NATIONAL RENEWABLE ENERGY LABORATORY

Chapter 6: Residential Lighting Evaluation Protocol

The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures

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1 Measure Description

In recent years, residential lighting has represented a significant share of ratepayer-funded electricity energy efficiency savings. The majority of these savings have been achieved by promoting the purchase and installation of compact fluorescent lamps (CFLs), both standard "twister" bulbs and specialty CFLs such as reflectors, A-Lamps, globes, and dimmable lights. Some energy efficiency programs have also promoted ENERGY STAR lighting fixtures. More recently, programs are introducing solid-state light-emitting diode (LED) lamps.

The future of savings claims from residential lighting programs is uncertain, due to the provisions of the 2007 Energy Independence and Security Act (EISA). This legislation requires that most screw-based light bulbs become approximately 28% more energy-efficient during the period from 2012 through 2014, as measured by the efficacy in units of lumens per watt (W). EISA requirements take effect in phases, beginning with 100-W equivalents in 2012, 75-W equivalents in 2013, and 60- and 40-W equivalents in 2014. To add further uncertainty regarding the baseline, the federal spending bill approved in December 2011 eliminated enforcement of the EISA standards through at least September 2012.

2 Application Conditions of Protocol

Residential lighting measures are typically delivered by program administrators through four mechanisms:

- ***Upstream Buy-Down/Mark-Down.*** The most common approach to achieve residential lighting savings has been through "upstream" incentives to either manufacturers to buy down (or have retailers mark down) the cost of lights for consumers. This delivery mechanism offers the discount at the time of purchase (that is, at the point of sale) and thus does not require any application or paperwork from the end-use customer.
- ***Direct Installation.*** Many program administrators who offer residential audit programs also provide direct installation of CFLs at the time of the audit. In most programs, the audit is offered at either no cost or at a highly discounted cost to the customer, and there is usually no additional cost for the CFLs.
- ***Giveaways.*** A number of program administrators have provided CFLs free of charge to residential customers through the mail, at customer service offices, or at community, religious, or local government events. In some programs, the CFLs are mailed to customers only upon request. In other programs, the CFLs are distributed without prior customer request. The amount of customer information collected at the time of giveaway events varies, with some program administrators requiring full name and contact information and other program administrators not requiring any.
- ***Coupons.*** Some program administrators have relied on instant (point-of-sale) or mail-in coupons as the incentive mechanism for residential lighting products. These coupons typically require that customers fill out their name and contact information to obtain the product at the discounted price or to receive the rebate.

Although this Residential Lighting Evaluation Protocol applies to all of these delivery mechanisms, the strategies for collecting and analyzing the data necessary to calculate the savings tend to vary. Where necessary, this protocol highlights and provides more detail regarding specific differences. Also, program administrators may need to prioritize their evaluation resources on particular combinations of measures and delivery strategies based on criteria such as the contribution to savings and the assessed uncertainty of those savings estimates. (For example, uncertainty can occur with programs that have not been evaluated for a while or that have shifting baselines.)

3 Savings Calculations[1]

Gross energy first-year savings from residential lighting measures can be calculated through a number of different algorithms. The approach recommended is based on the following general algorithm:

Equation 1

$$kWh_{saved} = NUMMEAS * (\Delta W/1{,}000) * HRS * ISR * INTEF$$

where:

kWh_{saved}	=first-year electricity savings measured in kilowatt-hours
NUMMEAS	=number of measures sold or distributed through the program
ΔW	=delta watts = baseline wattage minus efficient lighting product wattage
HRS	=annual operating hours
ISR	=in-service rate
INTEF	=cooling and heating interactive effects

The recommended techniques for estimating each of these parameters, based on either primary or secondary data, are described in this chapter.

1 As presented in the "Introduction" chapter, the methods focus on energy savings and do not include other parameter assessments such as net-to-gross, peak coincidence factor (or demand savings), incremental cost, or measure life.

4 Measurement and Verification Plan

The savings from residential lighting measures should be calculated through a mix of measured and estimated parameters. This approach, which is similar to Option A of the International Performance Measurement and Verification Protocol (IPMVP), is recommended because the values for some parameters can be directly measured through metering (such as annual hours of use), while others parameters (such as delta watts for upstream lighting programs) need to be estimated through other techniques.

