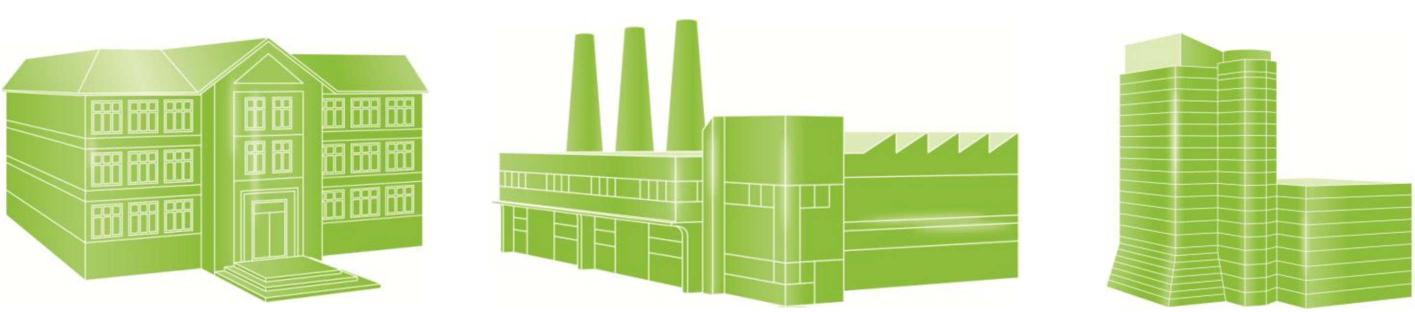
Wireless Lighting Controls: A Total Cost Analysis



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Concerns for Building Owners

Energy Efficiency

Doing more with less through energy efficiency-focused upgrades to existing buildings represents the fastest and most economical way to reduce our reliance on foreign sources of fuel and decrease our nation's greenhouse gas emissions. Although building technology investments can provide satisfactory payback periods, the current economic situation, combined with relatively low electricity rates, can make it difficult for building owners to make a case for retrofitting. As electricity rates continue to rise and as pressure builds to curb unsustainable energy consumption, the situation will change. The advent of wireless control systems justify retrofitting even considering low electricity rates.

Within the next few years regulators and utilities in several states will be revisiting electricity rates that have been frozen for years. These new rates will be needed to fund new infrastructure investments, like the smart grid, to help ensure that the electric industry provides reliable, affordable and clean electricity. The demand for energy is growing, with electricity consumption expected to increase 45 percent by 2030 according to the Energy Information Administration (EIA)[1].

Targeting Lighting

According to the EIA, lighting consumes 18 percent of the total electricity in the residential and commercial sectors[2]. The Rocky Mountain Institute (RMI) estimates that roughly 40 to 50 percent of this energy is wasted as a result of excessive lighting, inefficient equipment and careless usage[3]. Lights commonly remain on, well beyond the occupancy hours for buildings, not to mention that excessive lighting also generates waste heat, increasing energy costs.

According to RMI, 20 to 40 percent of air conditioning costs can actually be attributed to excess lighting[4]. This is an important consideration given the average building has energy costs of about $2.00 per square foot. An effective facility management strategy, including the utilization of advanced lighting controls, has the potential to save $0.60 to $1.00 per square foot in energy.

Modernizing an existing lighting system can significantly reduce electricity consumption. Lighting control systems adjust illumination levels to match the requirements of the space. Occupancy sensors and daylight harvesting photo-sensors can save electricity by automatically turning off lights when no one is physically in the space and can slightly and systematically adjust indoor lighting when natural light is available.. Sensors can replace a standard wall toggle switch and can be mounted on a ceiling, wall or be integrated into individual fixtures.

