The implementation cost for this project is estimated to be $16,600, yielding a simple pay back of over 20 years. This measure is not recommended.

5.3 Tier Three Measures: EEMs Requiring Significant Capital Investment

EEM 5: Connect First Floor and Basement Air Handlers to Main CHW Loop

This measure involves connecting the basement and first floor air handlers to the main chilled water loop, allowing the air handlers to use this source when available. The main chillers have much higher efficiencies (0.50 kW/ton with variable speed compressors), compared to the basement chiller, (about 0.75 kW/ton), and therefore potential savings can be significant. Additional piping, isolation valves and controls would allow the air handlers to switch between chilled water sources. This measure was modeled using DOE-2 and the summary energy savings modeling reports can be found in Appendix C.

This measure results in an increase of 7,100 kWh annually, while peak-period demand savings are estimated at 38 kW. The net annual electricity cost savings is about $5,100. The implementation cost is estimated to be about $55,000, resulting in a simple payback exceeding 10 years. This measure is not recommended.

EEM 6: Install Occupancy Sensors in Enclosed Spaces

The lighting survey and monitored results showed approximately 50% of the building (area-based) and 40% of the tenants do not have occupancy sensors installed. This measure involves the installation of occupancy sensors in these spaces, which include enclosed offices, conference rooms, copy, and storage spaces. Energy savings were calculated assuming one wall sensor per room (200 sq.ft) with enclosed spaces averaging 15% of floor area, and an installed LPD reduction of 20% for the enclosed office spaces, which is the reduction factor published in the 2001 Title 24 Energy Standards. Cost savings include summer and winter variations of electricity consumption and peak-period demand and are based on the electric rate of: Winter 0.1028 $/kWh, 5.74 $/kW, and summer 0.1278 $/kWh, 19.03 $/kW, derived from utility bill analysis. The cost of this measure was based on using wall switch sensors at $75/ sensor plus $45 in labor, for a total installed cost of $120 per sensor, which includes a 30% contractor markup. Details of the savings estimate are provided in Table 5.3.1 below.

Table 5.3.1
Occupancy Sensor Savings Calculation

Occupancy Sensor Installation	Enclosed Spaces	Total Savings
Total Operating Hours	3,120	
Operating Hours Reduction	20%	
Existing Total Wattage	33,406	
Wattage Reduction	6,681	
Number of Sensors	172	
Peak-Period Demand Savings	7	**7**
kWh Savings	20,800	**20,800**
Electricity Cost Savings		**$3,400**
Gas Increase		**$300**
Project Implementation Cost		**$17,900**
Simple Payback		**5.8**

The annual electricity savings is estimated to be 20,800 kWh, with a peak-period demand savings of about 7 kW, with electricity cost savings of $3,400. An increase in heating will result from this measure and is calculated to be $300, giving a total net cost savings of $3,100. The implementation cost is estimated to be $17,900, resulting in a simple payback of 5.8 years. This measure is recommended.

A preliminary analysis has shown an SPC incentive may be available for this project.

EEM 7: High Efficiency Motors

The air handler fan motors, auxiliary condenser water loop pump motors, and cooling tower fan motors are aging and are not high efficiency. This measure involves replacing these with high efficiency units. The new chilled water system's circulation pumps and the condenser water pumps are already premium efficiency. A list of the motors to be replaced is summarized in Table 5.3.2. This motor list includes size, equipment served, estimated existing efficiency and its equivalent high replacement option efficiency. This measure was modeled using DOE-2 and the summary energy savings modeling reports can be found in Appendix C.

The annual electricity savings are estimated at 25,000 kWh, with demand savings of 8 kW, and annual electricity cost savings of $4,300. The implementation cost is estimated at about $37,500, resulting in a payback of 8.8 years. This measure is recommended.

A preliminary analysis has shown that an SPC incentive may be available for this project.

