Opportunities of Conserving Energy on an Existing Institutional Building: Case Study

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ABSTRACT

The building considered in this case study is a two-story facility with total floor area of 3588 square meter; it is mainly educational facility (classrooms, laboratories, and workshops) as well as staff offices. The building is cooled by an air-cooled reciprocating chillers which is operating round the clock. A preliminary energy audit technique was conducted to evaluate the building energy performance and identify opportunities of saving energy. In addition to the walk-through technique also mini-data loggers were installed in each zone to monitor dry-bulb temperatures, relative humidity, and light intensity over the year 2008. Specific ANSI/ASHRAE/IESNA Standard 100-2006 "Energy Conservation in Existing Building" measures were implemented in the building. The recorded data showed large deviation of dry-bulb temperatures from comfort range in many zones. The building simulated using DesignBuilder simulation program controlling the indoor temperature and using the set-back temperature schedules. These two parameters showed an opportunity of saving energy of the existing building by 35%, and 15% respectively. Finally, a cost analysis of implementing Building Management System (BMS) was analyzed; the result showed a pay-back period of less than six months was obtained.

INTRODUCTION

Energy Audit is a continuous process to detect operating problems, improve comfort, and optimize energy use for new and existing buildings. A specified standard of existing buildings was introduced by ANSI/ASHRAE/IESNA under the title "Energy Conservation in Existing Building" Standard 100-2006 [ASHRAE 100-2006]. Efforts are underway by researchers and engineers to achieve best building performance with minimum energy. In 2002, the Energy Systems Laboratory at Texas A&M University examined system operations in a number of newly retrofitted buildings and found that optimizing the systems can double energy savings and improve building comfort [Liu et al., 2002]. Efficient-operation has produced typical savings of 20% with payback fewer than three years (often 1-2 years) in more than 130 large buildings [Claridge, D.E., et. al.].

The purpose of the Energy Audit is to identify opportunities for energy conservation [Haberl, J.S. and P.S. Komor, Mazzucchi, R.P., and Miller, W.]. Therefore periodic assessments are required because of possible changes in building use, in the condition of existing equipment, and in the available energy-efficient technologies. As per the ASHRAE 100-2006 standard, there are three levels of energy audits: 1) Walk-through assessment, 2) Energy survey and analysis, and 3) Detailed analysis of capital intensive modifications. The results of these levels of energy audit are list of energy conservation opportunities.

In this case study levels 1 and 2 were conducted. A Walk-through showed many deficiencies in the energy management of the building; exterior and emergency doors were opened and lights were left on after the occupancy period. Also, a survey of the staff members was conducted to find out the top office complaints. Furthermore, mini-data loggers were fixed on the teaching facility such as classrooms, laboratories, and workshops to record main effective comfort and energy consumer parameters: dry-bulb, relative humidity, and light intensity.

The purpose of this study is to identify when most thermal complaints occur, the nature of the complaints, and what building actions and improvements must be made to make sure that workers are comfortable and able to concentrate on their jobs as well as minimizing energy use.

Major Energy Audit measures in this case study included: 1) Walk-through assessment and 2) Energy survey and analysis. The remainder of this paper provides simple cost analysis of implementing the recommended energy-efficient controls and Building Management System (BMS).

BUILDING DESCRIPTION

The building considered in this case study is a two-story institutional facility, that houses the Mechanical Engineering Department (MED), College of Technological Studies(CTS), with a floor area of 3588 square meters, most of which is teaching facility (classrooms, laboratories, and workshops), see Figure 1. The system operates 24 hours a day, 7 days a week. The HVAC system is equipped with four air-cooled centrifugal chillers with capacity of 530 kW (150 ton) each. Fourteen constant air volume air handling units are serving the whole building apart from the workshops that which are served by 29 Fan-Coil-Units. The heating system is a matter of electric heaters that installed on the air downstream of the AHUs. The HVAC system is controlled manually by operators who work in two working-shifts (12 hour a shift). The building walls and roof/ceiling construction can be considered heavy as it is the common practice in the very hot climate such as in the State-of-Kuwait. Windows and doors are constructed from clear tempered double glazing filled with air.

