CODE CHANGE PROPOSAL FOR

Residential Hardwired Lighting

REPORT 5/7/02

Created on Tuesday, May 07, 2002

Overview

Description

This code and standards enhancement initiative will reduce residential new construction lighting energy use by encouraging the use of high efficacy lighting, occupancy sensors and photosensors in high-use areas of the home and exterior. This initiative also addresses low compliance rates, enforcement confusion, and unpopularity of the current residential lighting requirements with designers and builders. This initiative will apply to residential single-family and multifamily low-rise and high-rise new construction. Applicable sections will also apply to guest rooms of hotels and motels.

This proposal:

1. provides a definition of high efficacy lighting that can be shared with the nonresidential section of the code,
2. expands the required locations for high efficacy lighting to include utility areas, garages and exterior lighting (areas that previously were allowed as tradeoffs for bathrooms),
3. expands the definition of *bathroom* to areas with either a tub, toilet, or a personal hygiene sink, and requires all lighting in bathrooms to be high efficacy, but provides an exception if motion sensors are installed,
4. requires that at least 50% of the total installed lighting wattage in kitchens be high efficacy,
5. requires track, recessed and pendant lighting be high efficacy or be on dimmers,
6. requires all recessed lighting in insulated ceilings to be IC-rated and air-tight (ICAT).

Benefits

This requirement will increase the efficiency of lighting systems in residential occupancies. The success of this codes and standards enhancement hinges upon successful enforcement by field inspectors. Kitchens and baths have been targeted for high efficacy lighting since the 1988 code with limited success. Problems with room interpretation and subjective definitions like "general lighting" have been problematic. Builder acceptance has been limited due to a perception of the lack of aesthetically pleasing fluorescent fixtures at reasonable costs and quality of light issues. These requirements attempt to address these problems by clarifying definitions, and providing reasonable tradeoffs and exceptions. The proposal also reflects the market shift toward increased availability and reduced cost of pin-based compact fluorescent fixtures and greater market acceptance of the improved "tri-phosphor" compact fluorescent light sources (lamps).

Environmental Impact

The environmental impacts from the proposed changes are positive in the aggregate. Indoor air quality is improved if leakage-induced pressure differentials are reduced to pull less contaminants from attics, garages, and crawlspaces into the home through openings created by non-air-tight recessed lighting. Environmental emissions from power plants are lower because of the reduced annual energy consumption and, more importantly, because of the reduced consumption on peak when higher emitting power plants are on line.

The efficiency of compact fluorescent lamps depends upon a small amount of mercury vapor in each fluorescent tube. Increased use of compact fluorescent lamps has the potential to increase the presence of mercury in the environment and landfills in particular. The mercury in compact fluorescent lamps does not present an immediate hazard to the homeowner. However, the lighting industry is working to minimize the amount of mercury in fluorescent lamps and has an active recycling campaign. New lamp technologies include so-called "amalgam" materials that reduce mercury content and increase lamp life. Mercury is also released at power plants. Studies show that the energy savings at power plants related to high efficacy sources reduces mercury pollution more than what is added locally from the use of fluorescent lighting. Furthermore, power plant emissions of mercury are airborne, which produces more damaging effects.

Type of Change

This code change proposal involves a revision to the Mandatory Measures, Section 150(k) and Definitions and Rules of Construction, Section 101of the Energy Efficiency Standards. In addition, Section 130(b) is revised to eliminate the redundant mandatory measures for high-rise residential and hotel/motel occupancies by referring to the requirements in Section 150(k).

The revised Section 150(k) mandatory measures would be rewritten to expand locations, provide an objective measure for proportion of energy efficient lighting versus standard lighting for kitchens, eliminate tradeoffs for bathrooms, and specify that all lighting in bathrooms shall be high efficacy. Tradeoffs between rooms were previously introduced into the code in response to the builder request for an alternative to fluorescent lighting in bathrooms. Builders felt that a lack of a quality product limited their ability to comply with the requirement. Now that high quality compact fluorescent lamps are more widely available and have much more favorable lifecycle cost to incandescent bulbs, these tradeoffs should be removed.

The use of an occupancy sensor in a bathroom, utility area and garage is provided as an alternative for high efficacy luminaires in these rooms. Automatic occupancy controls with "manual on" functionality provide a reasonable tradeoff to high efficacy lighting. Limiting the operating hours of hardwired incandescent light fixtures saves approximately 20 percent when compared to manual control of incandescent luminaries. It also provides for more design choices for those who do not wish to install a high efficacy luminaire.

Lastly, ceiling-mounted pendant luminaires, recessed downlights and track lighting are of particular concern because of their energy use and their increasing prevalence in homes. This code proposal requires that these luminaire types be high efficacy throughout the home or be controlled by a dimmer. Dimmers provide some energy savings, can increase the longevity of the lamp, and provide for more design alternatives than requiring high efficacy lamps for these types of luminaires.

The ACM manual would not be affected by this change. The compliance forms would be modified to include a check-off list of required locations for high efficacy lighting. The manual would need to be modified to reflect this change, including application scenarios that would illustrate the requirements, the 50% test for the kitchen and clarification of approved generic high efficacy luminaire types. The appropriate mounting strategies for occupancy sensors should also be presented in the revised version of the manual. The change should be supported by the development of additional training materials targeted for builders and building inspectors.

Technology Measures

This measure would increase the number of pin-based compact fluorescent fixtures in a home. The measure allows the use of occupancy sensors, motions sensors and dimmers to reduce lighting energy use in the home cost effectively.

Measure Availability and Cost

There are many types of compact fluorescent fixtures available in today's market covering a wide spectrum of application types and styles. The standard types of fixtures commonly used in new construction are widely available at reasonable cost through the existing distribution channels. These fixtures will become more widely available in the coming years because the adoption of the code will increase the demand for such products. The Energy Star fixture program is also contributing to the increased availability of pin-based compact fluorescent fixtures.

The availability of replacement lamps for pin-based CFLs is currently somewhat limited to home improvement centers, hardware stores and specialty lighting stores.

It is accepted by the consensus of participants in the code development process that replacement pin-based CFLs lamps will become available in sufficient quantities and wider distribution channels as demand for these types of lamps increases due to wider use of pin-based CFL fixtures. In addition, industry groups are actively working to standardize the range of pin-based CFLs lamps which will reduce the variety of lamps needed to be stocked on retailer shelves further increasing the motivation and reducing the cost to stock such lamps.

The measure proposes to allow an occupancy sensor as an alternative to high efficacy lighting in bathrooms and other support areas. Two of the three largest manufacturers of residential occupancy sensors have at least one device that meets the criteria of the proposed code enhancement.

Useful Life, Persistence and Maintenance

The useful life and persistence of pin-based compact fluorescent fixtures is generally accepted to be the life of the building. The life of a residential compact fluorescent fixture is limited by the life of its ballast (typically 10 years). The ballast can be replaced without removing the fixture. In the absence of abuse, vandalism or inappropriate installation, motion sensors can be expected to last the life of the building. However, the success of this alternative compliance approach depends upon the likelihood that the motion sensor will remain installed in the building.

Performance Verification

The residential lighting mandatory measures have historically been a concern for some builders and building inspectors. This code change provides simplified and more specific requirements for building officials to enforce. In kitchens, building inspectors will need to determine the installed watts of fluorescent versus incandescent lighting sources. In addition, there are certain fixture types (ceiling-mounted pendants, track lighting, and recessed lighting) that will require some additional inspection. Additional compliance gains can be expected through education and outreach efforts.

The occupancy sensor alternative to high efficacy lighting in bathrooms may introduce some initial confusion because of the novelty of this measure. Builders may not be aware of the differences between occupancy sensor product lines. Some effort will be necessary to properly educate field inspectors and the building community about occupancy sensors that meet the proposed standards requirements.

Cost Effectiveness

Our analysis shows that the proposed change is cost effective for every room type included in the scope of the measure. These cost effectiveness estimates are based upon recent cost data obtained through surveys, and surveyed hours of operation per room from the California Baseline Study[1]. On a room-by-room basis, all of the proposed code enhancements involving the upgrade of the luminaire to a high-efficacy source have a 30-year discounted benefit/cost ratio greater than 1.0. No analysis of the TDV impacts of residential lighting was conducted due to a lack of hourly usage profile data for residential lighting.

Analysis Tools

A spreadsheet analysis of the cost effectiveness of the measures was performed.

Relationship to Other Measures

This change is related to the nonresidential lighting measures in that a common definition of "High Efficacy Luminaire" is provided for both sections of the code. Any definitions that go into Sec 101 must be applicable to nonresidential lighting as well. Some coordination between this proposal and the requirements for Section 130 (c) are needed. This subsection deals with mandatory measures for exterior lighting of nonresidential buildings. Currently, the code language refers to "luminaires with lamps rated over watts shall either: have a source efficacy of at least 60 lumens per watt, or be controlled by a motion sensor." Since a definition of "High Efficacy Luminaire" would now exist in Section 101, it would be advantageous to use this terminology in section 130(c) because it would further eliminate duplicate code language.

