Cost Analysis of Smart Lighting Control for Residential Buildings

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Abstract - *Building efficiency must be taken as the performance improvement of a complex design to deliver occupants with a safe, comfortable and attractive living environment. Higher architecture and engineering designs, quality construction, and intelligent operation of the structures are required for building efficiency. Gradually, operations will take in integration with sophisticated electric utility grids. Lighting signifies 20% of the total energy expenses of residential buildings and 38% of their electrical energy expenses. An efficient lighting-controlling system can significantly reduce the mentioned costs. This paper will discuss the cost-effectiveness of smart lighting control for residential buildings.*

***Key Words*: Energy, Lighting, Control, Cost, Residential Building.**

1. INTRODUCTION

Heating, ventilation, and air conditioning are the key areas of energy in buildings—35% of total building energy; lighting—11%; main appliances (water heating, dryers, refrigerators, and freezers)—18% with the enduring 36% in various areas counting electronics. In every case, there are chances both for improving the productivity of lighting devices and the manner they are controlled as a part of integrated building systems. The first and key factor in view of a possible investment in lighting control solutions is cautious monitoring of spending of energy of the building in the necessity of lighting. Since the technology is used in buildings and public spaces, it is very likely that there are many possibilities to reduce energy consumption through some simple strategies such as the utmost use of daylight; optimal distribution of luminaires, and enabling presence detection features. The usage of electrical energy for illuminating industrial plants, streets, or others can be expressively reduced by gaining the finest work system of lighting installation in any given environment. Lighting management is assisted by selecting the appropriate equipment for automatic lighting control. [1]

Fig -1 shows U.S. building energy use in 2014. Space conditioning and lighting represent well over half of the total, including energy used in outdoor lighting and cooling in most data centers. [1]

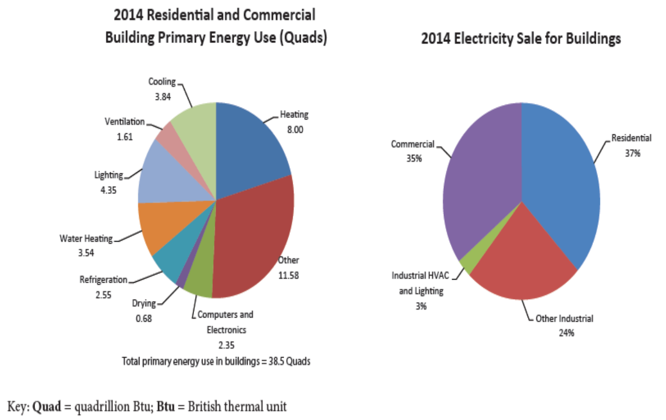

Fig-1 Energy Usage of Residential and Commercial Buildings of the U.S.A [1]

A decreased use of energy means less to pay for energy bills, reduced load on the grid, and less environmental impact. Lighting is the most common and naturally the most constant form of load. It represents a significant portion of the total electricity consumption of all building types, and it is more prominent in commercial buildings. For instance, according to the US Department of Energy, lighting load represents 11% of energy consumption in residential buildings on average [2]. Other studies show that the average lighting load can be significantly higher in some cases [3]. A European study shows that in the case of average and large buildings, about 40% of the total electricity is used for interior lighting [4]. Residential buildings hold great importance when it comes to energy consumption. Out of the total primary energy requirement of the United States, for example, over one-third is consumed [3]. If office buildings are considered separately, the contribution of lighting energy demand on overall energy consumption can be 20–25% [5]. So, a reduction in lighting load in residential buildings can have a noteworthy positive impact in decreasing the electricity demand, which in turn helps reduce carbon footprint [6,7], which is a key focus for energy engineers at the current time. Taking the energy impact of lighting systems into viewpoint, various governments and international organizations sponsor specific energy-saving guidelines for lighting systems [8,9]. Later researchers have been continuously booming to do better efficiency in lighting, which means maintaining optimum lighting conditions using as less energy as possible. Research shows significant savings from various types of lighting control schemes [10]. Manual lighting control depends mostly on occupant behavior, occupancy patterns, and general awareness about energy saving [11].

2. REDUCTION OF EXPENSES BY LIGHTING CONTROL

Lighting control (i. e. daylight sensors and devices dipping the light intensity or allowing remote control) can reduce energy feeding by 65%, and these systems will facilitate 35% by the end of 2030. Smart lighting controlling support to the users and companies of LED lighting to lessen the energy expenses related to the infrastructure of lighting. With these kinds of solutions, the companies can handle the work more easily and assist with the necessary lighting in rooms, when required. The lighting control system regulates when it is necessary to dim the light or when the lights need to go on/off. This is one of the basic ethics and resolutions used for the concept of smart buildings. This is how unwarranted energy consumption is eradicated while fulfilling the needs of the residents in the building.

