IMPORTANCE AND METHODS FOR REGULATION OF BUILDING RESOURCES IN AN ENVIRONMENTALLY CONSCIOUS WORLD

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Abstract

As energy costs nationwide are spiraling upward virtually out of control, more and more of the per capita salary goes into the gas tank, and as a result, less state revenue is generated from consumer spending. Therefore, universities and other state-funded establishments have been forced to make massive cutbacks, and almost all are seeking methods for conserving their own energy, thereby reducing expenditures. The University of Alabama at Birmingham (UAB) is no exception, as a $55 million budget cut in state funding has been proposed for the 2009 fiscal year. Therefore, enormous pressure has been placed on the UAB Facilities Management Department to identify ways to reduce energy-related expenditures, and one of the most important ways to do this is to regulate the resources that people within buildings use, including lighting, heating/air conditioning (AC), and water. This regulation also has favorable consequences for the environment, in terms of less contribution to global warming due to a reduction in burning of fossil fuels.

Building resources can be regulated a number of ways, from the extremely simple, such as lowering or raising thermostats depending on season or turning off light switches, to the more complex, such as implementation of motion sensors and lighting ballast controls. Other, long term solutions, such as implementation of green roofs or solar panels, typically require years of research to be effective. But, with environmental consciousness on the rise, and the skies ahead looking gloomy financially, the question that has been posed by building academic deans to the Facilities Management Department is, “what can we do about this now?”

With this in mind, the Civil, Construction, and Environmental Engineering Department of UAB has conducted collaborative research with the Facilities Management Department to perform occupancy surveys in a large number of buildings across campus on after-hours usage on weekdays, and on weekends. The aim of these surveys was to find out how efficiently building resources have been used, by counting the number of people occupying each room, and by noting whether lights have been left on if the room is unoccupied. Other “low hanging fruit” such as incandescent lighting, vending machines, freely-running water, and other non-efficient energy usages were also noted.

This data was used to provide overall recommendations to the Facilities Management Department and academic deans of measures they can take in order to reduce energy costs. Academic buildings that do not have large amounts of literature, for example, can withstand a 7-hour setback of air conditioning and dehumidification systems from 10:00 p.m. to 5:00 a.m. on weeknights, and possibly longer especially on weekends (48 hours from 6:00 p.m. on Friday to 6:00 p.m. on Sunday, for example). Research efforts could still be supported by the AC/humidity system; only large gatherings would find such a change uncomfortable. As for lighting, usage of lights only when the room is occupied or when natural lighting is unavailable is a favorable change at the building dean’s discretion, but more long-term measures include motion sensors

and layered lighting systems, as well as restricting access to certain floors at certain times of day. These measures have achieved favorable results in buildings where they have been implemented.

Introduction

The costs of operating each building at a large college campus such as UAB include a number of key utilities, including electricity, water, and natural gas. Each follows a distinct pattern, both in its monthly patterns each year and in its overall changes from year to year.

Electricity

The cost of electricity is usually cyclical in nature, but on the whole is rising year after year. For example, the Humanities Building had total electricity expenditures of $116,421 from March to December 2006, but $135,896 from March to December 2007. This rise also came despite the fact that there was a decrease from 2,003,951 kilowatt-hours from March to December 2006 to 1,879,222 kilowatt-hours during March-December 2007. Thus, the cost per megawatt-hour increased as seen in the graph below in Figure 1.