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1 http://www.eia.gov/cneaf/electricity/epa/epa_sum.html

2 http://www.eia.gov/tools/faqs/faq.cfm?id=99&t=3

3 The Hammersmith Group. "Clicks & Mortar: The Costs and Benefits of Intelligent Buildings. January 2010.

4 The Hammersmith Group. "Clicks & Mortar: The Costs and Benefits of Intelligent Buildings. January 2010.

Flexibility & Productivity

In addition to the potential for energy savings using lighting controls, wireless lighting control devices have the unique ability to control individual luminaries, groups of lights, entire floors and even entire buildings. Wireless control devices can be placed where they are needed, without limitations imposed by wiring, including areas that are difficult to wire. Using wireless technology also shortens electrical planning. Even after installation, devices can be moved and the system can be expanded to include HVAC, with relative ease. Studies have shown that proper lighting is beneficial for employees working in an office environment. The improved comfort and resulting employee satisfaction brought through day lighting strategies, task oriented lighting and individual control has resulted in reduced absenteeism and increased productivity.

One research study conducted by the Light Right Consortium of Albany, New York, found that occupant comfort increased by 15-20 percent with the use of indirect lighting, wall washing and personal dimming control. Additionally, occupants with personal control at their workstation had increased motivation and were able to sustain their persistence and vigilance over time, as compared to those without any control over their lighting[5].

Investing in Efficiency

Even with all of these documented benefits, it is important to recognize that decisions about upgrading lighting are often based upon "lowest first cost" rather than "true cost" analysis. Decision makers overlook benefits such as long-term energy savings and maintenance related cost savings. This whitepaper serves to provide perspective on lifecycle costs, not just the first costs to building owners, providing stakeholders with the information they need to invest in sustainable retrofit strategies.

Energy costs are important in commercial buildings because they are a significant component of operating costs and overall net operating income. Many organizations are working to ensure that building owners and developers receive a higher value for energy efficient properties upon resale or refinancing[6]. To fully realize the value of high performance buildings, developers, owners and managers need to engage with appraisers by documenting and demonstrating the financial benefits and risks of the energy management strategies undertaken.

According to a publication titled "Energy Efficiency and Appraisals", written by BetterBricks[7], energy should be examined as a separate line item within the operational budget of a specific building. Data provided on the life-cycle costs of energy investments, versus "first costs" is something that should be provided to the appraiser. Life cycle cost assessments, like the information provided in this whitepaper, has not historically been applied to the valuation of investment technologies, but will likely become more relevant as innovations and new best practices enter the mainstream.[8]

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5 http://www.lightright.org/research/albany_study.htm

6 Institute for Market Transformation. Project on Energy Efficiency and Property Valuation. Feb 1999.

7 http://www.betterbricks.com/

8 http://www.betterbricks.com/graphics/assets/documents/EEAppraisals_Final.pdf

Lighting Controls

Innovative and cost effective wireless strategies, when viewed from a life cycle cost standpoint, present an attractive solution for achieving energy savings, flexibility, productivity, reduced maintenance costs and personal control. In new construction, the ability to run wire to enable hard-wired controls is often considered a more cost effective solution, particularly when a building owner is only considering these "first" costs.

A wireless solution, in a new construction environment, can make for a difficult sell, unless total costs to the building owner are considered. If the project developer and the building owner are not on the same page, the person in charge of the building's construction is predominantly going to care about first costs. When it comes to building retrofits, wireless technology provides clear advantages, since no new wires are required, thereby reducing the labor related costs.

Existing Buildings

Regardless of the argument made, the reality is that the market for green buildings is exploding and there is an overwhelming interest in retrofits, not new buildings. McGraw-Hill's latest SmartMarket Report finds that new building construction represent only 2.5 percent of the US building market, while retrofitting provides an enormous market opportunity. According to the report, green building comprises 5 to 9 percent of the retrofit and renovation market activity by value. By 2014, that share is expected to increase by 20 to 30 percent, creating a $10 to $15 billion market for major retrofit projects[9].

The economic downturn is encouraging further adoption of energy efficient practices in retrofit projects. Sixty two percent of owners expect that the savings achieved from energy efficiency improvements will be recouped within 10 years. The case studies presented in this whitepaper demonstrate payback periods attained in much less time, typically within 3 years. The most frequently applied features for building retrofits include energy efficient lighting or natural lighting[10].

