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CONTRACT REPORT

Review of Chilled Water and Electricity Use at the West and North/South Buildings of the Orange County Convention Center

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Scope of Work Task 1
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Abstract

The Orange County Convention Center (OCCC) has the 2nd largest convention exhibition space in the nation. Two primary buildings provide about seven million square feet of conditioned space to approximately 1.5 million visitors each year. In efforts to reduce energy consumption, OCCC began implementing several energy conservation measures beginning in 2005 and continuing over the last 2 years with plans to continue additional efforts in the future. Examples of the types of energy conservation involved changing lighting and HVAC schedules and control methods, replacement of motors with higher efficiency, and turning off power to other unused equipment. An analysis of monthly chilled water and electricity used by the West and North/South Buildings has been completed in an effort to investigate reductions in energy use resulting from conservation measures. This work is intended as a macro analysis summarizing the impact of groups of measures rather than the impact of individual measures. The results may also be used as a basis of comparison to future measures as well. Three different periods during years 2005, 2006, and 2007 are investigated to evaluate the reductions in energy and energy costs

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Executive Summary

The primary objective of this study was to evaluate and report on gross energy savings related to previously completed energy management measures at the West and North/South buildings of the Orange County Convention Center (OCCC). An energy billing analysis study began during the summer of 2007 based on collected electricity and chilled water energy utility bills from January 2005 through June 2007.

Three periods during 2005, 2006 and 2007 were identified that represent different stages of energy management efforts. The most significant efforts were completed by the latter half of 2005 with additional efforts completed in 2006. Figures A and B show a substantial reduction in monthly energy costs from 2005 to 2007. Since rates change from month to month and tend to increase year after year, the costs are shown using the same rates derived from an average of 2007 rates. Much of the variability seen in these graphs for a given month from year to year is explained by changes in weather. Because weather has significant impacts upon energy usage, data was normalized using outside weather conditions in linear regression least- squares analysis explained in further detail later in this report. Adjustments made for variability in occupancy did not explain the remaining variability in best-fit linear regression analysis.

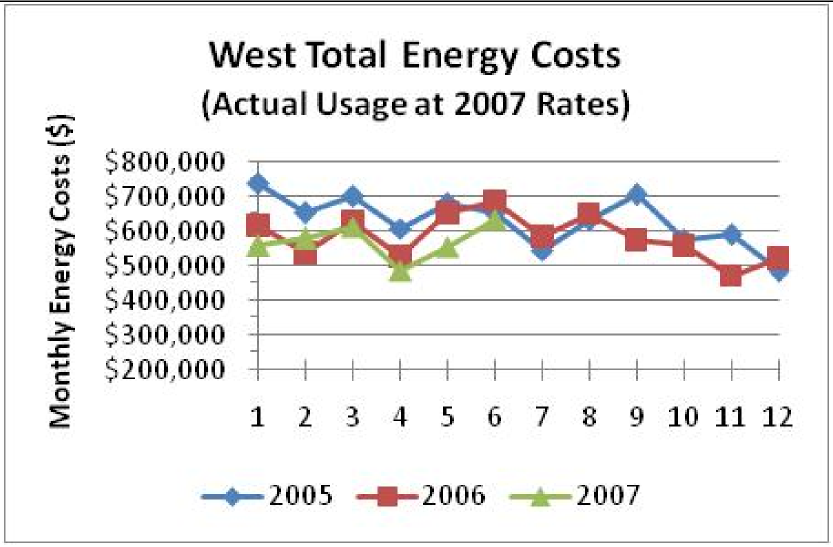


***Figure A** monthly cost for electricity kWh, kW and chilled water ton-hours and tons (excludes taxes and fees).*

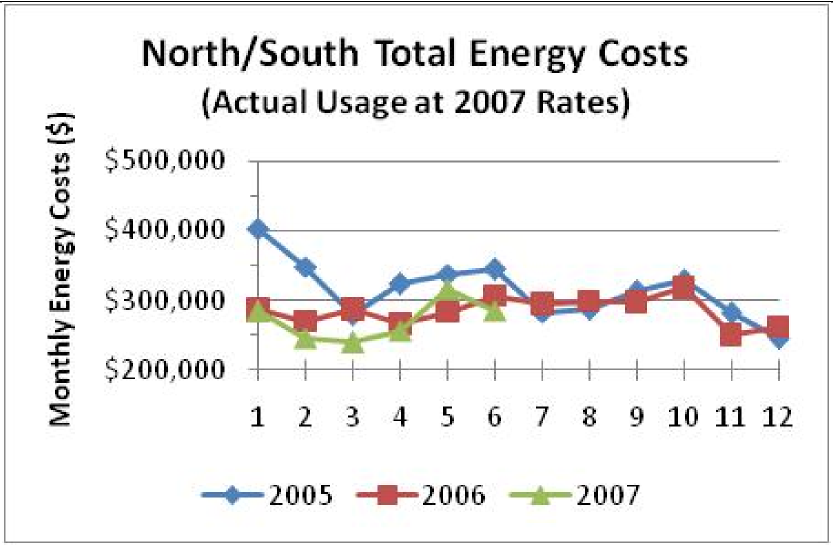


***Figure B** monthly cost for electricity kWh, kW and chilled water ton-hours and tons (excludes taxes and fees).*

Conclusions

This study finds substantial reductions in electricity and chilled water energy have occurred in the West and North/South buildings of the OCCC. Based on normalized utility billing analysis, the total West building energy cost reduction is calculated to be $1,223,837. This is a 15.2% reduction in cost from normalized 2005 usage calculated at 2007 costs. Reduction in the North / South building is calculated to be $989,715 per year and is a 24.4% reduction from normalized 2005 usage at 2007 costs.

Overall combined savings of chilled water and electricity for both buildings are estimated to be $2,213,552 per year compared to the energy used during 2005. This is an 18.3% reduction in electricity and chilled water expenses compared to 2005 usage normalized by weather.

Cost savings are broken down by electric consumption and demand and chilled water consumption for each building year by year in Tables A and B. No savings are shown for chilled water demand (not shown in tables) in both buildings or in coincident peak kW for North / South building since contractual minimums are greater than actual demand.

Table A. West building total estimated annual $ savings due to reductions in kWh, kW and ton-hrs

	kWh $ saved	Peak kW $ saved	Off-peak kW $ saved	Ton-hrs $ saved	Total $ saved
2005 to 2006	$352,769	$44,072	$39,836	$228,724	$665,401
2006 to 2007	$204,420	$15,144	$14,774	$324,098	$558,436
2005 to 2007	$557,189	$59,216	$54,610	$552,822	$1,223,837

Table B. North/South total estimated annual $ savings due to reductions in kWh, kW and ton-hrs

	kWh $ saved	Peak kW $ saved	Coincident peak kW $ saved*	Ton-hrs $ saved	Total $ saved
2005 to 2006	$475,545	$93,504	$0	$222,635	$791,684
2006 to 2007	$90,216	$5,859	$0	$101,956	$198,031
2005 to 2007	$565,761	$99,363	$0	$324,591	$989,715

* Average monthly coincident peak kW has been reduced 25.6% from 2005 to 2007, however OUC bills a minimum 6000 kW.

Energy density is a metric that presents the energy use of a facility on a per square foot basis. This is a convenient way to compare the energy use in buildings of different size and is useful when the buildings being compared have similar functions. OCCC energy density was calculated based on electricity kWh and kWh used for chilled water in the West and North/South buildings. The chilled water energy consumed (ton-hours) was converted to kWh assuming a chiller plant chilled water production and distribution of 0.80 kW per ton.

Combining electricity and chilled water consumption of 2007 results in an average monthly energy density in the West building of about 1.3 kWh/ft^2 and 0.8 kWh/ft^2 in the North / South building. The newer controls and technology of the North/South building are more effective in controlling indoor conditions and conserving energy. This is one reason the energy density is about 1.6 times greater in the West building. Variable frequency drive (VFD) controls that allow air handling fans to be run at slower speeds can improve humidity control in buildings designed with cooling capacities much larger than is needed much of the time. Humidity is under control in the West building, but requires more air conditioning to do so without the VFD equipment used in the North/South building. Current plans of OCCC staff to install VFD on air handler fans should result in good humidity control and much more electricity savings in the West building.

Emerging new low energy commercial buildings are reported to have an energy density ranging from 0.349 to 0.697 kWh/ ft^2 per month. This suggests there are more opportunities for conservation and that appropriate future energy management plans at OCCC should successfully result in additional savings.

Purpose

The purpose of this report is to show trends in monthly chilled water and electric energy use at the West and North/South buildings of the Orange County Convention Center (OCCC).

Analysis of monthly energy bills is a valuable method to track energy use patterns and to alert building owners if energy consumption is trending up or down. The primary objective is to observe substantive trends in energy consumption so that decisions can be made. There are, however, a number of factors that can cause what might appear to be random affects on building energy use and therefore the accuracy of this type of comparison. Perhaps the most important energy use variable is weather. Obviously, hotter and more sunny weather will increase cooling loads and cause increases in chilled water consumption. Variations in energy use are also affected by type and level of occupancy, variations in HVAC equipment operation and scheduling, lighting use, plug loads, or personnel conservation habits such as closing exterior doors. In more complex buildings, energy use is also affected by HVAC sensor accuracy such as temperature, relative humidity and carbon dioxide measurements responsible for controlling outside dampers, chilled water use or heating.

Occupancy

Occupancy can be considered the number of people in a space and the activities and requirements of those people. The Orange County Convention Center (OCCC) not only has very high levels of maximum occupancy, but it also has high variability in occupancy from one day to another and from one month to another. This is a key characteristic of the OCCC.

Data has been provided by OCCC management to FSEC in order to normalize building energy consumption to occupancy levels. “Ordered attendance”, an estimate provided in part by OCCC customers of their expected event attendance, is a value provided by an event coordinator to OCCC for specific spaces within the buildings. The monthly ordered attendance is shown in Figures 1 and 2 for each month of the year based on ordered attendance.