[1] Lighting Efficiency Technology Report, Volume I, California Baseline, Prepared by the Heschong Mahone Group.

Methodology

There were two main efforts used to support the final recommendations in this report 1) incremental cost and availability research and 2) cost effectiveness comparisons. Research efforts also hinged upon a careful review of the existing body of literature to determine market readiness, persistence and assumptions for operating hours. The analysis of the benefits of ICAT feature requirements for recessed downlights was conducted separately from the analysis of the other luminaire types.

Incremental Cost and Availability

The research team identified a variety of lighting fixture distribution channels in the mass market, including retail chain outlets, home improvement stores and grocery stores. In addition, the team searched the various Internet-based purveyors of residential lighting equipment. The first step in the process was to identify a set of commonly used residential fixture types including at least one fixture type for each room of the home. For each fixture type, we collected price information from the distribution channels for the base case (usually an incandescent fixture) and an equivalent upgraded fixture (a pin-based compact fluorescent and for some measures, an incandescent fixture with a control upgrade such as dimmer or occupancy sensor). These data were entered into a spreadsheet and used as the basis for the cost comparisons. The fixture data are based upon pricing and availability obtained in the first two weeks of April 2002. A table of the selected fixture types including an illustration of each is in Appendix A.

While contacting the suppliers and searching Internet databases for pricing information, we also kept track of the amount of shelf space devoted to pin-based compact fluorescent fixtures as compared to incandescent fixtures. This data supplemented the findings of other research organizations on the availability of pin-based compact fluorescent fixtures.

The cost effectiveness analysis depends upon a set of fixture upgrade functional equivalents. A fixture upgrade was considered a functional equivalent if it provided approximately the same number of lumens and was an appropriate luminaire selection (in terms of mounting, aesthetics and other factors) for use in the same room locations as the original. For example, an incandescent downlight can be upgraded to a fluorescent downlight, or an incandescent vanity light can be upgraded to a pin-based compact fluorescent vanity light, but a surface-mounted ceiling fixture could not be upgraded to a wall-mounted sconce. Upgrade equivalents for recessed downlights involving air-tight improvements were considered separately. A table of each base case and upgrade option is included in Appendix B.

The cost effectiveness analysis also depends upon a set of assumptions about the hours of operation of fixtures in each room of an average family home. This is accomplished by first computing the minimum hours per year that it is necessary to operate the fixture in order to be a cost effective upgrade. A fixture upgrade is deemed to be cost effective (independent of it actual usage) when its discounted energy savings and lamp replacement costs exceeds its incremental cost. For example, an upgrade from an IC-rated incandescent downlight to an IC-rated fluorescent downlight (Appendix B, B0→B2) was shown to save 65% of the energy of the base case luminaire and has an associated incremental cost of $63.25. To offset this cost, the luminaire must be operated at least 428.5 hours per year. The threshold "minimum cost effective hours" per fixture was computed according to the following formula:

Equation 1: $H_{min} = \Delta Cost / [(\Delta Energy / 1000 \bullet E_{Rate}) + (F_{PV} (D_{rate}, D_{term}, (LCost_1 / LLife_1 - LCost_0 / LLife_0)))]$

where:

H_{min} = minimum hours of operation
$\Delta Cost$ = incremental cost of the fixture
$\Delta Energy$ = reduced wattage of the fixture in watts
E_{Rate} = 30-year energy rate ($2.06/kWh)
D_{rate} = discount rate (.03)
D_{term} = discount term (30 years)
F_{PV} = Present Value Function
$LCost_0$ = original lamp cost
$LLife_0$ = original lamp life
$LCost_1$ = upgrade lamp cost
$LLife_1$ = upgrade lamp life

Equation 1. This equation calculates the minimum hours of operation per year (H_{min}) needed for a particular fixture upgrade before that upgrade can be considered cost effective. To simplify the calculation, the lamp replacement costs are amortized on an annual basis based on the expected life of the lamp.

A table of the incremental costs and "minimum cost effective hours" for each of the fixture upgrade options is shown in Appendix C. A summary of the results for each type of upgrade is provided in Table 1.

Table 1. Summary of incremental cost and minimum hours of operation to be cost effective for all luminaires in the cost effectiveness study.

		Incremental cost	min hours
pin CFL	min	-$72.72	0.0
	max	$63.25	915.1
	mean	$16.04	134.3
dimmer	min	$1.55	0.0
	max	$51.66	915.1
	mean	$17.81	327.9
occupancy sensor	min	$0.34	1.0
	max	$27.93	1773.9
	mean	$21.04	701.9

Assessing the threshold hours of operation for each upgrade option is the first step toward determining cost effectiveness. These thresholds were then compared to the hours of use on a room-by-room basis according to the California Baseline Study, which provides us with the average number of hours of use per year for nine areas of the home. If the threshold hours of operation to be cost effectiveness was less than the average number of hours provided in the baseline study, then the fixture upgrade was determined to be cost effective.

To determine the degree of cost-effectiveness, a benefit/cost analysis was performed using Equation 2:

Equation 2:

$$BC = \{ \Delta Energy \bullet H_{room})/1000 \bullet E_{Rate} — [F_{PV}(D_{rate}, D_{term}, (H_{room} / LLife_0 \bullet LCost_0 — H_{room} / LLife_1 \bullet LCost_1))] \} / \Delta Cost$$

where:

BC = 30-year discounted benefit/cost ratio
H_{room} = hours of use of fixture in a specific room (from the California Baseline study)
$\Delta Cost$ = incremental cost of the fixture
$\Delta Energy$ = reduced wattage of the fixture in watts
E_{Rate} = 30-year energy rate ($2.06/kWh)
D_{rate} = discount rate (.03)
D_{term} = discount term (30 years)
F_{PV} = Present Value Function
$LCost_0$ = original lamp cost
$LLife_0$ = original lamp life
$LCost_1$ = upgrade lamp cost
$LLife_1$ = upgrade lamp life

Equation 2. This equation calculates the 30-year discounted benefit/cost ratio of a luminaire upgrade considering the initial cost increment, energy savings, and annualized lamp replacement cost difference.

A complete list of the benefit cost ratios of each upgrade option for each area of the home is shown in Appendix D.

Air-tight (ICAT) Recessed Downlights

Recessed cans deserve special treatment in the standards because in addition to the electricity consumption by the fixture to create light, the fixture creates an air infiltration path across the envelope. To mitigate the problem of air infiltration through recessed cans, several manufacturers make IC-rated (insulated ceiling) and air-tight or "ICAT" recessed cans[2]. Recognizing that energy savings in recessed cans can be realized by converting to a compact fluorescent source and decreasing infiltration through the fixture, the Federal Government is making a bulk

[2] The use of the acronym "ICAT" in this context is a generic description and is not meant to refer only to the proprietary ICAT rating procedure used by some testing laboratories. The proposed standard to be used to define an air-tight recessed downlight is ASTM E283-91. We contacted Architectural Testing, Inc. in Fresno, CA and they indicated that they are equipped to perform ASTM E283 and can do this test on recessed cans.

procurement of compact fluorescent air-tight fixtures to support energy efficient fixture purchases for Federal facilities and large scale energy efficiency programs.[3]

Insulated ceiling air-tight (ICAT) recessed cans are currently required by the Washington State Energy Code,[4] the 1995 Model Energy Code (MEC)[5] and its successor, the 2000 International Energy Conservation Code (IECC).[6] The wording is similar in all of these standards. This proposal for Title 24 would be similar to these standards and would use the same maximum infiltration rate of tested fixtures (2.0 cfm at 75 Pascals differential pressure). This proposal also requires that the fixture have a gasket or be caulked to the drywall. The gasket/sealing requirement is a clarification of the current infiltration control requirements in section 117 of the Standards.

Though the test standard clearly limits the infiltration rate for ICAT cans, there was significant diversity in what the appropriate infiltration rate should be for non-air tight recessed cans. The data source used here for expected infiltration rate for non-ICAT cans came from the ASHRAE Handbook of Fundamentals[7] and is based upon the effective leakage area. These leakage area values were from published values in the technical literature[8] and are based upon a reference pressure difference of 4 Pa (0.016 in WC) and a coefficient of discharge, $C_D = 1.0$.

Table 2. Effective Leakage Areas (Low Rise Residential Applications Only)

Description	Best Estimate	Minimum	Maximum	Units
Recessed Lights	1.6	0.23	3.3	in^2/fixture

The following method was used to estimate the life cycle cost/benefit ratio for replacing standard IC recessed can lights with ICAT can lights.