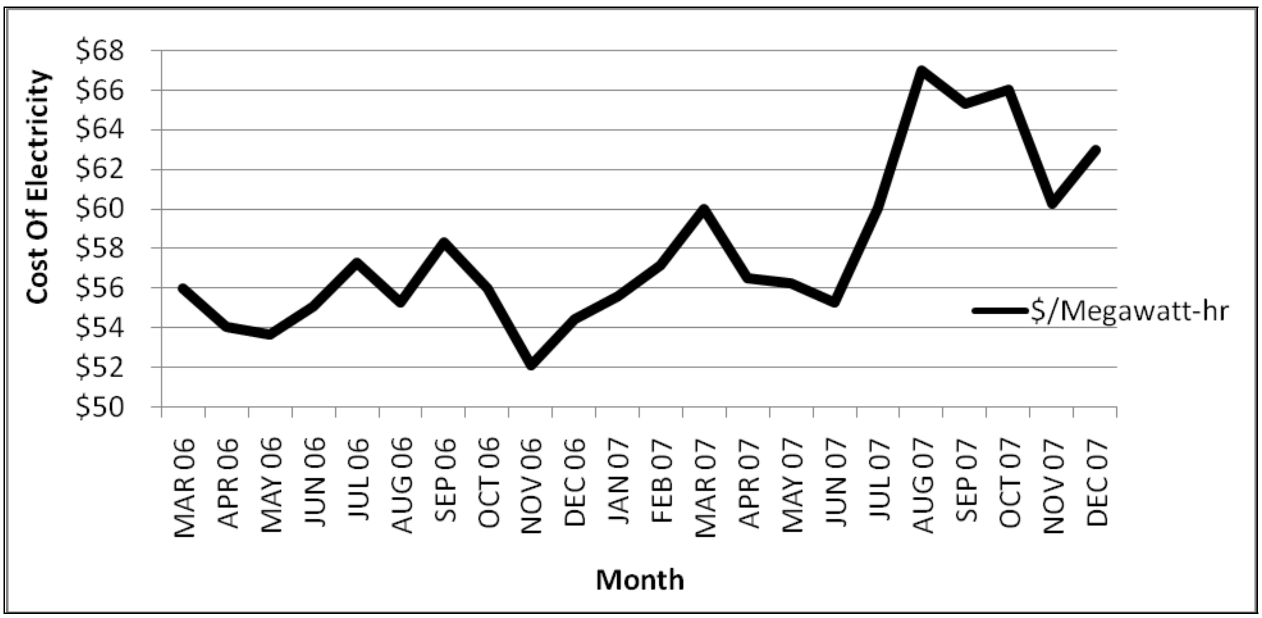

Figure 1. Electricity cost per Megawatt hour from March 2006 to December 2007 for the Humanities Building.

This indicates that there was a significant increase in the price of electricity independent of usage, especially during the time period from late summer to early fall.

Water

Costs of water supplied to buildings as a utility appear to be somewhat more random than electricity, but the same upward trend from one year to the next can be seen. In the Humanities building, total water costs for September-December 2006 were $4,736.93, and for the same period in 2007, they were $4,425.64, a 7% decrease. So, how can they be increasing? When you consider the unit of consumption, 100 cubic feet (CCF), there is a decrease from 526 CCF to 453 CCF, a 14% decrease. When the amount consumed decreases and the cost only decreases relatively half that amount, it indicates that total cost per unit increased, as can be shown in the graph in Figure 2.

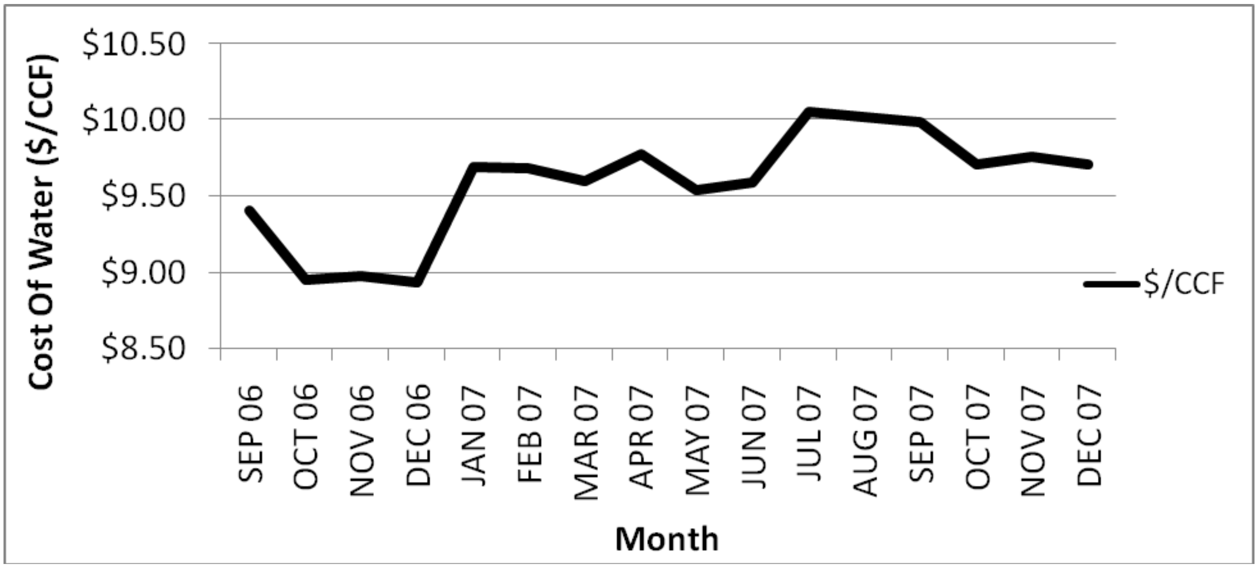

Figure 2. Water cost per CCF from September 2006 to December 2007 for the Humanities Building.