4.1 Number of Measures Sold or Distributed

The number of measures sold or distributed through a program should be collected by the administrator or a third-party implementation contractor. Data should be compiled in electronic format in a database that tracks as much detail as possible regarding the measures delivered. For example, for an upstream program, this should include detailed information for each transaction:

- Product shipment dates from manufacturer to retailer, where applicable
- Detailed product information
    - Bulb type (for example, CFL, LED)
    - Wattage
    - Style and features (for example, twister, reflector, A-Lamp, globe, dimmable)
    - Manufacturer and product identifier (for example, UPC or SKU codes)
    - Rated lumens
- Number of products incented (for example, number of packs and bulbs per pack)
- Date incentive paid
- Dollar value of incentives paid
- Company name receiving incentive
- Location where products were ultimately sold (including retailer name address, city, state, and ZIP code)
- Final retail sales price of product, if available
- Company contact information (store manager or corporate contact name and phone number)
- Assumptions regarding any parameters to savings estimates.

Similar details should be collected for programs using other delivery strategies. For example:

- Data collected for an audit program would include information about the date installed, the numbers and types of products installed, the wattage of the replaced bulb and location (room type), and contact information for the installation.
- Data collected for giveaway programs should contain at least the customer contact information and the quantity/type of product given away.

At a minimum, the evaluation should include a basic verification of savings, whereby the evaluator (1) sums up the detailed transactions and (2) attempts to replicate the calculation of total claimed savings for the specific time period in which the savings were claimed, such as a program year or cycle.

Discrepancies between claimed and verified number of measures should be treated as adjustments to the number of program measures. In other words, if the *total* number of measures distributed does not match the number of measures claimed by a program administrator, the number of measures assumed sold or distributed should be adjusted accordingly. (That is, if the number of measures claimed by a program administrator does not match what is in the detailed tracking data, the tracking data should be regarded as correct.)

4.2 Delta Watts

Delta watts represent the difference between the wattage of the efficient lighting measure and the wattage of the assumed baseline measure. As noted, the wattage of the efficient measure should be available from the program tracking database. Where possible—such as with direct installation programs—the program implementation contractor should record the wattage of the particular lamp that the program measure is replacing.

Typically, this is done at the time of the audit, when the existing measure is replaced with the efficient measure. However, this is not possible for most program delivery strategies, so baseline wattage often needs to be estimated. In addition, the baseline assumptions need to incorporate the transition to EISA standards beginning in 2012.

4.3 Approaches for Estimating Baseline Wattage

Recent studies have used a number of approaches for estimating baseline wattage, including:

- ***Self-Report.*** This approach uses customer surveys after the installation to collect the wattage that was used before the energy-efficient lighting was installed.
- ***In-Home Inspections to Examine Wattage of Equivalent Fixtures.*** Using this approach, the implementation contractor examines the labeled wattage of bulbs in similar fixtures in each home to estimate the wattage that was used before the energy-efficient lighting was installed.
- ***Multipliers.*** This approach assumes that the baseline is a multiple— for example, three to four times the wattage—of the efficient measure, so that one value (one multiplier) is used across all program bulbs.
- ***Manufacturer Rating.*** Most energy-efficient lighting products prominently list the replacement wattage assumptions on the box (see Figure 1). Manufacturers are also required to include detailed information regarding lamp output and efficacy as part of the "Lighting Facts" label that is now required on all retail lamp packaging. (www.ftc.gov/os/2010/06/100618lightbulbs.pdf)
- ***Lumen Equivalence.*** EISA standards include lumen ranges and assumptions regarding the equivalent wattage of incandescent lights.

Figure 1. Example of Manufacturer Rated Baseline Wattage

Source: http://www.energystar.gov/index.cfm?c=cfls.pr_cfls_lumens

4.4 Recommended Approach

Each of these approaches has a number of strengths and limitations (see Table 1). Weighing each of these, the Residential Lighting Evaluation Protocol recommends using a lumen equivalency approach to estimate delta watts for conditions where the baseline wattage cannot be collected by the program implementation contractor at the time of measure installation. This approach is recommended because (1) it provides consistency with the EISA requirements and (2) most manufacturers' rated baseline wattage is already based on similar lumen categories.[2]

Alternatively, for studies that have sufficient budget to screen for a statistical sample of recent CFL purchasers, the self-report approach may be used to estimate delta watts (as well as other purchase attributes, including location and price). The Residential Lighting Evaluation Protocol recommends, however, that the consumer recall approach apply these time limits:

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2 When the assumed baseline from the lumen equivalency approach differs from the manufacturer-rated baseline wattage, this is typically due to a lower-lumen bulb rated as a higher assumed baseline. For example, the manufacturer rates a bulb as a 120-W replacement, but the lumen output is more typical of a 75-W bulb. In these cases, consumers may "bin shift" up to a higher wattage of efficient product to get the light output they expect. Thus, the method recommends using the more conservative and lower assumed baseline wattage rather than what is printed on the box.

- A maximum of a six-month “window” (and preferably a three-month “window”) for standard spiral CFLs
- Up to a year for specialty CFLs and LEDs, as these have far lower incidence but represent larger purchase decisions.