A) Convert ICAT required flow rate of 2 CFM at 75 Pa (0.301 in WC) into an effective leakage area, A_{r1} (in^2), at the reference pressure of 4 Pa (0.016 in WC)[9].

$$A_{r1} = \frac{Q_{r2}}{C_6\, C_D \sqrt{\frac{2}{\rho}}\ (\Delta P_{r1})^{0.5-n}\ (\Delta P_{r2})^{n}}$$

where:

Q_{r2} = flowrate at pressure difference ΔP_{r2}, cfm
C_6 = conversion unit factor = 5.39
CD= coefficient of discharge = 1.0
ρ = density of air, 0.075 lb_m/ft^3
ΔP_{r1} = reference pressure differential, 0.016 in WC
ΔP_{r2} = pressure differential at alternate pressure, 0.301 in WC
n = pressure exponent, 0.65

$$A_{r1} = \frac{2.0}{5.39 \times 1 \sqrt{\frac{2}{0.075}}\ (0.016)^{0.5-0.65}\ (0.301)^{0.65}} = 0.084\ in^2$$

3 Buildings for the 21st Century Fact Sheet: July 2001. "Lighting Fixtures: Residential Recessed Downlights Technology Procurement" http://www.eren.doe.gov/buildings/emergingtech/pdfs/canscyan.pdf

4 Section 502.4.4 "Recessed Lighting Fixtures," Washington State Energy Code 2000 Edition. Seattle version available at: http://www.ci.seattle.wa.us/dclu/energy/Default.htm

5 Sections 502.3.4 and 602.3.3 1995 Model Energy Code, Council of American Code Officials (CABO), Falls Church, VA http://www.cabo.org/

6 Section 502.1.3 2001 International Energy Conservation Code (IECC), International Code Council, http://www.intlcode.org/

7 ASHRAE 2001 Fundamentals p 26.15 Table 1 - Effective Air Leakage Areas (Low Rise residential)

8 Colliver, D.G., W. Sun and W.E. Murphy. 1994. Development of a building component air leakage database. ASHRAE Transactions 100(1):293-305

9 Accomplished by rewriting Equation 35 and solving for Ar1 p. 26.13 2001 ASHRAE Fundamentals

Thus the effective leakage area of an ICAT can is 0.084 in^2.

The reduced effective leakage area is 1.6 – 0.084 = 1.52 in^2

B) Calculate a UA Infiltration, in units of Btu/hr·°F as follows:

UA Infiltration $= A_{r1} \bullet C_1 \bullet \rho \bullet Cp \bullet s_0 \bullet C_2$

where:

C_1 = conversion coefficient, 0.0069 ft^2/in^2
Cp = specific heat of air = 0.24 $Btu/lb_m \cdot °F$
$s_{0=}$ specific infiltration velocity = 140 ft/min.
C_2 = conversion coefficient = 60 min/hr
ρ = density of air, 0.075 lb_m/ft^3

therefore:

UA Infiltration = (1.52)(0.0069)(0.075)(0.24)(140)(60) = 1.59 Btu/hr·°F

C) Estimate annual energy savings, ES, using the infiltration degree-days (IDD) in ASHRAE Standard 119 and furnace efficiency. The infiltration degree days which account for variations in temperature and windspeed for different climates, have been normalized relative to the specific infiltration velocity.

ES = UA Infiltration x IDD $\bullet$ C_3 / AFUE

where:

IDD = infiltration degree-days from ASHRAE Std 119
C_3 = conversion constant, 24 hr/day
AFUE = annual fuel utilization efficiency, 0.78

As an example, the energy savings for San Diego with 1,128 infiltration degree days is:

ES = (1.59)(1,128)(24) / (0.78) = 55,000 Btu/yr or 0.55 therms

D) Multiply energy savings by the 30-year discounted value of the cost natural gas.

The defined discounted cost of gas for a 30-year period is $12.64/therm. It should be noted that we are treating the infiltration IDD's as if they represent only heating savings–actually ICAT fixtures result in both heating and cooling savings. Thus, these cost savings estimates are conservative.

E) Calculate the benefit cost ratio.

Divide the present valued cost savings by the incremental initial cost of ICAT cans versus standard IC-rated, non-air-tight cans. We took the average cost for 10 models of standard IC-rated cans and compared them to 10 models of air-tight cans and found the average incremental cost to be $4.12. Incremental cost data in more established markets for air-tight fixtures such as the Northwest show significantly lower cost increments. Table 6 summarizes the above calculations for 8 California locations ranked by their Infiltration Degree Days.

Results

A review of the literature and the recent availability research conducted for this measure found the selection and availability of pin-based fluorescent luminaires to be sufficient. A summary of the benefit/cost ratio for each type of upgrade (high efficacy, dimmer switch and occupancy sensor/motion sensor, air-tight recessed downlights) is shown in separate tables.

Table 3. High Efficacy Lighting upgrade Benefit/Cost ratio summary statistics.

B/C ratio high efficacy	Kitchen / Dining	Yard	Utility	Living	Garage	Hallway	Den	Bathroom	Bedroom
min	2.9	4.7	2.2	2.2	2.0	1.9	1.7	1.7	1.2
mean	21.9	16.4	15.8	17.1	13.4	14.9	13.6	16.4	10.9
max	76.2	47.8	58.3	58.3	51.5	49.3	44.8	44.8	31.4
Note: Minimums exclude 3 lighting upgrades that have zero additional first cost.									

Table 3 shows that the minimum benefit/cost ratio for any of the high efficacy luminaire upgrades in this study is 1.2 in bedrooms where hardwired luminaires have the fewest hours of use. On average, the benefit/cost ratio varies from 10.9 in bedrooms to 21.9 in the kitchen where operating hours are highest. The life cycle benefits far outweigh the costs for all of the luminaire upgrades under consideration with the greatest benefit in the high-use areas of the home.

Table 4. Dimmer Switch upgrade Benefit/Cost ratio summary.

B/C ratio dimmer switch	Kitchen / Dining	Yard	Utility	Living	Garage	Hallway	Den	Bathroom	Bedroom
min	2.8	n/a	1.0	n/a	0.9	1.8	1.7	1.7	1.2
mean	9.8	n/a	6.2	n/a	5.5	6.4	5.8	5.8	4.0
max	26.0	n/a	19.9	n/a	17.6	16.8	15.3	15.3	10.7

Table 5. Occupancy Sensor/Motion Sensor upgrade Benefit/Cost ratio summary statistics.

B/C ratio Occupancy Sensor	Kitchen / Dining	Yard	Utility	Living	Garage	Hallway	Den	Bathroom	Bedroom
min	n/a	0.6	0.8	1.0	1.0	n/a	n/a	0.6	1.2
mean	n/a	544.8	1.0	6.2	1.0	n/a	n/a	1.8	1.7
max	n/a	1088.9	1.2	19.9	1.0	n/a	n/a	3.1	2.2

The benefit/cost ratio of the proposed dimmer switch and occupancy sensor upgrades are not as favorable as the high efficacy lighting upgrades, but still show substantial benefits on average. The cost/benefit ratio is below 1.0 in some cases where the likelihood of using a dimmer or occupancy sensor is also quite low, for example, a motion sensor on a ceiling-mounted porch light is responsible for the minimum benefit/cost ratio of 0.6 in the yard.

Table 6. *Present Valued Infiltration Savings from ICAT Fixtures*

	Base	ICAT	Reduction	Units	ICAT
Effective Leakage	1.600	0.084	1.516	sq in	Increment
IUA	1.680	0.089	1.591	Btu/hr-deg F	$ 4.12
City	CTZ	IDD (ASHRAE 119)	Energy savings per fixture (therms/yr)	30 Year Cost Savings PV$ per fixture	B/C Ratio
San Diego	7	1,128	0.552	$6.98	1.7
Los Angeles	6	1,698	0.831	$10.51	2.6
Bakersfield	13	2,600	1.273	$16.09	3.9
Santa Maria	5	2,801	1.372	$17.34	4.2
Oakland	3	2,943	1.441	$18.22	4.4
Fresno	13	3,101	1.518	$19.19	4.7
Red Bluff	11	3,795	1.858	$23.49	5.7
Mt Shasta	16	5,801	2.841	$35.91	8.7

As is shown in Table 6, the life cycle benefits of ICAT cans greatly outweigh the initial costs of these cans, with greatest savings for colder climate zones. While not all climate zones are shown, due to a lack of data for the infiltration degree days in some parts of the state, representative climate zones covering all climate types are included in Table 6.

The general conclusion one can draw is that all of these fixture upgrades can be considered cost effective.

Measure Longevity and Enforceability.

Other important factors to consider when proposing a code enhancement include the likelihood that the measure would be enforced and the longevity of the measure. The development of this codes and standards enhancement involved the participation of individuals from the enforcement community and lighting designers familiar with the constraints of real-world applications. The participants addressed two concerns: the availability of compact fluorescent fixtures and replacement lamps.

The suppliers of lighting products involved in our study claim that compact fluorescent versions of just about every luminaire, if not already on the showroom floor, were available as a special-order item from the manufacturer. As the provisions of this proposed new measure become more widely known, it is expected that pin-based compact fluorescent alternatives for a greater variety of luminaries will become commonplace.