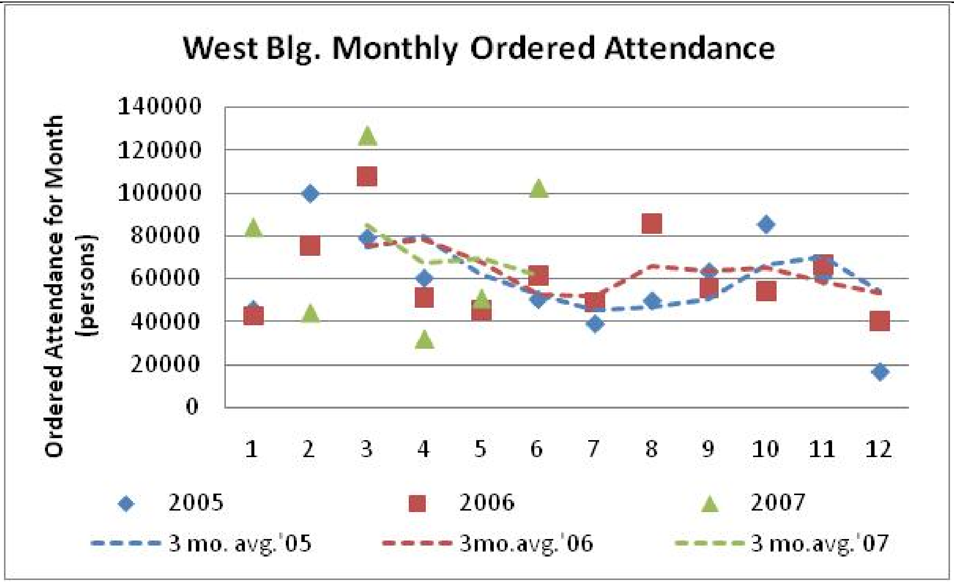


Figure 1 Ordered attendance for West Building

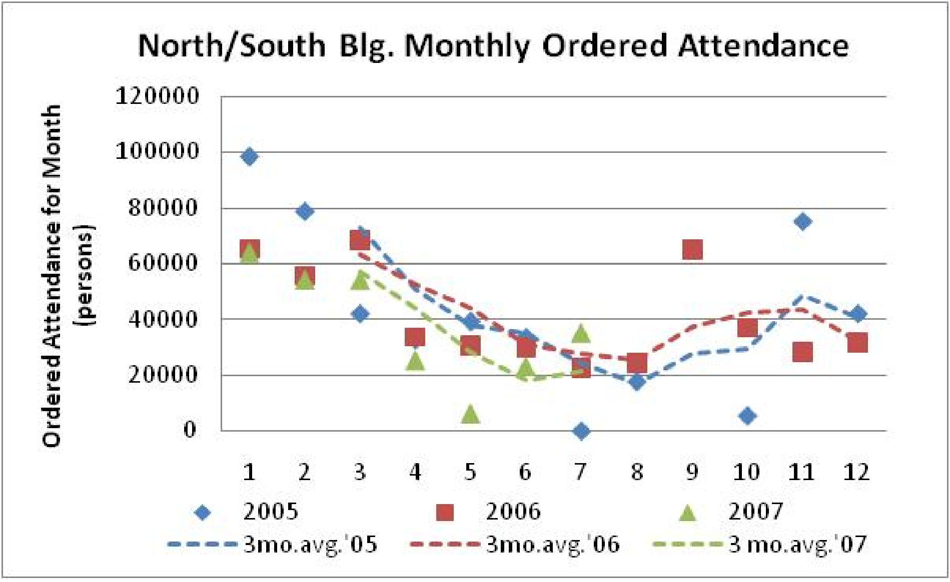


Figure 2 Ordered attendance for North/South Building

Occupancy is quite variable from one month to another, but generally is highest beginning in January, gradually decreasing until July or August with a slight increase to November. This general trend can be seen in the three month running average. It can be seen that the smaller the time unit compared, the greater the variability. This variability drops substantially when comparing average occupancy over five months. The average differences from 2005 to 2006 and from 2006 to 2007 for the period January through May are only 2% and 4%, respectively.

While the occupancy data provided by OCCC indicates significant variability in occupancy from month to month, it appears that these variations in occupancy have little or no effect on *total* building energy use, either electricity or chilled water. A more detailed analysis is presented later in this report. There appears to be a weak occupancy effect in the North/South building, but essentially no discernable effect in the West building. This may seem surprising; however, there are factors which may help to explain this lack of impact.

Perhaps most important is the HVAC systems are sized for very high levels of occupancy, and these systems (especially in the West building) operate at nearly full capacity regardless of the occupancy. Of special importance is that outdoor ventilation air, which requires a great deal of chilled water energy, operates at near full air flow regardless of occupancy, especially in the West building. In the North/South building, HVAC systems for meeting rooms are more commonly turned off unless used by an event and more of the systems use CO2 sensors to reduce ventilation as a function of occupant density.

Also important is the low occupancy penetration on a square footage and hourly basis for the West building. Occupancy penetration may be better understood by first considering typical office building occupancy which is about 5 persons per 1000 square feet for approximately 8 hours a day. Based on this, typical office occupancy penetration would be 1.67 persons/1000 ft^2 per day. The average occupancy reported in the West building is 121,967 persons per month and 74,759 persons per month in the North/South building. Assuming an average of 8 hours per day occupancy, this equates to 0.99 persons/1000 ft^2 per day in the West (41% less than office spaces) and 0.89 persons/1000 ft^2 per day in the North building (47% less than office spaces).

Weather Data

In order to normalize the building energy consumption to weather, a reliable and local source for weather data would be required for the period January 2005 through July 2007. It was determined that data collected at the Orlando International Airport (OIA) would be suitable after comparison of drybulb and dew point temperature data to other trusted data. Outdoor air drybulb temperature, dew point temperature, windspeed, precipitation, and cloud cover were collected at daily intervals, then averaged into monthly intervals to match monthly energy data. Chilled water was measured on the last day of the month. Electricity meter readings represented each calendar month within 1-2 days. Therefore, monthly CW and electricity meter readings match quite closely to the time intervals of the monthly weather data.

Monthly outdoor drybulb temperatures are shown in Figure 3 for 2005-June 2007. In general, the seasonal patterns of outdoor drybulb and dew point temperatures are similar for the three represented years, except that average drybulb and dew point temperatures for November and December 2006 are much higher compared to 2005 and to long-term averages. Weather data from stations in Conway, Lake Buena Vista and Cocoa, Florida also had readings of higher than normal temperatures for these two months. Typical Meteorological Year (TMY) data (a weather data base selected to be highly representative of long-term average weather patterns) is also shown in Figure 3 (for Tampa, the closest TMY database to Orlando) confirming that November and December 2006 temperatures are much higher than typical.

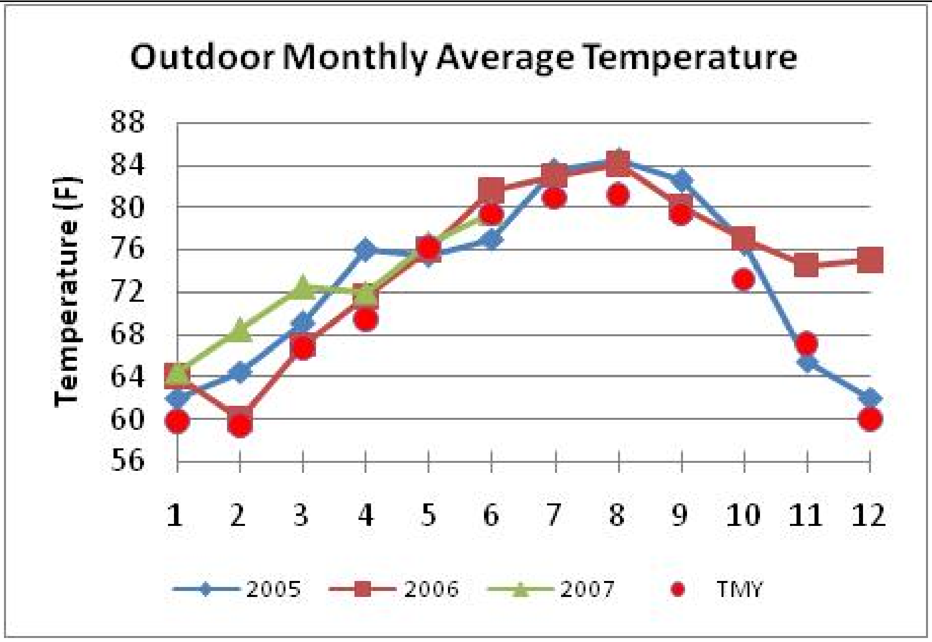


Figure 3 Monthly average outdoor temperatures

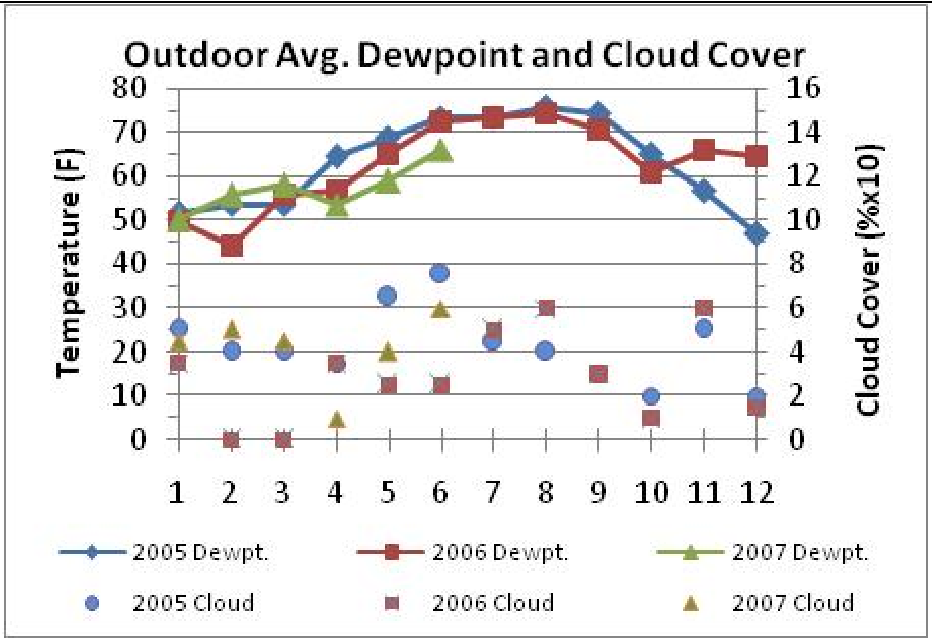


Figure 4 Monthly average outdoor dewpoint and cloud cover

Figure 4 shows outdoor averages of dew point temperature and cloud cover. Cloud cover is rated on a scale of 0 to 10 with 0 being a cloudless sky and 10 being dark clouds filling 100% of the sky. This measure is subjective in nature, but provides a relative comparison related to solar radiation onto building surfaces.

West Building

Electric Energy

Electricity utility meters in the West building record electricity use in the entire building including chiller plants owned and operated by OUC. For purposes of this analysis, the energy consumed by the OUC owned chiller plants must be subtracted from the total building reading. These chiller plants (central and north chiller plants) are sub-metered allowing us to examine only the power consumed for use at the West building alone.

The area known as Phase 2A is served by a 600 ton chiller plant owned and operated by OCCC. The electricity consumed by this chiller plant is included in the West building electricity analysis. There is no measurement, to our knowledge, of the chilled water production from this chiller plant. The effect of Phase 2A chiller power upon the total building electricity use is relatively small given the area served is only 2.4% of the total building floor area and 2.2% of the total building cooling capacity.

Occupancy effects on electricity usage

Monthly building energy data was assembled into spreadsheets from bills provided by OCCC. This data was matched with corresponding monthly weather and occupancy data. Attempts were made to identify the impact, if any, of building occupancy upon electricity consumption. To begin, building electricity usage was plotted against outdoor temperature. A best-fit line was developed based on least-squares regression analysis. Then individual monthly electricity consumption was plotted. In some cases, electricity consumption was higher than the best-fit line, In other case, electricity consumption was lower than the best-fit line. It would seem reasonable to expect that monthly values that were higher than the best-fit line would, in general, have higher occupancy, and those that were lower than the best-fit line would, in general, have lower occupancy. In order to test this, a multiplier was developed, delta-kWh divided by delta-occupancy that was then used to adjust the monthly kWh consumption values.

In Figure 5, which shows actual and adjusted data for 2005 and 2007, one can observe that in about 1/3rd of the cases the adjusted value moved closer to the best-fit line, in another 1/3rd of the cases the adjusted valued moved away from the best-fit line, and in the remaining 1/3rd of the cases, there was essentially no change. The coefficient of determination (r^2) for the 2005 data improved slightly from 0.237 to 0.270. The coefficient of determination (r^2) for the 2007 data improved significantly from 0.034 to 0.156.

A similar analysis was performed to compare 2005 and 2006 data. This analysis showed no significant change in the r2 values for 2005 and 2006 (2006 not shown). We can conclude, therefore, that occupancy has relatively little affect on building electricity usage, and that there are additional but unidentified variables (besides weather) which are creating variability in building electricity use.

Based on this analysis, and upon a similar analysis for the North/South building, we conclude that the occupancy adjustment yields essentially negligible change in the electricity consumption, either in the slope of the best-fit lines or the relative position of the best-fit lines comparing one year to another year. Therefore, we report that the remaining analysis of building electricity use will be performed without consideration of occupancy estimates.

The data sets used for analysis are small, thus they are more easily skewed by just one or two extreme values. This is the typical nature of using monthly billing data. A large data set of at least 25 energy measurements over a wide range of temperatures would provide a more robust analysis from which conclusions about occupancy impacts could be drawn.

