Hanford Site Lighting Occupancy Sensor Study

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Summary

This study was designed to assess the potential energy savings from the use of lighting occupancy sensor control in the U.S. Department of Energy (DOE) Hanford Site office facilities. The final results of the study provide useful information for assessing cost-effective use of occupancy sensor lighting control. The results also include specific application data for Hanford Site office building spaces that indicate where sensor technology could be applied for cost-effective energy savings.

The study involved the placement of sensor test equipment in multiple office spaces in eight buildings that are part of Hanford contractor facilities. A total of 121 sample data periods from various spaces in office buildings were collected and analyzed. The initial analysis of these data involved the assessment of wasted-light hours with respect to various characteristics of the building spaces, occupants, and operated lighting wattage. Further analysis included life-cycle costing (LCC) that followed the federally accepted methodology and used the current accepted discount rate of 4.0% and standard fuel escalation factors. The LCC analysis was performed for a set of possible lighting wattages across the building spaces and occupant types identified from the initial analysis. The product of this analysis was a set of net present values (NPVs) (the present value of the savings over the analysis period of 25 years) and payback year values (the number of years required to pay back the initial cost from yearly energy savings). These values are presented separately for both rate bases applicable at the Hanford Site (City of Richland - \$0.020/kWh and Westinghouse Hanford Company [WHC] - \$0.055/kWh).

The analysis indicates that lighting operations savings are affected by the work function and number of occupants for occupied spaces. For unoccupied spaces, the function of the space (photocopying, conference, lunch) affects the capacity for lighting operations savings. In all spaces, the total wattage of lighting being controlled in the space as well as the applicable electricity rate have a large effect on potential savings. The data suggest that for office-type spaces with secretarial, administrative, clerical, managerial, computer operation/programming, or library staff occupants, a threshold of approximately 700 to 800 W of lighting wattage must be controlled for occupancy sensor technology to be cost-effective under City of Richland utility rates. When WHC utility system rates are in effect, this threshold is approximately 300 to 400 W. Office spaces occupied by engineering-type staff have a wattage control threshold of 500 W for City of Richland rates. Under WHC rates, any lighting wattage level can provide cost-effective savings. The data also indicate that for office spaces that serve as home bases for technicians (primary work performed in other laboratory or process spaces), any lighting wattage level provides cost-effective savings. For unoccupied spaces, all spaces at any lighting level can provide cost-effective savings under WHC rates, as can photocopy and lunchrooms under City of Richland rates. Conference, library, and training rooms have a 500-W threshold under City of Richland rates.

Further testing was conducted to assess the effects of timer sensitivity adjustments on potential lighting energy savings. The timer sensitivity of occupancy sensor equipment is used to set a reasonable length of time lapse after no motion (no occupancy) is sensed before turning lights off. The results of this test indicated that up to 44% more lighting energy can be saved by using timer sensitivity settings (as low as 2.5 min) that are tighter than standard factory settings (usually 10 min).

The results of the study cover a majority of the building spaces that are considered potentially applicable to occupancy sensor technology. However, with the limited sample size and variety of other potential spaces, additional study is recommended. Further rounds of sampling among the space and occupant types presented in this study would be useful in providing larger sample sizes needed to more accurately assess potential savings. The addition of sample data for other nonoffice space types (e.g., process, high bay, hallway) would also be useful in assessing savings potential for a wider variety of spaces.

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Acronyms and Abbreviations

ADMN	administrative/finance
BPA	Bonneville Power Administration
CLRK	clerical
CMPR	computer room or computer operations/programming
CONF	conference room
COPY	photocopy room
DOE	U.S. Department of Energy
ENGR	engineering
HEMP	Hanford Energy Management Committee
kWh	kilowatt-hour
LAB	laboratory
LCC	life-cycle cost
LIBR	library space or library staff
LNCH	lunchroom
LOFF	large office
min	minute
MNGR	managerial
MOFF	medium office
NPV	net present value
PNL	Pacific Northwest Laboratory
RECP	receptionist office/area
SECR	secretarial
SOFF	small office
STOR	storage room
TECH	technical
TRNG	training/classroom
UPW	uniform present worth
V	volt
W	watt
WHC	Westinghouse Hanford Company

1.0 Introduction

Sensors that detect occupancy have been used for many years to monitor or control various mechanical and energy related functions, including the operation of lighting. As an energy-saving device, occupancy sensors are well suited to lighting operations by reducing lighting use whenever spaces are unoccupied. To determine the potential energy savings and cost effectiveness of sensor lighting control use, some measure of potential wasted-light hours must be known. Other factors, such as applicable energy costs, must also be considered.

This study is a part of the ongoing energy efficiency work sponsored by the Hanford Energy Management Committee (HEMP) and was designed to assess the general potential for lighting operation savings in office-type facilities that are part of the U.S. Department of Energy (DOE) Hanford Site. The assessment will provide needed data to facilities and energy management personnel for use in determining the cost-effective placement of sensors. The study was performed by Pacific Northwest Laboratory (PNL) in two phases between October 1991 and July 1993. Section 2.0 describes the extent and methodology of the data collection efforts for this study. Section 3.0 explains the analysis process and additional sensitivity testing performed on the test equipment. The results of the data analysis and economic evaluation are provided in Section 4.0, and conclusions are presented in Section 5.0.

2.0 Data Collection Methodology

This section describes the equipment and methods used in collecting the occupancy data and the criteria used in selecting test spaces. Detail is also presented on the characteristics data that were collected for each sample space.