Some participants in this codes and standards enhancement process expressed concern about the availability of replacement pin-based lamps for these fixtures. Pin-based compact fluorescent lamps come in a wide variety of base types which all look very similar. The lamp manufacturing industry is currently addressing this issue and is expected to provide a simplified system for CFL lamp ballast matching before the implementation of this measure. Nevertheless, replacement CFL lamps are available at home improvement and specialty lighting stores. Considering that lamp replacement will only happen once every 10 years, this is not considered to be a barrier to implementation.

Recommendations

The recommendations are reflected in the proposed standards language included below.

Proposed Standards Language

Additions to the Definition Section

SECTION 101 – DEFINITIONS AND RULES OF CONSTRUCTION

HIGH EFFICACY LUMINAIRE is a luminaire containing only HIGH EFFICACY LAMP(s).

HIGH EFFICACY LAMP is a manufactured source of illumination (light bulb) producing illumination in or around the visible spectrum that is rated:

1. for lamps rated less than 15 watts, no less than 40 initial lumens per watt, or
2. for lamps rated greater than 15 watts but less than 41 watts, no less than 50 initial lumens per watt, or
3. for lamps rated 41 watts or greater, no less than 60 initial lumens per watt, and

Note: In calculating the lumens per watt, only the watts of the lamp (not the ballast) are to be considered.

BATHROOM is a room containing a shower, tub, toilet or a sink that is used for personal hygiene.

Section 130 (k) changes:

§ 130 Lighting Controls and Equipment—General

(a) (This sub-section remains unchanged.)

(b) The design and installation of all lighting systems and equipment in high-rise residential living quarters and in hotel/motel guest rooms shall comply with the ~~following~~ applicable provisions of section 150(k).

EXCEPTION to Section 130(b): Up to 10 percent of the guestrooms in a hotel/motel need not comply.

(c) (Other sub-sections remain unchanged.)

Section 150 (k) changes:

§ 150(k) Lighting Requirements

~~150(k) **Lighting.**~~

~~1. Luminaires for general lighting in kitchens shall have lamps with an efficacy of not less than 40 lumens per watt. General lighting must provide a sufficient light level for basic kitchen tasks and provide a uniform pattern of illumination. A luminaire(s) that is (are) the only lighting in a kitchen will be considered general lighting. General lighting shall be controlled by a switch on a readily accessible lighting control panel at an entrance to the kitchen.~~

~~Additional luminaires to be used only for specific decorative effects need not meet this requirement.~~

~~2. Each room containing a shower or bathtub shall have at least one luminaire with lamp(s) with an efficacy of 40 lumens per watt or greater. If there is more than one luminaire in the room, the high efficacy luminaire shall be switched at an entrance to the room.~~

~~**ALTERNATIVE to Section 150 (k) 2:** A high efficacy luminaire need not be installed in a bathroom if:~~

~~A. A luminaire with lamps with an efficacy of 40 lumens per watt or greater is installed in a utility room, laundry room, or garage; and~~

~~B. All luminaires permanently mounted to the residence providing outdoor lighting shall be installed with the following characteristics:~~

~~(1) Luminaires with lamps with 40 lumens per watt or greater; or~~

~~(2) Luminaires with lamps with an efficacy of less than 40 lumens per watt shall be equipped with a motion sensor.~~

~~**Note:** When using this alternative for multiple bathrooms, after complying with Item B above for the first bathroom, each additional bathroom in which a high efficacy luminaire is not installed must comply with Item A above alone.~~

~~3. Luminaires installed to meet the 40 lumens per watt requirements of Section 150 (k) 1 or 2 shall not contain medium base incandescent lamp sockets, and shall be on separate switches from any incandescent lighting.~~

~~4. All incandescent lighting fixtures recessed into insulated ceilings shall be approved for zero clearance insulation cover (IC) by Underwriters Laboratories or other testing/rating laboratories recognized by the International Conference of Building Officials.~~

1. **High Efficacy Luminaire Requirement:** A High Efficacy Luminaire must not contain line voltage medium screw base lamp sockets including, but not limited to, E26/24 sockets.
2. **Kitchen Requirement:** Permanently installed luminaires in kitchens shall be High Efficacy Luminaires.

   EXCEPTION to §150 (k).1: Up to 50 percent of the total rated wattage of permanently installed luminaires in kitchens may be in luminaires which are not High Efficacy Luminaires, provided that these luminaires are controlled by switches separate from those controlling the High Efficacy Luminaires.

   Note: Luminaires which are not High Efficacy Luminaires but which are controlled by an occupancy sensor or a dimmer switch (pursuant to §150(k)2. or §150(k)3., respectively) do not qualify as a High Efficacy Luminaire for the purposes of meeting the kitchen high efficacy luminaire requirements of §150(k)1.

2. **Bathroom and Support Space Requirement:** Permanently installed luminaires in bathrooms, laundry rooms, utility rooms and garages shall be High Efficacy Luminaires.

   EXCEPTION to §150 (k).2: Permanently installed luminaires which are not High Efficacy Luminaires shall be allowed, provided that they are controlled by occupancy sensor(s) certified per section 119. Such occupancy sensors must not have a control which allows the luminaire to be turned on automatically or which has an override which allows the luminaire to be always on.

3. **Pendant, Track and Recessed Luminaire Requirement:** Any ceiling-mounted pendant luminaire, track luminaire, or recessed downlight shall be a High Efficacy Luminaire or shall be controlled by a dimmer switch.
4. **Recessed Luminaires in Insulated Ceilings Requirement**: Luminaires recessed into insulated ceilings shall be approved for zero clearance insulation cover (IC) by Underwriters Laboratories or other testing/rating laboratories recognized by the International Conference of Building Officials, and shall include a label certifying air leakage less than 2.0 CFM at 75 Pascals (or 1.57 lbs/ft^2) using ASTM E283 testing standards and shall sealed with a gasket or caulk between the housing and ceiling.
5. **Exterior Lighting Requirement:** Luminaires providing outdoor lighting and permanently mounted to a residential building or its surrounding structures shall be high efficacy lighting.

   EXCEPTION 1 to §150 (k).5: Exterior luminaires controlled by a motion sensor with integral photosensor need not be High Efficacy Luminaires.

   EXCEPTION 2 to §150 (k).5: Permanently installed luminaires in or around swimming pools, water features, or other locations subject to Article 680 of the 1998 California Electric Code need not be High Efficacy Luminaires.

Proposed ACM Language

Not applicable.

Acknowledgments

PG&E sponsored this proposal under direction of Pat Eilert. The contractor for this project is the Heschong Mahone Group *(HMG)*. This proposal was written by Charles Ehrlich of *HMG*, with assistance from Lynn Benningfield, Douglas Mahone, and Jon McHugh of *HMG* and Bill Mattinson of Sol Data.

Many experts were consulted for this study, including from the California Energy Commission: Bill Pennington, Mazi Shirakh and Gary Flamm; Advisors from the lighting industry included; Michael Siminovich, Jim Benya, Peter Bleasby, Terry McGowan, Lisa Heschong, and Cheryl English. Other advisors included Noah Horowitz, NRDC; Jeff McCulloch, Pacific Northwest Laboratory; Max Sherman, LBNL and Pete Guisasola, City of Rocklin Building Department. We thank all of the above advisors for their valuable input.

References

Papers and standards used to complete this report include:

ANSI. 1993. ANSI C82.11-1993 High-Frequency Fluorescent Lamp Ballasts, American national Standards Institute, Wash., D.C.

ASHRAE. 2001. ASHRAE 2001 Fundamentals Handbook. Chapter 26, "Ventilation and Infiltration." American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta

ASHRAE. 2001 ASHRAE Standard 152P: Method of Test for Determining the Energy Efficiency of Residential Thermal Distribution Systems under Seasonal and Design Conditions. Second Public Review Draft 08/01.

ASTM. 1999. "Standard Test Method for Determining the Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen." American Society for Testing and Materials, West Conshohocken, PA. ASTM E283-91(1999)

Brenneke, Maggie. 2002. Compact Fluorescent Lamps: Shedding Some Light, Energy Efficient Lighting Systems 2002.

Eley and Associates. 2001. Utility Cost Forecasts 2005-2035 February 19, 2001.

Heschong Mahone Group. 1997. Lighting Efficiency Technology Report, Volume I, California Baseline.

Heschong Mahone Group. 1997. Lighting Efficiency Technology Report, Public Workshop Introduction. Presented to the California Energy Commission.

Heschong Mahone Group. 1999. Lighting Efficiency Technology Report, Volume II – Appendix. Description of the California Lighting Model & Its Inputs.. CEC No. P400-98-004VIIA.
http://www.energy.ca.gov/efficiency/lighting/VOLUME02A.PDF

Heschong Mahone Group. 1997. Market Barriers Report, Volume III, Lighting Efficiency Technology Report. Prepared for the California Energy Commission. CEC contract # 400-95-0112.

Heschong Mahone Group. 1997. Recommendations Report, Volume IV. Lighting Efficiency Technology Report. Prepared for the California Energy Commission.