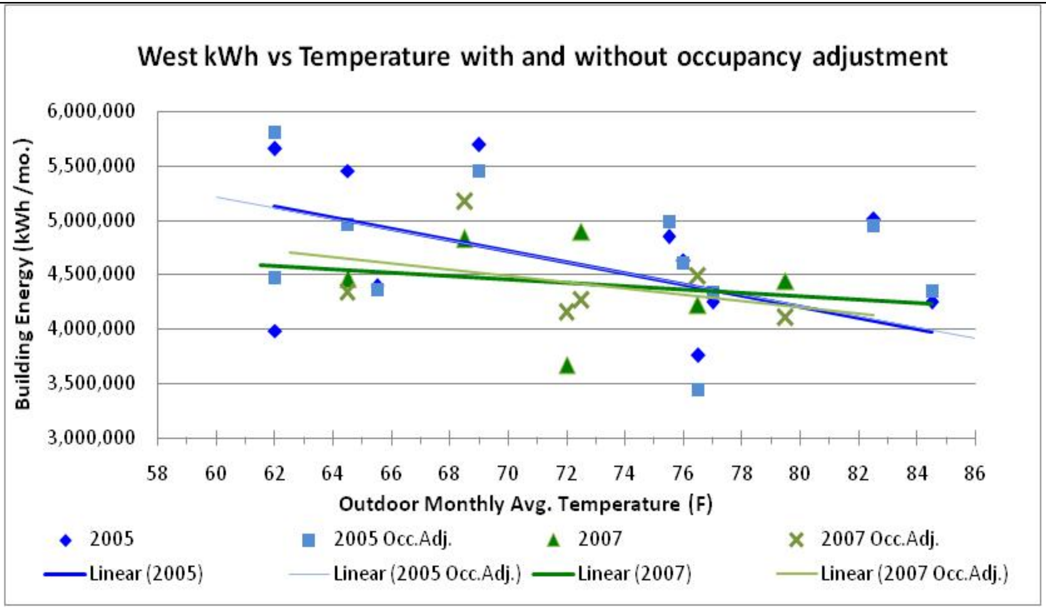


Figure 5 example of results from adjusting kWh based on difference between monthly occupancy compared to annual monthly average

Weather normalization of electricity usage

Figure 6 presents the results of occupancy adjusted electricity usage versus outdoor temperature for the West building for the entire period January 2005 through June 2007. A general trend is seen for each year with decreasing electricity usage as the average monthly temperature increases. From cold months with average temperature of 60^oF to the warmest months with average temperature of 84^oF, electricity consumption drops by about 20%.

Another trend that can be seen is that each subsequent year experiences significant weather-normalized reductions in electricity usage compared to the previous year. Energy conservation activities reported to have begun in July 2005 and which continued through the remainder of that year may account for this difference. A partial list of energy conservation measures are listed in Table 1 as examples of the types of effort. Table 1 also shows completion date, the building or buildings where the measures were implemented, a description of the conservation project, and the energy type expected to be impacted.

Table 1. OCCC reported energy conservation projects with indication of the anticipated primary and secondary energy type that would be affected.

Completion Date	Building	Conservation Description	Energy Category
July 2005	West	Reduce a/c in west entrance	Electricity/CW
September 2005	West	Shut down floor box transformers when not used	Electricity/CW
November 2005	West	Cycle fan coil units	CW/electricity
December 2005	West	Adjust a/c VAV controls	Electricity/CW
December 2005	West	Large Group code for lighting	Electric/CW
June 2006	West	South Fountain Upgrade	Electricity
September 2005	North/South	Shut down floor box transformers when not used	Electricity/CW
September 2005	North/South	Adjust a/c VAV controls	Electricity/CW
October 2005	North/South	Cycle fan coil units	CW/electricity
November 2005	North/South	Reconfigure MR a/c exhaust dampers	Electricity
December 2005	North/South	Daylight harvest code for lighting	Electricity/CW
January 2006	North/South	Reduce meeting room minimum lighting	Electricity
April 2006	North/South	schedule use of a/c in occupied mtg. rms.	CW/electricty
April 2006	North/South	Reduce oversight bridge lighting	Electricity
June 2006	North/South	Shut down AHU fans	Electricity/CW

Figure 6 presents the West building electricity consumption for all 30 months of data. The best-fit lines indicate a significant reduction in electricity usage from 2005 to the subsequent years. Limiting the data sets to the first six months of each year is expected to provide a better basis of comparison between years. This is due to the fact that a majority of the energy conservation measures (ECM) were completed in the later part of years 2005 and 2006. This is expected to cause a reduction in energy for the months after ECM were completed. This in turn will affect the best-fit line. Figure 7 shows the analysis limited to the first six months of each year.

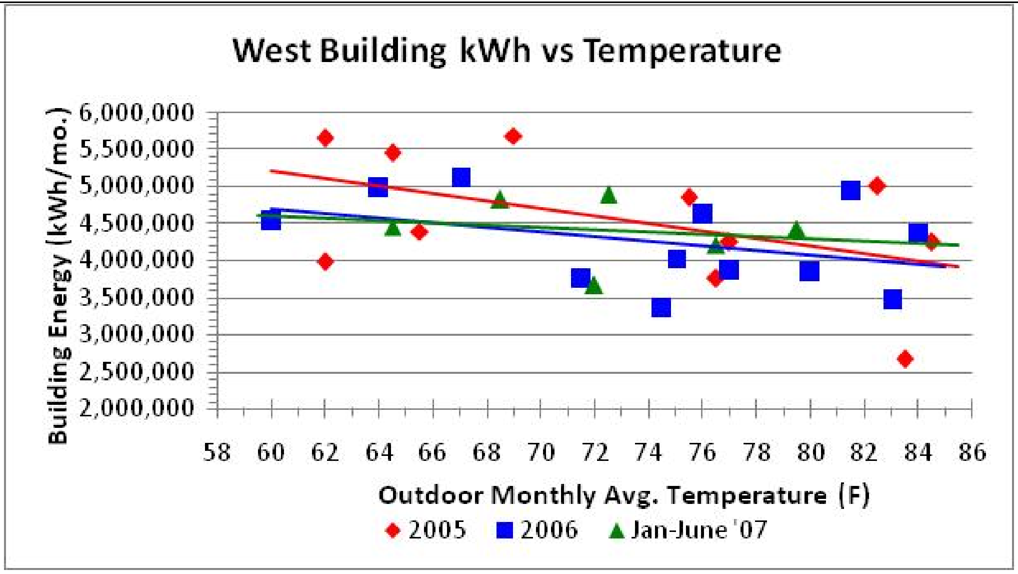


Figure 6 Best-fit lines based on 12 month data for 2005 and 2006

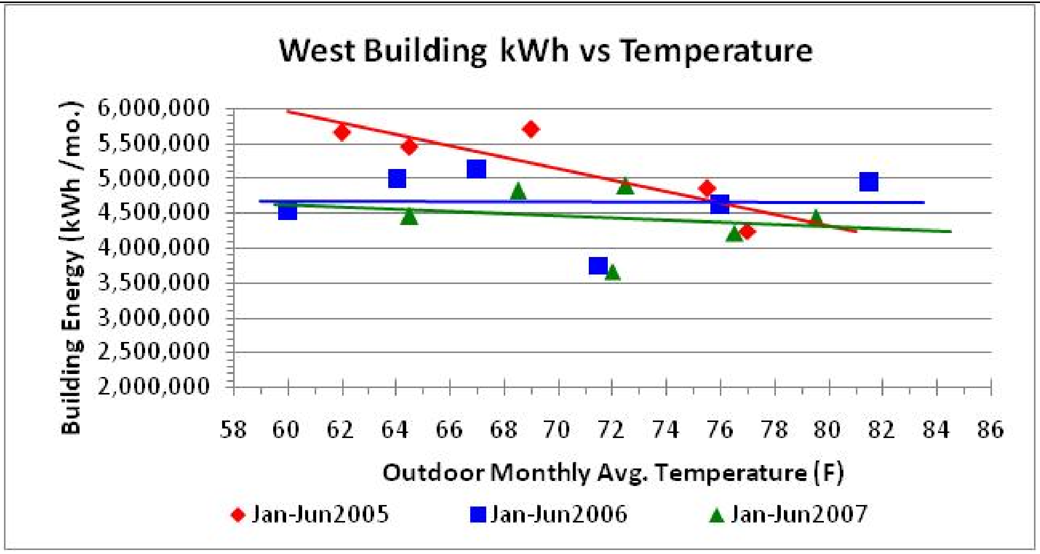


Figure 7 Best-fit lines based on 6 months from January through June

The best-fit line for the first six months of 2005 has the steepest slope which may be attributed to savings that were produced by the ECMs implemented during that year. The reason why the best-fit line for 2006 is remarkably flat over a wide range in temperature is unknown. The best-fit, least square equations and coefficients of determination are shown in Table 2. The equation can be used to predict an expected monthly kWh (Y) for the West building based on an input monthly temperature (X) and assuming an average occupancy. The twelve month based results are shown for comparison, but the six month results are used in the following discussion for determining changes in electricity consumption between years.

Table 2. Linear regression analysis results for 12 month and 6 month groups

Year	Best-Fit linear Equation Based on12 months (2005&2006)	Best-Fit linear Equation Based on 6 months	Average Monthly Occupancy (Ordered Attendance)
2005	Y=-50,853.2 * X+8,272,640 r^2=0.237	Y=-82,260.4 * X+10,900,993 r^2=0.784	57957
2006	Y=-31,641.8*X+6,603,546 r^2=0.158	Y=-1,349.9 * X+4,758,474 r^2=0.0005	61343
2007	12 months not available	Y=-15,372.6 * X+5,529,622 r^2=0.035	73435

Electricity consumption in the West Building has dropped somewhat steadily and significantly from one year to the next, during this 30 month analysis period. In order to calculate the reduction, and adjusting for variations in weather, the electricity use was calculated for each year based on the 6-month best-fit equation at an outdoor temperature of 71.1ºF, which is the typical yearly average outdoor temperature. The results of these calculations are shown in Table 3. Overall it is estimated that the ECMs have produced an approximate 12% reduction in total West building electricity consumption with estimated annual savings of $557,189 based on a weighted average cost of $0.07542/kWh (savings from demand reductions are considered at a later point in this report). This electricity rate of $0.07542/kWh is based on 27% of the energy consumption being billed at the peak rate and 73% at the off-peak rate.

Table 3. Estimated savings in electricity based on 6 month best-fit linear equations using annual outdoor temperature of 71.1 degrees F

	Reduction kWh/Month	% reduction	Monthly reduction ($)	Annual reduction (kWh/yr.)	Annual reduction ($/yr.)
2005 to 2006	389,783	7.7%	$29,397	4,677,392	$352,769
2006 to 2007	225,869	4.8%	$17,035	2,710,429	$204,420
2005 to 2007	615,652	12.2%	$46,432	7,387,821	$557,189

Electricity energy billing rate structure for West building

Electricity consumption is billed at different rates depending upon time of day. Figures 8, 9, and 10 show a breakdown of peak kWh, off-peak kWh, and total kWhs billed per month for 2005, 2006, and 2007 respectively. Figure 11 shows the on-peak kWh as a percentage of the total for each month of each year. There is very little difference between the same months of different years with exception of July and October of 2005 where the peak energy was a much higher percentage of the total. We have no information that would explain why this has occurred. Errors in meter reading or reporting are possible reasons.