Note the self-report approach does offer the advantage of capturing consumer “bin-shifting.”[3]

3 A literature review did not reveal any studies that assess the magnitude of bin shifting, although forthcoming studies conducted by Navigant Consulting and the NMR Group found some evidence that customers purchased a higher-wattage bulb than the recommended replacement.

Table 1: Strengths and Limitations of Alternative Delta Watts Estimation Approaches

Approach for Estimating Baseline Wattage	Strengths	Limitations	Recent Studies Using Approach	Estimated Incandescent to CFL Ratio[4]
Customer self-report	Capture customer intentions and bin shifting	Potentially low recall and social desirability bias	Duke Energy Residential Lighting Program (2010)	4.25
Examining equivalent fixtures	Actual recording of baseline wattage for existing measures	Difficult to truly identify equivalent fixtures; high cost to conduct statistically representative on-site study	2006-2008 California Upstream CFL Program	3.6
Standard multipliers	Low effort, low cost, accuracy derived from empirical program data and, perhaps, better funded studies	Determining the appropriate multiplier for the program is difficult without basing it on another approach, or relying on other studies. The resulting estimate can be biased depending on the distribution of bulb type and wattages.	Mid-Atlantic Technical Reference Manual (TRM) (Vermont Energy Investment Corporation 2011) Ohio TRM (Vermont Energy Investment Corporation 2010)	3.95 4.25
Manufacturer rated baseline wattage	Widely available, relatively inexpensive to implement; based off of wattage rating on package, often prominently displayed on the product	Some cases where the marketed baseline wattage exceeds the equivalent lumen output which may lead to "bin shifting"	Wisconsin Focus on Energy 2007 Residential Lighting Program	4.0
Lumen equivalence	Widely available, relatively inexpensive to implement; in most cases matches marketed baseline wattage, matches up with EISA standards	May provide conservative estimate in cases where marketed baseline wattage exceeds rated lumen output	ComEd PY3 Residential Lighting Program	N/A

4 The incandescent-to-CFL wattage will vary, based on both the types of bulbs promoted (for example, standard vs. specialty) and the typical program CFL wattage. In addition, this ratio is sometimes shown as the ratio of the delta watts to CFL. (For example, the Mid-Atlantic TRM [technical reference manual] recommends a delta watts-to-incandescent ratio of 2.95).

Table 2 provides the assumed baseline wattage based on lumen range and incorporates the timing of EISA requirements as the new baseline standards.

Table 2: Estimated Baseline Wattage for Lumen Equivalencies

Lumen Range	2011 Baseline	2012 Baseline	2013 Baseline	2014 Baseline
1490—2600	100-W	72-W	72-W	72-W
1050—1489	75-W	75-W	53-W	53-W
750—1049	60-W	60-W	60-W	43-W
310—749	40-W	40-W	40-W	29-W

Note: Shading represents initial year of EISA phase-in requirements

While there may be "sell through" of existing product during the phase-in years, the Residential Lighting Evaluation Protocol recommends using the new baseline values for the entire year in which they take effect *unless* research shows significant "sell through" periods. (See the *Uncertainty Regarding the Baseline and the Need for Ongoing Research* section later in this chapter).[5]

In addition, baseline wattage should be calculated for each lamp in the tracking database. The total estimated delta watts, therefore, is calibrated to the actual type and number of measures sold or distributed through the program.

There are two additional points of clarification for this approach:

- For lumens above or below these ranges, the marketed baseline wattage reported on the product should be used. In other words, lumens above the ranges in Table 2 might qualify for a 150-W baseline.
- EISA has a number of exceptions, including three-way bulbs, candelabras, and reflectors.[6] In these cases, the baseline wattage should continue to be the 2011 standard incandescent wattage based on the lumen equivalence.

4.5 Replacements of Efficient Lighting Products With Newer Efficient Lighting Products

This methodology assumes that at the time of measure failure, the consumer has the choice of installing an energy-efficient lighting product or a standard-efficiency lighting product, regardless of what was previously installed. In areas with long history of CFL promotion—and as market penetration increases for CFLs or other high-efficiency lighting products—there is a higher probability that some fraction of the energy-efficient lighting products distributed through programs are being used to replace installed CFLs that fail.

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[5] EISA requires an even more efficient lighting standard in 2020 that is on par with current CFL efficacies. The life cycle savings of CFLs, therefore, should terminate for any remaining years beginning in 2020, and the life cycle savings for LEDs should incorporate this upcoming baseline change.

[6] Note, however, that certain ER and BPAR reflector lamps have separate EISA requirements that took effect in July 2012, and should be used as the baseline for any program equivalent lamps.

