Yahoo – A Model for Demand Management and Response

Lisa Gartland and Ed Jerome
Nexant, Inc.

Rick Cuevas and Toby Smieciuch
Yahoo, Inc.

Synopsis

Yahoo's Sunnyvale campus, which includes 765,000 square feet of office space, is a model of effective electricity demand control in a commercial building. The campus systems are controlled by a robust direct digital control system that continuously monitors the electricity demand in four main buildings. When an individual building reaches a certain level of demand, the control system takes action to reduce load by adjusting thermostat setpoints and reducing lighting levels. There are three pre-set levels of load reduction, each shedding load more aggressively than its predecessor. The result is a remarkably flat demand profile during the utility's peak period, as well as lower utility bills.

However, Yahoo's building controls are reactive in nature, which means little is being done to curb demand before it reaches predefined levels. During recommissioning services being provided by the local utility, Pacific Gas and Electric, opportunities were identified for reducing facility demand and energy consumption. Implementing various control strategies and efficiency measures can shift the control systems into a more pro-active energy management mode.

This paper presents a case study of one building on Yahoo's campus, Building A, a four-story, 160,000 square foot building used mainly as office space. In this paper, we first provide information about Building A's construction, mechanical systems, and control system operation. As illustration, plots of load profiles, zone behavior, and cooling system operation are presented. Next, load control opportunities for Building A are evaluated, including:

- Adjusting HVAC setpoints,
- Implementing a demand control ventilation system (DCVS),
- Eliminating evening peaks by extending demand controls,
- Using daylight sensors to control perimeter zone lighting,
- Using occupancy sensors to control office space lighting,
- Installing window films to reduce solar loads in perimeter spaces,
- Installing cool roofs to reduce building cooling loads.

These measures reduce the energy use of Building A before critical usage levels are reached, thus transforming the control system into one that both manages and responds to energy demand. These control methodologies are expected to have a high level of repeatability within the commercial building market segment.

About the Authors

Lisa Gartland recently joined Nexant as a Senior Project Engineer. Before joining Nexant, Lisa was the sole proprietor of PositivEnergy, a consulting firm that focused on heat island mitigation, along with the monitoring, modeling and implementation of building energy conservation systems. Lisa was also a post-doctoral fellow at Lawrence Berkeley National Laboratory, where she researched cool roofing, building control systems and integrated chiller retrofits. Lisa holds a bachelor's degree in mechanical engineering from Carnegie-Mellon University, a master's degree in aerospace engineering from the University of Cincinnati, and a doctorate in mechanical engineering from the University of Washington.

Ed Jerome is a Project Manager for energy and resource efficiency projects at Nexant, Inc. Ed has over 10 years of experience developing, quantifying, and managing energy and resource efficiency projects. Prior to joining Nexant, Ed worked as a Development Manager for Enron Energy Services in California and as a Senior Consulting Engineer at Pacific Gas & Electric Company. Ed holds a Bachelor of Science in Mechanical Engineering from California State University, Sacramento and is a Certified Energy Manager (CEM).

Rick Cuevas is the Facility Manager for Yahoo, Inc. and is responsible for the operation and maintenance of seven different buildings on Yahoo's Sunnyvale, California campus.

Toby Smieciuch is a Supervisor and Facility Technician for Yahoo, Inc. and is responsible for building operations. He has 20 years of experience in all aspects of building management and operations, including 16 years as the owner and operator of his own HVAC firm.

Introduction

Yahoo, Inc.'s Sunnyvale, California campus consists of seven buildings, as shown in Figure 1. Buildings A, B, C and D are grouped together around a central courtyard. Building E is leased to a separate tenant. Buildings A through E were completed and occupied in 2001. Buildings F and G were built in a second construction phase, with occupants moving in during late 2004 and early 2005. All buildings except for Building C serve mainly as office space, and with some square footage dedicated to computer data centers. Building C houses the campus cafeteria, a fitness center, and various shops for the convenience of Yahoo employees.

This paper focuses on a single Yahoo building, Building A, as an example of what can be accomplished with simple, but effective, demand controls and operations. Building A is a four-story, 160,000 square foot building constructed as north and south wings. It serves mainly as office space, but also contains about 9,000 square feet of computer data centers. First, Building A's current envelope, lighting, HVAC equipment and operating conditions are presented. Next, Building A's current energy use and the effectiveness of its demand limiting control system are investigated. Finally, potential improvements are explored, including adjusting temperature setpoints, using a demand control ventilation system to control outside air levels, extending demand controls into the evening, using day lighting in perimeter spaces, using occupancy sensors to control lighting, and installing window films and cool roofing.

Figure 1: Map of Yahoo Campus in Sunnyvale, California

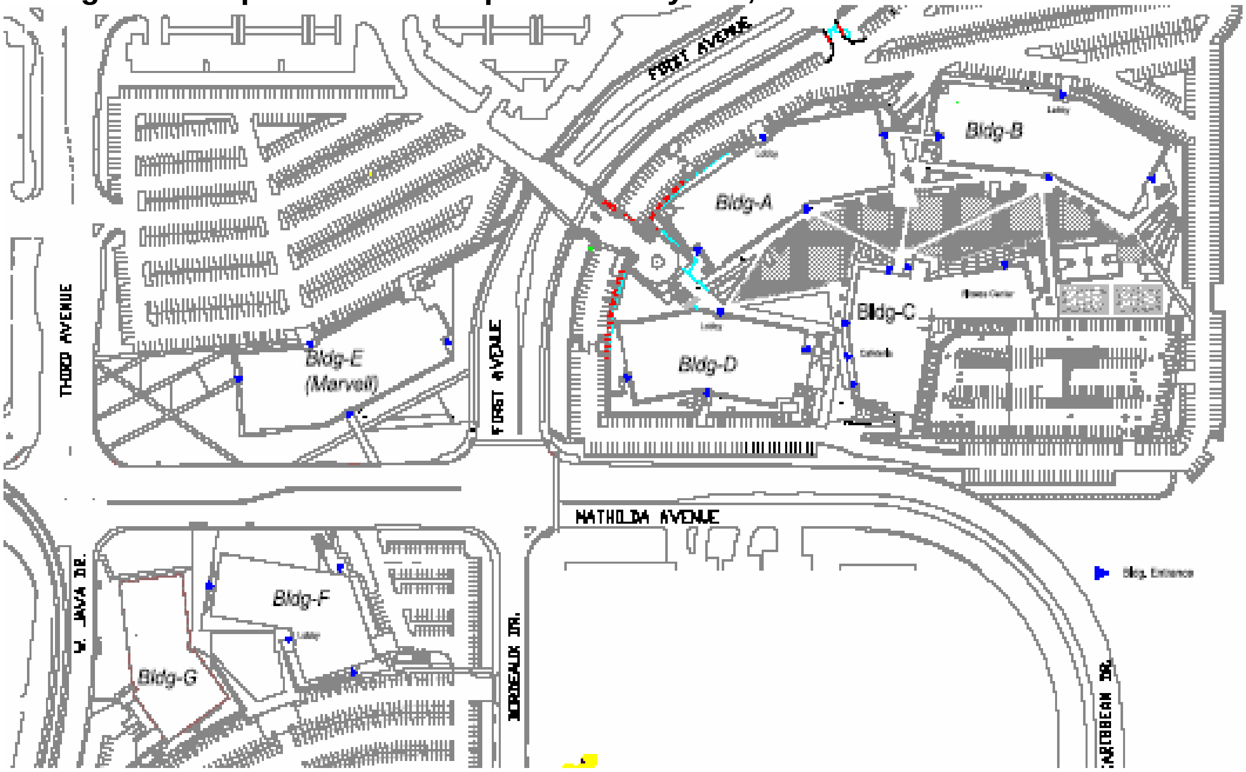


Table 1: Buildings on Yahoo's Campus

Building	# Stories	Square Footage	Usage
A	4	160,000	Offices, data centers
B	4	160,000	Offices, data centers
C	2	65,000	Café, fitness
D	5	200,000	Offices, data centers
E	5	(213,000)	Leased to tenant
F	3	90,000	Offices, data centers
G	3	90,000	Offices, data centers
Total	Not including E	**765,000 sf**	

Figure 2: Yahoo Campus

Description of Building 'A'

The current characteristics and operating conditions of Yahoo's Building A are described below.