Jump, D.A. and Modera, M.P. 1994. Energy Impacts of Attic Duct Retrofits in Sacramento Houses. Proceedings of ACEEE Summer Study, 1994.

Leaton, Kirk. 2002. Architectural Testing, Inc. Fresno, CA 93706. Personal correspondence.

Mowris, Robert & Assoc. 2001. Voluntary Existing Residential Baseline Values prepared for the California Public Utilities Commission. January 7, 2001. CPUC R01-08-028.

NEMA. 1999. Power Quality Implications of Compact Fluorescent Lamps in Residences, Prepared by Lamp Section, National Electrical Manufacturers Association, LSD 8-1999.

New York State Energy Research and Development Authority. 2000. High Quality, Energy Efficient Lighting Market Assessment, Final report 01-04. June 2000,

Lawrence Berkeley National Laboratory. 1997. Lighting Market Sourcebook for the U.S. Energy Analysis Program, Environmental Energy Technologies Division. LBNL-39102, December 1997.

Myers, Dowell and Kitsue, Alicia. 1999. Development in Time: Planning the Future of California's Housing. Lighting Institute of Land Policy, Working Paper.

NEMA. 1998. NEMA guide to Lighting Controls, Published by Lighting Controls Council. National Electrical Manufacturers Association.

Opinion Dynamics. 1998. Baseline Study of the Northeastern Residential Lighting Market. Prepared for the Northeast Energy Efficiency Partnerships, Inc.

Opinion Dynamics Corporation and Regional Economic Research. 1999. Baseline Study of the New Jersey Residential Lighting Market. November, 1999.

Pacific Gas and Electric. 2000. Final Report, Volume I: Project Description and Results, PG & E Study ID number: 411, August 31, 2000.

Pacific Gas and Electric. 2001. Residential MA & E workshop: Workshop on Recent Market Assessment and Evaluation Research Regarding Residential Energy Efficiency Programs in California. Pacific Energy Center. November 29, 2001.

Pacific Northwest National Laboratory. 2002. Data from unpublished survey.

San Diego Gas & Electric. 2001. 1994 & 1995 Residential Appliance Efficiency Incentive Program: Compact Fluorescent Lights, Sixth year Retention Evaluation, March 2001. San Diego Gas & Electric Marketing Programs and Planning.

Regional Economic Research, Inc. 2001. California Lamp Report, Volume I. Prepared for Southern California Edison.

RLW Analytics, Inc. 2000. Statewide Residential Lighting and Appliance Saturation Study, Final Report 2000.

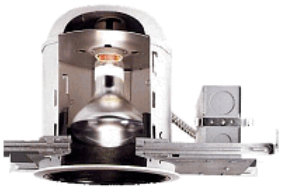
University of California, Berkeley Institute of Urban and Regional Development. 2000. Raising the Roof: California Housing Development Projections and Constraints, 1997-2020. Prepared for the State of California, Department of Housing and Community Development.

Williams, A. Kevin. 2000. The Long Wait: The Critical Shortage of Housing in California. Corporation for Supportive Housing and Housing California. June 2000.

Xenergy Inc. 2001. 2001 DEER Update Study Final Report, August 2001.

XENERGY Inc. 2000. Phase 2 Evaluation Report- California Residential Lighting and Appliance Program (CRLAP).

Appendix A—Table Of Fixture Types

Recessed Downlight, non-IC rated	A	 HALO H7T Non IC Housing H7T **$11.46** Order HALO click image to enlarge Versatility, reliability and ease of use have made the H7T the most widely used recessed ceiling mount fixture in the lighting industry. **Electrical:** Junction box is listed for through branch circuit wiring. Snap-on junction box covers allow quick installation and inspection. Ground wire included. Porcelain socket with nickel plated screw shell on adjustable socket plate. **Installation:** 7 1/2" height allows installation in 2" X 8" joist construction. Captive bar hangers won't fall out. H7T housing is designed with hanger brackets that can be broken off from plaster frame and repositioned 90 degrees to simplify clearance for wiring or eliminated to facilitate remodeling. Easy to read scale on adjustable socket plate allows uniform lamp positioning. Housing adjusts in plaster frame 1 3/8" to accommodate different ceiling thickness.
Recessed Downlight, IC rated	B	**Product Category:** Lighting > Fixtures > Recessed Lighting **Description** Standard Recessed ICAT Air Tight Housing Your Price: $16.80 Ship: Today Unit of Measure: 1 Grainger Item#: 6F552 Manufacturer: HALO/COOPER Mfg. Model#: H-7-ICAT Catalog Page: 800 Select. Qty. Add to Personal List ADD TO ORDER Price shown may not reflect your price. *Log-in* above, or click here to register. **NOTES & RESTRICTIONS** Modification & Service available contact your local branch. See Catalog Page for application and/or safety information.  TECHNICAL SPECIFICATIONS **Fixture Description:** ICAT Air Tight Housing **Height:** 7 1/2
Recessed Downlight, ICAT rated	C	 Lightolier 1000AICM AirSeal Insulated Ceiling IC Housing 5" LOL1000AICM **$22.99** Order LIGHTOLIER click image to enlarge Rated for direct contact with insulation. Fully gasketed to minimize air leakage and reduce energy loss. Complies with restricted airflow requirements of the WSEC and MEC energy codes. • **5" Aperature Size** • Click Here to Download Specs Adobe Acrobat is needed to download Specs - click to Download

Luminous ceiling, six porcelean sockets	D	**Product Category:** Lighting > Fixtures > Architectural Lampholders **Description** Lampholder, Medium Base, One Piece, Keyless, Urea, with 6 Inch Leads Your Price: $2.98 Ship: Today Unit of Measure: 1 Grainger Item#: 6LP13 Manufacturer: LEVITON Mfg. Model#: 8829-CW2 Catalog Page: N/A Select. Qty. Add to Personal List ADD TO ORDER 
Cloud light	E	**Utility Lights**  Click here to enlarge photo 24" White Fluorescent Light Puff LOWE'S PRICE: $59.90 Item availability and price may vary by location. Brand: Lithonia Item Number: 11740 Model Number: 5580 • 2 Lights • Uses 20 watt tubes • Durable white diffuser • Ideal for bathrooms
Under cabinet task light	F0	**Under Cabinet Lights**  Click here to enlarge photo 17" Incandescent Light Bar LOWE'S PRICE: $19.94 Brand: Good Earth Item Number: 27881 Model Number: G9212-WH-I • Easy to install • High-low dimmer • Uses 25 watt or 40 watt incandescent "T" bulbs. Two 40 watt bulbs included • 5 year warranty

Under cabinet task light	F2	**Under Cabinet Lights**  Click here to enlarge photo 12" Ultra Thin Plug-in with Outlet Under Cabinet Fixture **LOWE'S PRICE: $19.94** Brand: GE Item Number: 44797 Model Number: 27270 • Includes GE warm white lamps • Easy to install • Thin profile allows for hidden installation • Convenient 5' cord • 3 year limited warranty
multi-lamp vanity bath bar	G	robern Learn more about Robern ... **Fluorescent Top Lights** Product number: R-PLL16FB  Your Cost: $68.64 Includes Delivery Add List Price: $88.00 • Fluorescent top lights with black trim. • **Shown with 3-PLM1630B cabinets, 3-PLL16FT lights and one PLSK30 side kit, sold separately.** • For recessed mounted cabinets. • Requires 2 PL 9W bulbs. • Bulbs not included. • Side kit required for surface mounting. ALLOW 3 WEEKS FOR DELIVERY.
combo fan/light (for bathroom)	H	**Broan S80LU – 80 CFM Fan/Light/Night-Light**  BROS80LU Retail $226.99 Sale Price **$185.99** Order BROAN click image to enlarge • 80 CFM 0.6 Sones. • High-efficiency centrifugal blower provides virtually silent performance. • Bright 100-watt light capacity (bulb not included). • Separate 7-watt night-light for safety and security (bulb not included). • Motor engineered for continuous operation. • Exclusive 7 5/8" high housing accommodates 2" x 8" ceiling joists. • Includes 4" round duct connector. • UL listed for use over bathtubs and showers when connected to a GFCI-protected branch circuit. • AMCA licensed for both air and sound.