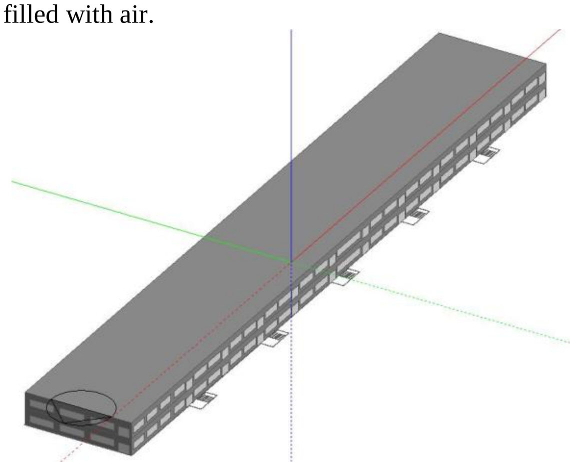


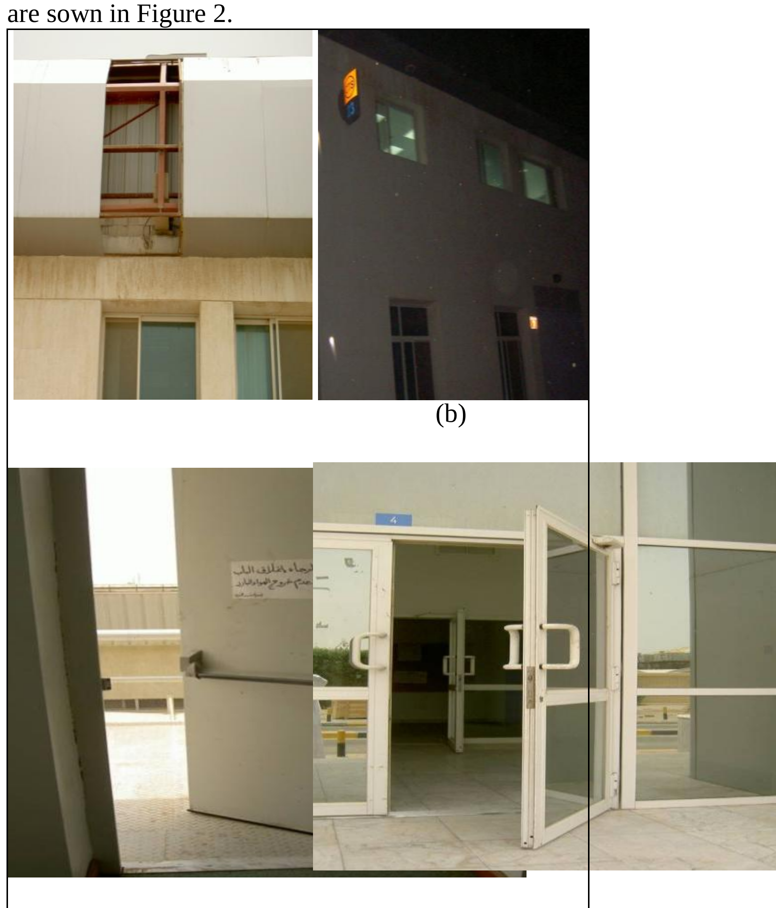
Figure 1: Isometric view of the studied Building CTS-MED.

ENERGY AUDIT MEASURES AND IMPLEMENTATION

Major Energy Audit measures in this case study included the following: 1) Walk-through assessment 2) Energy survey and analysis.

WALK-THROUGH ASSESSMENT

As per ASHRAE standard 100-2006 there are requirements for the survey of energy use in existing buildings. First, the building should by classified according to its usage. Then the building should be checked by the auditor covering the building envelope and HVAC system. Exterior joints around windows and door frames, between walls and foundation, between the wall and roof, between wall panels, and at penetration for utility services through walls, floors, and roofs. Missing saddles and door sweeps should be replaced. By doing this task a list of non comply to ASHRAE Standard 100-2006 by the building envelop was prepared and some samples are sown in Figure 2.