Envelope

Like all buildings on Yahoo's campus, Building A was constructed using metal framing and pre-cast concrete with aluminum siding. Walls are insulated to R-13 levels, and the built-up roof has four inches of polystyrene insulation (R-17) under a light gray asphalt capsheet surface with solar reflectance of about 15%. The building uses tinted windows over 30% of the wall surfaces, with visible transmittance of 77%, shading coefficient of 69%, and a 1.115 U-value.

Lighting

Overhead lighting within the building is provided by electronically ballasted T-8 light fixtures. These fixtures were recently re-lamped with energy efficient 28 watt tubes. The lighting is wired for separate control into circuits within three zones, and these circuits are controlled by a GE lighting control system. Lights in zone A and zone B illuminate the right and left sides of each row of cubicles and conference rooms, and zone C lights cover a perimeter space extending about 18 feet in from the building walls and windows. Each cubicle row and conference room in zones A and B has its own circuit, while zone C circuits cover one to five rows of cubicles. No daylighting sensors are installed, but the lighting control system is tied into the overall building control system and lighting use is adjusted according to building electricity demand. Motion sensors also control the lights in all conference rooms and bathrooms.

In addition to overhead lighting, Building A also has some decorative lighting in the corridors and lobbies. These wall sconces are also tied into the lighting control system and can be turned off during periods of high electricity demand. Office desks also have task lights with 13 watt compact fluorescent lamps.

HVAC Equipment

To cool the office areas, Building A uses two 250-ton Mammoth variable air volume packaged air conditioners. These units supply up to 92,000 cfm apiece at an energy efficiency ratio (EER) of 10.14, and can each deliver up to 2,884 MBtu per hour of total (sensible plus latent) cooling. These units generally operate only during scheduled occupied hours.

To cool the computer data centers, Building A uses three 100-ton Trane air-cooled rotary chillers to supply chilled water to five Liebert computer room air conditioner (CRAC) units. These systems run constantly to meet data center cooling and humidity loads. Cooling systems for these data centers were designed to meet loads of 85 watts per square foot, but the centers actually consume as much as 100 watts per square foot of electrical energy. The Trane units can supply up to 720 gallons per minute of 45°F water at an energy efficiency ratio (EER) of 10.7. The Lieberts transfer heat from the chilled water to supply up to 80,900 cfm of 54°F air, for a total of 1707.4 MBtu per hour. The Lieberts can also supply up to 110 pounds of water to the air every hour for humidification.

Building A also has two smaller Sun package units that cool the elevators and equipment rooms. These units can supply up to 2.850 cfm and 97.8 MBtu per hour at a 10.5 seasonal energy efficiency ratio (SEER). Heat is supplied to Building A by an 80% efficient boiler that can deliver up to 3,200 MBtu per hour. This boiler is used for VAV reheat, and runs year round.

Building Operation

Under current building scheduling, office areas in Building A are assumed to be occupied from 6 am to 9 pm on weekdays, and from 7 am to 7 pm on Saturdays, Sundays and holidays. Baseline temperature setpoints during occupied hours are 70°F for heating and 73°F for cooling. During unoccupied hours, setpoints are 55°F for heating and 90°F for cooling.

In order to limit electricity demand and reduce utility bills, Building A's control system is set up to reduce building loads during on-peak and partial-peak time-of-use periods. Yahoo pays for electricity according to Pacific Gas & Electric's E-20 Primary Firm rate schedule. The energy and demand charges for this rate are listed in Table 2. Tables 3 and 4 show how temperature setpoints and lighting levels are controlled when the entire building's demand reaches predefined levels. Demand levels during daytime hours are slightly higher than those in the evening; otherwise the daytime and evening controls are the same.

Table 2: Pacific Gas & Electric E-20 Primary Firm Rate, as of January 1, 2005

Customer Charge	Season	Time-of-Use Period	Demand Charges	Energy Charges
$10.18480 per day	Summer (May-October)	On-Peak (noon – 6 pm)	$11.65 / kW	$0.12795 / kWh
		Partial-Peak (8:30 am - noon, 6 - 9:30 pm)	$2.62 / kW	$0.07792 / kWh
		Off-Peak (9:30 pm – 8:30 am)	--	$0.07612 / kWh
		Maximum Monthly	$3.24 / kW	--
	Winter (November-April)	Partial-Peak (8:30 am – 9:30 pm)	$2.62 / kW	$0.08571 / kWh
		Off-Peak (9:30 pm – 8:30 am)		$0.07691 / kWh
		Maximum Monthly	$3.24 / kW	--

Table 3: Demand Response in Building A, 8:30 am to 6:00 pm

Level	Demand kW	Cooling Setpoint	Heating Setpoint	Lights
0	0 – 520	73°F	70°F	All on
1	520 – 580	74°F	69°F	All on
2	580 – 640	74.5°F	68.5°F	Row C (perimeter) & decorative lights off
3	> 640	75°F	68°F	Row A lights off (half of inner offices & conference rooms)

Table 4: Demand Response in Building A, 6:00 pm to midnight

Level	Demand kW	Cooling Setpoint	Heating Setpoint	Lights
0	0 – 520	73°F	70°F	All on

1	520 – 540	74°F	69°F	All on
2	540 – 600	74.5°F	68.5°F	Row C (perimeter) & decorative lights off
3	> 600	75°F	68°F	Row A lights off (half of inner offices & conference rooms)

Summer 2003 Energy Use Analysis

Building A does not have its own separate utility meter, but its energy use is collected on the sole meter for Buildings A, B, C, D and E. This meter's electricity and demand energy use have been analyzed for the summer of 2003. Figure 3 is a contour plot showing the values of electricity demand for each 15-minute interval over the entire summer season. The x-axis plots each day of the season, and the y-axis plots the hour, while the colors on the contour indicate the different levels of demand. Demand for all five buildings ranged between 1,000 kW and 4,500 kW, and follows fairly consistent daily and weekly patterns. Higher energy demand coincides with warmer weather. The hottest week of the summer, June 23 through 27, was also marked by a power outage that can be spotted as a light blue circle at 11:15 am on Friday, June 27.