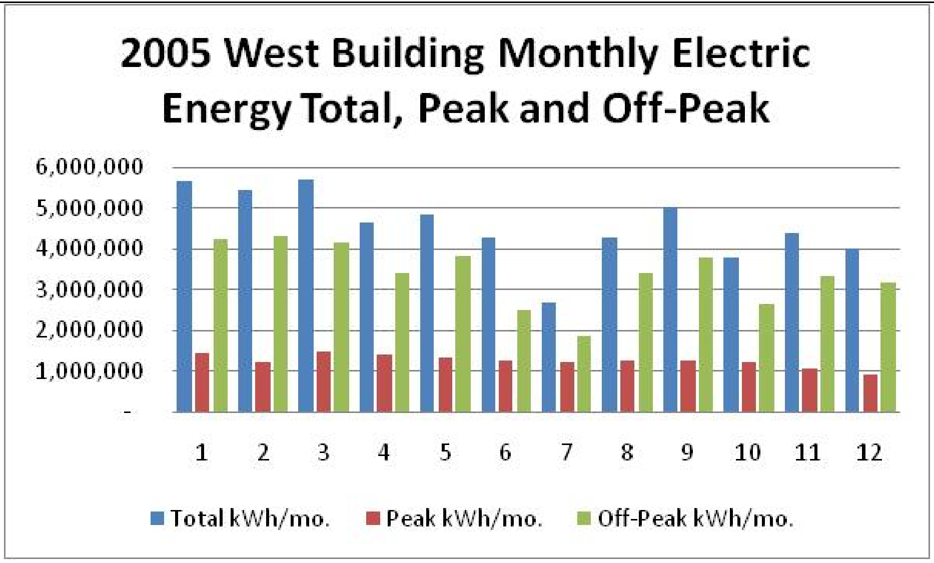


Figure 8 2005 breakdown of monthly kWh use into peak, off-peak and total kWh

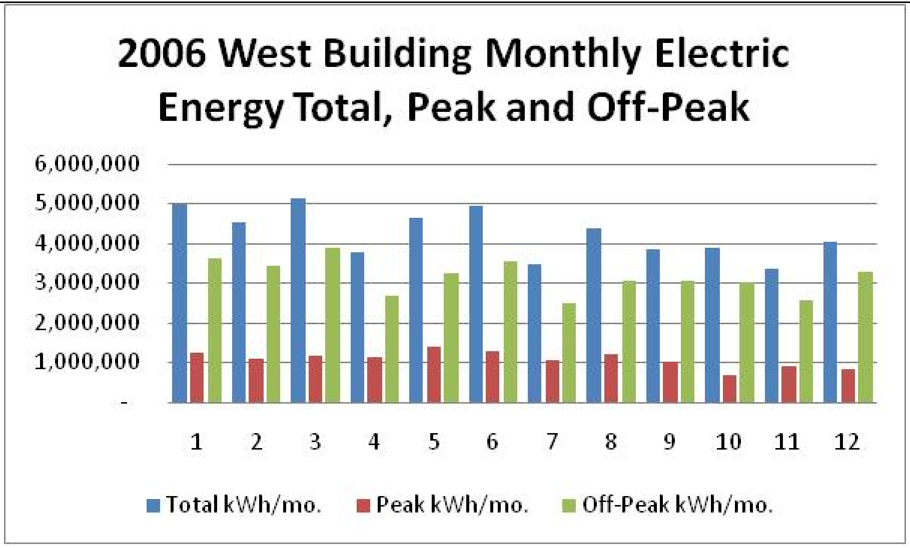


Figure 9 2006 breakdown of monthly kWh use into peak, off-peak and total kWh

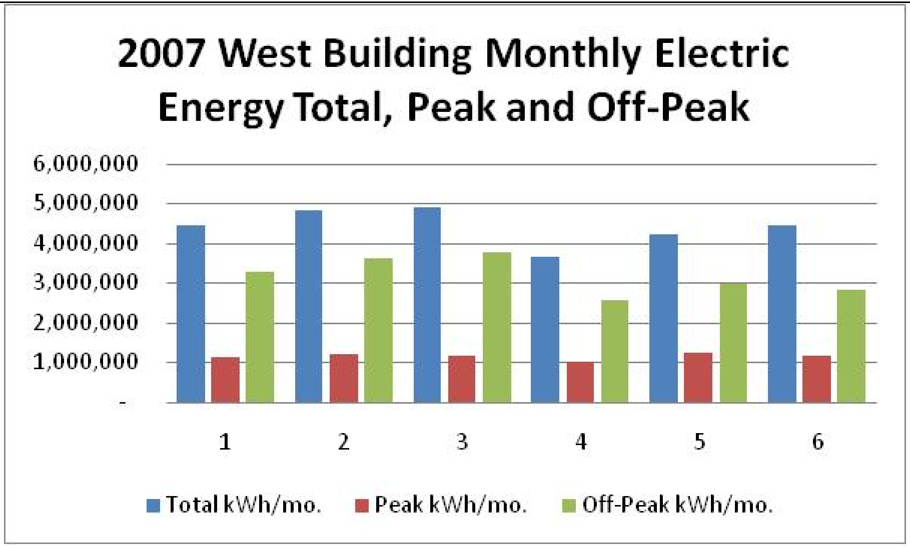


Figure 10 2007 breakdown of monthly kWh use into peak, off-peak and total kWh

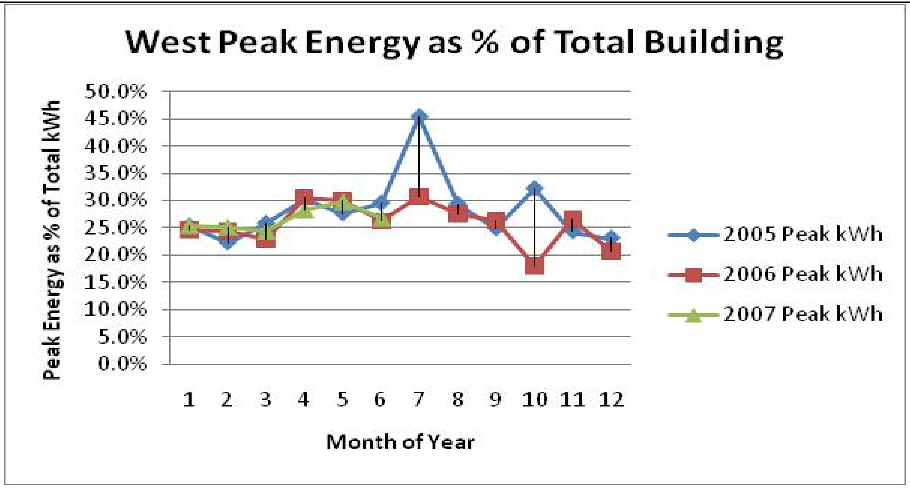


Figure 11 monthly on-peak kWh consumption as a percentage of total building kWh

The range of on-peak kWh varies from 20% to 30% most of the time. Table 4 shows that on-peak electricity consumption remains stable at about 26.6% of total for each year. For Progress Energy, the summer peak billing period from April through October is noon to 9 pm and the winter peak billing period from November through March is 6 am to 10 am as well as 6 pm to 10 pm. The fact that 73% of the electricity consumption occurs during off-peak periods saves OCCC a considerable amount since that rate is about 51% lower than the on-peak period.

Table4. January – June average breakdown of peak and off-peak energy use

Total kWh	On-Peak kWh	Off-Peak kWh	On-Peak %	Off-Peak %
5,087,926	1,348,185	3,739,741	26.7%	73.3%
4,663,982	1,226,890	3,437,092	26.5%	73.5%
4,418,949	1,166,099	3,252,850	26.5%	73.5%

Ordered exhibit electricity

Since the West building has the capacity to host a large number of exhibits, the impact of exhibitor power end use was evaluated. Exhibitor energy use is not monitored or charged by the actual amount of energy used, but rather is based on the power ordered. This order does not guarantee any level of actual energy to be used.

In order to perform this analysis, ordered power data was summarized for each month. Energy use was then estimated based on an estimate provided by OCCC staff that actual energy consumption might be 50% of the ordered capacity used for 10 hrs per day for an average three-day event. Figure 12 summarizes ordered electricity use for 30 months and shows that ordered power represents a very small percentage of the whole building kWh usage, varying from 0.4% to 2.8% and averaging 1.3%.

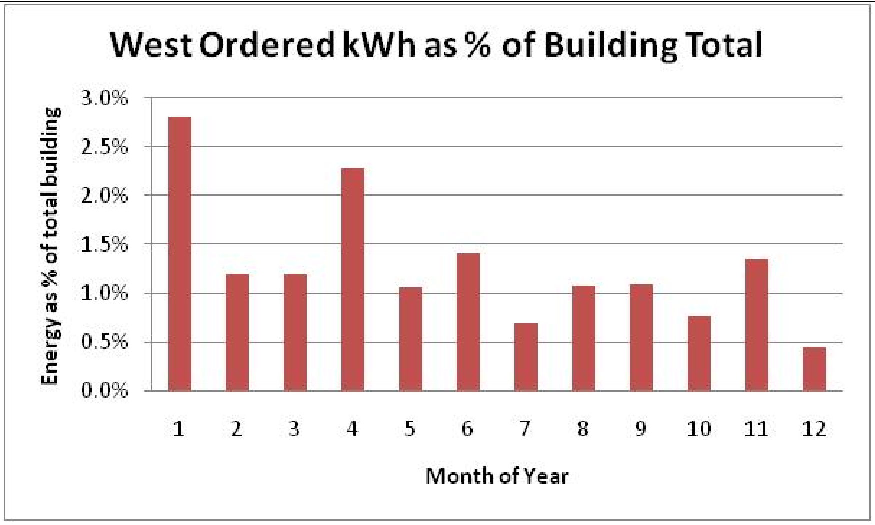


Figure 12 Average ordered power in the West building summarized from 30 months of data.

Electricity Demand

Peak electrical demand is summarized in Figures 13 and 14. The majority of West building peak demand (kW) occurs during the on-peak period, as can be seen in these Figures. Note that this data has been corrected to remove the power consumed by OUC’s chiller plants.

Two anomalies in the peak demand data should be mentioned. Subtracting the peak demand of the OUC chiller plants from the whole West building peak demand resulted in negative values for the months of September and November 2006. The value for December 2006 was also suspiciously low. These unreasonable values may be due to error in meter data. As a result of these suspicious results, off peak power for the period of September through December 2006 has been excluded from this analysis.