Table 5.3.2
Motor Replacement List

AHU-Number	Motor Use*	Size (HP)	No. of Motors	Existing Efficiency	New Premium Efficiency
AHU-1 & 2	Supply Fan	10.0	2	89.5%	91.7%
	Return Fan	7.5	1	88.5%	91.0%
AHU-3	Supply Fan	40.0	1	93.0%	94.1%
	Return Fan	25.0	1	91.7%	93.6%
AHU-4	Supply Fan	40.0	1	93.0%	94.1%
	Return Fan	25.0	1	91.7%	93.6%
AHU-5	Supply Fan	40.0	1	93.0%	94.1%
	Return Fan	25.0	1	91.7%	93.6%
AHU-6	Supply Fan	10.0	1	89.5%	91.7%
	Return Fan	3.0	1	86.5%	89.5%
AHU-7	Supply Fan	25.0	1	91.7%	93.6%
	Return Fan	15.0	1	91.0%	93.0%
AHU-8	Supply Fan	40.0	1	93.0%	94.1%
	Return Fan	25.0	1	91.7%	93.6%
AHU-9	Supply Fan	40.0	1	93.0%	94.1%
	Return	25.0	1	91.7%	93.6%
AHU-10	Supply Fan	40.0	1	93.0%	94.1%
	Return Fan	25.0	1	91.7%	93.6%
Cooling Towers	Fan Motor	15.0	2	91.0%	93.0%
	Fan Motor	40.0	1	93.0%	94.1%
Auxiliary Condenser Loop	Closed Loop	25.0	2	91.7%	93.6%
	Open Loop	15.0	2	91.0%	93.0%

EEM 8: Insulate Roof

There is currently no roof insulation, but an upgrade is planned for around 2004. This measure involves installing 3" of rigid insulation (R-20) at that time. The total square footage to be insulated is approximately 14,000 square feet, assuming that the ceiling to the mechanical penthouse is not insulated. This measure was modeled with DOE-2 and energy savings reports can be found in Appendix C.

The annual electricity savings are estimated at 48,800 kWh with electrical cost savings of about $5,300. There are virtually no peak-period kW demand savings. Heating energy savings are $3,500, resulting in total cost savings of $8,800. The total implementation cost is estimated to be about $84,400, resulting in a simple payback of 9.6 years. This measure is recommended.

EEM 9: Lighting Upgrade. Complete Replacement of T-12 fixtures with T-8 Fixtures

The lighting survey showed approximately 25% of the building relies on 2, 3 or 4-lamp T-12 fixtures with inefficient core-coil ballasts. This measure involves completing the replacement of all fixtures with electronic ballasts and T-8 lamps. The building lighting power density (LPD) is currently estimated to be 1.10 W/sq-ft. This LPD will be lowered by about 2% to 0.98 W/sq.ft after completion of the retrofit. A summary of the energy and cost savings calculation is shown in Table 5.3.3 below. Cost savings include summer and winter variations of electricity kWh consumption and peak-period kW demand.

Table 5.3.3
Lighting Retrofit Calculation

Complete T12 to T8 Retrofit	Two Lamp 4' T12 Fixture	Three Lamp 4' T12 Fixture	Four Lamp 4' T12 Fixture	Total Savings
Average Operating Hours	3,120	3,120	3,120	
Existing Fixture Wattage	76	112	144	
New Fixture Wattage	62	90	114	
Number Fixtures	800	330	490	
Peak-Period Demand Savings	11	7	15	**33**
kWh Savings	34,900	22,700	45,900	**103,500**
Electric Cost Savings				**$16,900**
Gas Cost Increase				**$1,300**
Project Implementation Cost				**$124,600**
Simple Payback				**8.0**

The annual electricity savings are calculated to be 103,500 kWh, with peak-period demand savings of 33 kW, and annual energy cost savings of $16,900. An increase in heating energy will result from this measure and is estimated to be about $1,300, resulting in a total net cost savings of $15,600. The implementation cost is estimated to be about $124,600, resulting in a simple payback 8.0 years. This measure is recommended.