Figure 3: Electricity Demand (kW) in Buildings A, B, C, D & E, Summer 2003

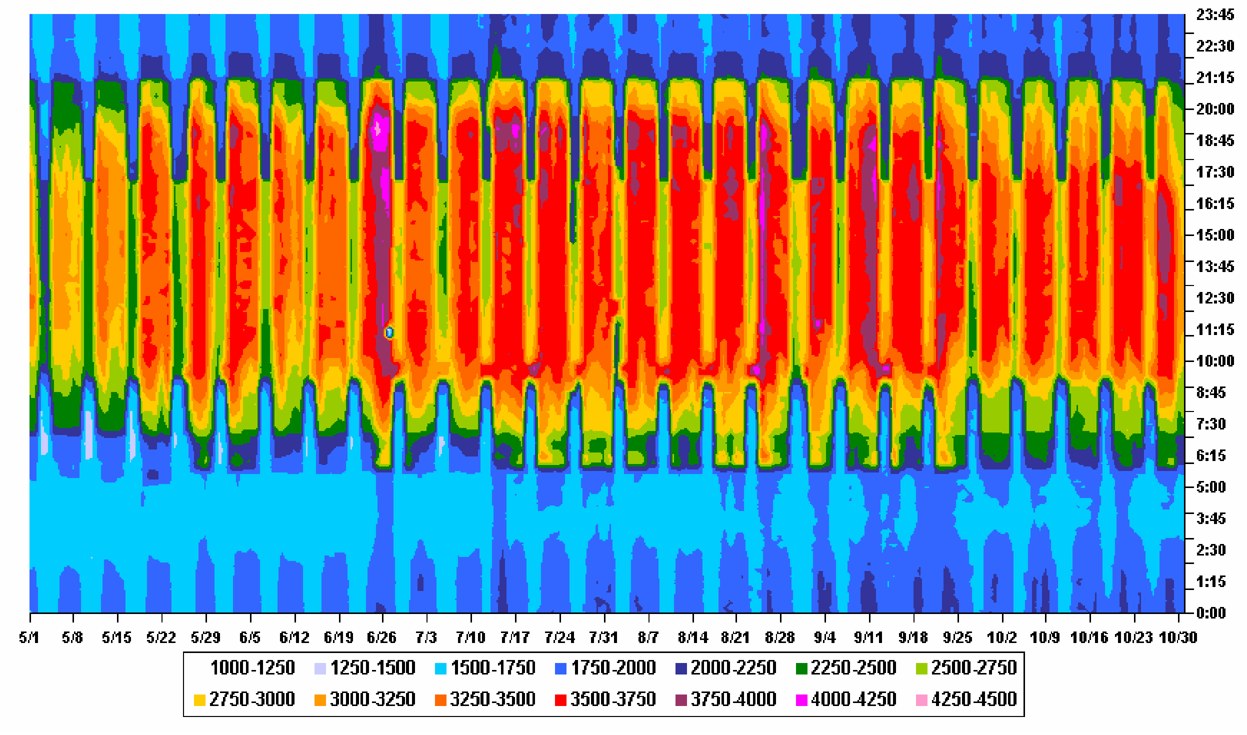


Figure 4: Building A-E Demand, Sunday, June 22 to Saturday June 28, 2003

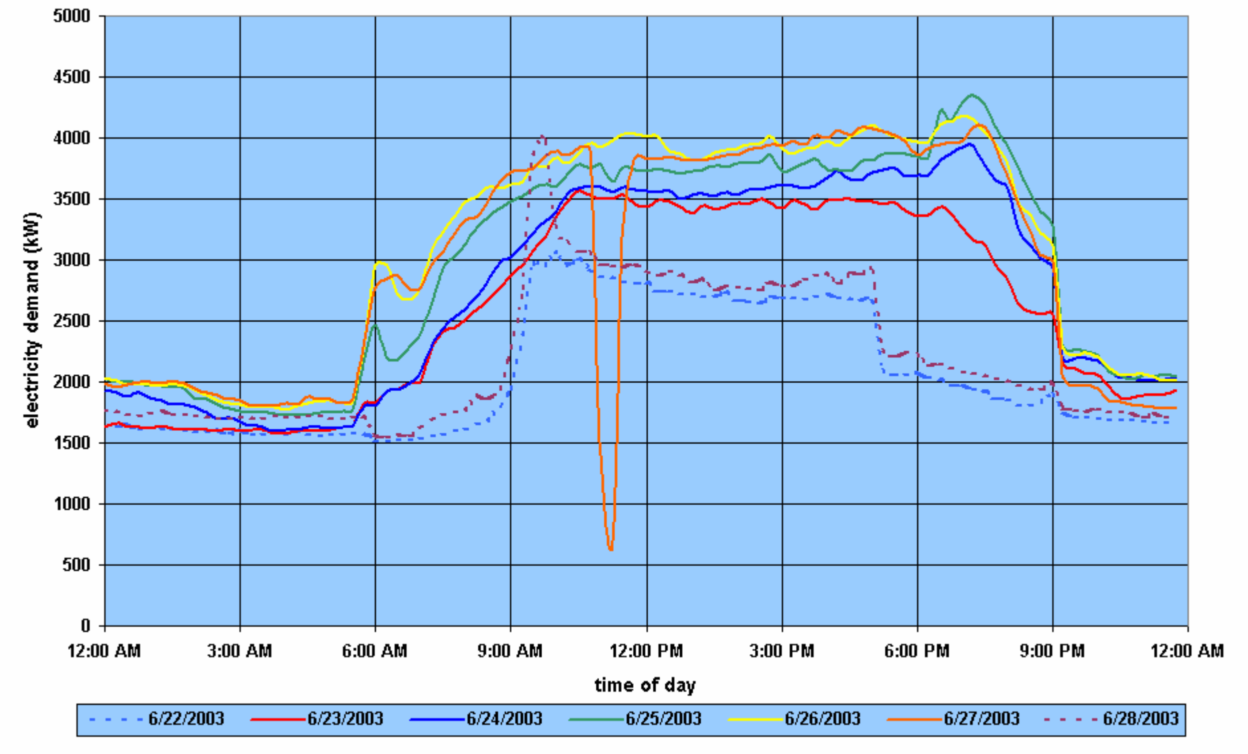


Figure 4 plots electricity demand for the hottest week of the summer, from Sunday, June 22 to Saturday, June 28, 2003. In addition to the power outage on Friday, June 27 at 11:15 am, there are a number of distinctive features shown in Figure 4 that, together with Figure 3, illustrate the energy demand profile of the Yahoo campus:

- Higher daytime energy demand, lower nighttime demand
- Higher weekday energy demand, lower weekend demand
- Demand spikes at 6 am on weekdays
- Demand spikes at 9 am on weekends
- Increased energy demand after 6 pm on weekdays
- Relatively flat weekday demand from 11 am to 6 pm

Lower nighttime energy demand is due to raising the cooling setpoints throughout the buildings and turning off lighting. On weekends, building occupant loads are lighter, therefore electricity use is lower and cooling loads are smaller.

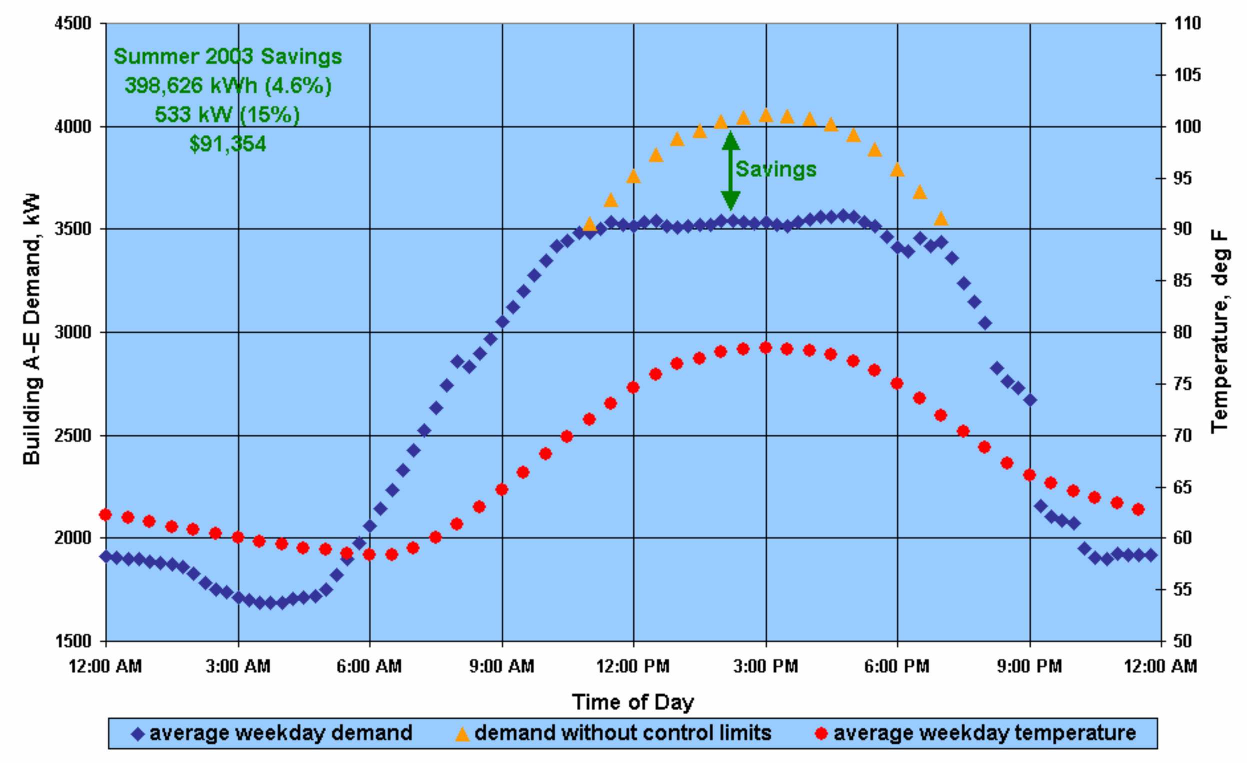
Demand spikes on weekday and weekend mornings, caused by the simultaneous start-up of building equipment, may be cause for concern. Increases in demand after 6 pm may also be of concern, and occur when the daytime demand control limits in Table 3 are lifted at 6 pm returning system setpoints and lighting levels to normal. The effect of eliminating these demand spikes is evaluated in the Efficiency Opportunities section of this paper.