(b)

(a)

Figure 2: Spotted wrong doing in the building: (a) uncladed structure (b) lights on during post-

occupance (c) & (d) emergency and exterior doors left opened.

The HVAC system was devoid of any basic control that could automatically start and stop the system under different time schedules. The operation was completely done manually and no system sequence operation, so increasing number of operated units left to the operators experience. Surprisingly, temperature supplies are controlled based on the occupants' complain from too hot or cold. Also, the whole 3-way valves of the air-handling units (AHUs) were not functioning properly. Many of the fan-coil-units (FCUs) valves were leaking and motors were not working.

SURVEY AND ANALYSIS

A survey was drafted with the assistance of several HVAC subject matter experts. Once the questions were developed, the survey was sent to a sample of 35 staff members who worked in the building for more than 10 years. The survey was specifically investigating the comfort of the staff over their past experience on the building (average 10 years). The survey was fielded June 2-4, 2009. A total of 25 responses were received by June 19, 2009. After subtracting the number of returned e-mails and hardcopies, the CTS-MED members calculated a response rate of 71 percent. The results of the staff survey is shown in Figure 3. As shown in Figure 3 most compliant was on the ability of controlling the environment (80%). More than half of the staff was complaining uncomfortable because of either too hot, while one third was complaining too cold. Common grievances offered include high noise levels, limited space and unusual odors. However, complaints of the temperature being too hot or too cold always topped the list, often alternating from zone to zone and person to person. Research has shown that improvement to thermal comfort issues often results in higher tenant satisfaction scores, so building owners and operators take these concerns seriously.

The staff'~~s~~ offices represent only 17 percent out of the total building area. Therefore, assessment of the remaining building zones (class rooms, workshops, and laboratories) should be considered, this what will be overviewed in the upcoming paragraphs.

Mini-data loggers, see Figure 4, were installed in each zone to recorded dry-bulb temperature, relative humidity, and light intensity.

Figure 3: Mini-Data logger used to assess the building performance.

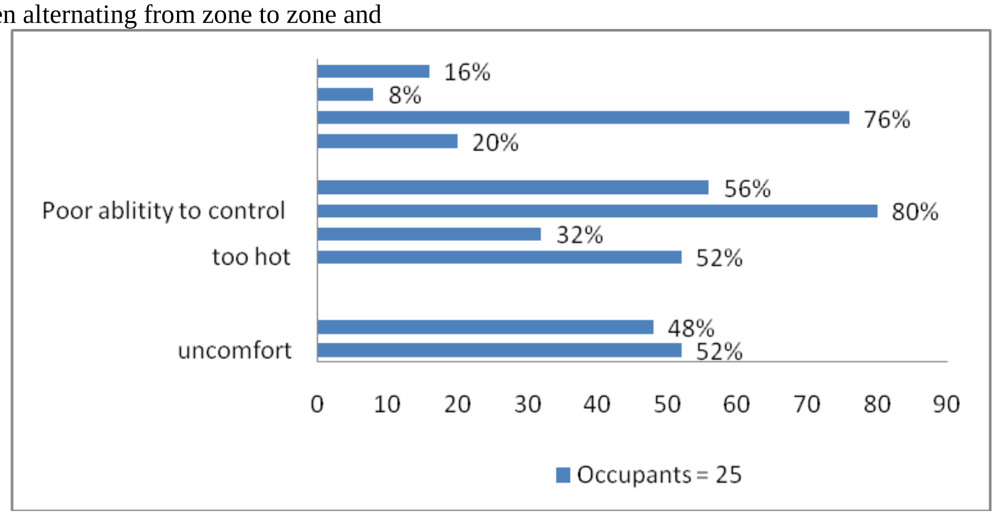


Figure 3: Results of the staff survey.

How the temperature and relative humidity were regulated in the remaining part of the facility is shown a sample in Figure 5. Two zones were selected, zone 1 (Z1) in the first floor which represent a staff office and the second (zone 7, Z7) in the ground floor which represent a workshop. The recorded temperature was below than recommended during most of the summer period and in Z7 ranged between 14 to 18°C most of the period. Also, the relative humidity slightly above typical 45-55% at typical corresponding indoor temperatures. This a clear indication of misuse of energy and creating uncomfortable indoor environment.