ceiling mounted globe light	I	 $34.87 each 14" 30 Watt Pewter with Alabaster Lens Ceiling Fixture Lights of America Lights Of America Features: • Up to 150 watt output from a 30 watt bulb • Beautiful Alabaster Glass Bulb • Soft white light, same color quality as a regular bulb • 80% more efficient than regular light bulbs, last up to 13 times longer • Instant on electronic ballast operation • Great for dining rooms, family rooms and bedrooms • Fully assembled, ready to install
Ceiling mounted Fan light	J	 Bronze Outdoor Ceiling Fan 52" SEA1540-10 $138.46 Order sea gull lighting click image to enlarge The Long Beach Outdoor Ceiling Fan by Sea Gull Lighting can be used as a regular ceiling fan or with an optional light kit. Three-speed motor has three forward and three reverse speeds controlled by a slide switch or pull chain to easily adjust the fan speed. Heavy duty die cast zinc hanging ball and bracket provide for safe installation. • **Finish**: Bronze Powdercoat with Oak Finish ABS Resin Blades • **Dimensions**: 52" Diameter X 14" Height • **Blades**: 5 with 12° pitch • **Optional Light Kit**: Use light kit SEA1649 (order separately below)
Wall mounted sconce	K	 Progress P7170 Eclipse Modern Wall Sconce P7170 Retail $74.00 Sale Price $59.00 Finish: Brushed Steel-13 Order PROGRESS LIGHTING Progress's eclipse single-light wall sconce has satin-white glass and comes in Polished Brass and Brushed Steel • **Finish**: Brushed Steel or Polished Brass • **Glass**: Satin White • **Dimensions**: Width/Diameter 15½" X Height 7½" • **Lamp**: One medium base 100w bulbs (not included)

Exterior wall mounted entry light	L	 Ext. Wall Sconce - 8755 This simple outdoor wall sconce features a polycarbonate base and white glass diffuser. Included is a photo electric control. This fixture is also available in an energy star version that uses an energy saving fluorescent bulb. The bulb is not included with this fixture. **Energy Saving Option:** Regular **Diffuser Options:** White glass **Finish Options:** Black Polycarbonate **Lamp Options:** (1) 60-watt A19 Med Frosted **1 to 2 Weeks** Our Price: **$39.68** Buy Now
Exterior ceiling mounted porch light (globe)	M	Exterior - *Ceiling*  **Sea Gull Lighting - Exterior Ceiling Fixture - 8453** **Model:** 8453-68 This functional outdoor ceiling fixture comes exclusively with a white base and a white polycarbonate globe. The bulb is not included with this fixture. **Dimensions:** 6"W x 7="H **Shipping & Handling:** $10.00 **As Shown:** White polycarb White (1) 60-watt A19 Med Frosted **Finish** / **List Price** / **Our Price** / **Add to Cart** Polycarbonate / $48.00.00 / **$36.00**
Exterior wall mounted flood light	N	 **X10 XPPHS01 Powerhouse Smart Floods** HCXPPHS01 **$49.95** Order click to enlarge When guests approach your home, the Smart Floods motion detector light control turn On its flood lights when dark, plus sends X-10 codes to turn On eight devices inside and outside your home. • Motion activates security floodlights with PIR Technology • Motion activates up to four X-10 signals • Dawn and dusk activates another four X-10 signals • Works with the X-10 Chime Module to annouce your guests with a pleasant chime • Can be used with Incandescent, Halogen or Flood Lights *(sold separately)* • Comes complete with mouting plate for round weatherproof box, flood lamp holders and complete instructions

Cove lighting	P	**Product Category:** Lighting > Fixtures > Fluorescent Fixtures **Description** 20 Watts Strip Fixture Without Lamp 2' L 120V Trigger Start White Your Price: $16.92 Ship: Today Unit of Measure: 1 Grainger Item#: 2V318 Manufacturer: METALUX Mfg. Model#: SN-120LTS-120V Catalog Page: 811 Select. Qty. 
Surface mounted Track lighting	Q	 Lightolier Track Lighting LIGHTOLIER click image to enlarge Find a wide selection of Lightolier track lighting including radius track, classic track heads, flatback track heads, basic track, accessories and more. If you can't find what you're looking for here, request a price by clicking here.
Surface mounted Decorative/accent	R	 **One Light Fluorescent Indoor Light** **Item #: 4934-33** Tulip shaped wall sconce finished in Polished Brass. Triplex Satin White glass over fluorescent light. Energy Star Compliant bulbs available. **Finish:** Satin White **Size:** Width: 10 1/4" Height: 10" Extends: 5 1/8" **Instruction Sheet** English **Detailed Spec Sheet** English
Suspended pendant (utility)	S	sea gull lighting Learn more about Sea Gull Lighting ... White Hanging Pendant Product number: SGL-6519-15  Your Cost: $34.65 Includes Delivery Add List Price: $38.50 • Requires (1) 100 watt maximum medium base. • 8 1/4"H, diameter 16". • Metal shade. • 54" overall. • UL listed.

Suspended pendant (utility)	S	 LITHONIA LIGHTING LITHONIA LIGHTING Lithonia Lighting Features: • Takes (2) 34 or 40 watt bulbs, sold separately • Commercial energy saving ballast $29.80 each 4' 2-Light Industrial Fluorescent Fixture with Reflector More Information Name / Price / Qty. / Add to Cart Lithonia Lighting 4' 2-Light Industrial Fluorescent Fixture with Reflector Model: #L240120ES SKU: #255031 29.80 1 BUY
Suspended pendant (dining)	T	 Ribbed Glass Pendant Sea Gull Lighting 6670-02 Our Price: $74.00 MSRP: $102.00 Description Dimensions Diameter: 15 in., Height: 10-1/2 in., Overall: 48-1/2 in.
Track Lighting	U	 Lightolier 8275 Prevue Compact Fluorescents LOL8275 $169.99 Color: White Order LIGHTOLIER click image to enlarge • Sleek & modern track head. • Available in black or white matte finish. • Dimensions: 8" W X 4 3/8" H • Overall height: 6 3/8"" • Uses 2 Lt. 13W Double Twin Tube (not included) • Fits Radius, Basic & Advent Tracks (available below) Availability: Usually ships in 1-2 weeks. LOL8275 $169.99 Color: White Order

Appendix B—Table Of Base Case And Upgrade Options

Recessed Downlights					
Base Case Description	**ID**	**Fixture Cost (incl. 1st lamp)**	**Watts**	**Lamp Life (hrs)**	**Lamp Cost**
Incandescent PAR Recessed Downlight, non-IC rated	A0	$43.78	75	2000	$5.76
Incandescent PAR Recessed Downlight, non-IC rated	A0	$43.78	75	2000	$5.76
Incandescent PAR Recessed Downlight, IC rated	B0	$44.78	75	2000	$5.76
Incandescent PAR Recessed Downlight, IC rated	B0	$44.78	75	2000	$5.76
Incandescent PAR Recessed Downlight, ICAT rated	C0	$48.90	75	2000	$5.76
Incandescent PAR Recessed Downlight, ICAT rated	C0	$48.90	75	2000	$5.76
Upgrade Description					
Pin-based CFL Recessed Downlight, non-IC rated	A2	$81.42	26	10000	$5.00
Incandescent PAR Recessed Downlight, non-IC w/dimmer	A3	$61.00	67.5	3000	$5.00
Pin-based CFL Recessed Downlight, IC-rated	B2	$108.04	26	10000	$5.00
Incandescent PAR Recessed Downlight, IC rated w/dimmer	B3	$54.09	67.5	3000	$5.00
Pin-based CFL Recessed Downlight, ICAT rated	C2	$83.66	26	10000	$5.00
Incandescent PAR Recessed Downlight, ICAT rated w/dimmer	C3	$58.21	67.5	3000	$5.00

Other Surface Mounted Luminaires					
Base Case Description	**ID**	**Fixture Cost (incl. 1st lamp)**	**Watts**	**Lamp Life (hrs)**	**Lamp Cost**
Incandescent Luminous ceiling, six porcelain sockets	D0	$20.42	600	816	$2.54
Four recessed Incandescent PAR downlights	E0	$175.11	300	2000	$23.04
Halogen Under cabinet task light	F0	$28.73	75	3000	$3.99
multi-lamp Incandescent vanity bath bar	G0	$17.12	210	816	$1.27
multi-lamp Incandescent vanity bath bar (high end)	G0H	$245.40	375	816	$1.91
Incandescent combo fan/light (for bathroom)	H0	$60.17	100	816	$0.42
Incandescent ceiling mounted globe light	I0	$28.06	120	816	$0.85
Incandescent Ceiling mounted Fan light	J0	$138.18	180	816	$1.27
Incandescent Wall mounted sconce	K0	$65.41	100	816	$0.42
Incandescent Exterior wall mounted entry light	L0	$38.74	65	1211	$2.20
Incandescent Exterior ceiling mounted porch light (globe)	M0	$23.00	60	816	$0.42
Incandescent Exterior wall mounted flood light	N0	$48.51	400	3000	$5.76
Incandescent Suspended pendant (utility)	S0	$107.02	120	816	$1.27
Incandescent Suspended pendant	T0	$67.39	123	816	$0.71
Incandescent Track (3 heads)	U0	$15.76	225	2000	$5.76
Upgrade Description					
CFL (screw-in) Luminous ceiling, six porcelain sockets	D1	$88.10	156	7100	$70.22
Luminous ceiling, 4 T12 fluorescents, magnetic balast	D2	$72.88	136	20000	$22.88
Fluorescent "cloud" light	E2	$79.75	68	20000	$11.44
Fluorescent Under cabinet task light	F2	$18.98	15	7333	$5.16
Screw-in CFL multi-lamp vanity bath bar	G1	$27.55	55.5	7100	$11.70
Pin-based multi-lamp fluorescent vanity bath bar	G2	$74.16	18	10000	$5.52
multi-lamp Incandescent vanity bath bar w/occpcy sensor	G3	$45.05	189	3000	$1.27
Screw-in CFL multi-lamp vanity bath bar (high end)	G1H	$262.34	23	8250	$18.84
Pin-based multi-lamp fluorescent vanity bath bar (high end)	G2H	$263.00	66	15000	$16.76
Other Surface Mounted Luminaires (continued)					