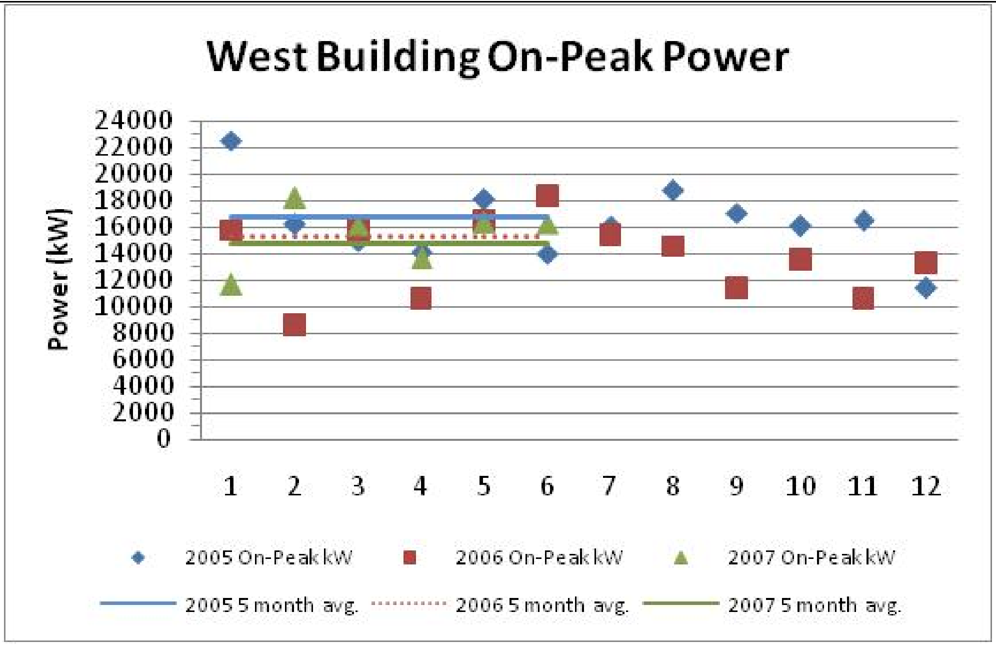


Figure 13 Power usage in West building for years 2005-2007

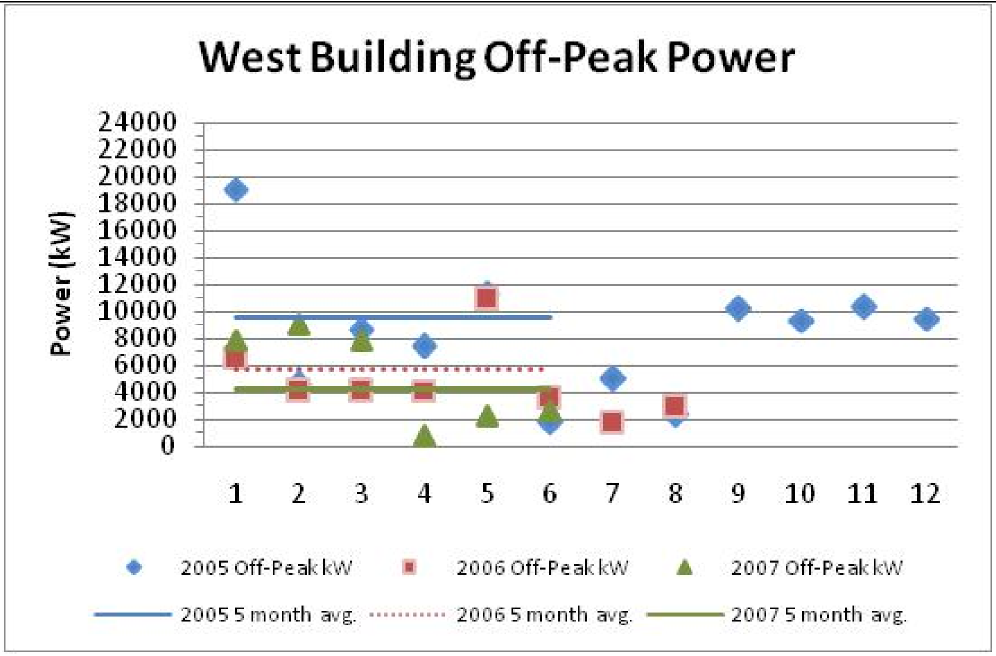


Figure 14 Power usage in West building for years 2005-2007

Similar to energy analysis, six month comparisons are reasonable since only January through June are available for 2007. Both Figures 13 and 14 have lines representing the average monthly power usage for each year using 5 months of data from January through June, but excluding February.

The month of February resulted in the lowest peak power for 2006 and highest for 2007. Using February in the averages, results in an indicated *increase* in peak power from 2006 to 2007. Table 5 summarizes the six month average of peak power usage for years 2005-2007.

Table 5. Six-month average of On-Peak Peak power

Year	Peak kW	Peak kW decrease	% peak decrease	$ / month reduction	$ / year reduction
2005	16,628	---	---	---	---
2006	14,249	2,379	14.3%	$6,113	$73,358
2007	15,365	-1,115	-7.8%	-$2,867	-$34,399
Total Reduction		1,263	7.6%	$3,247	$38,959

Ordered occupancy data provided by OCCC was reviewed and the maximum occupancy was obtained to see if this could explain larger variations such as February 2006 and 2007 in Figure13. Attempts were made to seek out relationships between occupancy and power, but adjustments made based on occupancy provided no additional clarity regarding the February data anomalies. This is not entirely unexpected given that it is suspected that actual occupancy does not necessarily correlate well with ordered occupancy. Table 6 shows that peak demand during on-peak periods has decreased from one year to the next when examining only the first six months of each year, and also excluding February of each year. Table 7 shows that peak demand during off-peak periods has decreased from one year to the next when examining only the first six months of each year, and also excluding February of each year.

Table 6. Peak demand for on-peak billing periods, for the five months of January, March, April, May, and June of each year

Year	Peak kW	Peak kW decrease	% peak decrease	$ / month reduction	$ / year reduction
2005	16,719	---	---	---	---
2006	15,290	1,429	8.6%	$3,673	$44,072
2007	14,799	491	3.2%	$1,262	$15,144
Total Reduction		1,920	11.5%	$4,935	$59,216

Table 7. Peak demand for off-peak billing periods, for the five months of January, March, April, May, and June of each year

Year	Off-peak kW	Off-peak kW decrease	% off-peak decrease	$ / month reduction	$ / year reduction
2005	9,655	---	---	---	---
2006	5,750	3,905	40.4%	$3,320	$39,836
2007	4,301	1,448	25.2%	$1,231	$14,774
Total Reduction		5,354	55.5%	$4,551	$54,610

Peak demand power reductions are much greater during the off-peak compared to the on-peak billing periods. However, the cost savings are greater from the on-peak reductions because the on-peak demand charges are three times greater per kW.

The combined electricity demand savings (kW) plus electricity consumption savings (kWh) resulting from ECMs implemented in the West building during 2005 and 2006 are substantial. Total annual electricity savings (from 2005 to 2007) are estimated to be $671,015; $557,189 from reduction in kWh, $59,216 from reduction in on-peak demand, and $54,610 from reduction in off-peak demand.

West Building Chilled Water Energy

Chilled water is used to remove heat from the building, and therefore CW usage is expected to increase during hot and sunny weather. One would also expect CW usage to increase during periods of high occupancy. Figure 15 plots monthly chilled water versus the monthly outdoor average temperature. The coefficients of determination (r2) for the best-fit lines are relatively high, indicating that variations in outdoor temperature account for approximately 75% of the difference in consumption from one month to another. For the same compatibility reasons mentioned in the electric energy section of this report, only January through July of each year was used in the analysis. As can be seen, chilled water consumption has decreased significantly each year since 2005 when normalized to weather conditions. Attempts to normalize the CW consumption data to occupancy resulted, on average, in more scatter of the data thereby decreasing r^2. Therefore, no adjustments for occupancy have been made to the data.

We suspect that CW consumption is not particularly sensitive to occupancy in the West building for two reasons. 1) HVAC systems are run much of the time (excluding exhibit hall equipment) regardless of occupancy and 2) building ventilation rates are not controlled (as in portions of the N/S building) by CO2 controllers.

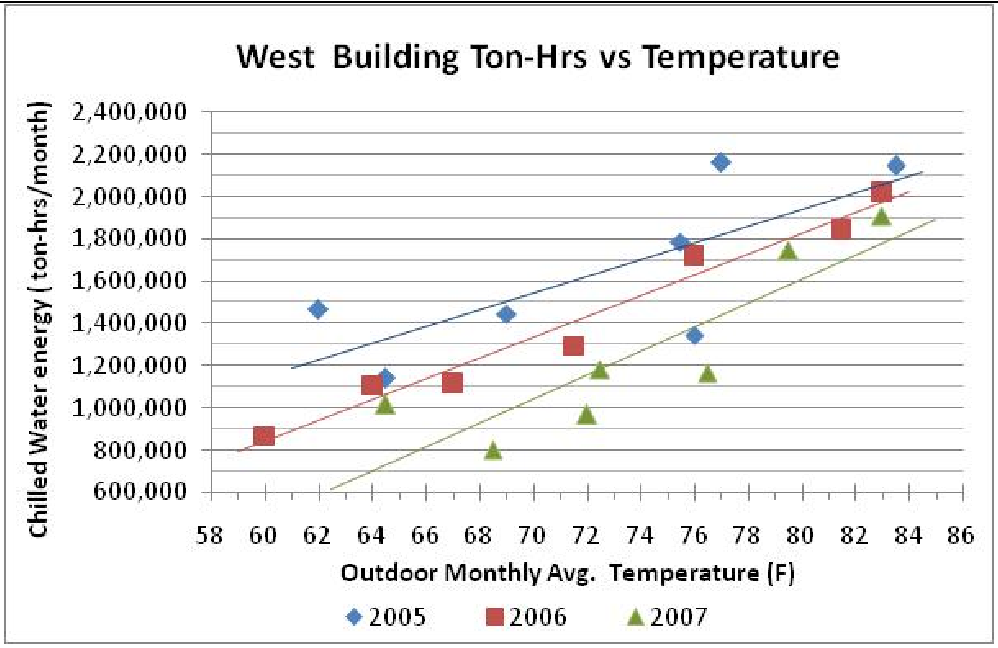


Figure 15 West building chilled water ton-hrs vs temperature using January-July of each year

Reductions in chilled water consumption in the West building are shown in Table 8. Based on our analysis, the ECMs implemented during 2005 and 2006 have accounted for an approximate 30% reduction in chilled water energy use yielding cost savings of $552,822 per year (based on the 2007 average cost of $0.09572/ton-hr).

Table 8 Estimated savings in chilled water ton-hours based on 6 month best-fit linear equations using annual outdoor temperature of 71.1 degrees F.

	Reduction ton-hrs/Month	% reduction	Monthly reduction ($)	Annual reduction (ton-hrs/yr.)	Annual reduction ($/yr.)
2005 to 2006	199,126	12.6%	$19,060	2,389,513	$228,724
2006 to 2007	282,158	20.3%	$27,008	3,385,897	$324,098

2005 to 2007	481,284	30.3%	$46,069	5,775,410	$552,822

The contract with OUC also includes an adjustment factor for CW consumption based on delta-temperature. Delta-temperature is the difference in CW temperature (delta-T) between the supply entering the building and return leaving the building. This delta-T adjustment calculation has not been implemented for the West building. It will, however, go into effect in the future.

This temperature difference is a weighted average over the billing month. Once implemented, it will result in an increase in the CW consumption rate for months with delta-T less than a 15º (F) temperature differential and will result in an decrease in the CW consumption rate for months with delta-T greater than a 15º (F) temperature differential. Figure 16 shows the % change in ton-hour cost as a function of delta-T. For example, an 11º (F) delta-T will result in a 13.6% increase in the billed rate, while a 19ºF delta-T will result in a 7.9% decrease in the billed consumption rate. Figure 17 shows that steps have been taken by OCCC staff and management to increase delta-T. Over the past three years (looking only at the first six months of each year), delta-T has increased from 8.14ºF to 9.09ºF from 2005 to 2006 (a 11.57 increase) and from 9.09ºF to 12.46ºF from 2006 to 2007 (a 37.1% increase).

If the delta-T adjustment was being used for the West building, the consumption charges (cost per ton-hour) would be 7.6% higher based on the 2007 average of 12.46ºF delta-T. Also taking into account the demand charges, which are not adjusted for delta-T, the entire cost of chilled water at the West building would be 4.0% higher than current bills.

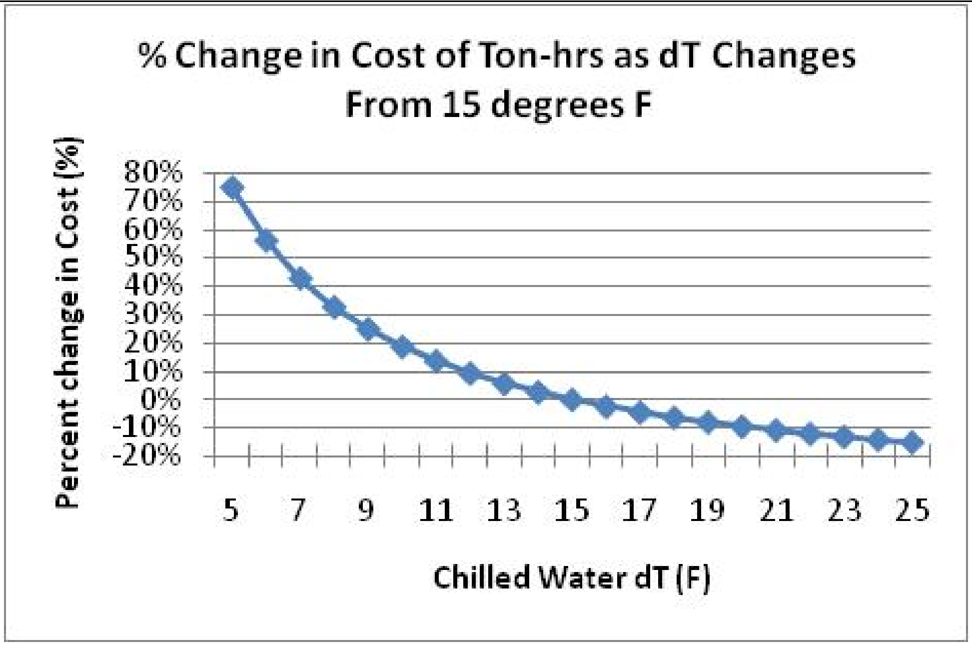


Figure 16 Percent change in cost of chilled water ton-hours for specific dT

In addition to charges for CW consumption (currently about $0.095 per ton-hour), OUC also charges for peak demand (also referred to as peak capacity). One important feature of the current contract with OUC is that a specific CW capacity is guaranteed by OUC and must be paid for by OCCC whether that peak demand actually occurs during any given month. In most months, actual peak CW demand has been substantially less than the contracted 8,750 tons (this peak capacity has shown up in more recent bills as 8,250 tons as of February 2007). Peak CW demand is determined based on the highest average 15 minute demand during the month. The contract with OUC calls for $9 per ton with adjustments for the Consumer Price Index (CPI). During the first six months of 2007, the average demand (capacity) charge has been $10.04 per ton.