The flat demand on weekdays from 11 am to 6 pm shows the effectiveness of setting simple demand response levels to curb energy use, like those listed in Tables 3 and 4 for Building A.

Reducing cooling setpoints and turning off blocks of lights keep electricity demand from increasing with outside temperature over the afternoon.

Figure 5 shows the average weekday energy demand (blue diamonds) for Buildings A through E during the summer of 2003, together with the average outdoor temperature (red circles). A correlation was made between outdoor temperature and energy demand for the operating hours without controls limits (yellow triangles), and was used to estimate the energy savings of the existing demand controls. Note that demand controls were only in effect in Buildings A, B and D, and not being used in Buildings C and E. Simply by reducing lighting levels and raising the cooling setpoint when different demand levels were reached, total energy use was reduced by 5%, peak demand went down 15%, and $91,354 was saved during the summer of 2003.

Figure 5. Summer 2003 Weekday Demand & Outdoor Temperature, Buildings A-E



January 2005 Control System Data Analysis

In addition to the 2003 utility bill information, data was collected from the control system during January of 2005. This data included the overall building energy demand, individual zone conditions and operational characteristics of the rooftop package units in various campus buildings. Figure 6 shows the energy demand in Buildings A, B, C and D over the week from Thursday, January 20 to Wednesday, January 27. Energy demand is clearly reduced at night and over the weekend, on January 22 and 23.[1]

Figure 6: Energy Demand in Buildings A, B, C & D, January 20-27, 2005

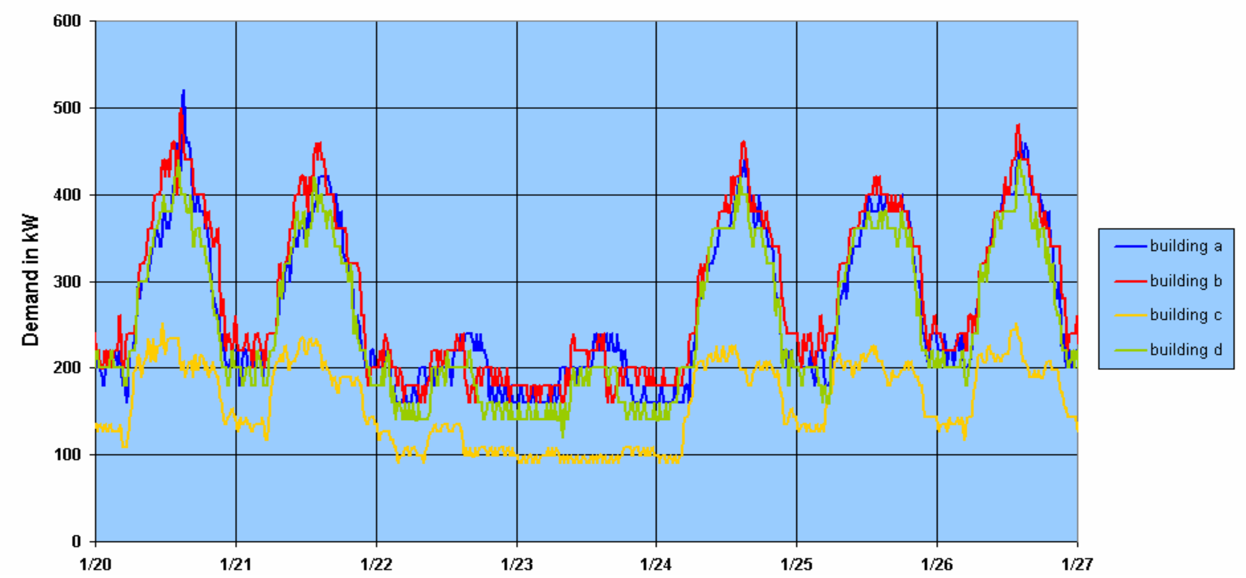


Figure 7 plots air temperatures in various zones around the perimeter of Building A on January 24, 2005. This graph illustrates the effect of solar heating over the course of this winter day. Zone 13, facing due east, shows the strongest solar heating effect, with a large temperature spike at 9 am. Traveling around the building's perimeter, zone temperatures peak later in the day as the sun travels from east to west.

Figure 8 illustrates the behavior of zone RH-A-4-1, located on the southwest corner of the 4th floor of Building A. The upper graph in Figure 8 shows cooling and heating setpoints and the zone temperature. The lower graph in Figure 8 plots the flow rate and temperature of the supply air to the zone. Most notable here is that heated air is being delivered to the space on five mornings, even though the zone temperature is only barely below the 70°F heating setpoint. The zone then heats up over the course of the day, and is then cooled in the afternoon – consequently removing the heat that was added in the morning. This addition and subsequent removal of heat occurs in many of Building A's zones during the January time period we studied.

---

[1] It is interesting to note that Buildings A, B and D have almost identical patterns of energy demand. Buildings A and B are virtually identical 4-story buildings, but Building D is a 5-story building and would be expected to use more energy.