EEM 10: Tinted Window Film

This measure involves installing a solar load reducing film to the windows on the east, south and west facades. The film could be applied during the exterior refurbishing project planned for a later date. This measure was modeled using DOE-2 by reducing window SHGC to 0.3 based on manufacturer's specifications. DOE-2 summary energy savings modeling reports can be found in Appendix C.

The annual electricity savings are estimated to be 127,400 kWh, with peak-period demand savings of 20 kW and cost savings of $12,900. An increase in heating energy will result from this measure, equivalent to about $4,500. The implementation cost is estimated to be about $114,100, resulting in a simple payback of 8.8 years. This measure is recommended as it will also improve the comfort level at the perimeter zones.

EEM 11: New Cooling Tower for Lead Chiller and Auxiliary Condenser Water Loop

This measure involves replacing the lead cooling tower with a new efficient unit and inter-connecting the auxiliary condenser water loop to this distribution system. This will isolate the existing (less efficient) second tower for dedicated operation with the second (lag) chiller which is rarely required. The new more efficient tower, sized using multiple cells totaling 600 tons, features a VFD and a 10°F approach temperature. This measure was modeled using DOE-2 and the summary energy savings modeling reports can be found in Appendix C.

The annual electricity savings are calculated at 67,300 kWh, with peak-period demand reduced by 30 kW, and energy costs reduced by about $12,800. The implementation cost is estimated to be $117,500, resulting in a simple payback of 9.2 years. This measure is recommended.

A preliminary analysis has shown that an SPC incentive may be available for this project.

EEM 12: Daylighting Control of Light Fixtures in Perimeter Zones

Interior lighting is now controlled only by manual switch or occupancy sensor. This measure involves installation of daylighting controls to reduce light energy consumption at the perimeter zones where appropriate to the task and function. The glazing areas allow sufficient natural light in approximately 32% of the building, excluding the east perimeter on the lower floors where there are no windows. Daylighting controls employ a photocell sensor to detect ambient light, in turn relaying that information to a dimmer actuator, which reduces light output by continuous dimming of electronic fluorescent ballasts. The calculation was performed based on a 20% reduction in installed LPD, which is the reduction factor published in the 2001 Title 24 Energy Standards based on window area. A summary of this calculation can be seen in Table 5.3.4.

Table 5.3.4
Daylight Sensor Calculation

Daylighting Sensor Installation	Enclosed Spaces	Total Savings
Daylit Area		
Total Operating Hours	3,120	
Operating Hours Reduction	20%	
Existing Total Wattage	163,011	
Wattage Reduction	32,602	
Peak-Period Demand Savings	33	**33**
kWh Savings	101,700	**101,700**
Electricity Cost Savings		**$16,600**
Gas Increase		**$1,200**
Project Implementation Cost		**$195,500**
Simple Payback		**12.7**

Cost savings include summer and winter variations of electricity consumption and peak-period demand. The annual electricity savings are estimated to be 101,700 kWh, with peak-period demand savings of 33 kW, and cost savings of $16,600. An increase in heating cost will result from this measure and is calculated to be $1,200. The implementation cost is estimated at about $195,500, resulting in a simple payback of 12.7 years. This measure is not recommended.

EEM 13: Air Handler Conversion to Variable Air Volume Zones

This measure involves converting the existing constant volume air handling systems to variable air volume (VAV). Savings are realized primarily in fan power, cooling energy and heating energy reduction. The variable speed drives on the supply fans will modulate the fan motor speed to maintain a static pressure setpoint. Motor horsepower is proportional to the cube of motor speed so as a motor slows down the power consumed by the motor decreases dramatically. With the existing constant volume system there are times when the large volumes of supply air overheat or overcool the space. With the recommended VAV system, the heating and cooling energy provided by the HVAC systems should better match the heating and cooling loads, thus saving heating and cooling energy. This measure was modeled using DOE-2 and the summary energy savings modeling reports can be found in Appendix C.