2.1 Sample Design

The spaces that made up the study sample were chosen to represent a nearly complete cross section of the space types found in office facilities. Generally, the spaces were selected because they were representative of typical office spaces of their type. Spaces with odd configurations or mixed uses were usually not selected. While these space types do exist in all buildings, their numbers are relatively few compared to standard spaces. Spaces were also selected where the operation was considered to be fairly stable. An additional criterion in selecting spaces was the variety of the spaces selected. Spaces that represented an additional configuration, such as small offices with and without daylight, were selected to provide a varied sample. Because of the mix of facilities found on the Hanford Site, the sample ultimately included some nonoffice spaces such as laboratories and libraries. Definitions of the acronyms used for the sample spaces and occupant types are shown in Table 2.1.

The initial phase of the study was directed at the Federal Building in Richland, Washington. A total of 63 samples were taken in this building. The second phase had a broader scope of facilities to sample that included any office-type building connected with DOE or Hanford contractor operations. In this second phase, 58 samples were taken from seven different buildings. The combination of these two sample sets produced a total of 121 sample test periods for potential use in the study. A small percentage of these sample test periods were considered to be suspect because of conditions that affected the individual test results, including failed lighting sources and inappropriate sensitivity adjustments. These conditions reduced the total usable samples to 109 that included the type and quantity of sample spaces shown in Table 2.2.

2.2 Sample Characteristics Data

For each sample space, a set of characteristics data was recorded for use in determining any relational effects of the sample space. These data were collected at the time the sensor equipment was installed and included the following:

- room number
- room type
- date of installation
- time of installation
- indication that occupants will not be away during sampling period
- location of equipment
- room dimensions

Table 2.1. Building Space and Occupant Type Acronyms and Descriptions

<u>Acronym</u>	<u>Description</u>
Building Spaces:	
- SOFF	small office (< 100 ft ²)
- MOFF	medium office (100 to 199 ft ²)
- LOFF	large office (200+ ft ²)
- CMPR	computer room
- CONF	conference room
- COPY	photocopy room
- LAB	laboratory
- LIBR	library space
- LNCH	lunchroom
- RECP	receptionist office/area
- STOR	storage room
- TRNG	training/classroom
Occupant types:	
- ADMN	administrative/finance
- CLRK	clerical
- CMPR	computer operations/programming
- ENGR	engineering
- LIBR	library staff
- MNGR	managerial
- SECR	secretarial
- TECH	technical

Table 2.2. Space Types and Quantities of Usable Sample

<u>Space Type</u>	<u>Sample Quantity</u>
CMPR	1
CONF	13
COPY	8
LAB	2
LIBR	4
LNCH	13
LOFF	5
MOFF	38
RECP	5
SOFF	16
STOR	3
TRNG	1

- sketch with room layout indicating doors, windows, and direction of sensors
- number and size of windows
- room orientation to sun
- lighting levels (foot-candles)
- lighting fixture count, including type, number of bulbs, and ballasts
- count and general work occupation of residents
- typical daily schedules for room
- unusual room configurations, furnishings, or conditions

Characteristics that may have an effect on lighting operation and savings potential, such as window area, lighting count, and occupant number and type, were entered in spreadsheet form along with the data collected from the sensor equipment.

2.3 Sensor Equipment and Setup

The sensor equipment setup included three primary parts—an ultrasonic motion sensor, a lighting logger with interactive circuitry for use with the sensor, and a stand-alone lighting logger. A total of eight setups were utilized throughout all of Phase 1 and most of Phase 2.

The ultrasonic sensor and companion logger are a product of Mytech Corporation.⁽¹⁾ The units used were Model OA-1000 motion sensors and Model EM-300 lighting loggers. The sensor units are designed to hang from the grid members of any grid ceiling system with a special clip provided with the unit. In the first phase of the project, concerns over possible asbestos in the ceiling area prohibited any movement of the panels to install the clip. For these installations, a bracket that attaches to the very bottom of the grid support was fashioned for each of the units.

The standard units provide for attachment of the companion logger to the sensor unit. In our study, it was sometimes imperative that the logger be installed inside a fixture. Again, the units were modified with an adapter cord from the sensor to companion logger. A 24-V power supply plugged into a standard 120-V socket provides power to the sensor unit and completes this setup.

In the operating mode, the companion logger counts time increments in tenths of an hour whenever the photocell reads sufficient light levels AND the sensor reads no motion. These values are considered to be wasted-light hours, indicating the potential savings from improved lighting control. Half of the companion loggers were supplied with a sensitivity adjustment used to capture appropriate light-on levels. The sensors were equipped with a signal sensitivity setting that allowed for adjustments of the motion-sensing signal in case of traffic in nearby areas that could cause false occupancy readings. Each sensor was also equipped with a timer sensitivity adjustment. This was used to set the length of time the unit would wait after sensing no motion before beginning to count

(a) References to specific manufacturers and models are not to be construed as an endorsement as compared to equivalent instrumentation available from other manufacturers.

wasted-light hours. This adjustment on actual nontest equipment keeps the lights from going off when occupants are infrequently making large motions (e.g., reading).

The third item used was a stand-alone lighting logger. While in operation, the logger records tenths-of-an-hour increments based on photocell indication of light. These units were supplied with sensitivity adjustments to provide effective reading of light-on time. This logger was attached in or near a subject lighting fixture and recorded total light-on time.

2.4 Sampling Procedure

Initial contacts were made with building operators or owners to present the study and request access to building spaces. The room occupants were also contacted to approve the installations. At each space, the characteristics described above were collected and the equipment installed. An operational check was completed as a part of each installation. This check involved testing and adjusting the equipment to ensure that no false reads were occurring or likely to occur. Careful adjustment was needed in some situations, such as oscillating fans, bare walls causing high reflectance of sensor waves, high partitions, and multiple-lighting controls.