Why Upgrade

With fewer buildings being built and a notable increase in retrofit projects, building owners and facility managers are beginning to investigate innovative building automation and control technologies. The opportunities, especially in North America, is growing, due in part to the fact that there are roughly 5 million commercial buildings in the United States totaling over 70 billion square feet of floor space.

Small and medium sized facilities account for 98 percent of the total number of commercial buildings and 65 percent of this floor space, yet only 5 percent of these sized buildings are equipped with a building automation system. Small and medium sized buildings are seldom equipped with building automation because of the relatively

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9 http://www.prnewswire.com/news-releases/green-retrofit-market-growing-projected-to-reach-20-30-of-all-commercial-building-retrofit-and-renovation-in-five-years-says-new-mcgraw-hill-construction-report-65584762.html

10 http://greeneconomypost.com/huge-growth-in-retrofit-buildings-predicted-10-15-billion-market-by-2014-5476.htm

high up front costs and longer payback periods related to retrofit installation of a BAS. Variable costs incurred by labor have also limited the adoption rate of building automation system (BAS)[11].

Energy harvesting wireless technology from EnOcean, including self-powered sensors, switches and controls, encompass a building automation system that has the ability to cut the cost and time of installation. Achieving the functionality of a BAS with wireless, battery-free controls is making energy harvesting wireless an excellent choice as building owners consider upgrading their facilities. Self-powered wireless sensor networks are the key to achieving an intelligent green building.

Personal Control

Within the range of illumination, people have preferences for how much and what kind of light they want. Given that preferences vary, some aspect of personal control should be afforded to building occupants. Recent laws in Denmark, some of the most stringent in Europe, require that all workplaces have access to daylight. Most experts agree that bringing some human control into the lighting mix provides an opportunity for further advancement. To that end, control technologies need to be easy, intuitive, robust and simple and should be easily integrated with interoperable building level controls. EnOcean enabled, energy harvesting technology can easily achieve these goals and provide a comfortable environment for the occupant.

Energy Harvesting

Energy harvesting is the process by which energy is derived from external sources, namely solar power, thermal power and kinetic energy. This energy is captured and stored for use in small, wireless, autonomous devices like those used in wireless sensor networks. Energy harvesting devices convert ambient energy into electrical energy. Energy can be stored using a small capacitor instead of needing batteries, which provide a constant flow of power. The history of energy harvesting dates back to the windmill and the future of energy harvesting is motivated by a desire to address climate change and global warming.

EnOcean GmbH, founded in 2001 as a spin-off from Siemens AG, is the originator of patented self-powered wireless technology. EnOcean has long embraced energy harvesting technology and as a result combined miniaturized energy harvesters and highly efficient wireless technology to create service-free, sensor solutions for use in buildings and industrial automation. Instead of batteries, EnOcean enabled technology uses energy converters to supply power through linear motion converters, solar cells and thermal converters.

EnOcean Alliance and Interoperability

There are now over 750 interoperable, EnOcean enabled, energy harvesting products available worldwide. Building automation sensors and controls enabled by

[11] http://www.enocean-alliance.org/en/ip-based-wireless-energy-harvesting-sensor-and-control-technologies/

EnOcean include wireless switches, sensors, actuators, controllers, gateways and building management systems. These products are available in both 315 MHz (for North America) and 868 MHz (for Europe).

Figure 1 – EnOcean-enabled Product Examples

Leviton 2-Channel Room Controller

Verve Living Systems Wall-mounted Occupancy Sensor

BSC LAN TCP/IP Access Point

After EnOcean technology experienced success, leading companies worldwide collected in 2008 to establish the EnOcean Alliance. This Alliance, which now boasts over 200 members, aims to standardize and internationalize EnOcean wireless technology and is dedicated to creating interoperability between the products of OEM partners. EnOcean GmbH remains one of seven promoter members of the EnOcean Alliance.