2.1 Lighting Control

From a lighting perspective, an optimal window would provide attractive light levels throughout the day while avoiding glare and unpleasantly intense light on surfaces such as computer screens. It would allow the user to control the amount of visible daylight transmitted through the window—possibly altering the direction of the transmitted light and adjusting transmission by color. Windows with varying optical properties can be built using mechanical systems such as adjustable blinds or louvers. Glazing can have adjustable optical properties such as thermochromic windows that automatically change transmissivity in response to temperature and electrochromic windows that change with electronic controls. Light pipes, light shelves, and skylights to direct sunlight from roofs deep into buildings can lead to large savings, but these will depend on effective building designs. Advances in optics and manufacturing of dynamically-controlled windows make it possible to redirect light into the window material itself. The energy needed to control an active window device is generally small compared to the available sunlight, so window and lighting control systems can harvest energy for their own operations from sunlight, greatly simplifying installation. Several self-powered systems are commercially available today. The challenge for all advanced window control systems has been cost, control integration, and in some cases, durability. Advanced and cost-effective wireless schemes, when viewed from a life cycle cost viewpoint, present a striking solution for completing energy savings, productivity, and flexibility, and can lessen maintenance and individual control. Mostly when a building landlord is only considering "first" costs, the capability to enable hard-wired controls is frequently taken as a more cost-effective solution. A wireless solution can make a difference. If the opinion of the building developer and the owner is different, the manager of the building's construction mostly cares about first costs. While taking building retrofits, the wireless solution offers clear benefits, since no new wires are essential, and can reduce labor costs as well.

2.2 Energy Savings Save Money

- **Daylighting assisted by artificial lighting**

Light control allows further artificial lighting when daylight is not sufficient, up to the best lighting level. By the utmost use of daylight, and reducing artificial lighting, the expenditures of energy feeding are decreased.

- **Motion Sensors**

Motion sensors can act wisely in places with a variable number of people and traffic frequency, such as housing areas, passages in residential buildings, or spaces with fewer activities by setting the lighting to 'minimum' most of the time. The level of illumination can be amplified when humans are detected. This 'light per demand' function can increase energy savings and reduction of LED lighting costs.

- **Photometric Controls**

It includes all data attained by calculating the photometric features of luminaires, which are then changed into a format applicable to the task. Grounded on these controls, the precise number of needed luminaires for gaining the desired light level is designed.

While it is difficult to assign a precise value to good design, recent studies indicate that good designs can achieve impressive results. A meta-study of daylighting and control systems showed a wide range of savings without using new high-efficiency lighting devices (see Fig-2). Savings range from an average of 30% using only occupancy sensors to an average of 45% when daylighting and more sophisticated controls were used. The U.S. Department of Defense also examined the performance of three advanced lighting systems and was able to achieve savings above 40% using only improved sensors, lighting design, and control systems.

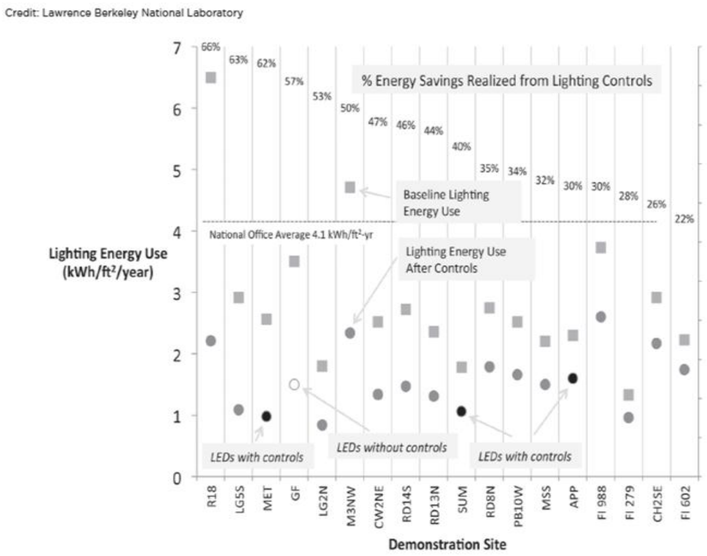

Fig -2 Energy Savings from Lighting Control

3. PAYBACK ANALYSIS

A significant part of making a fruitful argument for the execution of wireless energy controls in commercial, residential, and industrial buildings is indicating satisfactory payback. A payback period is a time necessary to repay the totality of the original share. Payback analysis doesn't account for risk financing, time value of money, or other thoughts like deeper cost analysis. This kind of modest analysis is very vital while making decisions about energy investments. The wireless technology deployed in the case study below includes occupancy sensors, time scheduling, and daylighting. Occupancy sensors offer automatic ON/OFF switching of lighting for energy savings. Occupancy sensors can also be used for monitoring living rooms, restrooms, stairwells, and parking garages. Time scheduling works well in open zones where automatic switching at certain hours of the day is probable. Daylighting uses light sensors to measure the amount of illumination in a space and can continuously and subtly regulate the preferred level of illumination. These lighting control techniques are the most common techniques in buildings today.