Conversion of the constant volume air handlers to variable air volume would involve the following implementation steps:

1. For each air handler, install a VFD and new premium efficiency motor on the supply fan and the return fan.
2. For each air handler install a duct static pressure sensor 2/3 of the way down the supply air duct; the supply fan VFD will modulate the supply fan motor speed to maintain the static pressure setpoint. Install a building static pressure sensor for each air handler; the return fan VFD will modulate to maintain the building static pressure setpoint.
2. Install new VAV boxes with new thermostats. For the interior zones, this study assumes that the existing heating coils could be re-used as the re-heat coils for the new VAV boxes; this should be verified during the engineering design phase. For the exterior zones it is recommended that new VAV boxes with new steam re-heat coils be used. With this approach the existing steam distribution system could be utilized.
3. Provide DDC controls for all the air handlers and VAV boxes and interface those controls with the existing BAS.
4. On completion of installation perform full functional commissioning and operator training.

Annual electricity savings are estimated at 821,700 kWh, with peak-period demand reduced by 122 kW, and the annual energy cost savings are about $145,600. The implementation cost is estimated to be about $1,368,200, resulting in a payback of 9.4 years. The implementation costs associated with this measure should be evaluated in more detail prior to a final recommendation.

A preliminary analysis has shown that an SPC incentive may be available for this project.

5.4 Measures Resulting in Steam Savings

Replace Hand Dials on Perimeter Steam Induction Units with Thermostats

The controls on approximately 40% of the perimeter steam terminal units are manual, using 'cooler' to 'warmer' hand dials. This measure involves replacing the remaining manual controls with controllable thermostats. Energy savings for this recommendation were not estimated but a modest reduction in steam usage and improved space comfort are expected.

Re-furbish Windows

Air and water leaks regularly occur at the building skin through the windows due to failed weatherproofing. Air infiltration leads to increased cooling in summer and increased heating in winter. Energy savings for this recommendation were not estimated but a modest reduction in steam usage is expected along with improvements in space comfort and lower maintenance costs.

5.5 Summary of Energy Efficiency Measures

Table 5.4 shows the energy savings and cost analysis for the energy efficiency measures discussed in Sections 5.1, 5.2 & 5.3.

Table 5.4
Energy Savings Analysis

	Annual Energy					Annual Savings								
	Electrical			Gas		Electrical			Steam		Total Cost		Project Cost	Simple Payback
Run ID	Usage (kWh)	Demand (kW)	Cost (Dollars)	Usage (Therms)	Cost (Dollars)	Usage (kWh)	Demand (kW)	Cost ($)	Usage (Therms)	Cost ($)	($)	%	($)	(Years)
BASE	**4,750,682**	**1,452**	**$788,890**	**118,908**	**$90,976**	–	–	–	–	–	–	–	–	–
EEM 1	4,737,898	1,451	$786,965	118,908	$90,976	12,800	1	$1,900	0	$0	$1,900	0.2%	$15,700	8.3
EEM 2	4,722,658	1,452	$786,719	118,908	$90,976	28,000	0	$2,200	0	$0	$2,200	0.3%	$10,100	4.6
EEM 3	4,750,085	1,451	$788,732	118,908	$90,976	600	1	$160	0	$0	$160	0.0%	$4,800	30.0
EEM 4	4,748,369	1,441	$788,623	118,208	$90,473	2,300	11	$270	700	$500	$770	0.1%	$16,600	21.6
EEM 5	4,757,799	1,414	$783,839	118,908	$90,976	-7,100	38	$5,100	0	$0	$5,100	0.6%	$54,500	10.7
EEM 6	4,729,882	1,445	$785,490	120,097	$91,886	20,800	7	$3,400	-355	-$300	$3,100	0.4%	$17,900	5.8
EEM 7	4,725,693	1,444	$784,553	118,962	$91,014	25,000	8	$4,300	-50	-$40	$4,260	0.5%	$37,500	8.8
EEM 8	4,701,869	1,452	$783,544	114,395	$87,460	48,800	0	$5,300	4,500	$3,500	$8,800	1.0%	$84,400	9.6
EEM 9	4,647,182	1,419	$771,990	120,097	$91,886	103,500	33	$16,900	-1,766	-$1,300	$15,600	1.8%	$124,600	8.0
EEM 10	4,623,234	1,432	$771,531	124,853	$95,525	127,400	20	$17,400	-5,900	-$4,500	$12,900	1.5%	$114,100	8.8
EEM 11	4,683,334	1,422	$776,136	118,908	$90,976	67,300	30	$12,800	0	$0	$12,800	1.5%	$117,500	9.2
EEM 12	4,648,982	1,419	$772,290	120,097	$91,886	101,700	33	$16,600	-1,736	-$1,200	$15,400	1.8%	$195,500	12.7
EEM 13	3,928,946	1,330	$660,778	94,268	$73,507	821,700	122	$128,100	24,600	$17,500	$145,600	16.5%	$1,368,200	9.4