Each sample space was monitored for a 2-week period. At the end of each period, the time readings on the two loggers were recorded and reset, and a post-test check of the unit's operation was made to ensure the appropriateness of the data. The recorded data were also compared with expected values to check for reasonableness. For example, the stand-alone logger reading was always expected to be higher than the sensor companion logger and was usually close to the work hours for a 2-week period. In a few cases, the equipment was left installed for another 2-week period if the current data were considered suspect for any reason. Examples of conditions that produced suspect data included failed lighting fixtures used as the logger light source, post-testing that indicated one or more loggers were reading daylight, and oscillating fans that trigger the sensor when occupants are out.

3.0 Analysis Process and Sensitivity Testing

This section describes the methods used to interpret and assess lighting savings potential from the collected data. It also discusses additional equipment sensitivity testing applicable to the assessment of potential energy savings.

3.1 Analysis Process

The analysis associated with this study has two primary objectives: 1) to identify factors that affect potential energy savings and assess their effects, and 2) to assess cost effectiveness of lighting control improvement in various building spaces.

The first step in both analysis objectives was to estimate the potential yearly wasted-light hours associated with each sample. For each 2-week sample, the hours of wasted light (as recorded by the sensor/logger setup) were extrapolated to a full year using the total hours the equipment was installed, according to the following formula:

$$\text{Yearly wasted-light hours} = \text{wasted-light hours} * (8760 \text{ yearly hours/hours equipment installed})$$

Because all sets of sensor equipment were set up and removed on the same day of the week and within several hours of each other, any skewing based on nonexact 2-week periods was considered negligible. Similarly, sample periods with holidays were identified, but not adjusted for working/nonworking hours.

Another primary factor in the overall savings analysis is the capacity of available lighting energy in each space that can be controlled. For each sample space, the total lighting wattage was estimated based on a lamp/fixture count and an estimation of ballast losses. In many sample spaces, individual fixtures were not working. These were noted at the data collection stage, but only operating fixtures were included in the lighting wattage count.

3.1.1 Lighting Energy Factors and Effects

To identify effective factors, the differences in wasted-light hours for each space characteristic were compared. The following characteristics are considered to have possible effects on lighting operation and were included in the analysis:

- availability of daylight
- space type (e.g., small office, large office, copy, conference)
- occupant type/function (e.g., engineering, administrative)
- number of occupants.

The applicable data for each of these characteristics were compared and/or plotted where appropriate to visually determine any apparent trends. Those characteristics exhibiting trends were divided into groups within each characteristic that could be associated with a discreet wasted-light hours value. These discreet values were then used to form relationships between building spaces/functions and potential lighting hours savings.

3.1.2 Life-Cycle Cost Effectiveness

The second area of analysis involved the assessment of the cost effectiveness of occupancy sensor installation for lighting control. For this study, the life-cycle cost (LCC) methodology in the *Life-Cycle Costing Manual for the Federal Energy Management Program* (National Bureau of Standards 1987) was used. The factors that were considered to have an effect on the cost effectiveness of occupancy lighting control were

- available wasted-light hours
- capacity (watts) of operated lighting
- cost of sensor equipment and installation
- electricity rate structure
- longevity of sensor equipment
- maintenance costs associated with new sensor/lighting systems
- maintenance and lamp savings because of decreased replacement needs
- stability of present building space function/operation.

The available wasted-light hours and lighting wattage data were determined in the first part of the analysis. The cost of equipment and installation was derived from existing industry data. Applicable rate structures (including energy and demand costs) can have the most variable effect on cost effectiveness. For this study, the applicable utility rates at Hanford Site facilities were used. The longevity of sensor equipment is considered to be at least as long as most lighting equipment it is controlling and should not have any adverse effect on cost effectiveness. Any additional maintenance costs associated with sensor applications were included in the LCC analysis. The need for replacement of burned-out lamps will be decreased with occupancy sensor control because each lamp will have a longer effective life. This could lead to potential maintenance and lamp purchase savings. However, these potential savings are generally considered small and may not materialize, depending on the lamp replacement system used by maintenance staff (group, spot replacement). These potential savings are conservatively ignored in this analysis.

The final factor, expected building space stability, is generally intangible. In cases where it is not known how long a building space will be occupied, the life portion of the LCC analysis may be much less than normally considered. Because it is nearly impossible to present multiple-lifetime scenarios on all of the options identified from other factors, some measure other than LCC effectiveness may be useful. In this study, because energy savings and material/installation costs are the major items in the analysis, a payback year metric, which should be a relatively stable indicator of cost effectiveness, was also calculated.

3.2 Sensitivity Testing

The lighting occupancy sensor equipment that is currently available can set the strength of the motion-sensing signal and the length of the time-delay function tied to the switching off of lights. This time-delay feature is useful when the strength of the motion-sensing signal must be set low to avoid the detection of occupancy outside the desired building space (ultrasonic) or nonoccupant heat sources within the building space (infrared). In many of these situations, more time will elapse between the kind of occupant actions required to trigger the sensor (at its lower setting). The time-delay can be set longer to avoid turning lights off on occupants in these situations.

This feature can also have an effect on the quantity of lighting hours saved by the equipment. Whenever the space is left vacant, the time allowed before turning the lights off affects the total amount of lighting hours saved. The difference in savings depends on the difference in timer setting as well as the number of stops or light-off cycles made by the equipment. The number of cycles are directly dependent on the occupant's work function and style and are not affected by the time-delay setting.