The Alliance's mission is to promote and enable intelligent green buildings through the creation of a broad range of interoperable, standards-based wireless products. Our member companies aim to create a better, safer, cost effective, energy efficient and environmentally friendlier world through intelligent, self powered wireless systems.

Another function of EnOcean Alliance involves the Energy Equipment Profiles (EEP), which encompass the technical characteristics of each device by defining profile elements. It is EnOcean Alliance's goal to configure each profile as universally as possible so as to target an adequate spectrum of devices in the building automation sector for all participating manufacturers. The Technical Working Group of the Alliance reviews and ratifies the profiles and then the Board of Directors approves or disapproves of the profile.

Payback Analysis: Open Office Area, Classroom & Warehouse

An importance part of making a successful argument for the implementation of wireless energy controls in commercial, educational and industrial buildings is demonstrating acceptable payback. A payback period is the time required for the return on an investment to "repay" the sum of the original investment. Unlike a deeper cost analysis, payback doesn't account for the time value of money, risk, financing or other considerations. This kind of simple analysis is very important when it comes to making decisions about energy investments.

The wireless technology deployed in the case studies below, included occupancy sensors, time scheduling and daylighting. Occupancy sensors provide automatic ON/OFF switching of lighting loads for convenience, security and energy savings. Occupancy sensors can be used for monitoring conference rooms, restrooms, stairwells and parking garages. Time scheduling works well in open office areas where automatic switching at fixed hours of the day is predictable and can save energy. The last means of control included daylighting, which uses light sensors to measure the amount of illumination in a space and can continuously and subtly adjust the desired level of illumination. These lighting control techniques are some of the most common used in buildings today.

This white paper serves to provide a payback analysis for three different building environments to show the true payback periods experienced after investing in wireless, building control technology. The wireless payback analysis was performed for an open office environment, a school classroom (K-12) and a typical warehouse. For each analysis we utilized industry accepted assumptions, as described in Table 1.

Table 1 – General Assumptions for Payback Analyses

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 Office Lights On	50 working weeks/5 days per week
Annual school days	Annual classroom days minimum
Hours per day before controls	DOE Study
Energy saved in open office area	DOE Study

Energy Use in Offices

Owners of commercial office buildings face rising energy costs, creating challenges with respect to managing a facility's budget. Costs of building maintenance products and services are also rising. Executives of owner occupied and tenant occupied buildings must take new and creative steps that put energy costs in check to maintain a healthy, sustainable business environment. The fact is that 70 percent of commercial office buildings are at least 20 years old[12] and the average building uses 20 percent more energy than necessary[13]. Energy use in offices has risen in recent years mainly due to growth in

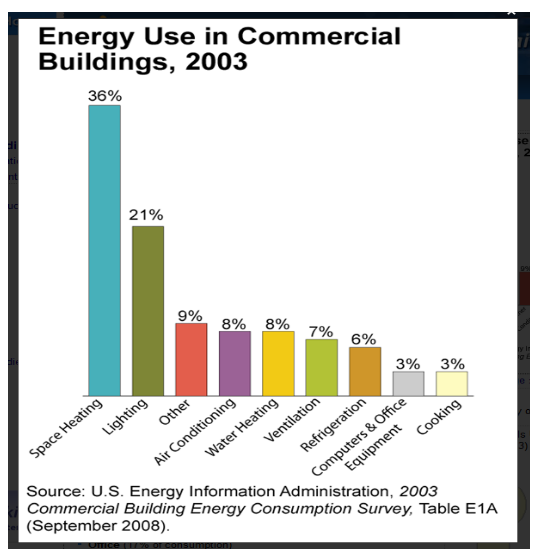

Figure 2 – Energy Use in

12 Frost & Sullivan, *North American BAS Controls Market*, 2004

13 American Council for an Energy Efficient Economy, *2005 Study*

information technology, air conditioning, density of use and a competitive market where tenants see higher value in a comfortable workplace.