There are two approaches available to address this issue.

- The first is to assume the baseline is the federal standard (for example, EISA), even if the consumer had previously installed a CFL or LED. In this approach the CFL-to-CFL replacement scenario is assumed to be handled under investigation of program attribution, where it is more likely that consumers replacing CFLs with other CFLs may be freeriders (Nexus Market Research, Inc. et al. 2009).[7]
- The second is to revise the baseline wattage assumptions to reflect the share of in-kind replacement of CFLs. This approach requires the collection of data on the proportion of high-efficiency lamps distributed through the program that are replacing existing CFLs.

To avoid underestimating program savings, the Residential Lighting Evaluation Protocol recommends that only one, rather than both, of these adjustments be applied. For jurisdictions that do not include any application of a net-to-gross adjustment, this would require using the second approach—conducting a market characterization study to determine the baseline and the percentage of high-efficiency lighting products that are replacing CFLs.

Finally, as more efficiency programs promote LEDs in the future, further research will be required to investigate the likelihood that energy efficiency minded consumers are replacing CFLs with LEDs.

4.6 Uncertainty Regarding the Baseline and the Need for Ongoing Research

The recommended protocol acknowledges uncertainties around the residential lighting market in the next few years. These uncertainties deal with the types and prices of future lighting products that will be available on the market. Another source of uncertainties regards consumer reactions to the requirements and new products—for example, potential product hoarding, "bin jumping" to different incandescent wattage levels, and how quickly retailers sell through the existing product inventories.

The uncertainty around EISA was further heightened in December 2011 with the passage of the fiscal year (FY) 2012 omnibus spending bill, which included a rider that halted funding for the U.S. Department of Energy to enforce the new standards. The National Electrical Manufacturers Association (NEMA), representing more than 95% of the U.S. lighting manufacturing industry, issued a press release after the passage of the bill stating that they did not support it. NEMA also points out that (1) American manufacturers have invested millions of dollars in transitioning to

7 The New England *Residential Lighting Markdown Impact Evaluation*, January 20, 2009 found that 43% of respondents (24 out of 56) stated that the CFLs recently purchased and not installed were intended for use to replace incandescent lighting. That is, 57% of the respondents intended to use the stored CFLs to replace existing CFLs when they failed. While this was used to discount the delta watts, if those respondents who are already intending to replace CFLs with CFLs are presumably counted as freeriders, then program attribution should already incorporate any necessary adjustments.

energy-efficient lighting and (2) EISA gave state attorneys general the authority to enforce the standards.

Thus, in cases where actual pre-program measure wattage is not available, the Residential Lighting Evaluation Protocol recommends that the EISA standards continue to be adopted as the new baseline. However, program administrators having adequate resources should conduct ongoing monitoring and research to determine whether the delta watts assumptions reflect actual market conditions during the phase-in of the EISA requirements, and use a lagged approach to phasing in the requirements. In particular, research in California—where the standards take effect one year in advance of the rest of the United States—may be informative for determining retailer and manufacturer reactions to EISA.

4.7 Annual Operating Hours

Hours of use (HOU) represents the estimated hours per year that the energy-efficient lighting product will be used. Recent studies have shown a wide range of estimated HOU for CFLs, from a low of 1.5 to a high of 2.98 hours per day (see Table 3). A myriad of factors affect differences in the expected number of hours that energy-efficient lighting products are used per year, including differences in demographics, housing types and vintages, CFL saturation, room type, electricity pricing, and even annual days of sunshine. As a result, extrapolation of data from one region has not proven successful in accounting for these influencing factors (Navigant Consulting and Cadmus Group, Inc. 2011).[8]

Based on these disparate results, this protocol recommends that program administrators collect primary data through a metering study for residential lighting measures.

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8 For example, Cadmus' analysis of metered CFL hours of use, conducted as part of the evaluation of 2010 EmPOWER Maryland Residential Lighting and Appliances Program, revealed a significant difference in average daily hours of use as compared to extrapolating the hours of use from the ANCOVA model developed as part of the evaluation of the 2006-2008 California Upstream Lighting Program.