Two sensitivity tests were conducted in two separate office spaces to assess the potential effect on wasted-light hours because of varied time-delay settings. Each test was conducted with the same two-unit setups. Each setup was identical with one exception; the timer adjustments were set at approximately 2 to 3 min and 16 to 18 min. The results of this test indicate the potential variability in lighting savings based on timer setting.

4.0 Analysis and Results

This section describes the analysis of the collected data and development of wasted-light hours for various building space/occupant categories. The effects of a sensitivity test are considered, and the results of the LCC analysis of all data categories considered in this study are presented.

4.1 Lighting Energy Factor Development

The initial step in determining lighting energy factors was the comparison and plotting of data based on the characteristics identified as having potential effects on lighting operation (i.e., room type, occupant type, daylight, and number of occupants). A total of 109 sample periods of data were considered to be without any bias or error and were used throughout this analysis.

The existence of daylight was the first characteristic explored in this analysis. An initial look at the data from all samples with respect to daylight availability indicated that wasted-light hours were more than twice as high (458 compared to 1080 yearly hours) when no daylight was available, supporting a theory that daylight conditions are generally used to reduce lighting operation. However, when occupied (permanently occupied rooms such as offices) and unoccupied spaces (support spaces such as photocopy rooms and conference rooms with no permanent occupancy) are considered separately, there is apparently only a slight increase in wasted hours for occupied spaces (16%) and a very large increase for unoccupied spaces (208%) when no daylight is available. To define these differences, the occupied and unoccupied groups were further considered.

Figure 4.1 shows a comparison of daylight (where available) and no-daylight wasted hours for all occupant types. The graph indicates no clear relationship between daylight and no-daylight spaces. In addition, a more unified sample of occupied spaces that included the combination of engineering and administrative occupant types only (larger samples in daylight and no-daylight categories - ENGR samples of 10 and 18, ADMN samples of 7 and 20) was considered. With this more unified sample, a small decrease in wasted hours (4.5%) was observed when no daylight was available. It is apparent from these data that in general, daylight availability appears to have no consistent effect on wasted-light hours in occupied spaces.

The unoccupied group of samples included a variety of different space types such as library spaces, lunchrooms, photocopy rooms, conference rooms, and training rooms. For daylight availability comparison, only four of these space types had daylight samples, which existed as SINGLE samples only. Figure 4.2 shows a comparison of all unoccupied spaces with averages of no-daylight samples compared to any available single-daylight samples. The 208% difference noted above for all unoccupied spaces is apparently driven by the large no-daylight values for photocopy rooms and lunchrooms. These spaces are generally considered unowned by anyone and therefore lights may tend to be left on for everyone. Conference rooms, library spaces, and training rooms tend to be temporarily owned by occupants and are therefore more likely to be controlled.

Figure 4.1. Wasted-Light Hours by Occupant Type and Daylight Conditions

Figure 4.2. Wasted-Light Hours by Unoccupied Area and Daylight Conditions

The graphed data for unoccupied spaces indicate no clear relationship in terms of daylight. Therefore, it is apparent (as with occupied spaces) that no differences in wasted-light hours can be attributed to daylight conditions ALONE. Levels of wasted-light hours in unoccupied spaces appear to be driven more by the space type than availability of daylight.

The characteristic of space type was considered next. To isolate space-type effects, reasonable samples of all space types with other similar characteristics are needed, which was impossible with the available data. Sample sizes, when consistent space types and occupant types are combined, range primarily from 1 to 4 (and up to 14) for occupied spaces and 1 to 9 for unoccupied spaces. A combined sample of small-to-medium-size offices for engineering and administration occupants was taken from the data with sample sizes from 5 to 14. These data are presented in Figure 4.3 and indicate no apparent relationship between space type and wasted hours for occupied spaces.

Figure 4.4 presents the data for all unoccupied spaces. There is a general trend here that is explainable based on known use of building spaces. Lunchrooms and photocopy rooms have high wasted light when compared to conference rooms, library spaces, and training rooms. This trend agrees with the reasoning mentioned above concerning perceived ownership of building space types.

Figure 4.3. Wasted-Light Hours by Space Type

Figure 4.4. Wasted-Light Hours by Unoccupied Area Groups

Based on the data shown in Figure 4.4, the average yearly wasted hours for these two groups are

- 582 - conference rooms, library spaces, and training rooms
- 2637 - photocopy rooms and lunchrooms

These yearly values are considered to be reasonable factors for use in assessing lighting energy savings.

The occupant type/function characteristic is perceived as having a large effect on lighting operation. Because daylighting and space-type effects have been shown to have no defined effect on lighting operation, a set of samples comprising averages of all samples of each occupant type (including spaces with multiple numbers of occupants) is considered. The yearly wasted-light hours for each occupant type are shown in Figure 4.5. The technical type appears out of place when compared to the others in the figure, but appears appropriate with respect to the data that make up that type. The three samples that made up the technical type were office or storage room spaces that served as home base for their occupants who performed much of their work in laboratories or other office spaces. Figure 4.6 is similar to Figure 4.5, but includes only occupant types other than technical. This graph gives a better picture of the differences in the remaining occupant types. The engineering occupant type is present in a group by itself. The secretarial, administrative, and clerical types form the second group. The managerial type, consisting of five samples, is the third group.

Figure 4.6. Wasted-Light Hours by Occupant Type

Figure 4.5. Wasted-Light Hours by Occupant Type for All Types

The remaining computer operations/programming and library staff types both have one sample each and cannot be considered representative of their respective types.

Their level of wasted hours is, however, consistent with what might be expected (little time spent away from the work space). For this study, these types were considered in a group that included other occupant types that are generally associated with equipment monitoring and public office or window tending. From these data, yearly wasted-hours values (weighted averages) were derived for the various occupant types and groups (including multiple occupants) in the study. These values are presented in Table 4.1.