At least two-thirds of all energy consumed in an average office building is due to electricity. Lighting, office equipment and HVAC account for 90 percent of this expenditure[14]. Even as energy costs climb, improvements and innovations on the consumption side are not likely to keep pace. There can be valuable benefits realized with energy efficiency improvements, like installing energy management controls. Energy efficient buildings have greater market value, gain improvements related to employee productivity and have more predictable energy costs.

Case Study: Office Area Payback Analysis

In our Office case study we investigated the impact wireless control technology would have in an open office space, similar to a cube farm, containing 25 lighting fixtures. The technology installed into the office included 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 $597. Labor to install the wireless devices was $119, for a materials and labor bill totaling $716.

To conduct the payback analysis, the assumptions in Table 1 above were utilized. Accordingly we used 250 as the total number of days per year, on average, that lights are illuminated in office spaces. For our calculations we utilized 9.1 as the average number of hours per day that office lights are typically left "on", before the introduction of controls. We also utilized existing data from studies demonstrating that occupancy sensors alone have the ability to achieve 12 percent energy savings in open office areas. Furthermore, daylighting has the ability to achieve 26 percent energy savings. When occupancy sensing and daylighting are combined, energy savings of 35 percent can be achieved.

The payback analysis for an open office space results in energy related cost savings of $307 for the 1250 square foot, open office area via the implementation of occupancy sensing and daylighting. With a total labor and materials cost of $716 and 41 percent savings compared to wired solutions, **the payback period for wireless controls in an open office environment was 2.3 years.**

Energy Use in Schools

According to the EIA, educational buildings account for 12 percent of all commercial energy consumption, leaving this sector the third highest consumer of total energy of all commercial building types. Nearly 41 percent of total energy in educational settings is utilized for space heating, making it the largest category of energy usage in educational facilities, followed by water heating and lighting, at 22 percent and 20 percent respectively. Large buildings, like colleges and universities, use energy intensively. On average, $0.92 per square foot is spent on energy in educational buildings, less than the national average for energy usage in commercial buildings, at $1.19 per square foot.[15]

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[14] http://www.eia.gov/emeu/consumptionbriefs/cbecs/pbawebsite/office/office_howuseenergy.htm

[15] http://www.eia.gov/emeu/consumptionbriefs/cbecs/pbawebsite/education/educ_howuseenergy.htm

Case Study: Classroom Payback Analysis

In our Classroom case study we investigated the impact wireless control technology would have in a typical K-12 classroom containing 9 lighting fixtures. The technology installed into the classroom included occupancy sensors, time scheduling and daylight harvesting technology. The devices installed were 2 wireless switches, 1 wireless occupancy & photo sensor, and 3 dimming controllers, at a total materials cost of $321. Labor to install the wireless devices was $73, for a materials and labor bill totaling $394.

To conduct the payback analysis, the assumptions in Table 1 were utilized. Accordingly, we used 180 as the total number of days per year, on average, that lights are illuminated in school classrooms. This is because 180 are the number of instruction days in a calendar year. For our calculations we used 10 as the average number of hours per day that classroom lights are typically left "on", before the introduction of controls. We also utilized existing data from studies demonstrating that occupancy sensing alone can achieve 45 percent energy in a classroom and that daylighting can achieve 26 percent energy savings. When combined, energy savings of 63 percent can be achieved.

The payback analysis for the classroom resulted in annual energy related cost savings of $118 for the classroom retrofitted with occupancy sensing and daylighting. With total labor and materials cost of $394 and 39 percent savings compared to wired solutions, **the payback period for wireless controls in a classroom was 3.3 years.**

Energy Use in Warehouses

According to E Source, warehouses are becoming increasingly sophisticated. As this occurs; energy consumption grows, making energy efficient measures, like the introduction of building automation, a good way to boost the bottom line. To operate a warehouse in the U.S., it requires spending an average of $0.70 per square foot on energy. These costs make up more than 10 percent of total revenue. Heating and lighting together account for 64 percent of total warehouse energy use.[16]

Wireless building automation and control technology can provide considerable energy savings in industrial settings. Wireless switches can be used to control lighting and window blinds; while room temperature sensors can ensure minimal consumption and still achieve maximum comfort. Climatic sensors, for humidity and carbon dioxide, monitor indoor air quality. Central control can occur from a touch panel or PC, with the capability to remotely monitor and control by using a mobile phone.

