APPLICATION NOTE

An In-Depth Examination of an Energy Efficiency Technology

Occupancy Controls for Lighting

Summary

Occupancy sensors-also called motion, or personnel sensors- react to variables like heat and/or motion by turning lights on or off. They turn lights on when people are detected and, after an adjustable predetermined period during which people are not detected, turn them off. While they have potential to reduce lighting energy consumption by 35 to 45 percent or more, their savings and applicability are very site specific.

The two primary types of occupancy sensors are ultrasonic and passive infrared. Passive infrared (PIR) sensors typically detect occupants' body heat. Triggering occurs when a change in infrared levels is detected, such as when a warm object moves in or out of view of one of the sensor's "eyes". Ultrasonic (US) sensors, by contrast, continuously emit and sample inaudible sound waves and listen for a change in frequency of the reflected sound.

There are two basic mounting configurations for occupancy sensors. Ceiling-mounted sensors have an independent controller and/or power supply. They may be mounted high on a wall or in a corner, as well as on the ceiling. Wallbox sensors are primarily designed as retrofit replacements for common wall switches. Both ceiling-mounted and wallbox sensors are available with either PIR or ultrasonic sensing units.

The performance and reliability of occupancy sensors are tied to a host of factors, including the shape and size of a room, the installer's experience, and interactions with ballasts, lamps and

Revised 4/25/97

other building components. Sensor installations sometimes yield smaller than expected savings due to improper product selection or installation, or unanticipated interactions with other building components. Users can maximize the performance and cost-effectiveness of sensor installations by considering these issues.

How This Technology Saves Energy

Occupancy sensors are switching devices that respond to the presence and absence of people in their field of view. The system consists of a motion detector, an electronic control unit and a controllable switch (relay). The motion detector senses motion and sends a signal to either close or open the relay that controls power to the lights.

Most motion detectors use either ultrasonic sound waves or infrared radiation technologies to sense motion. The control unit collects information from the sensor and determines the occupancy status of the space. In some cases, the control unit can be calibrated to adjust the ***sensitivity***[1] of the sensors to motion. The controller also has a programmable timing device that will turn off the lights after the room is unoccupied for a specific period. Output from the control unit energizes or de-energizes a relay which opens or closes the lighting circuit. A power supply is also an element of the system and is needed to transform the line voltage for powering the control unit's circuit and for sending output to the relay. The relationship between the power supply, relay, controller and motion detector is shown in Figure 1.

[1] Bold-Italic words are defined in the section titled Definition of Key Terms

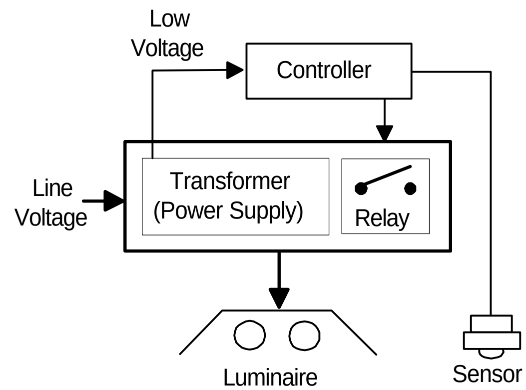

Figure 1: Occupancy Sensor Control System *(Source: CEC)*

In most occupancy sensor systems, the motion detector and controller are in one package; the power supply and relay are another integral unit, sometimes called a switch pack. In wallbox sensors, components are all in one compact package, designed to fit into an existing switch box. The solid-state switches often used in these packages are rated for relatively small loads.

Occupancy Sensors - Types and Placement

Most occupancy sensors turn lights on or off by detecting heat or a shift in the frequency of reflected ultrasonic sound waves. Units that use audible sound or microwaves are less common. Each of these sensor types is discussed below.