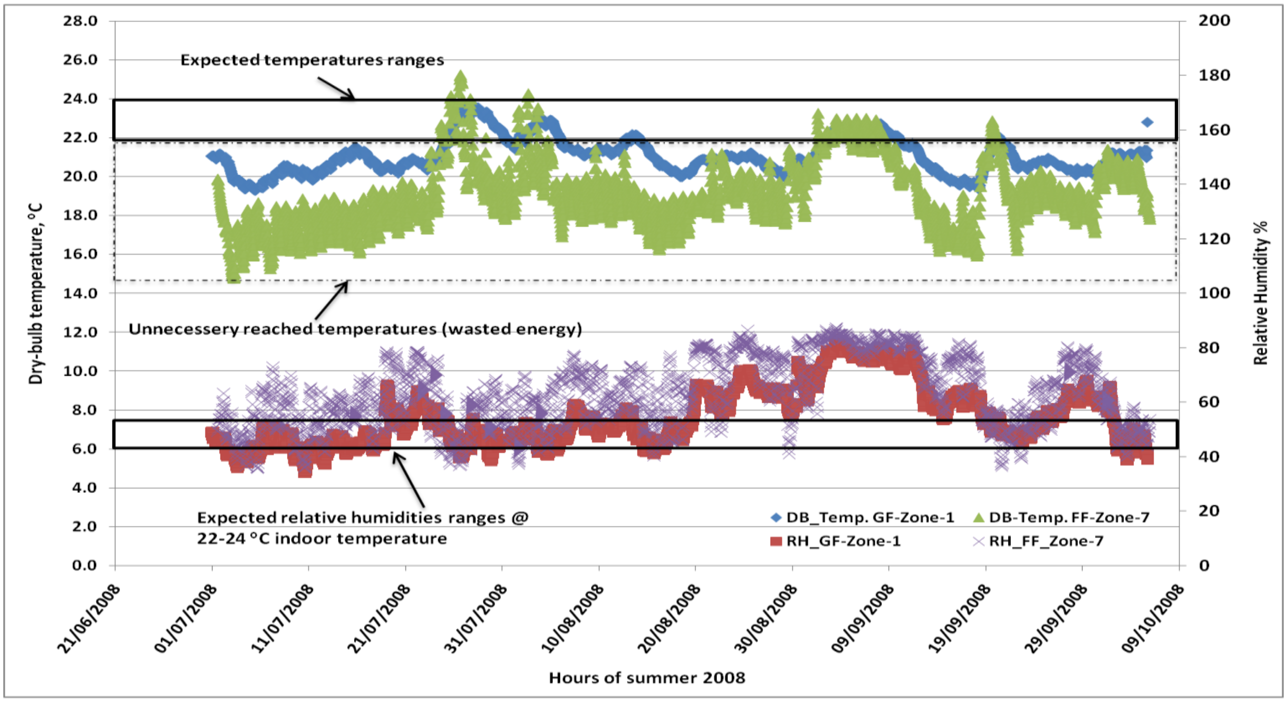


Figure 4: Temperature and relative humidity regulating during a summer season.

Some results of an analytical analysis performed to compare recorded data to recommended indoor temperatures and to determine the opportunities for saving energy are presented in Table 1. For each zone shown in the table, the first column shows the average recorded dry-bulb temperature for each month of the summer season (April to October) and the second column shows the energy that may be

Table 1: Opportunity of saving energy if the building operated properly.