Case Study: Industrial/Warehouse Payback Analysis

In our warehouse case study we investigated the impact wireless control technology would have in a typical industrial space containing 100 lighting fixtures. Unlike the lighting found in office and classroom scenarios, which utilize 32 watts, the high bay lighting used in a warehouse consume 450 watts. The technology installed into the warehouse space included only occupancy sensing, since many warehouses don't have natural light sources for daylighting. The devices installed included 20 wireless switches, 20 wireless occupancy sensors and 20 relay controllers, at a total materials cost of

[16] U.S. EIA, "CBECS: End-Use Consumption by Principal Building Activity" [1999], www.eia.doe.gov/emeu/cbecs/enduse_consumption/pba.html

$4,379. Labor to install the wireless devices was $1775, for a materials and labor bill totaling $6154.

To conduct the payback analysis, the assumptions in Table 1 were utilized. Accordingly, we used 250 as the total number of days per year that lights are illuminated in warehouses. For our calculations we utilized 16 as the average number of hours per day that warehouse lights are typically left "on", before the introduction of controls. We also utilized data from studies demonstrating that occupancy sensing alone has the ability to achieve 35 percent energy savings in warehouse environments.

The payback analysis for our warehouse resulted in annual energy related cost savings of $7,560 for the warehouse space with the implementation of occupancy sensing alone. With a total labor and materials cost of $6,154, a 28 percent savings compared to wired solutions, **the payback period for wireless controls in a warehouse was 0.8 years.**

Implications of Wired vs. Wireless

Although wired devices might be less expensive to purchase, the installation of wired solutions, particularly in retrofit scenarios, entail considerably more labor and materials than wireless solutions. In a conventional installation of a wired solution, the process involves pulling wires for sensors, switches and controllers. Wiring in commercial facilities typically requires metal conduit, secured to a structural member. Obstacles are frequently encountered when 'fishing' wires through existing walls. . Furthermore, wired installations can result in disruption of business operations due to the penetration walls for wiring. This intrusion can require patching and repainting, increasing the amount of time, and labor costs, required for the install.

When it comes to installation effort, building alterations and the desire for future expansion in buildings, wireless technology has the 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.

Wired vs. Wireless: Comparative Costs

Through the detailed payback analyses above, we have demonstrated that the implementation of wireless controls can achieve more than satisfactory return on investment for office spaces, classrooms and warehouses with payback periods of 2.2, 3.4 and 0.8 respectively. The question remains, is wireless technology a more cost effective solution than wired control technology in retrofit scenarios?

Open Office Area

The case study presented for an open office 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 $716. Utilizing a corresponding and comparable wired solution in the retrofit of the same open office area resulted in total material and labor cost of $1224 and a payback period of 4.0 years. 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.