Figure 7: Building A, 4th Floor Perimeter Zone Temperatures, January 24, 2005

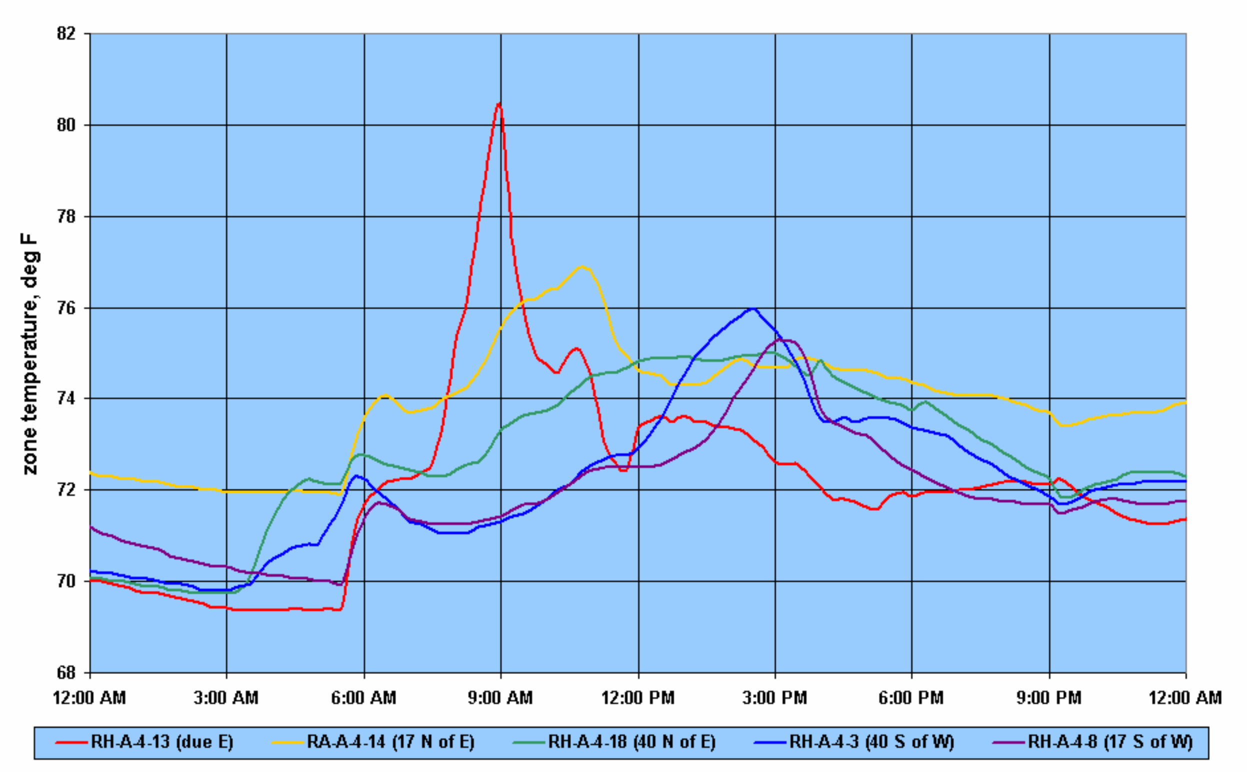


Figure 8: Building A, Zone 1, 4th Floor, West Perimeter, January 20-27, 2005

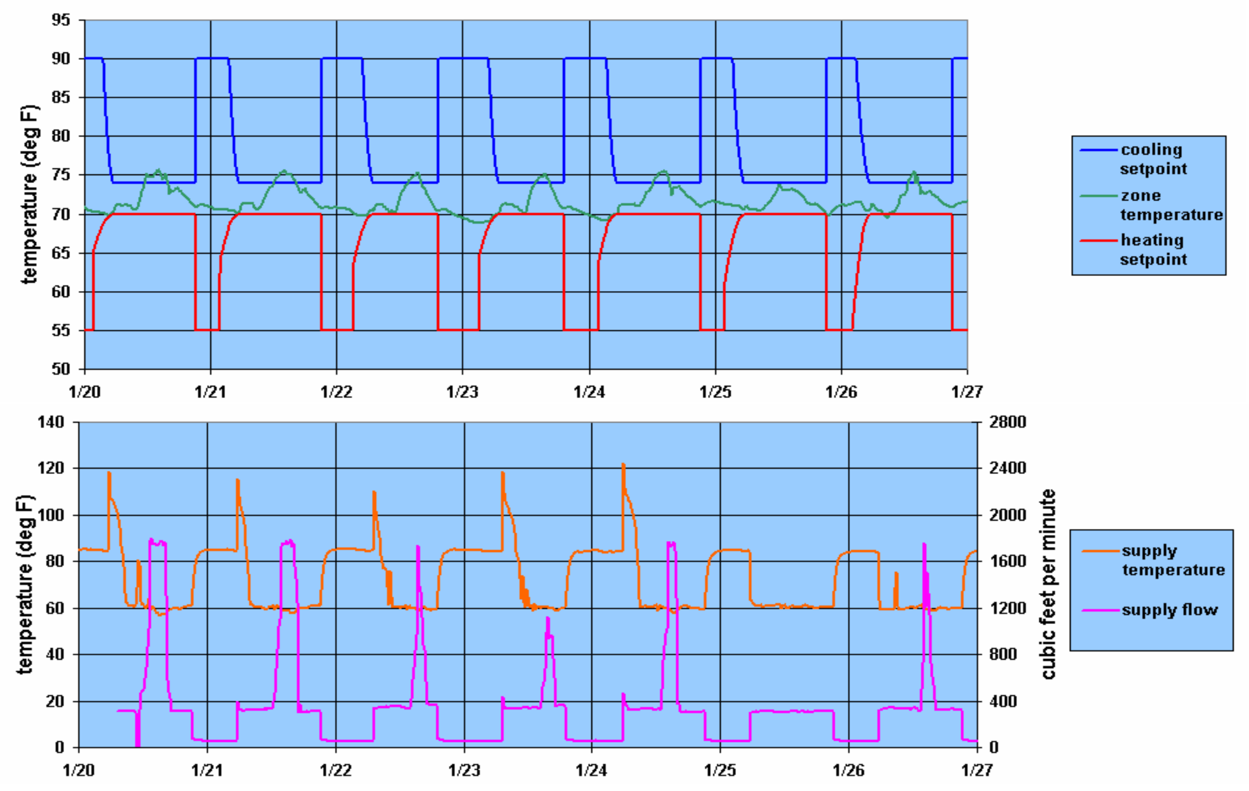
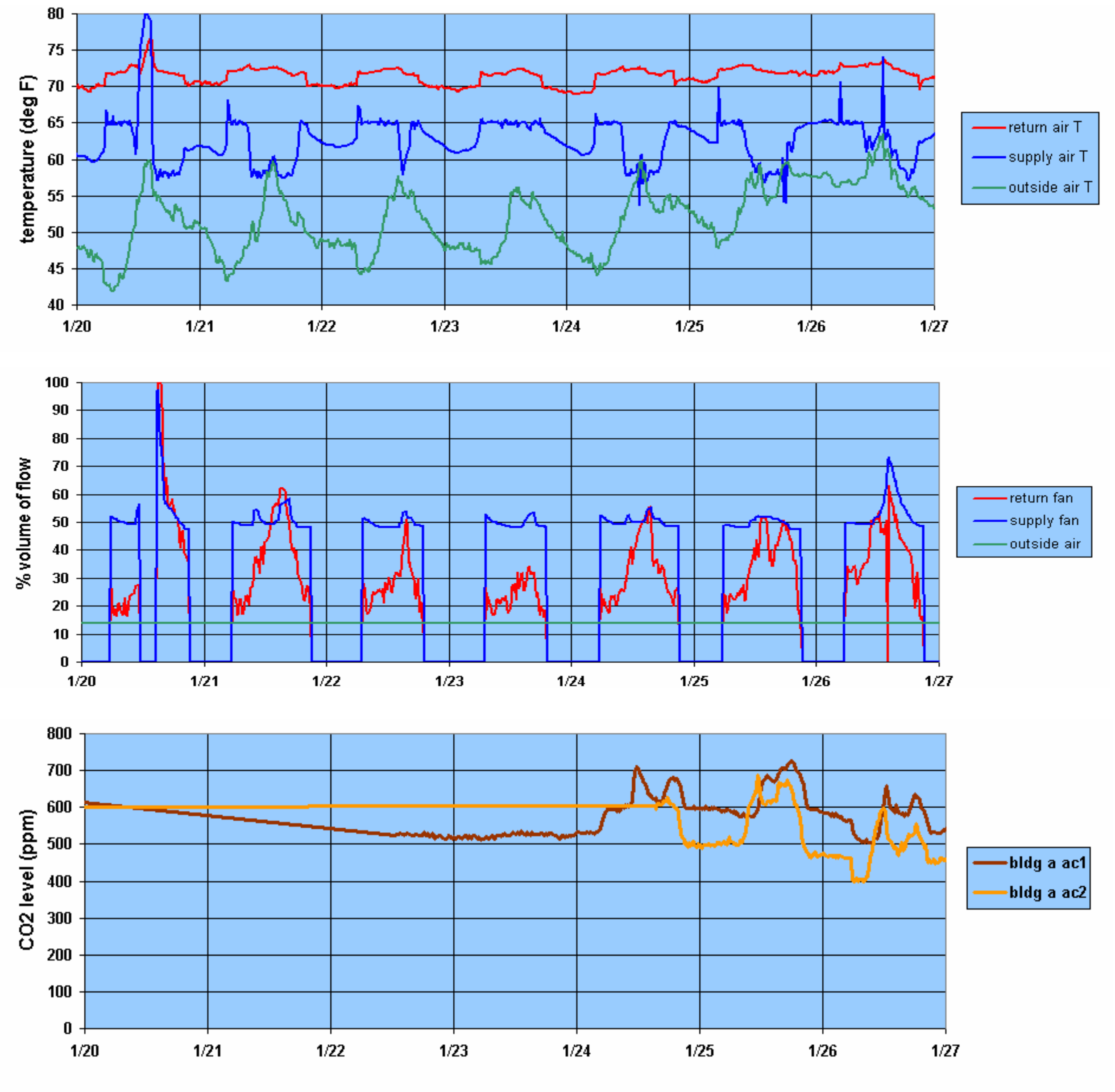