	First Floor Zones				Ground Floor Zones			
	Z3		Z4		Z3		Z4	
Month	Temp.	Opport. Of Saving Energy %	Temp.	Opport. Of Saving Energy %	Temp.	Opport. Of Saving Energy %	Temp.	Opport. Of Saving Energy %
April	19.6	43 - 79	19.5	46 - 82	19.0	60 - 100	20.0	33 - 67
May	19.0	60 - 100	18.8	67 - 108	18.6	74 - 117	20.8	18 - 47
June	18.5	78 - 122	18.7	70 - 113	18.2	91 - 138	21.4	8 - 35
July	19.6	43 - 79	18.3	86 - 133	18.4	82 - 127	20.7	19 - 49
August	19.8	38 - 72	18.9	63 - 104	19.1	57 - 96	21.1	13 - 41
September	20.4	25 - 56	19.6	43 - 79	19.7	40 - 75	21.4	8 - 35
October	21.7	4 - 30	19.5	46 - 82	19.7	40 - 75	20.6	21 - 52

saved if the zone were operated within the occupants' comfort temperatures ranges (22-24°C).
Another way of analyzing the building energy consumption is to review its record over the years as presented for the period (2005-2008) in Table 2. The building on average consumed 611 kWh/m² per year, while a similar usage and number of occupants over floor area, Kuwait Audit Bureau, consume on average 311 kWh/m² i.e. there is an opportunity to save up to 49% of energy.

Table 2: Building energy consumption history compare to typical.

Actual Building Energy Consumption (kWh/m².year)		Typical Building Energy Consumption (kWh/m².year)*	
2008	**2009**	**2008**	**2009**
599	622	295	327

*Normalized to be similar to the actual building specification.

PARAMETRIC STUDY

Facility managers should work continuously to keep facilities comfortable for workers, as this comfort is directly tied to worker productivity with minimum energy use. However, in this case study, the facility manager adjusted the thermostat to low settings in the summer which defiantly increased energy cost and consumption and did not satisfy the occupants' comfort. So, to quantify the amount of energy that could be saved if the building operated at recommended temperatures and relative humidity the building specification were fed to a building simulation program (DesignBuilder1). After the simulated building was ensured to behave similar to the actual, two parameters: indoor temperatures and proper schedule to set-back temperature on post-occupancy period, weekends, and holidays were manipulated. This showed a reduction of the building energy consumption by 35%. While the second parameter, set-back temperature, which is a matter of schedule the zone temperature to above recommended during the post-occupancy of the building (26-28°C) and reset to (22-24°C) pre-occupancy gave a reduction over the reduction of the first parameter by 15%, see Table 3.

Table 3: Amount of energy reduced by manipulating two effective parameters.

Parameter	**Simulated Building** Energy Consumption (kWh/m².year)	**Energy Saved (%)**
Control Indoor Temperature	397	35
Set-back Temperature	337	15

COST ANALYSIS

In order to implement the approach of control building indoor temperature and utilize the feature of scheduling the building indoor temperatures during post-occupancy, a building management system (BMS) is required. Therefore, it is important to analyze the cost of such system and to measure its feasibility. As this study is in its preliminary stage, level 1 and 2 energy audit, a simple payback period (SPP) of economic analysis will be used. This can be calculated using the following equation:

$$SPP = \frac{Invesment}{Annual\ saving} \qquad (1)$$

So, the amount of energy saved will be multiplied by its cost to the nation which is considered 32 fills/kWh, this will represent the amount of money saved annually by implemented the BMS system. While the money need to invest to purchase the BMS with its installation was found from average of three quotations offered from local BMS specialist companies, which was around 30,000 Kuwaiti Dinar (KD). Then using the Equation 1 the payback period will be as follow:

$$SPP = \frac{10{,}000}{1.98 \times 10^6\ kWh\ \times 0.032 \frac{KD}{kWh}} = 0.5\ year$$

The results of the cost analysis is very encouraging to implement such approach.

[1] DesignBuilder uses the EnergyPlus dynamic simulation engine to generate performance data (http://www.designbuilder.co.uk).

CONCLUSION

The implementation of a Building Management System (BMS) can significantly improve building comfort and reduce HVAC energy cost. As can be seen in Tables 1, and 2, both gave indication of energy consumption are substantially reduced. The electricity consumption is reduced by 44.6% based on typical building consumption and data collected from the utility ministry. The payback period showed about sixth months to get back the amount of money invested; very encouraging. So a strong recommendation will be made to the building management to implement the BMS.

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