Peak demand is shown in Figure 18. During the period from 2005 through July 2007, peak demand has exceeded the billed demand on two occasions, in January and July of 2005. During the first seven months of 2007, for example, the highest peak that has occurred was in July 2007 that was only 87% of the 8,250 ton billing capacity.

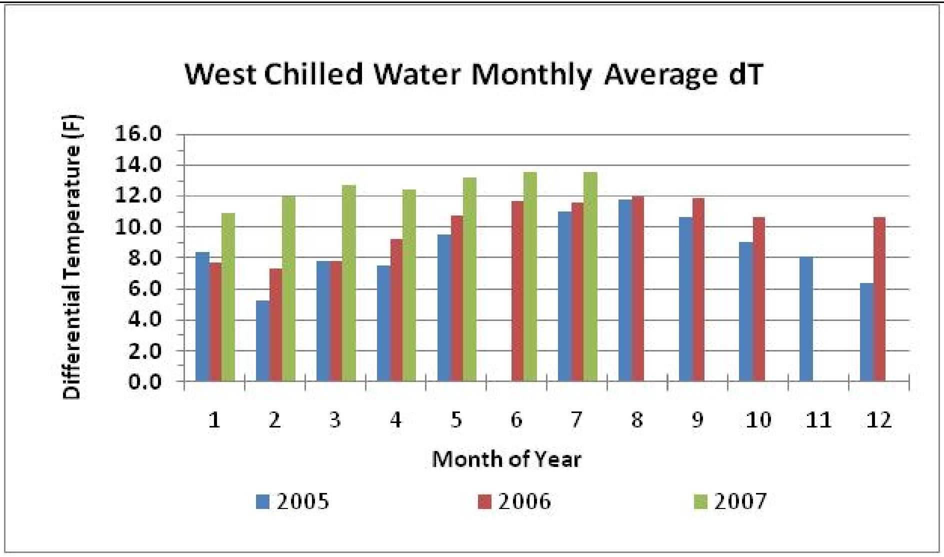


Figure 17 building chilled water temperature differentials

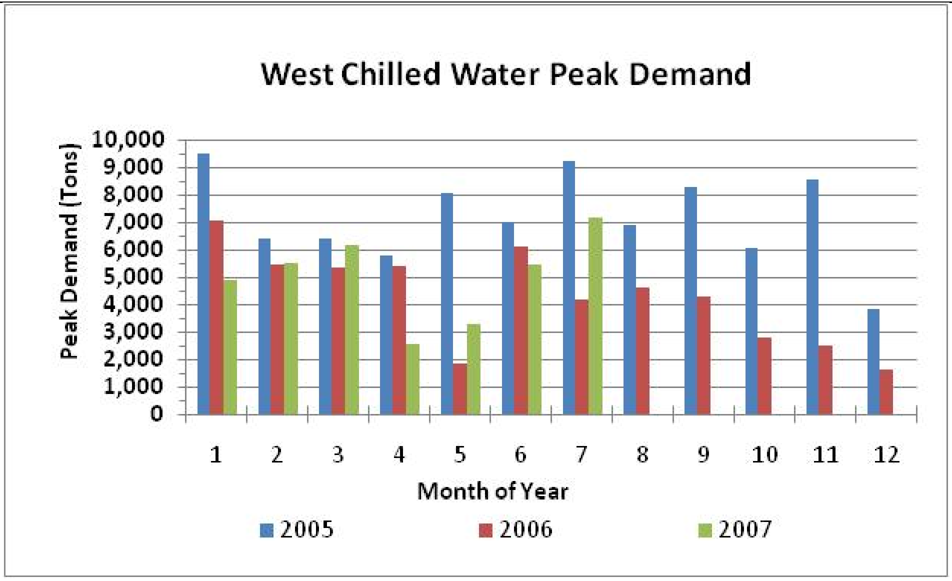


Figure 18 shows chilled water peak demand for each month of years 2005-2007

North/South Building

Electric Energy

Electricity is provided to the North/South (N/S) building by the Orlando Utilities Commission. The chilled water is also provided to the N/S building by OUC from a loop that serves OCCC and other customers.

Monthly building energy data was assembled into spreadsheets with corresponding monthly weather and occupancy data as was also done for the West building. Comparisons are made using the first six months of each year for the reasons previously discussed for the West building, to improve data comparability.

Weather normalization of electricity usage

Total building electricity usage is clearly a function of outdoor temperature (see Figure 19). As seen in the West building, electricity consumption decreases with increases in the outdoor temperature. Coefficients of determination (r2) are consistently high, in the range of 0.70 to 0.73 for each year, indicating that approximately 71% of the variability in month to month electricity consumption can be attributed to outdoor temperature (Table 9).

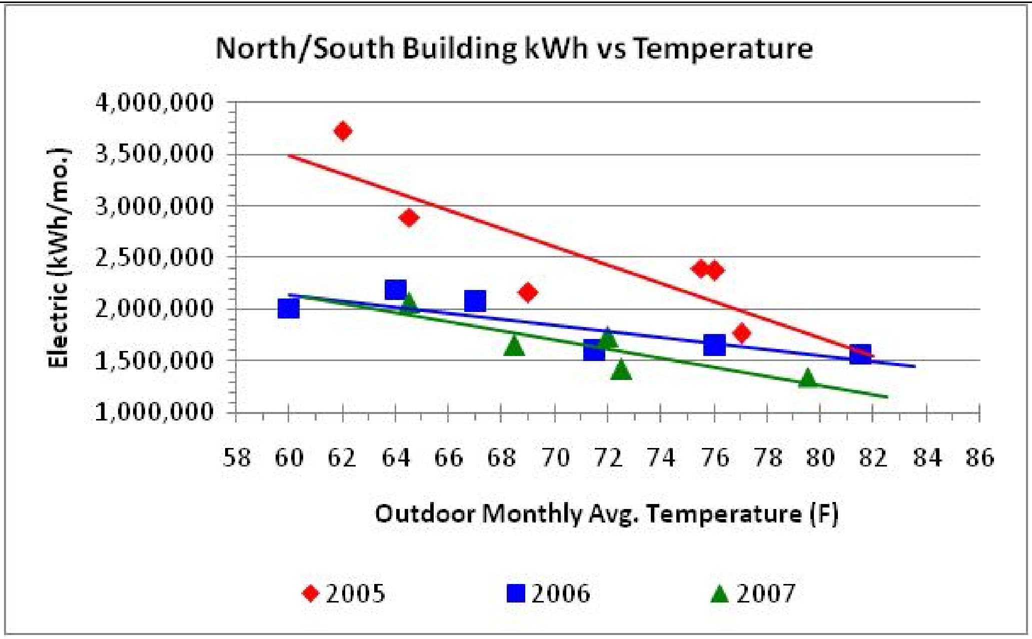


Figure 19 Best-fit lines based on 6 months from January through June

Figure 19 shows total building electricity consumption for the first six months of 2005, 2006, and 2007. Best-fit, least squares lines have been created for each year. The best-fit line for 2005 has a slope that is substantially steeper than for 2006 and 2007. This may be the result of ECMs implemented during 2005. One measure, in particular, might account for much of the reduction that is exhibited in the later years, namely the heating setpoint bias. FSEC staff were informed that Brian Kennedy increased the temperature differential between the cooling setpoint and the heating setpoint (also called the bias) for the AHUs that serve the atrium. Prior to this change, when the relative humidity control algorithm would go into effect, the chilled water coil would open, producing colder supply air, and this in turn would lower the space temperature. With the heating setpoint being only slightly below the cooling setpoint, space heating would almost immediately come on to prevent overcooling of the space. With the increased bias (to 5ºF), the space temperature could fall to five degrees F below the cooling setpoint before heating would be activated.

Best-fit linear equations and coefficient of determination characterizing electricity consumption as a function of outdoor temperature are shown in Table 9. These equations can be used to predict an expected monthly kWh consumption (Y) based on monthly temperature (X) and assuming an average occupancy.

Table 9. Best-fit line equations characterizing electricity consumption as a function of outdoor temperature, for the first six months of each year, and including ordered attendance

Year	Best-Fit linear Equation Based on 6 months	Average Monthly Occupancy (Ordered Attendance)

2005	Y=-87,852.7 * X+8,760,872 R2=0.696	54,025
2006	Y=-29,153.4 * X+3,889,048 R2=.711	47,225
2007	Y=-49,040.7 * X+5,170,560 R2=0.727	44,000

The six month best-fit linear equations were used with the annual average outdoor temperature of 71.1^o F to estimate the expected monthly average energy use under conditions represented for each year 2005-2007. This simple analysis results in monthly values that represent an annual average of all months. Looking at the slope of the 2005 data line in Figure19 it can be observed that 2005 energy used during months that are *cooler* than 71.1^o F would be *greater* than the single-point estimated average. Energy used during months *warmer* than 71.1^o F would be *less* than the estimate. So while a simple single point of comparison is used, it estimates the annual monthly average because the temperature used is the annual monthly average. This is expected to be balanced enough for an annual estimate given the already limited number of data points used to generate the best-fit data.

Based on the best-fit, least-squares regression equations, typical annual (weather-normalized) electricity consumption can be calculated (Table 10). From 2005 to 2007, calculated annual electricity consumption was reduced by 33% or $565,761, as a result of ECMs, based on a weighted average cost of $0.05675/kWh. Electric energy consumption is charged at one rate, unlike the West building which is charged at peak and off-peak rates.

Table 10. Estimated savings in electricity based on 6 month best-fit linear equations using annual outdoor temperature of 71.1 degrees F.

	Reduction kWh/Month	% reduction	Monthly reduction ($)	Annual reduction (kWh/yr.)	Annual reduction ($/yr.)
2005 to 2006	698,304	27.8%	$39,629	8,379,648	$475,545
2006 to 2007	132,475	7.3%	$7,518	1,589,704	$90,216
2005 to 2007	830,779	33.0%	$47,147	9,969,352	$565,761

Ordered exhibit electricity

Ordered exhibit electricity has been examined for the N/S building. As with the West building, exhibitor energy use is not monitored or charged by the actual amount of energy used, but by the ordered power. This data for 2006 is shown in Figure 20. Estimated actual energy consumption is calculated based on estimates by OCCC staff of average 50% of ordered capacity used 10 hrs per day for an average 3 day event. The analysis shows that ordered electricity use for 2006 is a very small percentage of the whole building electricity use, varying from 0.2% to 12.9% for individual months, and averaging 2.9% of building total. Excluding February, the average is 2.0%.