Passive Infrared (PIR) sensors

Passive infrared sensors are the most common type. They "see" infrared heat energy emitted by people. Triggering occurs when a change in infrared levels is detected, such as when a warm object moves in or out of view of one of the sensor's "eyes". PIR sensors are passive devices: they only detect radiation; they do not emit it. They are designed to be maximally sensitive to objects that emit heat energy at the wavelength emitted by humans. They are strictly line-of-sight devices. They cannot "see" around corners and a person will not be detected if there is an obstruction, such as a partition between the person and the detector. PIR sensors are quite resistant to false triggering.

The detection pattern of PIR sensors is fan shaped, formed by the cones of vision seen by each segment of the faceted lens. Since the sensor is most sensitive to motion that moves from one sensing cone to another, its sensitivity decreases with distance as the gaps between sensing cones widen. Most PIR sensors are sensitive to hand movement up to about 10 feet, arm and upper torso movement up to 20 feet, and full-body movement up to about 40 feet. The sensitivity range can vary substantially, however, depending on product quality and electronic circuiting design.

Ultrasonic (US) sensors

Ultrasonic sensors emit a high-frequency sound, above the human and animal audibility ranges, and listen for a change in frequency of the reflected sound. They are able to cover larger volumes than PIR sensors and are noticeably more sensitive, but are also more prone to false triggering. Air motion, due to a person passing an open doorway, or the on-off cycling of an HVAC system, may trigger a poorly located or adjusted sensor.

The ultrasonic sound waves cover the affected area in a continuous fashion—there are no blind spots or gaps in the ***coverage*** pattern. For this reason ultrasonic sensors are somewhat more sensitive to movement. For example, hand motion can be detected at about 25 feet, arm and body torso out to 30 feet and full-body motion out to over 40 feet. In narrow spaces such as corridors and warehouse aisles US sensors detect occupants up to 100 feet. The sensitivity range of different products will vary significantly.

Other sensor types

"Dual" technology (or hybrid) sensors are offered by several manufacturers. They use both the infrared and ultrasonic technologies simultaneously. These sensors combine the sensitivity of ultrasonics with the passive infrared unit's resistance to false triggering.

Audible sound sensors listen for noise made by people and machines, and assume that it is a result of occupant activity. They may react to nearby vibration (such as a slammed door) or to street noise, and require relatively high sound levels.

Microwave sensors are similar to ultrasonics in that they emit a signal—in this case a radio signal—and measure a change in frequency when that signal is reflected. At present, only one company

Mounting Location	Sensor Technology	Angle of Coverage	Typical Effective Range[1]	Optimum Mounting Height
Ceiling	Ultrasonic	360º	500-2000 ft^2	8-12'
Ceiling	Passive Infrared	360º	300-1000 ft^2	8-12'
Wall Switch	Ultrasonic	180º	275-300 ft^2	40-48"
Wall Switch	Passive Infrared	170-180º	300-1000 ft^2	48"
Corner Wide View	Passive Infrared	110-120º	To 40 feet	3-10'
Corner Narrow View	Passive Infrared	12º	To 130 feet	6-7'
Corridor	Ultrasonic	360º	To 100 feet	8-12'
High Mount	Passive Infrared	12º	To 100 feet	To 30'

[1] Sensitivity to minor motion may be substantially less than noted here, depending on environmental factors.

Table 1: Occupancy Sensor Performance Characteristics (Source: CEC)

makes microwave sensors and very little data exist on field experience or installed cost. They are used primarily in the security and alarm industries.

Mounting Configurations

There are two basic mounting configurations for occupancy sensors. Ceiling-mounted sensors employ an independent controller and/or power supply. They may be mounted high on a wall or in a corner, as well as on the ceiling. Wallbox sensors are primarily designed as retrofit replacements for common wall switches. Both ceiling-mounted and wallbox occupancy sensors are available with either PIR or ultrasonic sensing units. They can be combined to cover an oddly shaped or large room. A performance comparison of a variety of sensor/mounting combinations is provided in Table 1.

Ceiling-Mounted Sensors

Ceiling-mounted occupancy sensors are very popular. The typical system consists of a motion detector/controller unit connected to a "switchpack" housing, containing the power supply and relay. Low voltage wiring is all that is required for communication between the switchpack and the sensor.