Thus, water costs are also rising steadily from one year to the next, although there is an encouraging sign in that actual water use dropped in 2007. This may be due to the fact that the drought was still considerably intense at this time.

Natural Gas

Natural Gas may be the only exception to the rule, as its usage was 27% higher from March-June 2007 over the same period in 2006, but its cost was only 22% higher for the 2007 period. As the graph in Figure 3 reveals, natural gas costs per unit are more or less stable, though there can be some fluctuation from month to month.

For July–October ’07, the result was actually a division by zero, since 0 CCF were reported for those months.

Environmental Concerns

Energy concerns today are higher perhaps than ever before, and in Alabama, with its record high temperatures and drought levels in 2007, the effects of global warming are ever more of a concern [National Weather Service, 2008]. Carbon dioxide is the chief greenhouse gas in terms of emissions per year, and energy-related sources emit nearly 6 billion tons of carbon dioxide into the atmosphere [Energy Information Administration, 2008]. Since coal combustion generated 57% of the electricity in Alabama in 2005 [Birmingham Newschart, 2007], and burning 23 kg of coal produces 44 kg of carbon dioxide [Carnegie Mellon University, 2003], control of electricity usage is proven to reduce coal combustion, and thus decrease production of carbon dioxide which contributes greatly to global warming.

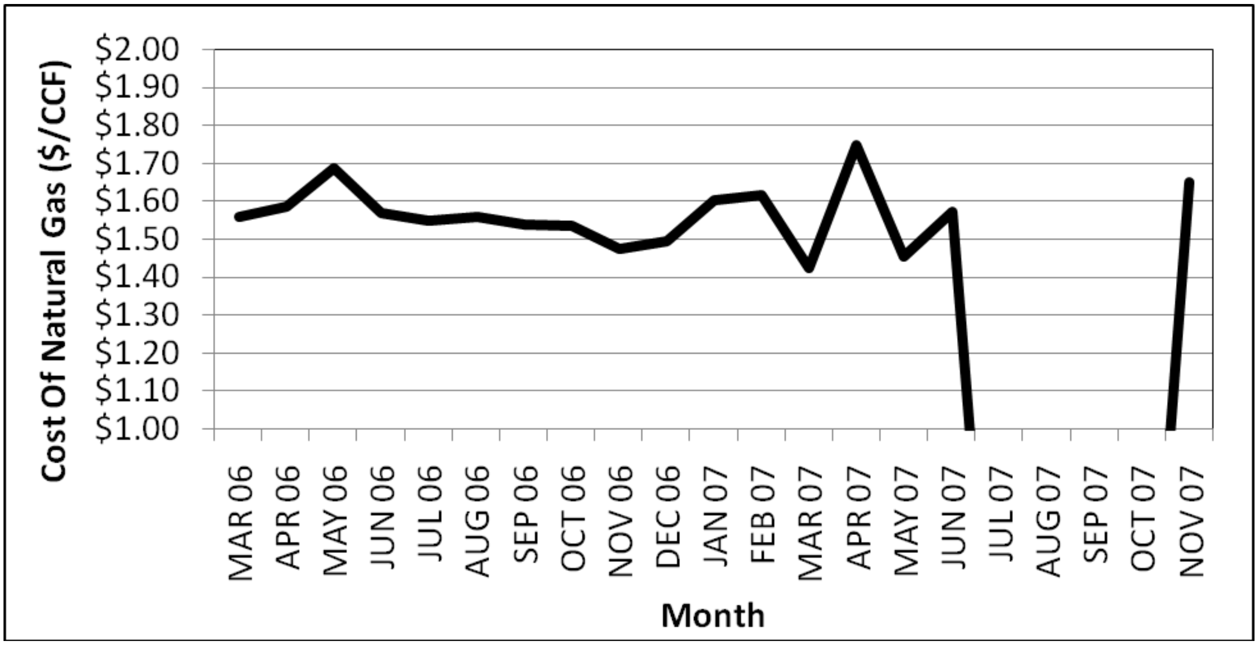

Figure 3. Natural gas cost per CCF from March 2006 to November 2007 for the Humanities Building.