Base Case Description	ID	Fixture Cost (incl. 1st lamp)	Watts	Lamp Life (hrs)	Lamp Cost
multi-lamp Incandescent vanity bath bar w/occupancy sensor (high end)	G3H	$273.33	337.5	15000	$1.91
Screw-in CFL combo fan/light	H1	$49.84	20	7100	$11.70
Pin-based CFL combo fan/light	H2	$59.00	13	10000	$5.52
Incandescent combo fan/light w/occupancy sensor (for bathroom)	H3	$88.11	90	1225	$0.42
Screw-in Fluorescent ceiling mounted globe light	I1	$38.92	40	7100	$11.70
Pin-based CFL ceiling mounted globe light	I2	$31.58	28.16	9033	$6.05
Screw-in Fluorescent Ceiling mounted Fan light	J1	$193.44	21.8	8250	$56.53
Pin-based Fluorescent Ceiling mounted Fan light	J2	$143.50	30	10000	$6.59
Screw-in CFL Wall mounted sconce	K1	$76.69	21.8	7100	$11.70
Pin-based Fluorescent Wall mounted sconce	K2	$71.49	13	10000	$5.52
Screw-in CFL Exterior wall mounted entry light	L1	$48.24	21.8	7000	$11.70
Pin-based CFL Ext wall mntd entry light	L2	$51.52	5.52	10000	$5.52
Screw-in CFL Ext. Ceiling mntd porch light (globe)	M1	$34.28	21.8	7100	$11.70
Pin-based CFL Ext. Ceiling mntd porch light (globe)	M2	$46.33	13	10000	$5.52
Incandescent Exterior ceiling mounted porch light w/motion sensor (globe)	M3	$50.93	54	1225	$0.42
Screw-in CFL Exterior wall mounted flood light	N1	$66.51	19.6	7600	$23.76
Pin-based CFL Exterior wall mounted flood light	N2	$35.66	34.5	10000	$5.76
Incandescent Exterior wall mounted flood light w/motion sensor	N3	$48.85	240	3000	$5.76
Screw-in CFL Suspended pendant (utility)	S1	$140.86	46	7100	$35.11
Pin-based CFL Suspended pendant (utility)	S2	$34.30	80	20000	$11.44
Incandescent Suspended pendant w/occupancy sensor (utility)	S3	$134.95	108	1225	$1.27
Pin-based CFL Suspended pendant	T1	$91.74	23	7100	$11.70
Pin-based CFL Suspended pendant	T2	$99.97	26	10000	$11.48
Incandescent Suspended pendant w/dimmer	T3	$119.05	98.6	1225	$0.71
Pin-based CFL Track (3 heads)	U2	$50.00	78	10000	$0.00
Incandescent Track (3 heads) with dimmer switch	U3	$32.98	180	3000	$0.00

Appendix C—Table Of Minimum Hour Cost Effective Upgrades

Upgrade Description	Change				Min Hours of Operation	
	Base--> Upgrade	Watt Reduction	Percent kW Reduction	Incremental Cost	Energy Only hours/yr	Energy & Maint hours per yr
Incandescent to CFL (pin)	A0->A2	49.0	65%	$37.65	372.95	255.05
On/off to dimmer	A0->A3	7.5	10%	$17.22	1114.64	438.84
Incandescent to CFL (pin)	B0->B2	49.0	65%	$63.25	626.64	428.55
On/off to dimmer	B0->B3	7.5	10%	$9.31	602.64	237.26
Incandescent to CFL (pin)	C0->C2	49.0	65%	$34.75	344.31	235.46
On/off to dimmer	C0->C3	7.5	10%	$9.31	602.64	237.26
Incandescent to screw-in CFL	D0->D1	444.0	74%	$67.68	74.00	86.58
Incandescent to linear fluorescent	D0->D2	464.0	77%	$52.46	54.88	52.76
Incandescent to linear fluorescent	E0->E2	232.0	77%	-$95.36	-199.52	-137.69
Incandescent to linear fluorescent	F0->F2	60.0	80%	-$9.75	-78.88	-71.76
Incandescent to CFL (screw-in)	G0->G1	154.5	74%	$10.43	32.78	32.97
Incandescent to CFL (pin)	G0->G2	192.0	91%	$57.04	144.22	137.39
On/off to occupancy sensor	G0->G3	21.0	10%	$27.93	645.69	426.82
Incandescent to CFL (screw-in)	G0H->G1H	352.0	94%	$16.94	23.36	23.33
Incandescent to CFL (pin)	G0H->G2H	309.0	82%	$17.60	27.64	26.64
On/off to occupancy sensor	G0H->G3H	37.5	10%	$27.93	361.59	231.84
Incandescent to CFL (screw-in)	H0->H1	80.0	80%	-$10.33	-62.70	-72.44
Incandescent to CFL (pin)	H0->H2	87.0	87%	-$1.17	-6.55	-6.57
On/off to occupancy sensor	H0->H3	10.0	10%	$27.93	1355.95	1164.50
Incandescent to CFL (screw-in)	I0->I1	80.0	67%	$10.86	65.88	71.05
Incandescent to CFL (pin)	I0->I2	91.8	77%	$3.51	18.57	17.89
Incandescent to CFL (Screw-in)	J0->J1	158.2	88%	$55.26	169.56	248.82
Incandescent to CFL (pin)	J0->J2	150.0	83%	$5.32	17.22	16.29
Incandescent to CFL (screw-in)	K0->K1	78.2	78%	$11.28	70.03	81.19
Incandescent to CFL (pin)	K0->K2	87.0	87%	$6.08	33.91	34.03
Incandescent to CFL (screw-in)	L0->L1	43.2	66%	$9.50	106.77	103.43
Incandescent to CFL (pin)	L0->L2	59.5	92%	$12.78	104.34	86.76
Incandescent to CFL (Screw-in)	M0->M1	38.2	64%	$11.28	143.35	199.51
Incandescent to CFL (pin)	M0->M2	47.0	78%	$23.33	240.93	242.59
On/off to motion sensor	M0->M3	6.0	10%	$27.93	2259.91	1773.86
Incandescent to CFL (screw-in)	N0->N1	380.4	95%	$18.00	22.97	23.69
Incandescent to CFL (pin)	N0->N2	365.5	91%	-$12.85	-17.06	-16.48
On/off to motion/photocell	N0->N3	160.0	40%	$0.34	1.04	1.04
Incandescent to CFL (screw-in)	S0->S1	74.0	62%	$33.84	222.00	393.56
Incandescent to CFL (pin)	S0->S2	40.0	33%	-$72.72	-882.48	-715.23
On/off to occupancy sensor	S0->S3	12.0	10%	$27.93	1129.96	800.81
Incandescent to CFL (screw-in)	T0->T1	100.3	81%	$24.36	117.84	127.31
Incandescent to CFL (pin)	T0->T2	97.3	79%	$32.58	162.49	167.14
On/off to dimmer	T0->T3	24.7	20%	$51.66	1016.73	915.08
Incandescent to Pin-based CFL	U0->U2	59.16	68%	$31.90	261.78	207.06
On/off to dimmer	U0->U3	8.75	10%	$1.54	85.77	47.76

Appendix D—Table Of Cost Effective Room Applications

Benefit/Cost Ratio, room-by-room analysis												
Upgrade Description	**Luminaire Upgrade Code**	**Incremental Upgrade Cost**	**Min Hrs to be Cost Effective**	**Kitchen / Dining**	**Yard**	**Utility**	**Living**	**Garage**	**Hallway**	**Den**	**Bathroom**	**Bedroom**
shaded areas are inappropriate luminaire/room combinations			***Hours of operation per day***	***3.4***	***3.1***	***2.6***	***2.6***	***2.3***	***2.2***	***2***	***2***	***1.4***
			Hours of operation per year	***1241***	***1131.5***	***949***	***949***	***839.5***	***803***	***730***	***730***	***511***
Incandescent PAR Recessed Downlight, non-IC rated to Pin-based CFL Recessed Downlight, non-IC rated	A0->A2	$37.65	255.05	4.9	4.4	3.7	3.7	3.3	3.1	2.9	2.9	2.0
Incandescent PAR Recessed Downlight, non-IC rated to Incandescent PAR Recessed Downlight, non-IC w/dimmer	A0->A3	$17.22	438.84	2.8	2.6	2.2	2.2	1.9	1.8	1.7	1.7	1.2
Incandescent PAR Recessed Downlight, IC rated to Pin-based CFL Recessed Downlight, IC-rated	B0->B2	$63.25	428.55	2.9	2.6	2.2	2.2	2.0	1.9	1.7	1.7	1.2
Incandescent PAR Recessed Downlight, IC rated to Incandescent PAR Recessed Downlight, IC rated w/dimmer	B0->B3	$9.31	237.26	5.2	4.8	4.0	4.0	3.5	3.4	3.1	3.1	2.2
Incandescent PAR Recessed Downlight, ICAT rated to Pin-based CFL Recessed Downlight, ICAT rated	C0->C2	$34.75	235.46	5.3	4.8	4.0	4.0	3.6	3.4	3.1	3.1	2.2