The final characteristic, number of occupants, is considered in case multiple occupancy has an effect on lighting control. To provide a consistent sample of similar spaces (same occupant-type group), the data for the engineering and secretarial/administrative/clerical types were considered. All other types were either missing data for an occupant category and/or had samples too small to be effective in any category. Occupant categories were defined as one occupant, two occupants, and three or more occupants. Figure 4.7 depicts the relative changes in wasted-light hours as the number of occupants changes.

There appears to be a definite trend from one to two occupants that indicates less wasted light for two occupants (ENGR = 632 to 478 hours, SECR/ADMN/CLRK = 435 to 305 hours). When going to three or more, however, there is a mixed change in lighting hours and no trend is apparent. These three or more values are also based on low sample numbers (4 and 1). The data for other occupant types are very mixed, going between all categories. These data suggest that occupancy of a space by more than one person decreases the wasted-light hours. Because these two occupant types are composed of similar quantities of one, two, and three or more occupant samples, their total averages from Figure 4.6 can be considered to be medians of the range derived from Figure 4.7. The aggregate percentage differences between these values (range and median) are applied appropriately to the other occupant values from Figure 4.6 to derive one and two or more values for all other

Table 4.1. Wasted-Light Hours for Occupant Types

<u>Yearly Hours</u>	<u>Occupant-Type Category</u>
2245	Technical
519	Engineering
371	Secretarial, Administrative, and Clerical
269	Managerial
232	Computer Operations/Programming, Library Staff and other staff who tend equipment or offices/counters

Figure 4.7. Wasted-Light Hours by Occupant Count

occupant types. For technical and computer operations/programming types, the sample data comprise nearly all two or more occupant data points, and the initial average value is considered appropriate for that category.

The remaining types, managerial and library staff, are considered similarly. The missing value for each type is derived using the percentages described above. The values for the various occupant and nonoccupant groups, as revised from Table 4.1 or developed here, are presented in Table 4.2.

4.2 Timer Sensitivity Effects

The sensitivity testing performed on the timer adjustment of the sensor equipment provides some insight into the importance of equipment adjustment at installation and during use. Most occupancy sensor equipment has both a signal strength/direction and timer adjustment. The signal strength/direction adjustment must be used to set the unit for the space within which it is installed. This adjustment sets how far and where it reads, which is critical for correct operation. Once this is set, the timer adjustment can be used to temper the effects of the strength/direction setting or other occupant behavior characteristics. The timer adjustment simply determines how long the unit will wait after sensing no motion or occupant presence before turning lights off.

Table 4.2. Wasted-Light Hours for Occupant Types and Count

<u>1 Occupant</u>	<u>2 or More Occupants</u>	<u>Occupant Type/Building Space Type</u>
2245	1648	Technical
632	478	Engineering
435	305	Secretarial, Administrative, Clerical
367	269	Managerial
316	232	Computer Operations/Programming, Library Staff, other staff who tend equipment or offices/counters
582	582	Conference Room, Library Space, and Training Room (no permanent occupancy)
2637	2637	Photocopy Room, Lunchroom (no permanent occupancy)

A test was conducted on two separate office spaces to determine the general effect of different timer sensitivity on the hours of recoverable wasted-light hours. Two identical sensor equipment setups, with timer adjustments set at approximately 2.5 min and 17 min, were installed in the office spaces. After a 1- to 3-week period, the readings showed a relatively large difference in the potential lighting savings based on the timer setting. The office spaces showed wasted-hour ranges of 4.42 to 10.66 and 16.1 to 43.7. The settings on the sensor equipment for the primary data samples were all around 10 min, which is considered a standard industry setting. The 10-min value falls almost directly between the 2.5- and 17-min values. For this study, the primary collected data are considered to fall in the middle of the ranges experienced in the sensitivity test. By taking midpoints of the sensitivity ranges (representative of the primary data), a percentage reduction or increase in potential hours can be calculated. The derived percentage values are approximately 41% and 46% for an average of 44%. Because the primary analysis data are based on a typical conservative 10-min setting, the lighting factor values shown in Table 4.2 are considered reasonable conservative estimates. The conclusion to be drawn from the sensitivity testing is that the timer setting applied at installation or later can have a large effect on potential lighting energy savings. Settings should be made as low as possible to achieve maximum savings without introducing occupant inconvenience.

4.3 Life-Cycle Cost Analysis

An LCC analysis is considered to be the best method for assessing overall cost effectiveness of energy retrofit options. The result of the LCC analysis is a net present value (NPV) that is *the present dollar value of the net savings of the action over the period of analysis (25 years)*. Other metrics of cost effectiveness can also be useful in making energy reduction and funding decisions. In this study, a payback year value is also calculated and presented for cases where the relatively long LCC analysis period of 25 years may not apply. The payback year is *the number of years required to pay back the first cost of the retrofit from the present value of yearly energy savings*.

The LCC analysis of possible occupancy sensor retrofits must consider several factors (listed in Section 3.1.2). The available wasted-light hours factor has been addressed in Section 4.1. The capacity of installed/operated lighting is a variable that has a large effect on cost effectiveness. For this study, the lighting wattage was recorded for each space type and ranged from a low of 192 W to a high of 1800 W. These values depend on the size of the space and other space characteristics. The approach chosen for this analysis was to identify specific capacity points between 200 W and 1800 W for LCC analysis that would provide the basis for determining LCC effectiveness.