ID	Measure Description
BASE	
EEM 1	Repack/Overhaul lead cooling tower
EEM 2	Install VFD on open loop condenser water pump
EEM 3	New pneumatic control compressors
EEM 4	Implement a CO_2 based demand ventilation control for all air handlers
EEM 5	Connect basement and first floor air handler to main chilled water loop
EEM 6	Install occupancy sensors in enclosed spaces
EEM 7	High Efficiency Motors
EEM 8	Insulate roof
EEM 9	Lighting Upgrade. Complete Replacement of T-12 fixtures with T-8 Fixtures
EEM 10	Tinted Window Film
EEM 11	New cooling tower for lead chiller and auxiliary condenser water loop
EEM 12	Daylighting control of light fixtures in perimeter zones
EEM 13	Air handler conversion to variable air volume zones

APPENDIX A
Cost Estimates

Measure Description	Item Size	No of	Cost/Unit	Material Cost	Labor Hours	Labor Cost	Labor + Material Cost	Design	Const. Man.	Comm-issioning	Contractor Profit and Overhead	Total Fringe Cost %	Total Cost
Tinted window film													
Windodw Films	sf	31464	$2.9	$91,246	-		$91,246	0%	5%	0%	20%	25%	**$114,057**
Insulate roof													
Roof Insulation	sf	14000	$4.3	$60,200	-	$7,280	$67,480	0%	5%	0%	20%	25%	**$84,350**
Lighting Upgrade. Complete Replacement of T-12 fixtures with T-8 Fixtures													
Ballast + Lamps	Unit	1389	$39.0	$54,171	695	$41,700	$95,871	5%	5%	0%	20%	30%	**$124,632**
Install occupancy sensors in enclosed spaces													
Occupancy Sensor Switch	Unit	172	$50.0	$8,600	86	$5,160	$13,760	0%	5%	0%	25%	30%	**$17,900**
Daylighting control of light fixtures in perimeter zones													
Light Sensor	sf	150398	$1.0	$150,398			$150,398	0%	5%	5%	20%	30%	**$195,500**
High efficiency motors													
Return Fan 7.5 HP Motors	Unit	1	$490.0	$490	3	$150.00	$640	0%	5%	0%	20%	25%	$800
Supply Fan 7.5 HP Motors	Unit	1	$490.0	$490	3	$150.00	$640	0%	5%	0%	20%	25%	$800
Supply Fan 10 HP Motor	Unit	1	$595.0	$595	3	$150.00	$745	0%	5%	0%	20%	25%	$931
Cooling Tower Fan 15 HP Motors	Unit	2	$790.0	$1,580	3	$300.00	$1,880	0%	5%	0%	20%	25%	$2,350
Supply Fan 15 HP Motor	Unit	1	$790.0	$790	3	$150.00	$940	0%	5%	0%	20%	25%	$1,175
Return Fan 15 HP Motors	Unit	1	$790.0	$790	3	$150.00	$940	0%	5%	0%	20%	25%	$1,175
Supply Fan 25 HP Motors	Unit	1	$1,175.0	$1,175	3	$150.00	$1,325	0%	5%	0%	20%	25%	$1,656
Return Fan 25 HP Motors	Unit	4	$1,175.0	$4,700	3	$600.00	$5,300	0%	5%	0%	20%	25%	$6,625
Closed Loop Cond Pump 25 HP Motors	Unit	2	$1,175.0	$2,350	3	$300.00	$2,650	0%	5%	0%	20%	25%	$3,313
Cooling Tower Fan 40 HP Motor	Unit	1	$1,775.0	$1,775	3	$150.00	$1,925	0%	5%	0%	20%	25%	$2,406
Supply Fan 40 HP Motors	Unit	5	$1,775.0	$8,875	3	$750.00	$9,625	0%	5%	0%	20%	25%	$12,031
Return Fan 75 HP Motor	Unit	1	$3,250.0	$3,250	3	$150.00	$3,400	0%	5%	0%	20%	25%	$4,250
Subtotal													**$37,513**
Implement a CO_2 based demand ventilation control for all air handlers													
CO2 Sensors	Unit	23	$55.0	$1,265	80	$4,800	$6,065	10%	5%	10%	20%	45%	$8,794
Programing					80	$5,400	$5,400	10%	5%	10%	20%	45%	$7,830