Figure 9 plots information from the rooftop package units during the week of January 20 – 27, 2005. The top graph shows supply, return and outside air temperatures of package unit AC-2. The middle graph shows the percentages of supply, return and outside air flows. Supply and return flows vary over the day, and are turned off at night, while a constant amount of outside air is drawn into the building, day or night, regardless of the building's occupancy. The lowest graph in Figure 9 shows the concentration of carbon dioxide in the return air to each of the two rooftop package units, only recorded correctly from January 24 to the 27. Note the two humps in each day's CO2 levels, with reduced levels during lunchtime as people leave the building.

Figure 9: Building A Rooftop Package Unit Operation



Building 'A' Efficiency Opportunities

A number of energy savings opportunities have been identified and investigated for Building A. Seven measures are recommended for implementation:

- Adjusting heating and cooling setpoints
- Controlling outside air relative to indoor CO2 levels
- Eliminating evening demand spikes
- Using daylighting in perimeter spaces
- Using occupancy sensors to control office lighting
- Installing window films
- Installing a cool roof

Two other measures were investigated, but are not recommended for implementation:

- Shutting down the boiler during the summer months (not recommended)
- Eliminating weekdays and weekends start-up demand spikes (not recommended)

The next sections of this paper describe how energy savings were estimated for each of these opportunities, and presents the results together with estimated costs of installing measures.

Using DOE-2 Modeling to Estimate Energy Savings

Many of the efficiency opportunities listed above were evaluated using a DOE-2 energy model of Building A. Building A is modeled as a rectangular 4-story building, 320 feet long by 125 feet wide. In order to get the correct solar loading, the orientations of both building wings are weight-averaged to come up with a single azimuth for the model. Weather data for California climate zone 4 was used. Electricity time-of-use costs were scheduled according to PG&E's E-20 Primary Firm rate as of January 2005, listed in Table 2, and natural gas costs were assumed to be equal to the average monthly rates in 2004 for PG&E's G-NR2 Large Commercial Customer schedule listed in Table 5.

Table 5: Pacific Gas & Electric G-NR2 Natural Gas Service to Large Commercial Customers, Average of 2004 Monthly Rates

Customer Charge	Season	First 4,000 therms	Excess therms
$4.95518 per day	Summer (May-October)	$0.87255	$0.77532
	Winter (November-April)	$0.93570	$0.81555

Adjusting HVAC Setpoints

The DOE-2 model for Building A is used to evaluate the effects of changing temperature setpoints. Although actual setpoints vary throughout the building's zones, it is estimated from the January 2005 control system data that the building's average heating and cooling setpoints are currently 70°F and 73°F respectively, and these setpoints are adjusted downwards (for heating) and upwards (for cooling) when the demand levels listed in Tables 3 and 4 are reached. These baseline 70°F / 73°F setpoints are fairly conservative, and there is a narrow range of only 3°F between heating and cooling setpoints. As was seen in Figure 8, in reheat systems this can lead to some potentially wasteful heating and subsequent cooling of building spaces. DOE-2 modeling was done to estimate the effects of changing weekday baseline setpoints to 69°F / 74°F, with adjustments to 68°F / 75°F under Level 1 conditions, and 67°F / 76°F under Level 3 conditions. Weekend and holiday operating hour setpoints are held at 68°F / 75°F. Table 10 lists the potential savings available from adjusting setpoints.

Table 10: Adjusting HVAC Setpoints in Building A – Annual Savings*

Option	Use Savings (kWh)	Demand Savings (kW)	Gas Savings (therms)	Utility Savings ($)	Installation Cost ($)	Payback Period (years)
69-68-67 heat / 74-75-76 cool, 68/75 weekend	49,028	22	1,713	$9,712	$1,100	0.1

* From the current 70-69-68 heat/73-74-75 cool, 70/73 weekend.

Controlling Outside Air

Building A currently brings in a constant 26,000 cubic feet per minute (cfm) stream of outside air, which represents 14% of the maximum 184,000 cfm that can be supplied to the building by its two supply fans. Facility managers believe that California Title 24 mandates this level of outside air. The 2001 Title 24 Standard calls for a building to be able to supply the larger of either 0.15 cfm per square foot of building area, or 15 cfm for each building occupant, whenever the space in normally occupied.[2] For Building A, this means the minimum level of outside air that must be provided during operating hours is the larger of:

$$\text{OA} = (0.15 \text{ cfm / square foot}) \times (160{,}000 \text{ square feet}) = 24{,}000 \text{ cfm, or,}$$
$$\text{OA} = (15 \text{ cfm / person}) \times (850 \text{ people}) = 12{,}750 \text{ cfm,}$$

or only 24,000 cfm, indicating that the outside air being provided now, 26,000 cfm, may be a bit high compared to the actual requirement in place at this time.

Under the 2005 Title 24 Standard, which takes effect October 1, 2005, considerably lower outside air levels may be supplied.[3] The 2005 Standard calls out an important exception,

---

[2] Section 121 (b) 2 and Table 1.F, 2001 Energy Efficiency Standards for Residential and Non-Residential Buildings, Effective June 1, 2001, California Energy Commission, P400-01-14, August 2001.

[3] Section 121 Requirements for Ventilation, 2005 Building Energy Efficiency Standards for Residential and Non-Residential Buildings, Effective October 1, 2005, California Energy Commission, P400-03-001F, September 2004.

allowing buildings with demand control ventilation systems (DCVS) to supply less outside air, as long as they keep carbon dioxide within the building below certain levels.

A DCVS monitors CO2 levels in the building and adjusts ventilation levels accordingly. Building A appears to meet most of the requirements for the DCVS: it has two CO2 monitors, one in the return air duct to each of the two rooftop package units. Building A's control system currently checks these levels and opens dampers to provide more than the minimum amount of outside air if needed. To comply with the DCVS requirements, Building A may only need a few additional CO2 sensors located within zones such as conference rooms, where more than 25 people per 1,000 square feet tend to gather.

If there is no outside air CO2 sensor (as is the case at Yahoo), then the outside air is assumed to have a constant CO2 level of 400 ppm, and the indoor air must keep CO2 levels below 1,000 ppm. Data collected from the control system during January of 2005 yielded about 2 ½ days of CO2 data from the two CO2 sensors in Building A (see Figure 9). Although this data is not completely indicative of the building's year-round operation, it does show that CO2 levels were well below the 1,000 ppm limit. CO2 levels started in the morning at 400 to 600 ppm, and tended to increase by 200 ppm or less during occupied hours. The highest CO2 level recorded during these winter days was about 725 ppm. This indicates that less outside air could indeed be used in Building A.