The equipment and installation cost factor in this analysis is another major factor in LCC effectiveness. Many products are available on the market at varying costs. For the applications represented by this study, it was determined that two classes of sensor equipment would cover nearly all applications. In all but a few of the study cases, a wall-mounted sensor located in place of existing switch(es) provided appropriate control. This switch control type is the most common type of sensor control and is available in capacity ratings to meet the needs of most room sizes. For this study, units with capacities of up to 1000 W and up to 2000+ W were considered. Average vendor costs for the units were approximately \$48.00 and \$59.00, respectively. Personnel at the Hanford Site estimated the labor rate for electricians at approximately \$65.00 per hour. Labor hours for tasks similar to the installation of a switch-mounted sensor, including all training, were estimated to be approximately 0.4 hour. Based on this information, the estimated cost for installation of either unit was \$26.00. For the LCC analysis, any capacity greater than 1000 W uses the cost of the larger unit (\$85.00 total). All other analyses use the smaller unit cost (\$74.00 total).

Electricity costs also have a major impact on LCC analysis. For the Hanford Site, two primary electricity sources are identified that cover over 99% of the total site energy consumption. These sources are the City of Richland utility and the Westinghouse Hanford Company (WHC) utility system. The City of Richland utility service supplies Bonneville Power Administration (BPA) power as well as distribution supply support to the point of building entrance at a specific rate structure. The WHC utility system includes the cost of the electricity supplied directly from BPA as well as facilities and distribution supply support into each building. Although the cost components are similar, the rate calculations performed by WHC are not subject to the rate regulations applicable to municipal utilities. Therefore, the WHC rates can change more rapidly. However, because support costs tend to be consistent from year to year, this rate is considered to be stable in a similar manner to the City of Richland rate. It should be noted that a large reduction in energy use at the Hanford Site (WHC service) can cause consumption to drop sharply, but may not lower actual total costs by a corresponding amount because the support cost component may not be reduced accordingly. This is only noticeable with a large reduction. Similar economics apply to the City of Richland service, but rate changes occur much slower. Other external city load growth can temper support costs, and the total reduction in city-supplied energy from Hanford Site buildings is a small percentage leading to little actual effect on rates. In addition, if actual building consumption under WHC service drops (because of occupancy sensor control) but cannot be ascertained because of lack of actual metering, then no actual cost savings are realized.

For this study, the two total rates applicable to city and WHC supplies were used. Because lighting use is generally consistent throughout typical working days and weeks of the year, an average yearly rate was used in this analysis. Electricity demand costs are affected by occupancy sensor control. However, it is impossible to evaluate the actual effect because lights are controlled randomly throughout the day. In this case, the WHC rate value includes demand costs and cannot easily be backed out. However, as discussed above, the WHC rate may not change because of decreased demand load and therefore is a reasonable number to use. The city rate does not include demand costs. Because the demand is charged separately for each building, the possible cost savings from demand reduction (relatively low compared to consumption savings) were conservatively not included.

The yearly rates were calculated at approximately \$0.055/kWh for WHC service (includes demand and many support costs) and approximately \$0.020/kWh for City of Richland service (does not include demand). The City of Richland value was derived from a typical office building yearly consumption value applied to the current seasonal rates. The actual seasonal use of each facility determines the actual energy saved.

The longevity of equipment factor was ignored in this LCC analysis because the sensor equipment is considered to last as long as the lighting fixtures themselves. Maintenance costs associated with the sensor equipment were also ignored. There is no additional maintenance associated with the sensors that replace wall switches. If small maintenance work is needed, it does not likely affect the stable maintenance budgets associated with Hanford Site facilities. The stability of current building space functions/operation cannot be assessed in most cases. For this analysis, each space was considered to be stable (usable) for the life of the analysis (25 years), which must be taken into consideration with each possible retrofit situation.

The analysis must also use standard acceptable monetary discount factors and fuel escalation values to produce consistent results. For this study, the discount rate and uniform present worth (UPW) discount factors, taken from the *Energy Prices and Discount Factors for Life-Cycle Cost Analysis 1993* (National Institute of Standards and Technology 1993), were used. A discount rate of 4.0% and associated UPW discount factor of 15.99 were used in this analysis to adjust the current yearly energy consumption to a present value of savings over the analysis period of 25 years.

For each appropriate building space type or occupant type, a set of LCC calculations was made for a range of possible installed lighting capacities. The appropriate analysis period of 25 years, UPW of 15.99, and equipment installation cost of \$85.00 or \$74.00 were applied to each space type and lighting wattage possibility. The calculations produced both NPV and payback year values.

Tables 4.3 and 4.4 contain the NPVs of each of the various space/occupant types and installed lighting capacities analyzed in this study. A negative NPV indicates that over the period of analysis, the action will lose money in the amount noted. Table 4.3 is based on the WHC utility rate and Table 4.4 on the City of Richland utility rate.

When reading Tables 4.3 and 4.5, it is important to remember that

- No savings (in terms of dollars) are seen unless the facility is metered or otherwise credited with appropriate savings.
- These values are based on total WHC rates. If a large energy reduction is accomplished, the support cost part of this rate may be redistributed and savings may be LESS than shown.
- The values for *occupant type* are based on occupants in office spaces ONLY. Similar occupants in nonoffice spaces may not exhibit the same lighting operation characteristics.

Tables 4.5 and 4.6 are the same as Tables 4.3 and 4.4, but present payback year values rather than NPVs. Because the only components of the analysis are energy savings and initial cost, the payback values are considered reasonable metrics for indicating potential viability of a project.

When reading Tables 4.4 and 4.6, it is important to remember that

- Any cost savings associated with demand are additional to the savings presented. Therefore, these values can be considered conservative low-end estimates.
- The values for *occupant type* are based on occupants in office spaces ONLY. Similar occupants in nonoffice spaces may not exhibit the same lighting operation characteristics.