Table 3: Estimated CFL Hours of Use from Recent Metering Studies

Region	Publication Year	Author	Sample Size (Homes)	# of Efficient Bulbs Metered	Estimated Average Daily HOU
California (PG&E, SCE, and SDG&E service areas)	2010	KEMA, Inc. (KEMA, Inc. and Cadmus Group, Inc. 2010)	≈1,200	N/A	1.9
California (PG&E, SCE, and SDG&E service areas)	2005	KEMA, Inc. (KEMA 2005)	375	983	2.3
Massachusetts, Rhode Island, Vermont, Connecticut	2009	Nexus Market Research, Inc. et al. (Nexus Market Research, Inc. et al. 2009)	157	657	2.8
Illinois	2012	Navigant Consulting	67	527	2.7
Massachusetts, Rhode Island, Vermont	2004	Nexus Market Research, Inc. and RLW Analytics, Inc. 2004	NA	≈75	3.2
Maryland (EmPOWER)	2011	The Cadmus Group, Inc. and Navigant Consulting (Navigant Consulting and Cadmus Group, Inc. 2011)	61	222	3.0
North Carolina, South Carolina	2011	TecMarket Works and Building Metrics (TecMarket Works and Building Metrics 2011)	34	156	2.5 (North Carolina) 2.7 (South Carolina)
Ohio	2010	Vermont Energy Investment Corporation (from Duke Energy)	N/A	N/A	2.8
Pacific Northwest	2010	Northwest Regional Technical Forum, based on CA, 2010 KEMA, Inc.	N/A	N/A	1.9 for existing homes, 1.5 for new homes

4.8 Metered Data Collection Method

Metering should be based on the following factors and associated guidelines, which are described in this section:

- Logger type
- Length of metering period
- Information collected on site
- Data integrity.

4.8.1 Logger Type

Change-of-state loggers are preferred over periodic readings because they can capture short intervals and switch rates (the number of times lights are turned on and off). In addition, current-sensing meters (rather than light-sensing meters) are one approach for outdoor conditions in which ambient light can potentially inflate the estimated hours of use.

4.8.2 Length of Metering Period

Due to the seasonality of lighting usage, logging should (1) be conducted in total for at least six months and (2) capture summer, winter, and at least one shoulder season—fall or spring. At a minimum, loggers should be left in each home for at least three months (that is, two waves of three-month metering will attain six months of data). All data should be annualized using techniques such as sinusoidal modeling to reflect a full year of usage.[9]

4.8.3 Information Collected On Site

In-home lighting audits should be conducted for all homes participating in the metering study. The audits should record the number and type of high-efficiency lighting products by fixture and room type. It is highly recommended that a full socket inventory be conducted to allow for an estimate of saturation of high-efficiency lighting equipment. In addition, on-site information specifically related to the logger placements should also be collected, including room type, window orientation, fixture type, notes about possible ambient light issues, etc.

4.8.4 Data Integrity

All metered data need to be thoroughly cleaned to check for errant and erroneous observations. For example, downloaded data need to be clipped at the moments of installation and removal to eliminate extraneous readings, any loggers that are broken or removed from the fixtures by residents should be removed from analysis, and the data need to be examined for “flicker” (that is, very frequent on/off cycling).

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[9] Sinusoidal modeling assumes that hours of use will vary inversely with hours of daylight over the course of a year. Sinusoid modeling shows that (1) hours of use change by season, reflective of changes in the number of daylight hours and weather and (2) these patterns will be consistent year to year, in the pattern of a sine wave. An example of this approach is provided in the evaluation of the 2006-2008 California Upstream Lighting Program evaluation.

4.8.5 Metering Sample Design

Ideally, metering is conducted for large samples of all major lighting types (including incandescent baseline lamps and fixtures); however, in practice, most evaluations do not have adequate resources for a scope of this size. Consequently, to optimize the allocation of moderate evaluation resources, target the metering to select lighting measures—typically CFLs—that represent the majority of savings in a residential lighting program. For measures representing a small percentage of savings (such as LEDs in more recent programs), the overall HOU should be estimated by examining the CFL hours of use for similar rooms and fixture types.

Given the difficulty of identifying program bulbs in an upstream program, loggers may be placed on energy-efficient bulbs in a random sample of homes that have installed similar measures, even if those measures are not definitely known to be part of a mark-down or buy-down. For homes that have many energy-efficient lighting products, a subsample of fixtures may be selected, so long as they are selected randomly within the home. For example, if a home selected for a metering study has CFLs in 10 fixtures, meters can be placed on three to five randomly selected fixtures.[10] This will both minimize the invasiveness in homes that are highly saturated with energy-efficient lighting products and allow for a more cost-effective approach to include a larger sample of homes in the study.

The total number of loggers installed should be determined based on the desired levels of statistical confidence and precision, assuming a coefficient of variation (CV) based on recent studies of programs with similar CFL saturation (using maturity of program as a proxy, if necessary) and housing characteristics (Cadmus 2010) (Navigant Consulting and Cadmus Group, Inc. 2011).[11]

Following metering and annualization of results, the distribution of loggers by room type should be compared to the actual distribution of energy-efficient lighting products per room type, as collected at the time of the audit. The hours of use should then be weighted to reflect the actual distribution of lighting products by room type. For example, if 10% of the loggers are installed in kitchen fixtures, but the audit data reveals that 15% of all CFLs are installed in kitchens, the data from the loggers in kitchens should be weighted up by 1.5 when calculating total hours of use.