Some calculations have been made to determine how much lower outside air levels can be reduced, while staying below the 1,000 ppm CO2 maximum. ASHRAE has recently released new guidelines for calculating ventilation air, in the form of Addendum 62n to ANSI/ASHRAE Standard 62, *Ventilation for Acceptable Indoor Air Quality*. This guideline separates the amount of air needed for occupants (people-source contaminants) from the amount of air needed to ventilate the building itself (building-source contaminants). The old Standard 62 relationship called for 20 cfm per person, while the new equation in Addendum 62n calls for 5 cfm for each person *plus* 0.06 cfm for each square foot of office and conference room spaces.[4] For Building A, this becomes:

$$\text{Minimum outside air (Addendum 62n)} = (5 \text{ cfm / person}) \times (850 \text{ people}) + (0.06 \text{ cfm / square foot}) \times (160{,}000 \text{ square feet}) = 13{,}850 \text{ cfm},$$

…in other words, almost half of the 26,000 cfm that is currently being delivered to Building A. A simple check indicates that this value may be reasonable, since at 26,000 cfm, CO2 levels increase 200 ppm during occupied hours to about 700 ppm; with half the outside air, CO2 increases during occupied hours would be expected to double to 400 ppm, raising CO2 levels to a maximum of about 900 ppm.

The DOE-2 model for Building A was run to see how much energy and utility bill savings could be achieved by reducing outside air levels, and Table 11 lists the results. To reduce the outside air levels to 24,000 cfm from the current 26,000 cfm assumes installation costs based on two hours of labor at $110 an hour. To reduce ventilation levels further using a DCVS, installation costs include adding four additional CO2 sensors to Building A conference rooms at a purchase

---

[4] Dennis Stanke, "Addendum 62n, Single-Zone and Dedicated OA Systems", *ASHRAE Journal*, October 2004, pp 12–20.

cost of $335 plus $170 installation for each sensor. Labor to adjust the control system so that it functions as a DCVS is expected to take 5 hours of work at $110 an hour.

Table 11: Reducing Outside Air to Building A – Annual Savings*

Option	Use Savings (kWh)	Demand Savings (kW)	Gas Savings (therms)	Utility Savings ($)	Installation Cost ($)	Payback Period (years)
24,000 cfm	2,922	8	549	$1,484	$550	0.4
13,850 cfm w/DCVS	18,275	46	1,996	$7,443	$2,570	0.4

* From the current 26,000 cfm.

Eliminating Demand Spikes

As shown in Figures 3 and 4, equipment start-up in Buildings A through E causes demand spikes of 500 watts on weekday mornings and 1,000 watts on weekend mornings. Another spike of up to 500 watts is also seen on weekday evenings, after the day's demand control measures are lifted. If equipment start-up is staggered, instead of taking place all at once, the weekday and weekend demand spikes could be avoided. Demand control measures could also be extended until 8 pm to eliminate evening demand spikes.

Calculations were made using the data from the summer of 2003 to determine how much could be saved on utility bills if these demand spikes were eliminated. Electricity demand and use data were smoothed to replace demand spikes with linear values on weekdays from 5 am to 9 am, and from 5 pm to 8 pm, and on weekends from 8 am to 11 am. New utility charges for these values were then calculated. Table 13 shows the reductions in utility charges due to reducing demand spikes in Buildings A through E. Installed costs are for 20 hours of labor at $110 an hour.

Under the current time-of-use rates for electricity (see Table 2), eliminating weekday and weekend morning spikes in electricity demand does not appear to be a big money saver. These spikes occur during off-peak hours, when there are no additional demand charges and usage charges are low. So while demand during this morning period could be lowered, this reduction will not translate into any significant utility bill savings. Reducing morning demand spikes is therefore not a recommended action.

Eliminating weekday evening spikes does save some money, since this reduces both electricity demand and use that is priced at partial-peak rates. Note that this savings estimate is for Buildings A through E, not just for Building A.

Table 13: Eliminating Demand Spikes in Buildings A – E – Annual Savings

Option	Use Savings (kWh)	Demand Savings (kW)	Gas Savings (therms)	Total Savings ($)	Install Cost ($)	Payback Period (years)	Action
Weekday morning spike	1,490	0	0	$114	$2,200	19.3	Not recommended

Weekend morning spike	- 13,213	0	0	- $1,011	$2,200	negative	Not recommended
Weekday evening spike	1845	161 (partial-peak)	0	$5,464	$2,200	0.4	Recommended

Daylighting

Building A does not currently have any daylight sensors, but its lighting system is wired so that overhead lighting in perimeter spaces can be separately controlled. The DOE-2 model is used to estimate savings from using daylight sensors to control the lights in a simple on-off fashion within a 15 feet interior perimeter around the building. It is assumed that light levels in these areas can be reduced to 30 foot-candles, as is deemed suitable for hallways, general exercise, bathrooms, and the use of keyboards[5]. A light level of 50 foot-candles is more suitable for reading, but task lights (13 watt CFL) are available in each office if needed. The DOE-2 model not only calculates the energy savings from lighting reductions, but also finds the cooling energy reductions and heating penalties that result from lower heat loads to the building.

To calculate installation costs, it is assumed that 80 daylight sensors are needed in Building A at a purchase price of $85 plus $170 installation cost for each sensor.

Table 8: Daylighting Used in Perimeter Spaces of Building A – Annual Savings

Option	Energy (kWh)	Demand Savings (kW)	Gas Savings (therms)	Utility Savings ($)	Installation Cost ($)	Payback Period (years)
Daylighting	144,012	75	-1,345	$23,963	$20,400	0.9

Lighting Occupancy Sensors

Occupancy sensors are already being used to control lights in conference rooms and bathrooms, but are not in use in office areas. The Building A DOE-2 model was used to predict the effects of using occupancy sensors, not just on the lighting needs, but on the building's heating and cooling energy. Lighting levels are first assumed to stay constant at 80% of full lighting levels during all operating hours (from 6 am to 9 pm weekdays, from 7 am to 7 pm weekends and holidays) and stay at 5% overnight. To simulate the effects of occupancy sensors, lighting levels are varied with occupancy from 5% at night to 90% during weekday hours, but with light levels tapering up and down over the first and last hours of the occupied period. Weekend and holiday schedules assume that when occupancy sensors are used light levels will peak at 30% of normal. Table 9 lists energy savings estimates due to the use of occupancy sensors. Installation costs of these sensors are calculated assuming that 80 occupancy sensors will be needed, at a purchase price of $106 plus another $106 for installation of each sensor. Costs also take into account a rebate of $44 per sensor currently being offered by Pacific Gas & Electric's 500 Plus Peak Energy Program.

---

[5] http://www.lithonia.com/schools/light_levels/

Table 9: Lighting Occupancy Sensors in Building A – Annual Savings

Option	Energy (kWh)	Demand Savings (kW)	Gas Savings (therms)	Utility Savings ($)	Installation Cost ($)	Payback Period (years)
Occupancy Sensors	301,998	16	-4,725	$18,091	$13,440	0.7

Window Films

Yahoo is already considering installing window films on the west-facing windows of Buildings A and B. They have received a quote to install Panorama 4 mil Sterling-40 window films for $4 to $5 per square foot. Pacific Gas and Electric currently offers a rebate of $1.35 per square foot for installing window films under their Express Efficiency program. These films have a U-value of 1.015, 40% visible light transmittance and shading coefficient of 42%. Taken together with the existing windows (U-value 1.115, visible transmittance 77%, shading coefficient 69%), windows with films are modeled in DOE-2 as having a U-value of 0.53, visible transmittance of 31% and shading coefficient of 29%. DOE-2 was used to estimate the effects of adding window films to either the west, east or south windows of Building A, as well as adding films to west, east and south windows at the same time. Estimates of energy savings, installation costs, and payback periods are given in Table 6.