Subtotal													**$16,624**
New pneumatic control compressors													
Compressors	Unit	2	$1,758.0	$3,516	4	$200	$3,716	10%	0%	10%	10%	30%	**$4,831**
Install VFD on open loop condenser water pump													
15 HP VFD	Unit	2	$2,846.5	$5,693	16	$960	$6,653	10%	0%	0%	20%	30%	$8,649
Programing					16	$1,080	$1,080	10%	0%	0%	20%	30%	$1,404
Subtotal				**$5,693**		**$2,040**	**$7,733**	**$0**	**$0**	**$0**	**$0**	**$1**	**$10,053**
Connect basement and first floor air handler to main chilled water loop													
Piping	Unit	1		$30,000	120	$6,000	$36,000	10%	5%	10%	20%	45%	$52,200
Programing	Unit	1		$0	24	$1,620	$1,620	10%	5%	10%	20%	45%	$2,349
Subtotal				**$30,000**		**$7,620**	**$37,620**						**$54,549**
Repack/Overhaul lead cooling tower	Unit												
Tower Fill				$10,000	40	$1,600.00	$11,600	10%	5%	0%	20%	35%	$15,660
							$0	10%	5%	0%	20%	35%	$0
Subtotal				**$10,000**			**$10,000**	**10%**	**0%**	**0%**	**20%**	**30%**	**$15,660**
New cooling tower for lead chiller and auxiliary condenser water loop													
600 Ton Tower	Unit	1	$35,000	$35,000	80	$7,713	$42,713	10%	5%	10%	20%	45%	$61,934
50 HP VFD Fan	Unit	1	$9,170	$9,170	16	$1,125	$10,295	10%	5%	10%	20%	45%	$14,928
Rigging/Helicopter	Unit	1	$20,000	$20,000		$0	$20,000	10%	5%	10%	20%	45%	$29,000
Piping	Unit	1	$2,000	$2,000	40	$2,000	$4,000	10%	5%	10%	20%	45%	$5,800
Electrical					40	$2,400	$2,400	10%	5%	10%	20%	45%	$3,480
Programing					24	$1,620	$1,620	10%	5%	10%	20%	45%	$2,349
SUBTOTAL			**$44,170**	**$44,170**		**$8,838**	**$81,028**						**$117,491**
VAV Conversion, Use Existing Heat Coils, VFD on All Main Fans, New VAV Boxes for Interior Zones													
VAV Boxes (Interior)	Unit	200	$1,000	$200,000	1,600	$80,000	$280,000	10%	5%	10%	20%	45%	$406,000
VAV Boxes (Exterior)	Unit	200	$1,500	$300,000	3,200	$160,000	$460,000	10%	5%	10%	20%	45%	$667,000
VFD 7.5 HP Supply Fan	Unit	1	$2,292	$2,292	24	$1,440	$3,732	10%	5%	10%	20%	45%	$5,411
VFD 10 HP Supply Fan	Unit	1	$2,381	$2,381	24	$1,440	$3,821	10%	5%	10%	20%	45%	$5,540
VFD 15 HP Supply Fan	Unit	1	$2,847	$2,847	24	$1,440	$4,287	10%	5%	10%	20%	45%	$6,215
VFD 25 HP Supply Fan	Unit	1	$4,749	$4,749	24	$1,440	$6,189	10%	5%	10%	20%	45%	$8,974
VFD 40 HP Supply Fan	Unit	6	$8,209	$49,253	96	$5,760	$55,013	10%	5%	10%	20%	45%	$79,768
VFD 7.5 HP Return Fan	Unit	1	$2,292	$2,292	24	$1,440	$3,732	10%	5%	10%	20%	45%	$5,411
VFD 15 HP Return Fan	Unit	1	$2,847	$2,847	24	$1,440	$4,287	10%	5%	10%	20%	45%	$6,215
VFD 25 HP Return Fan	Unit	4	$4,749	$18,995	96	$5,760	$24,755	10%	5%	10%	20%	45%	$35,895
VFD 75 HP Return Fan	Unit	1	$10,763	$10,763	24	$1,440	$12,203	10%	5%	10%	20%	45%	$17,694
Controls (Static pressure, building pressure sensors) & Programming	Unit	20	$500	$10,000	320	$21,600	$31,600	10%	5%	10%	20%	45%	$45,820
Programming VAV Boxes					800	$54,000	$54,000	10%	5%	10%	20%	45%	$78,300
Subtotal				**$596,416**		**$337,200**	**$933,616**	**10%**	**0%**	**0%**	**20%**	**30%**	**$1,368,242**