Table 4.3. Lighting Control NPV Using WHC Utility Rates

Building Space or Occupant Type	Wasted Hours	Installed Lighting Capacities (watts)															
		200	300	400	500	600	700	800	1000	1100	1200	1300	1400	1500	1600	1700	1800
Occupant Type:		Net Present Value (\$)															
TECH (2+ occup)	1648	216	361	506	651	796	941	1085	1375	1509	1654	1799	1944	2089	2234	2379	2524
TECH (1 occup)	2245	321	518	716	913	1111	1308	1505	1900	2087	2284	2482	2679	2877	3074	3271	3469
ENGR (2+ occup)	478	10	52	94	136	178	220	262	346	377	419	461	504	546	588	630	672
ENGR (1 occup)	632	37	93	148	204	259	315	371	482	526	582	638	693	749	804	860	915
SECR/ADMN/CLRK (2+ occup)	305	-20	6	33	60	87	114	141	194	210	237	264	291	317	344	371	398
SECR/ADMN/CLRK (1 occup)	435	3	41	79	117	156	194	232	309	336	374	412	451	489	527	565	604
MNGR (2+ occup)	269	-27	-3	21	44	68	92	115	163	175	199	223	246	270	294	317	341
MNGR (1 occup)	367	-9	23	55	87	120	152	184	249	270	302	335	367	399	431	464	496
CMPR/LIBR (2+ occup)	232	-33	-13	8	28	48	69	89	130	139	160	180	201	221	241	262	282
CMPR/LIBR (1 occup)	316	-18	9	37	65	93	121	148	204	221	248	276	304	332	360	387	415
Space Type:																	
CONF/LIBR/TRNG	582	28	80	131	182	233	284	335	438	478	529	580	632	683	734	785	836
COPY/LNCH	2637	390	622	854	1086	1317	1549	1781	2245	2466	2698	2930	3162	3394	3626	3857	4089

Table 4.4. Lighting Control NPV Using City of Richland Utility Rates

Building Space or Occupant Type	Wasted Hours	Installed Lighting Capacities (watts)															
		200	300	400	500	600	700	800	1000	1100	1200	1300	1400	1500	1600	1700	1800
Occupant Type:		Net Present Value (\$)															
TECH (2+ occup)	1648	31	84	137	190	242	295	348	453	495	547	600	653	706	758	811	864
TECH (1 occup)	2245	70	141	213	285	357	429	500	644	705	777	848	920	992	1064	1136	1207
ENGR (2+ occup)	478	-43	-28	-13	2	18	33	48	79	83	98	114	129	144	160	175	190
ENGR (1 occup)	632	-34	-13	7	27	47	67	88	128	137	158	178	198	218	238	259	279
SECR/ADMN/CLRK (2+ occup)	305	-54	-45	-35	-25	-15	-6	4	24	22	32	42	52	61	71	81	91
SECR/ADMN/CLRK (1 occup)	435	-46	-32	-18	-4	9	23	37	65	68	82	96	110	124	138	151	165
MNGR (2+ occup)	269	-57	-48	-40	-31	-22	-14	-5	12	10	18	27	35	44	53	61	70
MNGR (1 occup)	367	-51	-39	-27	-15	-4	8	20	43	44	56	68	79	91	103	115	126
CMPR/LIBR (2+ occup)	232	-59	-52	-44	-37	-29	-22	-15	0	-3	4	11	19	26	34	41	49
CMPR/LIBR (1 occup)	316	-54	-44	-34	-23	-13	-3	7	27	26	36	46	56	67	77	87	97
Space Type:																	
CONF/LIBR/TRNG	582	-37	-18	0	19	38	56	75	112	120	138	157	176	194	213	231	250
COPY/LNCH	2637	95	179	263	348	432	516	601	769	843	927	1011	1096	1180	1264	1349	1433

Table 4.5. Lighting Control Payback Year Values Using WHC Utility Rates

Building Space or Occupant Type	Wasted Hours	Installed Lighting Capacities (watts)															
		200	300	400	500	600	700	800	1000	1100	1200	1300	1400	1500	1600	1700	1800
Occupant Type:		Payback Years															
TECH (2+ occup)	1648	4.1	2.7	2.0	1.6	1.4	1.2	1.0	0.8	0.9	0.8	0.7	0.7	0.6	0.6	0.6	0.5
TECH (1 occup)	2245	3.0	2.0	1.5	1.2	1.0	0.9	0.7	0.6	0.6	0.6	0.5	0.5	0.5	0.4	0.4	0.4
ENGR (2+ occup)	478	14.1	9.4	7.0	5.6	4.7	4.0	3.5	2.8	2.9	2.7	2.5	2.3	2.2	2.0	1.9	1.8
ENGR (1 occup)	632	10.6	7.1	5.3	4.3	3.5	3.0	2.7	2.1	2.2	2.0	1.9	1.7	1.6	1.5	1.4	1.4
SECR/ADMN/CLRK (2+ occup)	305	22.1	14.7	11.0	8.8	7.4	6.3	5.5	4.4	4.6	4.2	3.9	3.6	3.4	3.2	3.0	2.8
SECR/ADMN/CLRK (1 occup)	435	15.5	10.3	7.7	6.2	5.2	4.4	3.9	3.1	3.2	3.0	2.7	2.5	2.4	2.2	2.1	2.0
MNGR (2+ occup)	269	25.0	16.7	12.5	10.0	8.3	7.1	6.3	5.0	5.2	4.8	4.4	4.1	3.8	3.6	3.4	3.2
MNGR (1 occup)	367	18.3	12.2	9.2	7.3	6.1	5.2	4.6	3.7	3.8	3.5	3.2	3.0	2.8	2.6	2.5	2.3
CMPR/LIBR (2+ occup)	232	29.0	19.3	14.5	11.6	9.7	8.3	7.2	5.8	6.1	5.6	5.1	4.8	4.4	4.2	3.9	3.7
CMPR/LIBR (1 occup)	316	21.3	14.2	10.6	8.5	7.1	6.1	5.3	4.3	4.4	4.1	3.8	3.5	3.3	3.1	2.9	2.7
Space Type:																	
CONF/LIBR/TRNG	582	11.6	7.7	5.8	4.6	3.9	3.3	2.9	2.3	2.4	2.2	2.0	1.9	1.8	1.7	1.6	1.5
COPY/LNCH	2637	2.6	1.7	1.3	1.0	0.9	0.7	0.6	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.3	0.3