3.1 Case Study: Residential Building Payback Analysis

In our case study, we investigated the impact wireless control technology in a residential building would have in a close space, containing 5 lighting fixtures. The technology installed in the room had occupancy sensors and daylight harvesting technology. The devices installed were 2 wireless switches, 4 wireless occupancy & photo sensors, and 4 dimming controllers, at a total materials cost of $97. Labor to install the wireless devices was $19, for a materials and labor bill totaling $16. To conduct the payback analysis, the assumptions in Table 1 below were used. Accordingly, we consider 25 days per year, on average, when lights are illuminated in rooms. For our controls, we took 9.1 as the average number of hours per day that room lights are typically left "on", before the introduction of controls. We used existing data from studies demonstrating that occupancy sensors alone have the ability to achieve 12% energy savings in the room. Also, daylighting has the capability to get 26% energy savings. When occupancy sensing and daylighting are combined, energy savings of 35% can be achieved. Payback analysis for a living space results in energy-related cost savings of $207 for the 1200-square-foot, area via the application of occupancy sensing and daylighting. With a total labor and materials cost of $516 and 41% savings compared to wired solutions, the payback period for the wireless controls environment was 2.3 years.

Table -1: Assumptions for Payback Analysis

General Assumptions and Inputs for Payback Analyses	
Full Electricity Rate kWh per DOE	$0.12
Tubes per fixture	4
Watts per tube	32
Annual Days/Year Lights On	7 days per week
Hours per day before controls	DOE Study [2]
Energy saved in flat	DOE Study [2]

4. COMPARATIVE COSTS: WIRED VS. WIRELESS

Although the price of wired devices might be less, the installation of wired solutions in retrofit scenarios needs more labor and materials than wireless solutions. In a traditional installation of a wired system, the process needs dragging wires for sensors, controllers, and switches. Wiring typically entails metal conduit as well. Besides, wired installations can result in disruption of living because of the penetration walls for wiring. This intrusion can require patching and repainting, increasing the amount of time, and labor costs, required for the installation.

When it comes to installation efforts, building alterations, and the desire for future expansion in buildings, wireless technology has a clear advantage. Wireless components, like switches, can be easily mounted on surfaces inaccessible to wired solutions. With wired solutions, installers can never be sure what they will find when they begin the installation. With wireless solutions, since no walls need to be disturbed, there is much less uncertainty.

Through the detailed payback analyses above, we have demonstrated that the implementation of wireless controls can achieve more than a satisfactory return on investment with payback periods of 2.3. So, the question remains, "is wireless technology a more cost-effective solution than wired control technology in retrofit scenarios?"

The case study presented for a living area resulted in a payback period of 2.3 years through the installation of wireless occupancy sensing and daylighting controls. The total material and labor cost was $516. The cost for wired occupancy sensors, photosensors, and switches was less expensive than their wireless counterparts. The labor costs of installing the wired devices, however, were many times more expensive than the labor costs for the wireless solution.

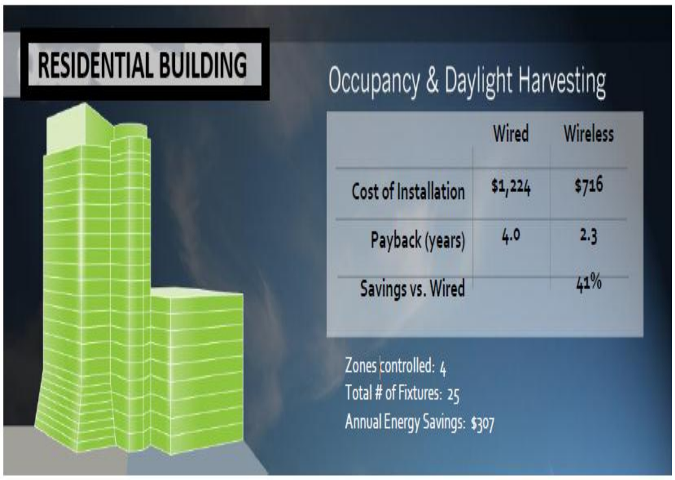

Fig- 3 Wired Vs. Wireless Cost Comparison

This kind of payback analysis is important because many building owners and facility managers make purchasing decisions based solely on the upfront/first costs and don't consider the total costs. The installation of a wired solution requires dedicated control wiring and raw materials. Damage to walls, drywall patching, and repainting all contribute to the total costs of a wired solution. For a flat, similar to a cube farm, a wireless solution is more cost-effective than a wired solution.

5. CONCLUSION

Though there is a slight difference between the energy savings abilities of wired vs. wireless solutions, there are differences related to the costs of setting up. However, wired building control and automation strategies are more cost-effective choices. That is primarily due to the ability of installers to run wire while construction is taking place. Since wired controls are, on average, less expensive than wireless technology, especially energy-harvesting wireless controls, they tend to be much more cost-effective when it comes to new construction. When it comes to building retrofits, which are by far the more popular energy efficiency strategies for buildings today, wireless technology has been proven to be more cost-effective as compared to wired solutions. The ease of installation and no new wire requirement of wireless technology makes it a cost-effective solution for retrofits of nearly all types of buildings.

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