Ceiling-mounted sensors are typically used in larger rooms because they can cover greater areas, and usually have these characteristics:

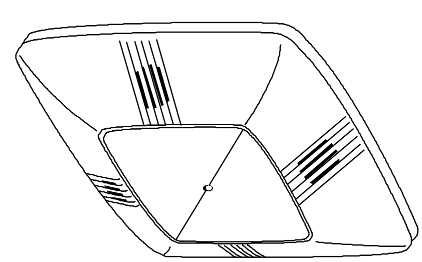

Figure 2: Example Ceiling Sensor (Source: Manufacturer's Literature)

- Most cost between $50 and $120, uninstalled, with relay and low-voltage power supply.

- Ceiling-mounted ultrasonic occupancy sensors are available in coverage patterns ranging from about 250 to 2,000 square feet.

- ***Time delay*** and sensitivity controls are mounted on the sensor, making them inaccessible to occupants.

- Installation of these units requires opening the ceiling or wall, since they must be hardwired to the electrical distribution system. This results in a relatively high installation cost for retrofit applications.

Wall-Mounted Sensors

Wallbox-mounted occupancy sensor units were introduced for smaller offices and similar applications where the higher cost ceiling-mounted units were considered too expensive. These units have all components in a single housing and can be easily wired into existing switch boxes in the room.

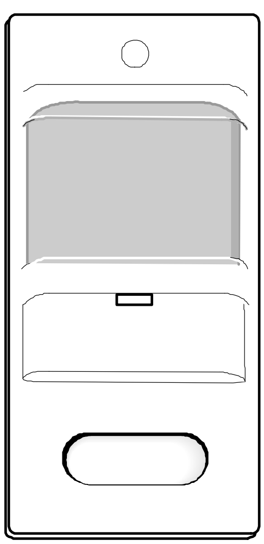

Figure 3: Example Wall Sensor
(Source: Manufacturer's Literature)

Most have the following characteristics:

- They typically cost between $30 and $90, uninstalled.

- Their sensor pattern spreads primarily to the left and right (60° to 90° in each direction) in the horizontal plane, but only minimally in the vertical plane.

- An off-auto switch is available to either manually shut off the lights when a space is occupied, or allow the sensor to control lighting. Some also have a manual override to keep lights on when a room is empty, ensuring that light is available even if a sensor fails. A special key or tool is often required to activate the manual override.

- Time-delay and sensitivity controls are usually accessible without removing the sensor from the switch box. The time delay before turning the lights off is adjustable in most wallbox units, typically from 30 seconds to 15 minutes. Shorter and longer adjustment ranges of from 10 seconds to 30 minutes are available.

Integration With Daylighting Control

Several manufacturers have recently begun to combine occupancy sensors with photocell sensors for daylighting control. Integrated devices are now available for both ceiling-mounted and wallbox units. Integration of daylighting controls with occupancy sensors in the same control spaces is, at best, of limited utility. While there are some good potential applications, such as in warehouses and malls, where simple controls will be effective, the utility of these units is severely limited in spaces that contain more precise and/or difficult visual tasks. In addition, integrated daylighting-occupant sensing schemes limit lighting control to on/off switching (as opposed to dimming). This can be annoying to occupants. Dimming is most often the superior approach in daylighting applications.

Case Study: Large scale Lighting Control in Manufacturing/Office Park

The retrofit of occupancy sensor controls in a large manufacturing/office complex in California provides an example of how this lighting control technology can be applied cost-effectively. More than 5000 occupancy sensors were installed throughout the 27 building, 3 million square foot campus facility that included manufacturing, engineering and development offices and computer facilities. The building lighting was previously controlled manually through central panels. The majority of the buildings contained no light switches in the individual offices. Energy monitoring of the lighting panels indicated that the lighting was on an average of 22 hours per day. A new, more energy-efficient method was needed that would be flexible, reliable and responsive to individual behavior.