APPENDIX B
Utility Bills

Utility Bill Data Year 2001/2002

Month Year	Electricity (Bills)					Month Year	Steam (Bills)		
	kWh	kW	$	$/kWh			lbs	$	$/lbs
Jan-02	349,072	1,050	$41,924.12	$0.12		Jan-01	1139200	$24,800	$0.022
Feb-02	398,424	1,223	$47,625.63	$0.12		Feb-01	831200	$18,095	$0.022
Mar-02	379,728	1,306	$46,234.71	$0.12		Mar-01	743700	$16,196	$0.022
Apr-02	385,088	1,310	$46,749.78	$0.12		Apr-01	845100	$18,396	$0.022
May-02	409,160	1,304	$72,043.17	$0.18		May-01	709400	$15,451	$0.022
Jun-02	400,396	1,458	$79,141.58	$0.20		Jun-01	699300	$15,232	$0.022
Jul-02	411,507	1,476	$79,779.29	$0.19		Jul-01	694800	$18,896	$0.027
Aug-02	393,354	1,468	$78,501.14	$0.20		Aug-01	705700	$19,192	$0.027
Sep-02	412,043	1,484	$81,006.89	$0.20		Sep-01	727500	$19,783	$0.027
Oct-02	397,836	1,478	$79,526.81	$0.20		Oct-01	700900	$19,061	$0.027
Nov-02	393,968	1,382	$59,780.72	$0.15		Nov-01	663400	$15,132	$0.023
Dec-02	369,275	1,068	$44,009.71	$0.12		Dec-01	978900	$22,302	$0.023
Total	**4,699,851**	**1,484**	**$756,324**	**$0.16**		**Total**	**9,439,100**	**$222,535**	**$0.024**

APPENDIX C
DOE-2 Model Output

----- (appendix data removed) -----