In addition, the demographic and household characteristics of the metering sample should be compared with the characteristics of the total population of homes believed to have purchased energy-efficient lighting products. (This information can be collected through telephone surveys.) If significant differences appear *and* there is a large enough sample to support re-

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10 A number of studies, including the evaluation of the California Upstream Lighting Program, provide publicly available examples of how to randomly select fixtures for metering.

11 Recent Cadmus studies for Ameren Illinois and EmPOWER Maryland found CVs of approximately 0.6; however, the CV could be higher for mature programs where CFLs are in a wider selection of fixtures with more variable hours of use. Actual sample size should exceed the required number by at least 10% to allow for attrition due to data cleaning.

weighting based on such characteristics, the results should be weighted to reflect these differences.

4.9 Using Secondary Data

While metering is the recommended approach, program administrators who are just launching a program—or do not have sufficient resources to conduct a metering study—may use secondary data from other metering studies.[12] This protocol recommends using the following criteria when selecting and using secondary data to estimate hours of use:

- Similarities in service territories
- Maturity of program or measure saturation
- Appropriate sample size
- Length of metering period
- Adjustments to reflect hours of use by room type.

4.9.1 Similarities in Service Territories

Selecting a similar service territory based on geographic proximity and as many common demographic and household characteristics as possible will increase the likelihood that the secondary data provide a valid, reasonable, and accurate estimate.

4.9.2 Maturity of Program or Measure Saturation

Hours of use are expected to drop as the saturation of energy-efficient products increases, resulting in the installation of these products in less-used fixtures. Saturation is typically tied to the maturity of the program. In other words, regions with longer-running energy efficiency programs that have higher saturation rates are expected to have lower hours of use.[13] Using secondary data from programs of similar maturity levels will increase the data's applicability.

4.9.3 Sample Size

The number of observations varies considerably between studies, so the sample size, standard errors, and precision levels at equivalent confidence levels should be compared across studies.

4.9.4 Length of Metering Period

Studies that capture both winter and summer usage may be more appropriate for estimating overall annual use.

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[12] As discussed in *Considering Resource Constraints* in the "Introduction" chapter to this UMP report, small utilities (as defined under the U.S. Small Business Administration [SBA] regulations) may face additional constraints in undertaking this protocol. Therefore, alternative methodologies should be considered for such utilities.

[13] For example, hours of use in California dropped from an average of 2.3 hours per day in the 2004-2005 program year study to 1.9 hours per day in the 2006-2008 program year study. CFL socket penetration (the percentage of sockets containing CFLs) increased from 9% in the 2004-2005 study to 21% in the 2006-2008 study.

4.9.5 Adjustments to Reflect Hours of Use by Room Type

Extrapolating data from one region to another should be conducted by calibrating to the different levels of measure saturation by room type. If possible, the hours of use by room type from a secondary data source should be weighted by the room type distribution of CFLs for the region under study.

4.10 Snapback/Rebound or Conservation Effect

"Snapback" or "rebound" refers to changes in use patterns that occur after the installation of an energy-efficient product and result in reducing the overall measure savings. For example, when residential lighting customers use a CFL for more hours per day than they used the replaced incandescent bulb, this constitutes snapback. This behavior change may be due to factors such as the cost savings per unit of time from the CFL or a concern that turning CFLs on and off shortens their effective useful life (although it is unlikely most consumers are aware of this effect on life). Some customers, however, might have lower hours of use after installing a CFL, perhaps due to a corresponding desire to reduce energy consumption.

Due to the nature of residential lighting programs, it is not typically possible to conduct metering both before and after installation of energy-efficient lighting. Therefore, the Residential Lighting Protocol does not recommend adjusting for snapback/rebound effects in the hours of use estimates.[14]

4.11 In-Service Rate

The in-service rate represents the percentage of incented residential lighting products that are ultimately installed by program participants. In-service rates vary substantially based on the program delivery mechanism, but they are particularly important in giveaway or upstream programs where the customer is responsible for installation *and* the customer may not have requested the more energy-efficient lamps.

For upstream programs, three factors—as shown in Table 4—have led to first-year, in-service rates well below 100%: (1) the often deeply discounted price, (2) the inclusion of program multipacks, and (3) the common practice of waiting until a bulb burns out before replacing it.

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[14] Although surveys can be used to estimate potential snapback behavior, these efforts are considered more qualitative. Also, surveys cannot easily capture the relationship of hours of use between multiple fixtures. For example, after a retrofit, a home owner may consciously choose to use a fixture for more hours—rather than a standard-efficiency fixture—as a strategy to save additional energy.