For these reasons, the Facilities Management Department at the University of Alabama at Birmingham commissioned a study in which graduate students of the Civil, Construction and Environmental Engineering (CCEE) Department were tasked with researching ways that the building deans and administrators could reduce electricity use even further, and thus keep the utility bill down and greenhouse gas emissions to a minimum.

Brief Background

A similar study was performed in 1981 by George A. Jackins and Michael E. Scruggs. This study encompassed 11 buildings on the UAB campus, three of which were also surveyed in the more recent effort [Jackins, 1983a-e]. The objectives and goals of each of the two studies were also remarkably similar, though their methods differed. The 1981 studies involved an in-depth walkthrough of each building, including visual inspections of Heating, Ventilation, and Air Conditioning (HVAC) systems, lighting systems, and a complete cost analysis of the building as it was, and as it would be if their operation, maintenance, and energy conservation measures were adopted. The 2007–2008 studies involved 20–30 different walkthroughs of each building; however, due mainly to a lack of access to complex building systems by CCEE graduate students, only two major types of data were collected from each building:

1. Number of occupants in each room and corridor, and
2. If the room was unoccupied, noting whether or not lights were on in the room.

Additionally, notes were made of any “low-hanging fruit” (incandescent lights, vending machines, etc.), but these were not reported for each room in the building like the two main criteria were.

Project Goals/Objectives

The goal of the study was to determine how efficient each building was in terms of energy use by its occupants. A total of 14 buildings were covered in this study; in 2007, the Education Building, Hill University Center (HUC), Business and Engineering Complex (BEC), Sterne Library, Hoehn Engineering Building, Humanities Building, Scrushy Building, Ryals Building, University Boulevard Office Building (UBOB), and Campbell Hall were surveyed, while in 2008, Lister Hill Library, the Peters Building, the Worrell Building, and the Center for Biological Sciences and Engineering (CBSE) were surveyed. Each entire building that was surveyed in 2007 was surveyed roughly every two hours on weeknights from 6:15 p.m. to 12:15 p.m. and on weekends from 7:00 a.m. to 11:00 p.m. A little more freedom was granted with the buildings surveyed in 2008, so they were surveyed at varying times, roughly every two hours during the period of 5 p.m. to 9 or 11 p.m. on weeknights and every 2–3 hours during the period of 9 a.m. to 9 p.m. on weekends. As each room was surveyed, a symbol was recorded for that room for that nominal time: if the room had occupants, the number of occupants was recorded, and if not, the percentage of lights on in the room was estimated and recorded as follows: “P” for 1–50%, and a zero with a slash through it (Ø) for 51–100%. Using this method, the only building resource that could not be implied was water, due to the fact that it is not inherently used by occupants of rooms like electricity for lighting and natural gas for heating are.

The time period covered by each study was roughly 6 hours on weeknights and 16 hours on weekends (a total of 62 hours) for 2007 studies, and 4–6 hours on weeknights and 12 hours on weekends (a total of 44–54 hours) for the 2008 studies, or that portion thereof in which the building was open (HUC, Sterne, Lister Hill), By taking the cost of the resources that were expended during the month of the study, prorating it for the actual after-hours time period covered by each study, and dividing it by the average number of occupants witnessed over all studies, an expenditure per occupant figure can be calculated. A comparison of this will determine which buildings are being used less efficiently during this period. In addition, a qualitative judgment can be made about what time each weeknight HVAC systems can be set back, which varies from building to building, based on at which point occupancy tapers off significantly. Finally, a comparison of the number of fully lit rooms against the number of total rooms should give an idea of what buildings have the worst problem with lights being left on when rooms are not in use.