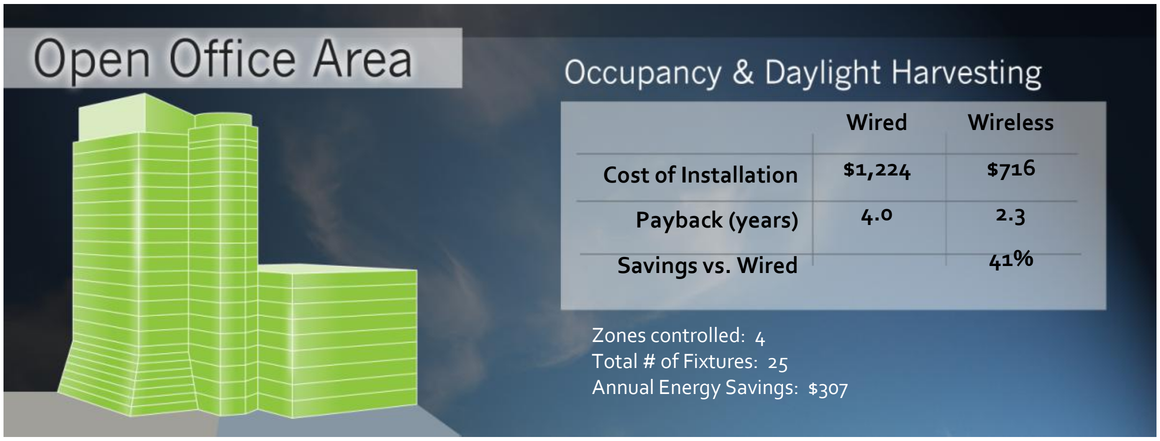


Figure 3 – Wired versus Wireless Cost Comparison: Open Office / Cubical Area

This kind of payback and comparative 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, switch legs, traveler wires and other raw materials. Damage to walls, drywall patching and repainting all contributes to the total costs of a wired solution. **For an open office area, similar to a cube farm, a wireless system is more cost effective than a wired solution.**

Classroom

The case study presented of a classroom resulted in a payback period for the installation of wireless occupancy sensing and daylighting controls of 3.3 years with a total materials and labor cost of $394. Utilizing a corresponding and comparative wired solution in the retrofit of the same classroom area resulted in a total material and labor cost of $646 and a payback period of 5.5 years. Although the materials cost of the wired occupancy sensors, photosensors and switches were less expensive than their wireless counterparts, the labor costs of installing the wired devices was nearly twice the labor costs for the wireless solution. **For a school classroom, a wireless solution is more cost effective than a wired solution.**

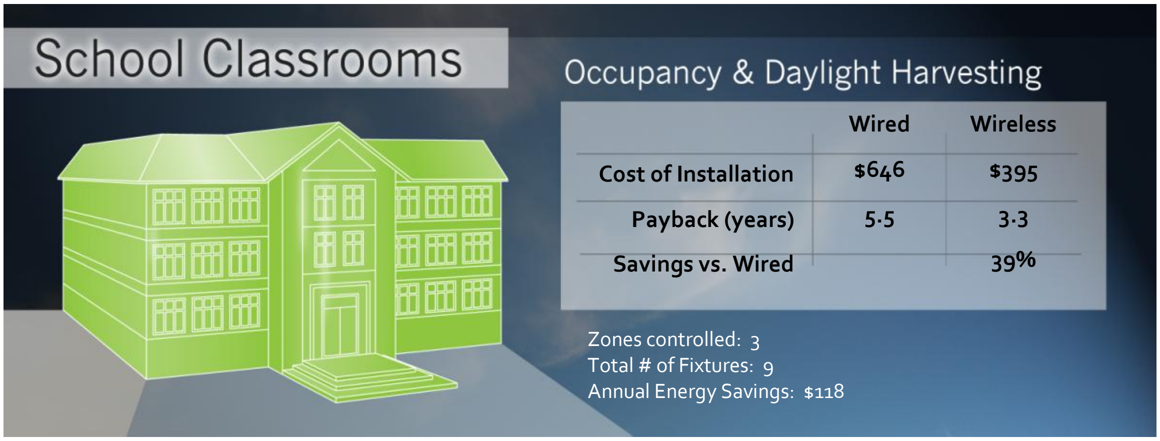
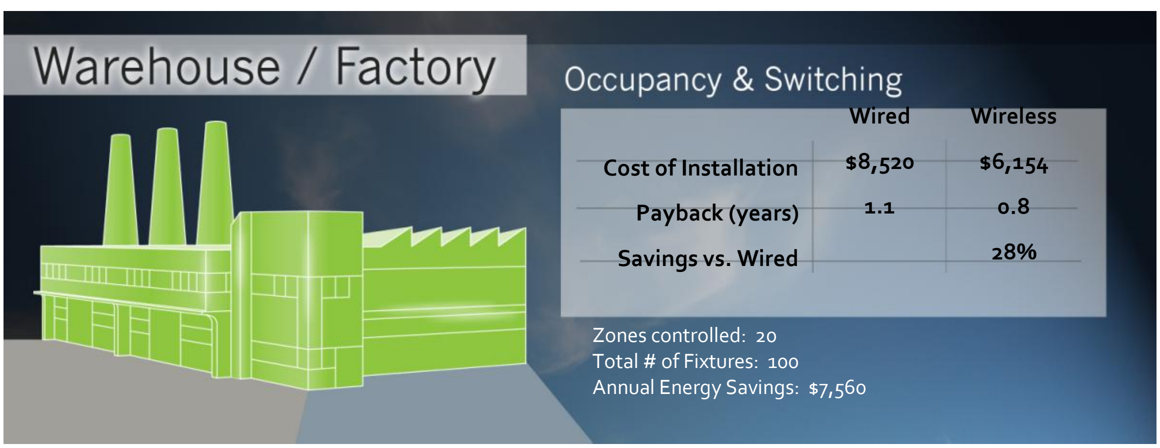