After a detailed study of three lighting control alternatives, ultrasonic occupancy sensors were selected as the most appropriate and cost-effective lighting control strategy. The new control system was implemented in three phases. In the test phase, seven units were installed in a standard office bay and their performance was monitored. On average the units saved 55 percent of pre-retrofit energy consumption. In Phase I of the project, 550 additional units were installed in a pilot program in offices and conference rooms to further evaluate product performance, occupant satisfaction and energy savings. Phase I results showed high employee satisfaction and energy savings of about 50 percent. In the final phase, 4600 units were installed at a cost of $850,000. A follow-up analysis estimated a payback for the retrofit of 1.1 years.

Applicability

In the past, the biggest application pitfalls associated with occupancy sensors have been problems caused either by using inappropriate sensor sensitivity patterns for the application at hand, or by the improper mounting location of sensor units. Studies suggest that when occupants find lighting controls of any type to be obtrusive, they will disable them, thus negating any potential energy savings. In most applications, sensor types, sensitivity patterns, mounting heights, and locations should be based on the recommendations of the manufacturer. Typical applications of occupancy sensors are shown in Table 2.

Applicability to Lamp-Ballast Systems

Occupancy sensors are appropriate for controlling both incandescent and rapid-start fluorescent lamps. With these lamps, reduced lamp life due to frequent switching is not a significant problem.

OCCUPANCY SENSOR APPLICATIONS		
Sensor Type	**Applications**	**Notes**
Ceiling Mount	Open Partitioned Areas, Small Open Offices, File Rooms, Reproduction Rooms, Conference Rooms, Restrooms, Garages	Provides for 360° coverage; derate range by 50% if partitions >48" are in place
Corner Mount Wide View	Large Office Spaces, Conference Rooms	Mount high on wall
Wall Switch	Private Offices, Copy Rooms, Residences, Closets	Especially suitable for retrofits. Not recommended for areas with obstructions.
Narrow View	Hallways, corridors, aisle ways	Work best if mounted on centers with range control
High Mount Narrow View	Warehouse aisle ways	Must be set back from aisle so that they do not detect motion in cross aisles

Table 2: Typical Occupancy Sensor Applications (Source: CEC)

Occupancy sensors are less compatible with both preheat and instant-start fluorescent lamp-ballast systems, such as compact fluorescent lamps, F96T12 slimline systems, and F32T8 lamps operated in instant-start mode. Lamp life in these lamps is more sensitive to frequent switching applications than is the case for rapid-start lamps. In applications with occupancy sensors, it may be wise to consider the use of rapid-start electronic ballasts for T-8 lamps rather than the more typical instant-start ballasts.

Some wallbox sensor circuitry designs may not be completely compatible with certain electronic ballasts, when combined with solid-state switching devices. Before using electronic ballasts in combination with occupancy sensors, the designer is urged to check with the respective component manufacturers for compatibility.

Occupancy sensors should not be used with high intensity discharge (HID) source lamps, except in a few specific circumstances. Since HID lamps have extended warm-up periods and can take several minutes to restrike after having been extinguished, occupancy sensors are impractical for these sources. A few manufacturers of HID equipment, however, offer two-level (stepped dimming) HID systems specifically designed to be used with occupant detectors. In these applications, the low-light level is provided when no occupancy is detected. When the occupant detector senses motion, it triggers the lighting system to go to the high level.

Since the lamps are already warm, these systems can go to full light output very quickly, provided they start from a low-light level rather than from off. These two-level systems may be quite useful in warehouse aisles, prisons, gymnasiums, and other interior applications where a low light level is desirable even when the space remains unoccupied.

Field Observations to Assess Feasibility

This section discusses considerations that should be made in selecting and placing occupancy sensors. The discussion also includes actions that can be taken to ensure that energy savings achieved by occupancy sensors will be sustained.

Basic Sensor Specification

A good sensor should have:

- An easily accessible, well-labeled, and adjustable "on" period between sensed motions, preferably as short as 15 seconds (or shorter with a "cheater key", for easy testing) and as long as 20 minutes to ensure no false "offs" (such as when a computer operator's back is to the sensor).

- An easily accessible, well-labeled, and adjustable sensitivity control that provides a wide range of sensitivity to account for sensor placement and possible sources of false triggering (e.g., a nearby air diffuser).