Table 4: Estimated First-Year, In-Service Rates from Recent Evaluations of CFL Upstream Lighting Programs

Region	Publication Year	Author	Percentage of CFLs Installed in Program Year*
Arizona (APS service area)	2008	Navigant Consulting	90%
Connecticut, Massachusetts, Rhode Island, Vermont	2009	Nexus Market Research Inc., et al.	76%
Illinois	2012	Navigant Consulting and Itron, Inc.	71%

*Based on program year only, not years subsequent to the program year or several years in a multiyear program cycle.

The Residential Lighting Protocol recommends that in-service rates be estimated using different methods, as determined by the delivery mechanism:

- For ***direct installation programs***, conduct verification (such as telephone survey or site visits) to assess installation and measure persistence, regardless of whether working bulbs were removed before they failed.
- For ***giveaway or coupon programs***, conduct verification when customer contact information is available. Also, ask respondents whether (1) the installation location was within the relevant service territory and (2) the measure was installed in a home or business. (If the installation was in a business, ask about the type of business.)

  If customer information is not available, rely on either secondary data (such as for a similar program where customer information was collected) or, if necessary, on the in-home audit approach (described in the next bullet).
- For ***upstream programs***, calculate in-service rates through an in-home audit. Because program bulbs cannot be easily identified, the in-service rate can be calculated as the number of installed bulbs purchased in a recent 12-month period divided by the total number of bulbs purchased in the same 12-month period. If the sample size of homes with bulbs purchased in the recent 12-month period is insufficient to provide the necessary levels of confidence and precision, apply a long-term, in-service rate using all bulbs, regardless of the time of purchase.
- Although the in-home audit is the recommended approach, a telephone survey can be used when program administrators are just ***launching a program or do not have sufficient resources*** to conduct an in-home audit. To minimize recall bias, the callers should focus questions only on products purchased in the recent 12-month period rather than the period covering the long-term, in-service rate. (Studies have shown that respondents tend to have better recall about the percentage of bulbs purchased and installed within the past 12 months, as compared to the percentage of bulbs that has ever been purchased and installed.)

Although first-year, in-service rates for upstream programs are less than 100%, recent studies have demonstrated that consumers plan to install virtually all of the incented bulbs; however, they sometimes wait until an existing bulb burns out.[15] As a result, program administrators have been able to take credit in one of two ways for savings that occur in years following the year that the incentive was paid:[16]

- ***Discount Future Savings.*** In this method, all of the costs and benefits are claimed during the program year, but the savings (in terms of avoided costs, kWh, or kW) from the expected future installation of stored program bulbs are discounted back to the program year using a societal or utility discount rate.
- ***Stagger Timing of Savings Claims.*** In this method, all of the expenses are claimed during the program year, but the savings (and, therefore, the accompanying avoided cost benefits) are claimed in the years in which the program measures are estimated to be installed.

To calculate the installation rate trajectories, the Residential Lighting Evaluation Protocol recommends using the findings from the evaluation of the 2006-2008 California Residential Upstream Lighting Programs, which estimated that 99% of program bulbs get installed within three years, including the program year.[17] Because the study examined three years of program activity, it does not specifically include the percentage of bulbs installed by the year following program activity; it only estimates the total after three years. Therefore, program administrators should assume the bulbs that will be installed in future years are split equally between one and two years following the program year, calculated as:

$$ISR_{PY2} = \frac{99\% - ISR_{PY1}}{2}$$

$$ISR_{PY3} = \frac{99\% - ISR_{PY1}}{2}$$

where:

ISR =in-service rate

As noted in the delta watts discussion, this methodology does not adjust for CFL-to-CFL replacement, which will likely be handled by assessments of program attribution.

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15 For example, the evaluation of the Program Year 2 Commonwealth Edison Residential ENERGY STAR Lighting Program found that about 90% of customers with CFLs in storage were waiting until a working incandescent or CFL burned out before they installed the stored CFLs (Table 3-6).

16 The selection of which approach to use will depend upon the study purpose and regulatory requirements.

17 Few studies have attempted to quantify installation rate trajectories, and these protocols recommend this as an additional area for further research.

4.12 Interactive Effects With Heating, Ventilating, and Cooling

CFLs and LED lamps give off less waste heat than incandescent bulbs, which affects heating, ventilating, and cooling (HVAC) energy requirements. These effects vary based on space conditioning mode, saturation of space heating and cooling technologies and their relative efficiencies and climate zones. The influence of climate zone on interactive effects depends on a variety of house-specific factors. Taking all of these factors into account, the net impact on lighting energy cost savings could be positive, negative, or neutral (Parekh et al. 2005) (Parekh 2008). In cooling-dominated climates, the interactive effects are positive, resulting in additional savings due to decreased cooling load. However, in heating-dominated climates, the interactive effects are negative, with decreased savings due to increased heating load.