Results and Discussion

The results for the entire study cannot be displayed within a limited number of pages, but they can be summarized and analyzed in four key ways that will each point out a feature of the building’s efficiency:

1. After-hours utility cost per occupant
2. Time of drop-off in occupancy
3. Percent of building fully lit in after-hours
4. Utility cost per gross square foot

After-Hours Utility Cost per Occupant

Table 1 shows a calculation of total expenditure on utilities for the after-hours period of each building for each person in average after-hours occupancy (AAHO). AAHO is defined as the mean of all results for total occupancy of the building regardless of nominal time. The amount of each utility bill is also prorated by the following equation:

$$\$Prorated = \frac{\$Bill * Survey\ Hours}{Total\ Hours\ in\ Month}$$

For surveys that took place in two different months, a simple average of number of days (usually 30.5) and bills was used. By dividing this value by the AAHO, a cost-per occupant (CPO), can be determined. Finally, a rank is given to each building, with lowest per-person occupancy amounts being the most efficient in terms of its CPO.

Table 1. Determination of Utility Cost per Occupant and Rank.

Building	AAHO	Study Month(s)	MHrs	PHrs	Prorated, ($)	CPO, ($)	Rank
Education	60.26	2/07	672	62	2,249.71	37.33	2
Ryals	6.53	11/07	720	62	3,568.36	546.77	10
BEC	97.97	10/07, 11/07	732	62	3,087.33	31.51	1
HUC	26.69	10/07, 11/07	732	62	3,175.22	118.96	5
Humanities	21.95	11/07	720	62	1,476.11	67.26	4
Hoehn	3.55	10/07, 11/07	732	62	764.98	215.33	7
UBOB	9.89	10/07, 11/07	732	62	1,397.08	141.19	6
Scrushy	1.82	11/07	720	62	1,413.80	778.61	12
Lister Hill	45.81	4/08	720	77	2,220.22	48.47	3
CBSE	3.70	4/08, 5/08	732	44	2,247.28	607.37	11
Peters	7.90	5/08	744	54	1,805.65	228.56	8
Worrell	2.67	5/08	744	44	1,282.25	480.84	9

Campbell Hall and Sterne Library could not be analyzed due to the fact that data was missing. Classroom buildings such as BEC, Humanities, and Education buildings and the Lister Hill Library, tend to be on the low range in CPO, due mainly to the fact that they have higher AAHOs. Research-oriented buildings had lower AAHOs, often fewer than 5 people, and thus their CPOs tend to be upwards of $480. Therefore, simply put, they are far more expensive to operate in terms of their benefits to each occupant. Many are also likely candidates for early closure in after-hours, but there is the major obstacle that research activities would be greatly hindered. A better solution would be to save as much as possible while leaving the buildings just barely hospitable for their sparse occupants.

Suggestion for Setback Times

Setting back of HVAC systems to a value that is still hospitable for the few occupants that are left inside later in after hours would result in 25% of the working-hours expenditure, according to Facilities Management. Assuming no current measure is in place, and that electricity and water bills would get lowered by the same amount, savings would be according to the last two columns in Table 2.

Table 2. 2007 Occupancy Taper-off, Suggestion for Setback Hours, and Potential Savings.

Building	**6:15 p.m.**	**8:15 p.m.**	**10:15 p.m.**	**12:15 a.m.**	**Setback Time**	**Setback Hours**	**Savings*, ($)**	**Savings, (%)**
Ryals	31	5	3	2	7:00 p.m.	98	18,129.58	43.75
BEC	352	209	32	21	10:00 p.m.	86	13,911.15	38.39
HUC	51	24	11	Closed	9:00 p.m.	90	14,716.29	40.18
Humanities	149	25	5	1	9:00 p.m.	90	6,887.36	40. 18
Hoehn	10	8	4	0	7:00 p.m.	98	3,685.61	43.75
UBOB	52	4	Closed	Closed	7:00 p.m.	98	7,903.03	43.75
Scrushy	12	2	2	2	7:00 p.m.	98	7,183.02	43.75

The setback hours used in the third-to-last column above call for full setback on weekends (never on those days does the total occupancy exceed 100 people in any building), setback from the given time until 5:00 a.m. on weekdays, and beginning at 7:00 p.m. on Friday night. In most instances, this would result in a roughly 40% decrease in the monthly bill, as seen above. As for the 2008 surveys, results were very similar, as is seen in Table 3.

Table 3. 2008 Occupancy Taper-off, Suggestion for Setback Hours, and Potential Savings.