- Protection from false triggering due to radio frequency interference, or poor grounding.

- Circuitry that fails in the "on" position so failure will avoid a hazardous condition, and provide light while the failed sensor is being removed.

- No means to override it to "on" without a special key or tool.

- Clear and accurate diagrams showing shape and size of the sensed zones (and preferably a scaled template to allow easy design layout with scaled floor plans) during full body motion, and separately for hand/arm motion.

- Warranty covering replacement for at least three years after installation.

- No troublesome circuitry that limits its applicability with other basic equipment, such as electronic ballasts. Such assurances should be written into the warranty.

- Sufficient sensitivity to be triggered by a minor arm motion, such as reaching for a telephone, anywhere in the room.

Related to Applicability

An important design consideration is determining the location of the detector. The following factors should be considered in determining proper placement.

- The wallbox sensor is effectively limited to the position of the wall switch. One must be certain that there are no obstructions to limit its effectiveness. For the wallbox sensor to effectively monitor a space with obstructions, it may be easier to simply move the obstructions rather than relocate the wall-box.

- Ceiling-mounted sensors should be mounted and aimed so that they activate the lighting system as soon as a person enters the space.

- Ceiling-mounted sensors may be mounted high on the wall as well as on the ceiling. Mounting the system high has two advantages: there are fewer possibilities of obstructions, and the system will be near to the electrical distribution system, thus easing installation. Sensors should not be mounted in locations, such as behind door swings, that may temporarily obstruct the detection pattern. Neither should they be mounted so that they monitor areas outside of the controlled space.

- To reduce the possibility of false detection, PIR sensors should be mounted no closer than four to six feet from HVAC vents or other heat sources.

- Ultrasonic sensors should not be placed in close proximity to ventilation ducts or open windows, where air movement may cause false triggering.

- Environmental factors may limit some applications. For example, temperature and/or high humidity can affect the electronics of occupancy sensors and reduce the detector's range of sensitivity. The monitoring range of ultrasonic sensors, for instance, may be reduced by temperatures under 0 °C (32 °F).

- The rated range of ceiling-mounted sensors should be derated when they are located in partitioned spaces, where barriers block the line of sight of the devices. For example, in spaces with partitions of 48 inches or higher, the range of ceiling-mounted sensors will be reduced by a minimum of 50 percent. The rated range of occupancy sensors will also be reduced if the mounting height is more than 13 feet.

- Occupancy sensors in all applications should be tested for sensitivity both initially and at intervals to ensure that specified performance is met and has not deteriorated or been compromised by environmental factors.

- Some buildings have area-wide dimming systems that change the wave form of the power to the fixture circuits, resulting in an across-the-board power reduction. Some sensors will work acceptably well for a time and then fail because their solid-state circuitry may be stressed by such a corrupted wave form.

Related to Energy Savings

Unlike an unseen electronic ballast that, once installed, will continue to draw fewer watts than its predecessor, sensors are quite visible and can be improperly adjusted, stolen or vandalized, or fooled into perceiving human motion when a space is unoccupied. Manual override switches on some sensors can cause lights to remain on even when spaces are unoccupied.

If occupants complain about sensor operation, a common response is to raise sensitivity to the maximum, which may cause more frequent false triggering. If such action still fails to resolve the problem, a manual switch may be re-installed, eliminating any savings. Proper installation design and follow-up adjustment are therefore essential parts of any sensor program. Building maintenance personnel must be trained to keep sensors operational, rather than disconnecting them when problems occur.

Estimation of Energy Savings

Energy savings for any particular occupancy sensor application will vary considerably depending on the size of the area covered and the occupancy pattern. Savings claims made by manufacturers range from 5 to 75 percent. Energy saving potential is highly dependent on baseline assumptions and operation, but values of 35 to 45 percent are typical. Table 3 illustrates the typical range of savings from sensor installation in various types of spaces. In all cases except open plan offices, the savings often range by a factor of two or three. This uncertainty makes it difficult to predict the performance and cost-effectiveness of any given installation.