Figure 4 – Wired versus Wireless Cost Comparison – School Classroom

Warehouse

The case study presented of a warehouse resulted in a payback period for the installation of wireless occupancy sensing controls of 0.8 years, at a total material and labor cost of $6,154. Utilizing a corresponding wired solution in the retrofit of the same warehouse resulted in a total material and labor cost of $8,520 and a payback period of 1.1 years. Although the cost of the wired occupancy sensing solution were less expensive than their wireless counterparts, the labor costs of installing the wired devices were significantly more expensive than the labor costs for the wireless solution. **For a warehouse environment, a wireless solution is more cost effective than a wired solution.**

Figure 5 – Wired versus Wireless Cost Comparison: Warehouse / Factory



Energy Harvesting vs. Batteries

When it comes to procuring a building automation system, total costs must be considered by the building owner. Although initial costs remain the prominent consideration, lower costs over the long-term should influence a better buying decision. Labor costs for wired control installations as well as battery usage, replacement of batteries and disposal of used batteries are additional cost considerations.

Building control sensors powered by batteries must be monitored for battery condition. Batteries must be stocked, changed out and disposed of properly. This equates to time and money spent unnecessarily, particularly in locations where reliable operation is essential, like in office buildings and hotels. EnOcean is currently the sole provider of battery-free technology - made possible by the extremely low energy requirements of EnOcean devices.

To ensure performance in wireless, battery powered building technology solutions, batteries must be replaced on a regular schedule, resulting in wasted battery life or resulting in users accepting the risk of changing batteries only when a low voltage threshold is indicated. This might be acceptable for tens to a few hundred nodes, but the potential maintenance cost of replacing batteries for thousands of nodes becomes a continuous, cost prohibitive undertaking.

Furthermore, commercial businesses are supposed to take their spent primary batteries directly to a hazardous waste facility. There is fee of around $1.37/lb for the disposal of "flashlight" like batteries. The cost for the disposal of non-rechargeable batteries is expensive for commercial entities, with the cost for disposing AAA batteries at about $0.44 per cell[17]. Although smaller, lighter batteries, like those found in wireless controls and sensors are the least expensive, it is still a cost that a business has to consider when using battery operated, wireless solutions. ON World estimates the labor cost for changing batteries in wireless sensors will be greater than $1 billion over the next several years[18]. These costs for battery replacement are a significant disadvantage to the growth of wireless, battery powered sensor networks, therefore opening the door to EnOcean's energy harvesting technology.

Conclusion

Although there is little difference between the energy savings capabilities of wired versus wireless solutions, there are difference associated with the costs of their installation. In new construction scenarios, wired building control and automation strategies are more likely to be the cost effective choice. 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.

17 http://www.kicknpower.com/disposal.html

18 http://onworld.com/power/