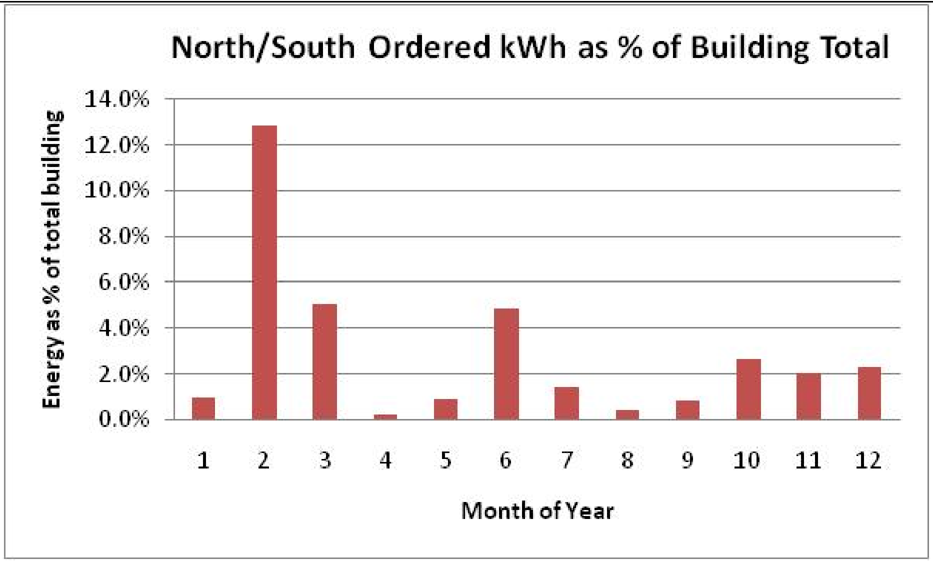


Figure 20 Ordered exhibitor electricity for 2006

Electricity Demand

Power usage for the North/South building is billed at two rates by OUC. The highest rate is called the peak charge at $4.37/kW and the second rate is the coincident peak charge at $1.81/kW. The peak rate is based on the highest reading of all meters combined, while the coincident peak is based on the highest 15 minute average peak of all meters. Since usage classifies this building as part of OUC General Service Large Demand, coincident peak charges are for a minimum of 6,000 kW. Figure 21 shows peak power used in the North/South building. Figure 22 shows results for coincident peak power usage.

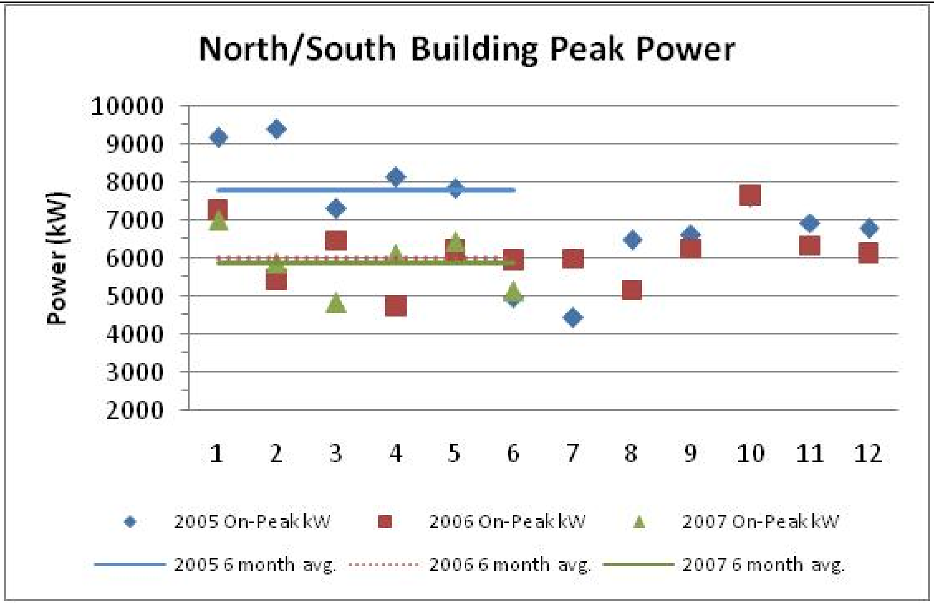


Figure 21 Power usage in North/South building for years 2005-2007

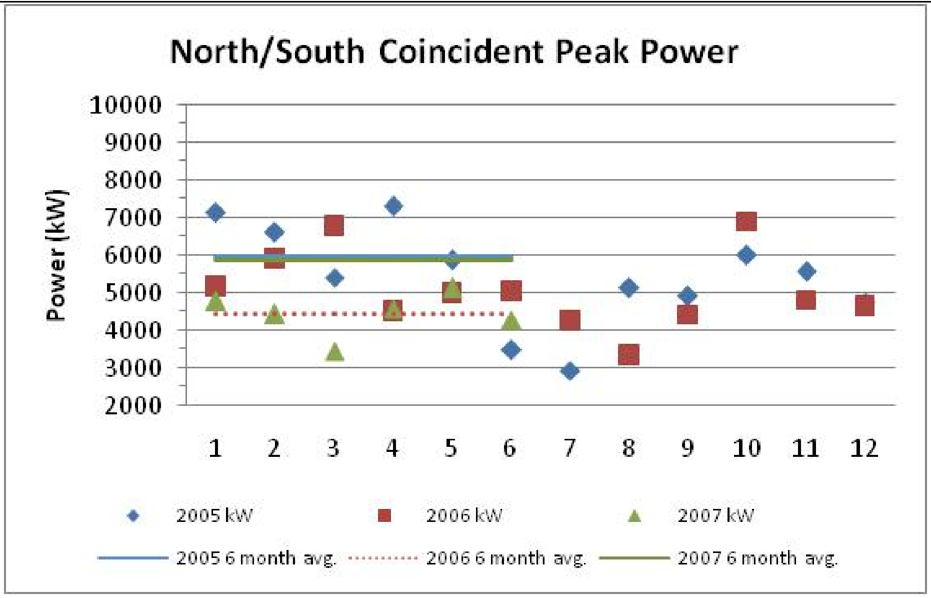


Figure 22 Power usage in North/South building for years 2005-2007

Similar to energy analysis, six-month comparisons are reasonable since only January through June are available for 2007. Figures 21 and 22 show monthly peak power and have lines representing the average monthly power demand for each year using 6 months of data from January-June. No adjustments have been made for variations in weather or for occupancy for same reasons noted previously in West building discussion of power.

Examination of the data reveals that peak electrical demand, for both on-peak (coincident) and off-peak demand, has generally declined from one year to the next (see Tables 11 and 12). The decline is less substantial than was observed in the West building. On-peak demand reduction from 2005 to 2007 was 24.3%. Off-peak demand reduction from 2005 to 2007 was 25.6%. Together these demand reductions, which are most likely the result of ECMs implemented in the N/S building, are yielding $132,542 per year savings.

Table 11. Six- month average occupancy adjusted peak power and estimated savings each year after 2005 with reduction occurring between year noted and one year prior

Year	Peak kW	Peak kW decrease	% peak decrease	$ / month reduction	$ / year reduction*
2005	7,795	---	---	---	---
2006	6,012	1,783	22.9%	$7,792	$93,504
2007	5,900	112	1.9%	$488	$5,859
Total Reduction		1,895	24.3%	$8,280	$99,363

* $4.37 / peak kW and $1.81/ coincidental peak kW

Table 12. Six- month average coincident peak power and estimated savings each year after 2005 with reduction occurring between year noted and one year prior

Year	Coincident peak kW	Coincident kW decrease	Coincident % decrease	$ / month reduction	$ / year reduction*
2005	5,975	---	---	---	---
2006	5,406	569	9.5%	$1,030	$12,359
2007	4,447	959	17.7%	$1,735	$20,820
Total Reduction		1,528	25.6%	$2,765	$33,179

* $4.37 / peak kW and $1.81/ coincidental peak kW

Indicated peak power reductions are about 19% greater than coincident peak, but financial savings from peak reductions are about 3 times greater due to a peak kW cost that is 1.4 times greater per kW.

Cost savings inform reductions in electricity consumption and electricity peak demand, resulting from ECMs implemented during 2005 and 2006, are yielding total annual electric energy savings of $698,303; $565,761 from kWh reduction, $99,363 from total peak demand reduction, and $33,179 coincident peak reduction.

North/South Building Chilled Water Energy

Chilled water energy use in the North/South building has decreased each year since 2005 when normalized to weather conditions. Figure 23 shows total building chilled water used per month versus the monthly outdoor average temperature for January through July for 2005, 2006, and 2007. Attempts to adjust energy use based on occupancy did not result in a meaningful improvement in the best-fit linear regressions and therefore Figure 23 presents the energy without any occupancy adjustment.

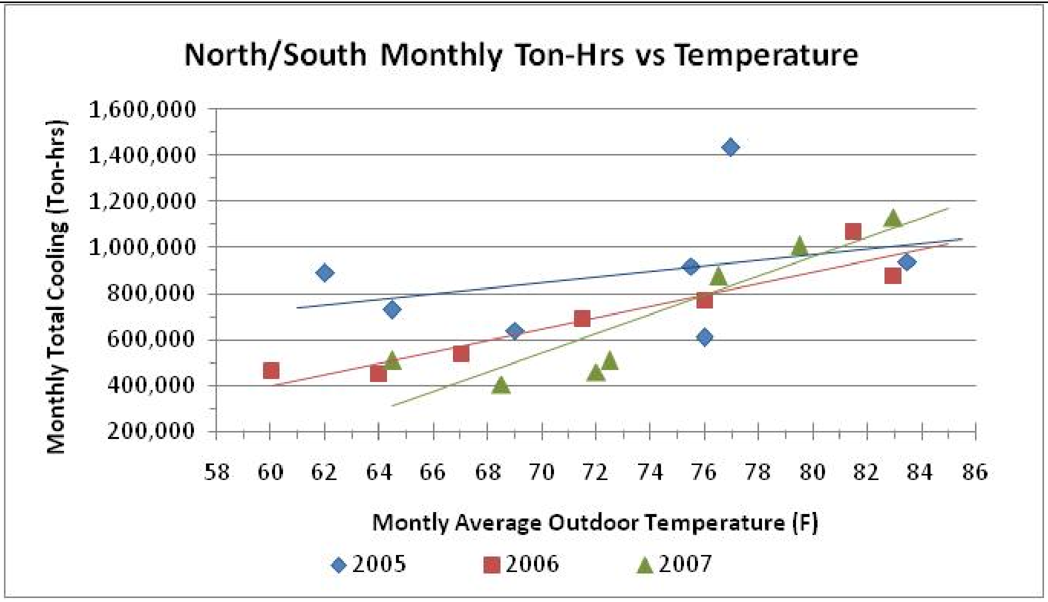


Figure 23 North/South building chilled water usage versus outdoor temperature for January-July of each year

Chilled water consumption is summarized in Table 13. Based on our analysis, ECM account for a 31.8% reduction in chilled water use and consumption savings of $324,591 per year using the 2007 average cost of $0.0987/ton-hr.

Table 13. Estimated savings in chilled water ton-hours based on 6 month best-fit linear equations using annual outdoor temperature of 71.1 degrees F.

	Reduction ton-hrs/Month	% reduction	Monthly reduction ($)	Annual reduction (ton-hrs/yr.)	Annual reduction ($/yr.)
2005 to 2006	187,973	21.8%	$18,553	2,255,678	$224,635
2006 to 2007	86,082	12.4%	$8,496	1,032,987	$101,956
2005 to 2007	274,055	31.8%	$27,049	3,288,665	$324,591

Peak chilled water demand falls substantially short of the contracted 7,500 tons most months. Peak chilled water capacity used in the West building is shown in Figure 24. During the period from 2005 through July 2007, peak demand has exceeded billed capacity three times; April and November of 2005 and October 2006. Looking at chilled water demand during seven months in 2007, the highest peak occurred in June which was only about 78% of the 7,500 ton-hour billing capacity.