Incandescent PAR Recessed Downlight, ICAT rated to Incandescent PAR Recessed Downlight, ICAT rated w/dimmer	C0->C3	$9.31	237.26	5.2	4.8	4.0	4.0	3.5	3.4	3.1	3.1	2.2
Other Surface Mounted Luminaires												
Incandescent Luminous ceiling, six porcelain sockets to CFL (screw-in) Luminous ceiling, six porcelain sockets	D0->D1	$67.68	86.58	14.3	13.1	11.0	11.0	9.7	9.3	8.4	8.4	5.9
Incandescent Luminous ceiling, six porcelain sockets to Luminous ceiling, 4 T12 fluorescents, magnetic balast	D0->D2	$52.46	52.76	23.5	21.4	18.0	18.0	15.9	15.2	13.8	13.8	9.7
Four recessed Incandescent PAR downlights to Fluorescent "cloud" light	E0->E2	-$95.36	-137.69	no cost	no cost	no cost	no cost	no cost	no cost	no cost	no cost	no cost
Halogen Under cabinet task light to Fluorescent Under cabinet task light	F0->F2	-$9.75	-71.76	no cost	no cost	no cost	no cost	no cost	no cost	no cost	no cost	no cost
multi-lamp Incandescent vanity bath bar to Screw-in CFL multi-lamp vanity bath bar	G0->G1	$10.43	32.97	37.6	34.3	28.8	28.8	25.5	24.4	22.1	22.1	15.5
multi-lamp Incandescent vanity bath bar to Pin-based multi-lamp fluorescent vanity bath bar	G0->G2	$57.04	137.39	9.0	8.2	6.9	6.9	6.1	5.8	5.3	5.3	3.7
multi-lamp Incandescent vanity bath bar to multi-lamp Incandescent vanity bath bar w/occpcy sensor	G0->G3	$27.93	426.82	2.9	2.7	2.2	2.2	2.0	1.9	1.7	1.7	1.2
multi-lamp Incandescent vanity bath bar (high end) to Screw-in CFL multi-lamp vanity bath bar (high end)	G0H->G1H	$16.94	23.33	53.2	48.5	40.7	40.7	36.0	34.4	31.3	31.3	21.9
multi-lamp Incandescent vanity bath bar (high end) to Pin-based multi-lamp fluorescent vanity bath bar (high end)	G0H->G2H	$17.60	26.64	46.6	42.5	35.6	35.6	31.5	30.1	27.4	27.4	19.2
multi-lamp Incandescent vanity bath bar (high end) to multi-lamp	G0H->G3H	$27.93	231.84	5.4	4.9	4.1	4.1	3.6	3.5	3.1	3.1	2.2

Incandescent vanity bath bar w/occupancy sensor (high end)												
Incandescent combo fan/light (for bathroom) to Screw-in CFL combo fan/light	H0->H1	-$10.33	-72.44	no cost	no cost	no cost	no cost	no cost	no cost	no cost	no cost	no cost
Incandescent combo fan/light (for bathroom) to Pin-based CFL combo fan/light	H0->H2	-$1.17	-6.57	no cost	no cost	no cost	no cost	no cost	no cost	no cost	no cost	no cost
Incandescent combo fan/light (for bathroom) to Incandescent combo fan/light w/occupancy sensor (for bathroom)	H0->H3	$27.93	1164.50	1.1	1.0	0.8	0.8	0.7	0.7	0.6	0.6	0.4
Incandescent ceiling mounted globe light to Screw-in Fluorescent ceiling mounted globe light	I0->I1	$10.86	71.05	17.5	15.9	13.4	13.4	11.8	11.3	10.3	10.3	7.2
Incandescent ceiling mounted globe light to Pin-based CFL ceiling mounted globe light	I0->I2	$3.51	17.89	69.4	63.2	53.0	53.0	46.9	44.9	40.8	40.8	28.6
Incandescent Ceiling mounted Fan light to Screw-in Fluorescent Ceiling mounted Fan light	J0->J1	$55.26	248.82	5.0	4.5	3.8	3.8	3.4	3.2	2.9	2.9	2.1
Incandescent Ceiling mounted Fan light to Pin-based Fluorescent Ceiling mounted Fan light	J0->J2	$5.32	16.29	76.2	69.5	58.3	58.3	51.5	49.3	44.8	44.8	31.4
Incandescent Wall mounted sconce to Screw-in CFL Wall mounted sconce	K0->K1	$11.28	81.19	15.3	13.9	11.7	11.7	10.3	9.9	9.0	9.0	6.3
Incandescent Wall mounted sconce to Pin-based Fluorescent Wall mounted sconce	K0->K2	$6.08	34.03	36.5	33.2	27.9	27.9	24.7	23.6	21.5	21.5	15.0
Incandescent Exterior wall mounted entry light to Screw-in CFL Exterior wall mounted entry light	L0->L1	$9.50	103.43	12.0	10.9	9.2	9.2	8.1	7.8	7.1	7.1	4.9
Incandescent Exterior wall mounted entry light to Pin-based CFL Ext wall mntd entry light	L0->L2	$12.78	86.76	14.3	13.0	10.9	10.9	9.7	9.3	8.4	8.4	5.9

Incandescent Exterior ceiling mounted porch light (globe) to Screw-in CFL Ext. Ceiling mntd porch light (globe)	M0->M1	$11.28	199.51	6.2	5.7	4.8	4.8	4.2	4.0	3.7	3.7	2.6
Incandescent Exterior ceiling mounted porch light (globe) to Pin-based CFL Ext. Ceiling mntd porch light (globe)	M0->M2	$23.33	242.59	5.1	4.7	3.9	3.9	3.5	3.3	3.0	3.0	2.1
Incandescent Exterior ceiling mounted porch light (globe) to Incandescent Exterior ceiling mounted porch light w/motion sensor (globe)	M0->M3	$27.93	1773.86	0.7	0.6	0.5	0.5	0.5	0.5	0.4	0.4	0.3
Incandescent Exterior wall mounted flood light to Screw-in CFL Exterior wall mounted flood light	N0->N1	$18.00	23.69	52.4	47.8	40.1	40.1	35.4	33.9	30.8	30.8	21.6
Incandescent Exterior wall mounted flood light to Pin-based CFL Exterior wall mounted flood light	N0->N2	-$12.85	-16.48	no cost	no cost	no cost	no cost	no cost	no cost	no cost	no cost	no cost
Incandescent Exterior wall mounted flood light to Incandescent Exterior wall mounted flood light w/motion sensor	N0->N3	$0.34	1.04	1194.3	1088.9	913.3	913.3	807.9	772.8	702.5	702.5	491.8
Incandescent Suspended pendant (utility) to Screw-in CFL Suspended pendant (utility)	S0->S1	$33.84	393.56	3.2	2.9	2.4	2.4	2.1	2.0	1.9	1.9	1.3
Incandescent Suspended pendant (utility) to Pin-based CFL Suspended pendant (utility)	S0->S2	-$72.72	-715.23	no cost	no cost	no cost	no cost	no cost	no cost	no cost	no cost	no cost
Incandescent Suspended pendant (utility) to Incandescent Suspended pendant w/occupancy sensor (utility)	S0->S3	$27.93	800.81	1.5	1.4	1.2	1.2	1.0	1.0	0.9	0.9	0.6
Incandescent Suspended pendant to Pin-based CFL Suspended pendant	T0->T1	$24.36	127.31	9.7	8.9	7.5	7.5	6.6	6.3	5.7	5.7	4.0
Incandescent Suspended pendant to Pin-based CFL Suspended pendant	T0->T2	$32.58	167.14	7.4	6.8	5.7	5.7	5.0	4.8	4.4	4.4	3.1

Incandescent Suspended pendant to Incandescent Suspended pendant w/dimmer	T0->T3	$51.66	915.08	1.4	1.2	1.0	1.0	0.9	0.9	0.8	0.8	0.6
Incandescent Track (3 heads) to Pin-based CFL Track (3 heads)	U0->U2	$31.91	207.06	6.0	5.5	4.6	4.6	4.1	3.9	3.5	3.5	2.5
Incandescent Track (3 heads) to Incandescent Track (3 heads) with dimmer switch	U0->U3	$1.55	107.78	11.5	10.5	8.8	8.8	7.8	7.5	6.8	6.8	4.7