Building	**<6 p.m.**	**6–8 p.m.**	**8–10 p.m.**	**>10 p.m.**	**Setback Time, (p.m.)**	**Setback Hours**	**Savings, ($)**	**Saving, (%)**
Lister Hill	69	53	47	24	10:00	86	7,970.55	38.39%
Peters	25	4	4	2	6:00	103	11,439.34	45.98%
Worrell	10	2	2	2	6:00	103	9,969.70	45.98%

CBSE data was missing; therefore its analysis is unavailable. Research facilities in particular would benefit the most, as a 46% savings could be realized by the suggested setback.

Percentage of Rooms Fully Lit and Utility Cost per Gross Square Foot **(GSF)**

Up until now, all parameters have dealt with the occupancy of the rooms if they were occupied, but how about the rooms which were fully lit and unoccupied? The next phase of the study deals with rooms in that condition, and the average number of these rooms per survey per building is displayed below under the heading AAHL, which means "average after-hours lighting". This value is simply divided by the total number of rooms in the building to yield a percentage of fully lit rooms. This is displayed, among other things, in Table 4.

Table 4. Percent Fully Lit Rooms, Cost per GSF, and Energy Efficiency Scores.

Building	**AAHL**	**Room**	**Fully Lit, (%)**	**Rank**	**Average $/GSF**	**Rank**	**CPO, ($)**	**Rank**	**Score**
Ryals	33.45	312	10.72%	6	$0.41	8	546.77	9	23
BEC	52.64	305	17.26%	10	$0.25	3	31.51	1	14

HUC	19.82	310	6.39%	3	$0.25	4	118.96	4	11
Humanities	18.50	170	10.88%	7	$0.26	5	67.26	3	15
Hoehn	17.75	139	12.77%	8	$0.26	6	215.33	6	20
UBOB	12.90	70	18.43%	11	$0.42	9	141.19	5	25
Scrushy	7.52	194	3.88%	1	$0.21	2	778.61	11	14
Lister Hill	15.21	155	9.81%	5	$0.13	1	48.47	2	8
CBSE	18.90	270	7.00%	4	$0.49	10	607.37	10	24
Peters	16.90	296	5.71%	2	$0.29	7	228.56	7	16
Worrell	23.50	176	13.35%	9	$0.51	11	480.84	8	28

Unlike the previous analysis, the ranking seems to be independent of building usage, as the best is Scrushy, a nursing building, while the worst is UBOB, the criminal justice building. The other major classrooms and research facilities alternate, which seems to indicate a higher degree of bias based on each surveyor's judgment of what constituted a fully lit room. The utility cost per GSF is just that, and is a parameter which does not rely on any survey's results. It follows that, similar to CPO, it tends to favor libraries, administrative buildings, and classroom buildings, while research facilities perform poorly. However, that does not mean that there are no exceptions, as the Scrushy building, which is the second-best in terms of cost per gross square foot, is the worst in terms of after-hours CPO!

Summary and Conclusions

The final column in Table 4 in the previous section is a "score" of the utility efficiency of each building, based on three major criteria above:

1. After-hours cost per occupant;
2. Percentage of fully lit rooms; and
3. Cost per gross square foot.

All 11 buildings for which each parameter could be determined were ranked 1 to 11. The score was determined by summing the rankings for the percent fully lit rooms, the average cost/gross square foot, and the cost per occupant. The buildings with the lowest scores can be termed ideal models for how buildings should operate, while the ones with the highest scores appear to require some work. Lister Hill Library is the only building with a score less than 10, and HUC, which was determined by the team to be "an ideal model for how a building to operate" scored an 11. Five buildings had scores in the 20s: Ryals; UBOB; Hoehn; Scrushy; and Worrell. By this analysis, it appears these buildings could use some work in making them more utility-efficient.

Whether a building "scores" low or high, there are a few things that can be done to make it more energy efficient:

- Academic deans can pressure personnel to turn out lights when they are not in use;
- Replacing all incandescent lights with fluorescent lights, both straight and compact;
- Layered lighting in hallways and corridors for security;
- Motion/occupancy sensors in hallways and classrooms not currently equipped with such devices;
- Setback of HVAC systems to 25% of the daytime level in after-hours usage;
- Replacing washers and other parts in water systems which may lead to leaks; and
- Controlling water temperature in water fountains based on the building's occupancy.

If all of these measures were followed to regulate building resources, a potential savings of 50% or more could result.

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