In order to determine the cost-effectiveness of occupancy sensors, the designer should have some knowledge of the expected occupancy patterns of the spaces under consideration and of the amount of the power to be controlled. It may not be cost-effective, for instance, to use occupancy sensors in spaces where occupancy is constant and predictable, like a school classroom. A better choice in these cases might be a time scheduling system or a countdown timer.

Application	Energy Savings[1]
1-2 Person Offices	25 - 50%
Open Offices	20 - 25%
Rest Rooms	30 - 75%
Corridors	30 - 40%
Storage Areas	45 - 65%
Meeting Rooms	45 - 65%
Conference Rooms	45 - 65%
Warehouses	50 - 75%

[1] Figures are based on Manufacturer's estimates and represent maximum potential savings under optimum circumstances. Actual savings may differ.

Table 3: Savings Potential with Occupancy Sensors (Source: CEC)

In retrofit applications, it is important that the designer know the layout of the wiring system in use. If the installation of occupancy sensors requires extensive rewiring, it may not be cost effective.

Standard Savings Calculation

The following equations are recommended for use in estimating energy savings from occupancy sensors. Alternative equations and further information concerning the estimation of energy savings can be found in the CEE program documentation filed with the CPUC.

$$kW_{savings} = \#\,fixtures\_controlled$$
$$\times (Watts\ /\ fixture_{as\text{-}built}\ /\ 10^3)$$
$$\times Utilization\_factor$$
$$kWh_{savings} = kW_{savings}$$
$$\times \left(hours_{base} - hours_{as\text{-}built}\right)$$
$$\times HCIF_{kW}$$
$$therm_{takeback} = kW_{savings}$$
$$\times \left(hours_{base} - hours_{as\text{-}built}\right)$$

$HCIF_{kw}$ and *$HCIF_{heat}$* are the heat/cool interaction factors which account for reduced electric air conditioning loads and increased gas heating loads, respectively, due to the decreased lighting energy. A table of these factors can be found in the program documentation.

Utilization_factor is the ratio of "on" fixtures to the total installed fixtures. This factor accounts for fixtures or lamps which are not operational due to burned out lamps, failed ballasts, or not being turned on.

Cost and Service Life

Factors That Influence Service Life

Occupancy Sensors

It is difficult to adequately assess the life span of occupancy sensor systems. Only one manufacturer has been making occupancy sensors for 15 years, so any manufacturer's claim of life spans in excess of 15 years have yet to be proven empirically. Life cycle testing procedures seem to suggest that a reasonable life span estimate for most occupancy sensors would be between 12 and 15 years. Control units, on the other hand, are estimated to have a life expectancy of between 6 and 10 years. Generally, control unit failures are caused by deterioration of the transformer or relay within them. Deterioration may be exacerbated by high humidity environments and/or temperature extremes.

Effects on Lighting Systems

While lamp life in rapid-start lamps may be significantly reduced by constant switching, in most occupancy sensor applications, average switching cycles (>15 minutes apart) are usually long enough to avoid problems.

Manufacturers of occupancy sensors have argued that although frequent switching may reduce lamp operating life, the overall service life of the lamp will be increased. This analysis is complex, as one must compare the lamp life lost due to frequent switching and the life lost due to deterioration of the tungsten electrodes.

The use of certain wallbox sensors with compact fluorescent lamps may cause reduced lamp life, as some of these devices do not completely shut off the current to the lamp's ballast, causing the lamp to remain partially energized. In most cases, lamps controlled by wallbox sensors supplied with a separate neutral connection will not experience any problems. For other devices, the designer should examine the sensor's specifications (often printed right on the box) for application limitations. Often, the specifications will list minimum loading requirements or state that the device is intended for incandescent use only. When in doubt, contact the manufacturer.

Factors That Influence First Cost

Decision-makers are faced with three types of application choices for a lighting control system: retrofit, renovation and new construction. Table 4 shows the five major cost factors that should be considered for each type of application.

Typical Service Life

The PG&E CEE program assumption for both wall-mounted and ceiling-mounted occupancy sensors is 8 years.