Table 6: Adding Window Films to Building A – Annual Savings

Option	Use Savings (kWh)	Demand Savings (kW)	Gas Savings (therms)	Utility Bill Savings ($)	Installation Cost ($)	Payback Period (years)
West windows	51,264	60	5	$12,895	$18,428	1.4
East windows	28,001	17	469	$5,081	$18,428	3.6
South windows	17,706	7	-40	$3,109	$7,228	2.3
E, S & W windows	90,928	83	376	$20,374	$44,084	2.2

Cool Roofing

The existing roof surface is a light gray asphalt cap sheet with an assumed solar reflectance of about 15%. This roof is only 4 years old and is in good condition, but could benefit from the addition of a cool roof coating. This bright white coating would not only save energy, but would protect the underlying built-up roof, lengthening its lifespan from an estimated 14 years to 50 or more years, with periodic re-coatings every 10 years. A cool roof coating is assumed to have solar reflectance of 70%, and to cost about $1.00 per square foot to install. Incentives of $0.08 per square foot are also available under Pacific Gas & Electric’s 500 Plus Peak Program. Resulting savings estimates are listed in Table 7. The payback period stated does not reflect savings on roof maintenance costs over the life of the roof.

Table 7: Adding a Cool Roof Coating to Building A – Annual Savings

	Use	Demand	Gas	Utility Bill	Installation	Payback

Option	Savings (kWh)	Savings (kW)	Savings (therms)	Savings ($)	Cost ($)	Period (years)
Cool Roof	64,120	58	-3,838	$9,917	$36,800	3.7

Summer Boiler Shutdown

The 3.2 MBtuh boiler on Building A's variable air volume reheat system runs continuously throughout the year. It is possible to save both natural gas and electricity by shutting down the boiler during part of the summer, but it is important not to compromise comfort in the building if this is done. Building A's DOE-2 model was used to estimate energy savings and zone temperature changes when the boiler is shut down over various summer periods. Table 12 lists these effects. Utility bill savings have to be weighed against unmet heating loads and minimum zone temperatures. This compromise in comfort does not appear to be worth the savings, therefore this measure is not recommended.

Table 12: Building A Boiler Shutdown in the Summer – not recommended

Option	Use Savings (kWh)	Demand Savings (kW)	Gas Savings (therms)	Utility Savings ($)	Unmet Heating Loads* (hrs)	Min Zone T* (°F)
Off July - August	7,354	7	124	$1,076	81	64
Off June - September	18,634	7	438	$2,986	220	61
Off May - October	39,648	7	1,235	$7,667	466	55

Compared to 0 hours of unmet heating loads and 71°F minimum zone temperature when the boiler is on all summer.

Recommended Energy Efficiency Measures

Based on the analysis presented in the previous section of this report, the measures listed in Table 14 are recommended for implementation.

Table 14: Recommended Energy Efficiency Measures

Building A Option	**Use Savings (kWh)**	**Demand Savings (kW)**	**Gas Savings (therms)**	**Utility Savings ($)**	**Installed Cost ($)**	**Payback Period (years)**
Adjust HVAC Setpoints	49,028	22	1,713	$9,712	$1,100	0.1
Reduce Outside Air to 13,850 cfm	18,275	46	1,996	$7,443	$2,570	0.4
Eliminate Evening Demand Spikes*	1,845	161 (partial-peak)	0	$5,464	$2,200	0.4
Daylighting	144,012	75	-1,345	$23,963	$20,400	0.9
Lighting Occupancy Sensors	301,998	16	-4,725	$18,091	$13,440	0.7
Films on E, S & W Windows	90,928	83	376	$20,374	$44,084	2.2
Cool Roof	64,120	58	-3,838	$9,917	$36,800	3.7
TOTAL	**670,206**	**300** (on-peak only)	**-5,823**	**$94,964**	**$120,594**	**1.3**

* This measures applies to Buildings A-E, not just Building A.

HVAC setpoints in Building A vary from zone to zone, as a product of numerous adjustments to the control system based on occupant feedback. However, the baseline heating and cooling setpoints found in the sample of zones analyzed are firmly within the middle of the comfort range, at 70°F for heating and 73°F for cooling. Significant energy savings can be obtained by expanding this range by one degree on either side, to 69°F for heating and 74°F for cooling. Increasing the band between heating and cooling can also eliminate the problem of heating in the morning and then subsequently removing this heat in the afternoon, as shown in Figure 7. In the demand response mode used in Building A, heating temperatures would range from 69°F to 68.5°F at Level 1, 68°F at Level 2 and 67°F at Level 3, and cooling temperatures would change from 74°F to 74.5°F at Level 1, 75°F at Level 2, and 76°F at Level 3. Extending weekend and holiday temperature levels one more degree, to 68°F for heating and 75°F for cooling, is also recommended. The installation cost for this measure is only an estimate of the time needed to reprogram the control system and adjust temperatures in each zone based on occupant feedback. Getting a firmer estimate of this adjustment cost is recommended before proceeding to implement this measure.

When the 2005 version of Title 24 goes into effect on October 1st, Building A may be able to reduce its outside air intake by almost half. There is currently a minimum of 26,000 cfm being brought into the building, but preliminary calculations indicate that as little as 13,850 cfm may be enough to keep Building A properly ventilated. More outside air and CO2 data needs to be collected under various weather and occupancy conditions before this can be confirmed, but significant energy savings are very likely. It is recommended that more data be collected, and effort needed to reprogram the control system to lower ventilation levels be evaluated more fully.

Extending the action of demand response controls through the evening hours, until the end of the partial peak time-of-use period, is recommended. This will eliminate spikes in electricity demand and use that are costing more than $5,000 a year in Buildings A through E. The scope of work and the cost of adjusting the control system need to be estimated more accurately before implementing this measure.

The use of day lighting to light perimeter spaces and occupancy sensors to control lighting are both attractive energy savers. It is recommended that estimates for the installation of daylight and occupancy sensors and accompanying controls be obtained from two or more reliable installers in order to more fully evaluate this option.

The facility manager is currently interested in installing films on the west windows of Buildings A and B, but this analysis found that payback periods for adding films to the east, south and west windows are all below one year. These films are not only cost-effective, but they can also help reduce the temperature spikes due to solar heating seen in perimeter spaces throughout Building A (see Figure 6).

Although the payback period for adding a cool roof is fairly high at 3.7 years, this measure is still recommended for implementation for two reasons. First, Building A’s built-up roof with an asphalt cap sheet surface is currently in good condition, but the addition of a cool roof coating can help preserve this roof long beyond its 14 year projected life span. Keep in mind that the 2005 version of Title 24, which takes effect October 1, 2005, mandates the use of cool materials on new roofs and when retrofitting existing roofs, so any future roof work will need to use cool materials anyway. Installing a cool coating now is less expensive than waiting until the roof needs to be repaired before coating, and the energy savings will accrue sooner rather than later. Second, there is good evidence that cool roof energy savings predictions using DOE-2 are very conservative, and may be under-predicting savings by as much as 50%.[6] It is recommended that bids be solicited for the addition of cool roof coatings to Building A.

---

[6] Gartland, Konopacki and Akbari, Modeling the Effects of Reflective Roofing, Lawrence Berkeley National Laboratory, Report No. LBNL-38580, Berkeley, CA, 1996.

Summary

Yahoo's Building A control system currently does an excellent job of keeping electricity demand flat during the on-peak time-of-use period, from noon to 6 pm on weekdays. By simply adjusting thermostat setpoints and reducing lighting levels when energy demand reaches certain levels, energy use is reduced 5% and energy demand falls by 15%.

However, Yahoo can more effectively manage electricity demand by implementing measures to reduce demand *before* critical levels are reached. Six measures were found that can reduce Building A's electricity demand and use: 1) adjusting HVAC setpoints to a lower heating temperature and higher cooling temperature, 2) reducing ventilation levels by up to half while monitoring CO2 levels to ensure adequate indoor air quality, 3) extending demand response controls through the evening's partial-peak hours, 4) making use of daylight in perimeter spaces, 5) using occupancy sensors to control lighting, 6) adding films to east-, south- and west-facing windows, and 7), installing a cool roof coating. All together, these seven measures can save another 670,200 kWh (7.8% of total energy use), 300 kW (8.4% of maximum demand) and $95,000 annually.

After these measures are implemented, it is likely that Building A's demand response levels, listed in Tables 3 and 4, can be reduced to lower values, for even more efficient control system operation.