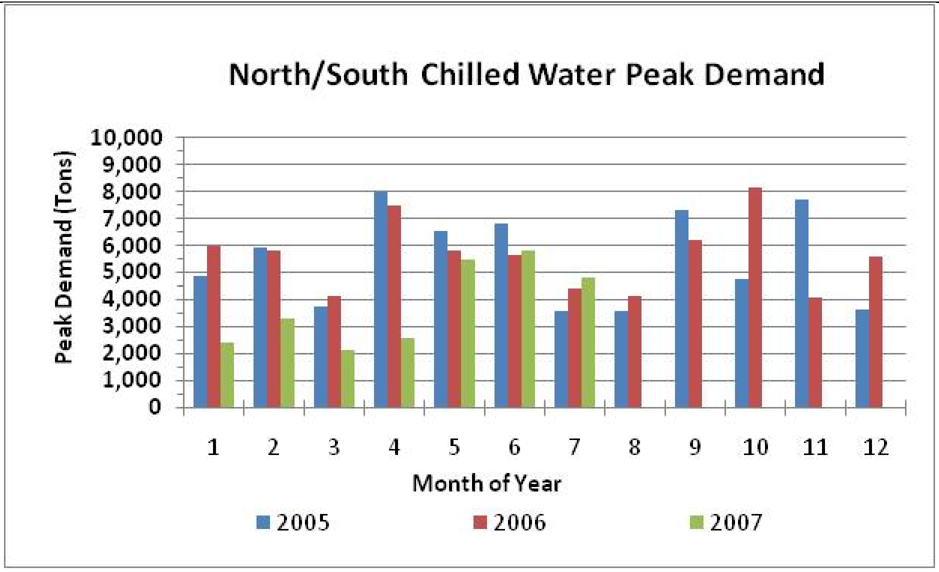


Figure 24 shows chilled water peak demand for each month of years 2005-2007

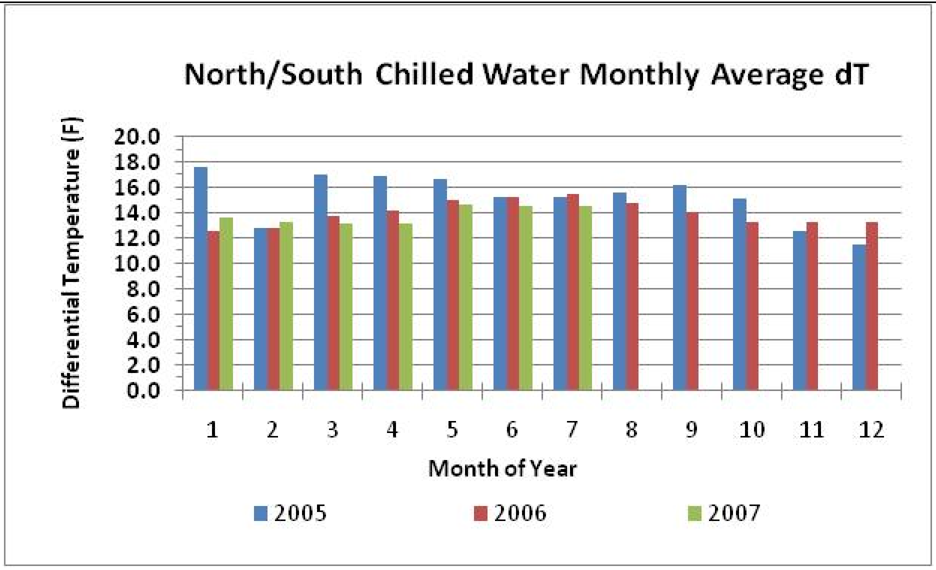


Figure 25 Monthly average return minus supply chilled water temperature

Unlike the West building, the chilled water temperature difference (dT) between the supply into the building and return out of the building is a factor in billing calculations. The same billing analysis applies to the N/S building as applies to the West Building. Figure 25 shows the delta-T for each month. Unlike the West building, delta-T is not increasing. Six-months average delta-T decreased by 13.1% from 16.08ºF to 13.97ºF from 2005 to 2006, and six-months average delta-T decreased by 1.5% from 13.97ºF to 13.77ºF from 2006 to 2007. The decline in delta-T from 16.08ºF to 13.77ºF is causing an approximate $5,700 monthly increase in the 2007 chilled water bills.

Current plans to run water-source heat pumps off of the return water (drawing from and return to the CW return piping) will help increase delta-T.

Summary

Substantial savings have been achieved from 2005 through 2007 at the OCCC, in both the West and North/South buildings. Tables 14 and 15 summarize calculated utility cost savings from reductions in electricity usage (kWh), electricity demand (kW), and chilled water usage (ton-hours) for the West and North/South buildings. Changes in chilled water peak demand are not presented because the contractual minimum billable amount is almost always higher than actual peak demand for both buildings. Actual coincident peak kW at the North/South building has decreased by 25.6% from 2005 to 2007, however coincident peak kW shown in Table 15 does not show any savings since the actual amount is lower than the contractual minimum charge of 6000 kW. Total cost savings, which we believe can be attributed to energy conservation measures implemented in 2005 and 2006, are estimated to yield total annual savings of $2,213,552. Savings represent an 18.3% reduction in energy costs in both buildings ($12,119,966) when compared to weather normalized 2005 utility bills at 2007 rates.

Table 14. West building total estimated annual $ savings due to reductions in kWh, kW and ton-hrs

	kWh $ saved	Peak kW $ saved	Off-peak kW $ saved	Ton-hrs $ saved	Total $ saved
2005 to 2006	$352,769	$44,072	$39,836	$228,724	$665,401
2006 to 2007	$204,420	$15,144	$14,774	$324,098	$558,436
2005 to 2007	$557,189	$59,216	$54,610	$552,822	$1,223,837

Table 15. North/South total estimated annual $ savings due to reductions in kWh, kW and ton-hrs

	kWh $ saved	Peak kW $ saved	Coincident peak kW $ saved	Ton-hrs $ saved	Total $ saved
2005 to 2006	$475,545	$93,504	$0	$222,635	$791,684
2006 to 2007	$90,216	$5,859	$0	$101,956	$198,031

2005 to 2007	$565,761	$99,363	$0	$324,591	$989,715

The reader should keep in mind that the indicated savings are based on “typical” meteorological conditions, which means that they are normalized to weather. One of the limitations of the current analysis (presented in this report) is that the data is limited to monthly time steps. This large time step means that there were only 30 data points for the analysis, one for each month. It was, we believe, this paucity of data points which prevented greater resolution in identifying causes of energy use variations, such as for occupancy. Future analysis should consider using daily data to determine if correlations between energy consumption and demand on one hand and occupancy metrics on the other can be developed. The weakness in the coefficient of determination (r^2) results, we believe, primarily from the small number of data points.

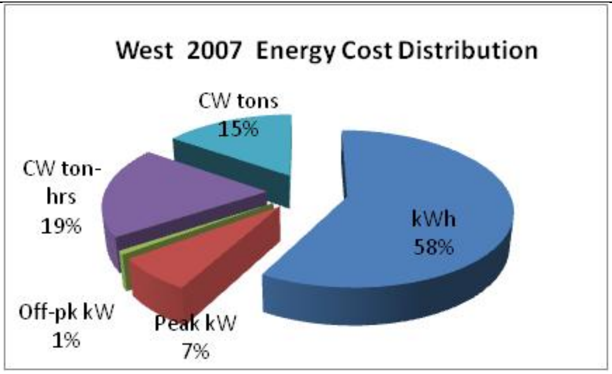
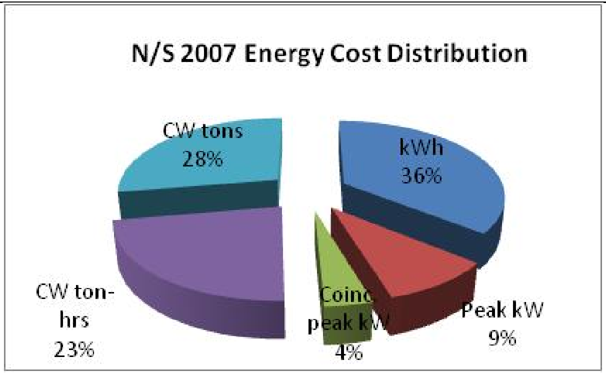
Inconsistencies in conservation activities over time will also have a greater impact on variability of a small data set. A hypothetical example of inconsistent conservation would be activities that rely on people to remember to turn things off. Whenever energy consuming systems rely on manual control, the potential for energy consumption variability increases.

Future analysis based on daily energy consumption would yield more useful results. Plotted of daily kWh or ton-hour consumption versus average outside temperature would likely yield r^2 values > 0.85 for data sets made up of about 25 days covering a range of average outdoor temperatures from about 70º F to 83º F. This type of analysis will be possible with an Energy Information System that can collect and store this type of information.

Breakdown of Energy Costs

Actual monthly billing data for the first six months of 2007 were examined to break down the total cost by fuel type and demand versus consumption, excluding taxes, service charges and other fees.

- In the West building, the greatest proportion of energy costs come from electricity consumption (58%) and electricity demand (8%) charges. Chilled water consumption and chilled water demand charges represent 19% and 15% of the total energy costs, respectively.
- In the North/South building, the greatest proportion of energy costs come from chilled water consumption (23%) and chilled water demand (28%) charges. Electricity consumption and electricity demand charges represent 36% and 13% of the total energy costs, respectively.
- Overall, approximately 60% of total (electricity and chilled water) utility bills is for electricity and 40% is for chilled water.

 Figure 26 West building energy cost breakdown	 Figure 27 North/South building energy cost breakdown

Energy Density

One way to compare energy used in different buildings is to normalize by building size (floor area). Tables 16 and 17 present size-normalized energy consumption in the West and North/South buildings, respectively. In order to make this analysis, we have converted chilled water energy (ton-hours) into equivalent electricity consumption (kWhs). We have made the assumption that the chiller plants producing the chilled water, including the pumping power associated with the primary CW loop and energy (conduction and leakage) losses associated with the CW loop, operate at an efficiency of 0.80 kW per ton. Under this assumption, 15,000 Btus of chilled water are produced by each kWh of electricity input.

Combining electricity and chilled water consumption of 2007 results in and average monthly energy density in the West building of approximately 1.3 kWh/ft^2 and approximately 0.8 kWh/ft^2 in the North/South building. These results can be compared to an average 2,000 ft^2 home (minimum efficiency, and without a pool or irrigation pump) which uses about 1,600 to 1,800 kWh/month. The energy density of the average residence is then between 0.8 to 0.9 kWh/ ft^2 per month. An energy-efficient home would have a density closer to 0.5 kWh/ ft^2 per month. The use and demands of the convention center are very different, of course, from residential spaces, but the comparison helps put the energy use into perspective of familiar spaces to which everyone can relate. Nevertheless, we can conclude that the energy density of the West building is relatively high, and therefore this building represents the greater opportunity for energy savings.

Table 16. West building energy footprint based on annual energy / 4.1million square feet

	Electricity kWh/ft^2	Chilled water Ton-hrs/ ft^2	Chilled water* kWh/ft^2	Total kWh/ft^2
2005	1.232	0.387	0.310	1.542

2006	1.137	0.338	0.270	1.407
2007	1.082	0.269	0.215	1.297

* Assumes average EER of 15btu/w

Table 17. North/South building energy footprint based on annual energy / 2.8million square feet

	Electricity kWh/ft^2	Chilled water Ton-hrs/ ft^2	Chilled water* kWh/ft^2	Total kWh/ft^2
2005	0.898	0.308	0.246	1.144
2006	0.649	0.241	0.193	0.842
2007	0.601	0.210	0.168	0.769

* Assumes average EER of 15btu/w

The newer controls and technology of the North/South building are more effective in controlling indoor conditions and conserving energy. This is one reason the energy density is about 1.6 times greater in the West building. Variable frequency drive (VFD) controls that allow air handling fans to be run at slower speeds can improve humidity control in buildings designed with cooling capacities much larger than is needed much of the time. Humidity is under control in the West building, but requires more air conditioning to do so without the VFD equipment used in the North/South building. Current plans of OCCC staff to install VFD on air handler fans should result in good humidity control and much more electricity savings in the West building.

Emerging new low energy commercial buildings are reported to have an energy density ranging from 0.349 to 0.697 kWh/ ft^2 per month. This suggests more opportunities for conservation and that appropriate future energy management plans at OCCC should successfully result in additional savings.