Table 4.6. Lighting Control Payback Year Values Using City of Richland Utility Rates

Building Space or Occupant Type	Wasted Hours	Installed Lighting Capacities (watts)															
		200	300	400	500	600	700	800	1000	1100	1200	1300	1400	1500	1600	1700	1800
Occupant Type:		Payback Years															
TECH (2+ occup)	1648	11.2	7.5	5.6	4.5	3.7	3.2	2.8	2.2	2.3	2.1	2.0	1.8	1.7	1.6	1.5	1.4
TECH (1 occup)	2245	8.2	5.5	4.1	3.3	2.7	2.4	2.1	1.6	1.7	1.6	1.5	1.4	1.3	1.2	1.1	1.1
ENGR (2+ occup)	478	38.7	25.8	19.4	15.5	12.9	11.1	9.7	7.7	8.1	7.4	6.8	6.4	5.9	5.6	5.2	4.9
ENGR (1 occup)	632	29.3	19.5	14.6	11.7	9.8	8.4	7.3	5.9	6.1	5.6	5.2	4.8	4.5	4.2	4.0	3.7
SECR/ADMN/CLRK (2+ occup)	305	60.7	40.4	30.3	24.3	20.2	17.3	15.2	12.1	12.7	11.6	10.7	10.0	9.3	8.7	8.2	7.7
SECR/ADMN/CLRK (1 occup)	435	42.5	28.4	21.3	17.0	14.2	12.2	10.6	8.5	8.9	8.1	7.5	7.0	6.5	6.1	5.7	5.4
MNGR (2+ occup)	269	68.8	45.8	34.4	27.5	22.9	19.6	17.2	13.8	14.4	13.2	12.2	11.3	10.5	9.9	9.3	8.8
MNGR (1 occup)	367	50.4	33.6	25.2	20.2	16.8	14.4	12.6	10.1	10.5	9.7	8.9	8.3	7.7	7.2	6.8	6.4
CMPR/LIBR (2+ occup)	232	79.7	53.2	39.9	31.9	26.6	22.8	19.9	15.9	16.7	15.3	14.1	13.1	12.2	11.4	10.8	10.2
CMPR/LIBR (1 occup)	316	58.5	39.0	29.3	23.4	19.5	16.7	14.6	11.7	12.2	11.2	10.3	9.6	9.0	8.4	7.9	7.5
Space Type:																	
CONF/LIBR/TRNG	582	31.8	21.2	15.9	12.7	10.6	9.1	7.9	6.4	6.6	6.1	5.6	5.2	4.9	4.6	4.3	4.1
COPY/LNCH	2637	7.0	4.7	3.5	2.8	2.3	2.0	1.8	1.4	1.5	1.3	1.2	1.2	1.1	1.0	0.9	0.9

5.0 Conclusions and Recommendations

The primary conclusion of this analysis is that there are many opportunities for energy savings at the Hanford Site through the use of lighting occupancy sensor control. The types and quantity of spaces that will benefit from this technology depends primarily on the function of each building space and its occupants, the amount of lighting to be controlled, and the applicable utility rate. The data presented in Tables 4.3 through 4.6 provide the specific conclusions based on the analysis performed for this study. Specific conclusions drawn from the analysis are as follows:

- The availability of daylight in a building space does not appear to have any noticeable aggregate effect on the quantity of wasted-light hours in occupied or unoccupied spaces. This is based on the lack of any noticeable correlation between the daylight and no daylight levels of wasted-light hours for various occupant and space types.
- An important factor in the level of wasted-light hours in unoccupied spaces (e.g., conference rooms, photocopy rooms) is the perceived ownership of the building space. Conference and training rooms tend to be temporarily owned by an individual or organization and lights are generally turned off when the space is left by the occupants. Photocopy and lunchrooms are generally owned by everyone and therefore lights are more likely to be left on for the next occupant.
- More than one permanent occupant in an occupied space tends to decrease the wasted-light hours (approximately 27%). This is attributed to staggered use of a space that is associated with multiple occupancy.
- Setting the timer control on a sensor device below the normal factory setting of 10 min can have a significant effect on reduced wasted-light hours (up to 44% fewer if set to 2.5 min).

Although values of wasted-light hours for various building spaces and occupant types were derived from the data, there is still a great deal of variability in how spaces are used. The values in Tables 4.3 through 4.6 are not particularly useful as single points of data for single applications. A single application may not achieve the savings presented because of the many factors that can affect lighting use in a specific space. The tables are recommended only for use in determining probable potential savings for groups of similar building spaces.

Companion issues to occupancy control exist that can have a major effect on lighting energy use. These issues include daylighting control, lighting technology upgrade, and appropriate lighting reduction. These issues are not addressed as part of this analysis, but should be considered for future study and consideration with occupancy lighting control.

6.0 References

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