Laws, Codes and Regulations

The National Energy Policy Act of 1992 mandates ASHRAE 90.1, which encourages sensors as its standard for acceptable lighting design in new facilities. ASHRAE 90.1 allows discounting of installed lighting wattage in a new facility to meet its power density limits, if controlled by automatic devices such as timers and sensors. Under the National Energy Policy Act, all state energy codes should include the procedures in 90.1 or else demonstrate how an alternative is comparable.

Under Section 119 of California's Title 24, occupancy sensors must meet the following additional requirements:

- Shall extinguish the lights no longer than 30 minutes after last occupancy

- Shall have adjustable calibration for sensitivity to movement (non-PIR sensors)

- Shall be equipped with a visual and/or auditory status indicator

Occupancy sensors, like all other lighting equipment, should be listed by Underwriters Laboratories (UL), and they should meet ANSI requirements. Ultrasonic sensors must also meet the U.S. Food and Drug Administration's standards for decibel levels and must be inaudible to human hearing.

Application	Initial Cost	Operating Cost	Installed Cost	Supply Circuit Layout	Building Design
Retrofit	√	√	√	√	√
Renovation	√	√			√
New Construction	√	√			

Table 4: Major Cost Factors for Lighting Control Applications
(Reprinted with permission. Copyright 1989, Fairmont Press. All rights reserved)

(Note: Reference to Title 24 or any other regulatory standard is intended for informational purposes, and any such reference is not intended to be authoritative when applying any standard.)

Definition of Key Terms

- **Coverage**: Typically refers to the square footage around the sensor in which whole body motion is detected at maximum sensitivity.

- **Instant-On Circuitry**: Will automatically switch on the lights, or be capable of immediately sensing occupancy, when power is restored following an interruption.

- **Line-of-Sight**: Indicates that a sensor cannot see around corners. Since most substances reflect (or otherwise fail to transmit) heat, any surface blocking the line-of-sight of a passive infrared (PIR) sensor will "blind" it to activity behind that surface—even if it appears to be transparent. Ultrasonic (US) sensors are similarly limited, but can sense air moving around a barrier due to motion behind it.

- **Masking**: A method for limiting the view of infrared sensors by attaching precut opaque labels to portions of the sensor's lenses; doing so avoids detection of movement outside the controlled area (for example, near an open doorway).

- **Sensitivity**: Defines how well a typical body motion is "seen" at a given distance. Such motions are usually divided into two categories: whole body (such as a person walking through a doorway) and hand/arm, or limb, motion (such as someone reaching for a phone). There is no precise standard for a typical limb motion, so one sensor may be more sensitive than another when both claim to sense the same motion at the same distance. Most sensors have adjustable sensitivity.

- **Time Delay or Cycle Time**: The period between the last sensing of motion and shutoff of the lights. This period is adjustable on most sensors for periods as short as 15 seconds (while testing sensitivity) or as long as 30 minutes.

References to More Information

1. California Energy Commission, “Occupant Sensors,” Advanced Lighting Guidelines, Second Edition, P400-93-014, March 1993.

2. E-Source, “Occupancy Sensors: Promise and Pitfalls,” Tech Update, TU-93-8, August 1993.

3. E-Source, “Lighting,” Technology Atlas Series, Volume 1, 1994.

4. Thumann, Albert, “Lighting Efficiency Applications,” Fairmont Press, 1989.

Major Manufacturers

The Watt Stopper
2800 De La Cruz Blvd.
Santa Clara, CA 95050
Tel (800) 879-8585
Fax (408) 988-5373

Novitas, Inc.
1657 Euclid Street
Santa Monica, CA 90404
Tel (800) 888-8006
Fax (310)-452-7890

Unenco, Inc.
2555 Nicholson Street
San Leandro, CA 94577
Tel (800) 227-0452
Fax (415) 895-5753

Additional lists of occupancy sensor manufacturers can be found in References 1,2 and 3. Information on this technology can also be found by contacting relevant trade organizations, such as the National Electrical Manufacturer's Association and the Illuminating Engineering Society of North America.