Because of the potential impacts of interactive effects, the Residential Lighting Evaluation Protocol recommends these effects be included in evaluations of residential lighting programs.[18] One approach is to estimate these effects through the use of simulation models, examining a mix of typical housing types (such as different vintages) and reflecting the estimated saturation, fuel shares, and size/efficiency of HVAC equipment (that is, the percentage of homes that have air-conditioning or electric versus gas heat). If necessary, secondary sources—such as the Residential Energy Consumption Study (RECS)—can be used to estimate these inputs. Other recent approaches include a billing analysis (Brunner et al. 2010).

Some regions have developed interactive effects calculators based on such simulations (for example, in California, the Database for Energy Efficiency Resources (DEER)[19] and the Regional Technical Forum (RTF) in the Northwest. Such regional collaboration can minimize the cost of determining the interactive effects for those regions that do not already have such a tool.

If regional collaboration is not an option *and* the program administrator does not have the resources to complete the simulations, the Residential Lighting Evaluation Protocol recommends using a value from an existing resource, but ensuring that at least the climate (heating and cooling degree days) and, ideally, the latitude, HVAC system types, and saturations are similar between the program administrator's territory and the territory from which the data are taken.

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[18] Note that interactive effects are only relevant for bulbs installed in conditioned spaces. Thus, exterior lights will not have HVAC interactive effects.)

[19] www.deeresources.com/DEER2011/download/LightingHVACInteractiveEffects_13Dec2011.xls

5 Other Evaluation Issues

The incentive structure of upstream lighting programs does not inherently allow for assurances that each purchaser of a program bulb is a residential customer in the sponsoring program administrator's service territory. Therefore, some program bulbs may go to non-residential customers or to customers served by other utilities. These parameters are discussed in this section.

5.1 Cross-Customer Class Sales

Non-residential customers typically use lighting products for more hours per day than do residential customers. Typically, non-residential customers also have higher peak coincidence factors. Therefore, lighting products incentivized through a residential lighting program but that are installed in non-residential sockets may lead to higher savings than those assumed through the methods outlined above.

The typical approach to estimating this parameter has been through customer intercept surveys, where customers who purchase lighting products participate in a short survey—asking about intended installation location and facility type—at the time of sale. This parameter has also been estimated through surveys with store managers (asking them to estimate the percentage of bulbs sold to non-residential customers) or with the owners of small businesses (asking them where they typically purchase lighting products).

The Residential Lighting Evaluation Protocol recognizes several key limitations in estimating this parameter, including:

- ***Customer intercepts may not represent all program sales***. Conducting customer intercept surveys can be expensive, and they are typically conducted only in high-volume stores (such as Home Depot, Lowe's, Walmart, etc.). In some cases, these surveys are conducted only during high-volume promotions. Also, because some retailers refuse to allow the surveys to be conducted, the surveys may not be representative of total program sales.

  Accuracy from intercepts is further challenged because business owners and contractors (1) may be a minority of purchasers, (2) may purchase more units per visit than residential purchasers, and (3) may not purchase during the same time as the average residential purchaser.

- ***Surveys lack high reliability***. Store managers usually do not have detailed information on program bulb purchasers, so their estimates of sales to non-residential customers may be unreliable. Surveys of small business customers also face challenges, as there is nonresponse bias (that is, calling a small business and not getting cooperation from the business decision maker to take a survey). Additionally, quantifying the number and type of bulbs purchased by channel may have recall bias.

5.2 Cross-Service Area Sales (Leakage)

Recent studies have also attempted to estimate the number of program bulbs sold to customers outside of the program administrator's service territory. This is commonly referred to as "leakage" or "spillage."

This protocol recognizes several key limitations in estimating this parameter, including:

- ***Cross-Region Sales.*** Many neighboring service territories are now targeted by residential lighting programs; thus, there is less of an incentive to shop outside one's own service territory to purchase less-expensive lighting products. In some cases, leakage of program bulbs occurs in both directions across service territory boundaries, which may offset the effect in either or both territories.
- ***Many programs now limit participating retailers, so that leakage is minimized***. Many program administrators now require retailers participating in upstream programs to be located far enough within the service territory or to be surrounded by a certain percentage of population of program customers as to minimize potential leakage.

5.3 Estimating Cross-Customer Class and Cross-Service Area Sales

Based on the limitations of estimating these parameters—and the fact these parameters may offset each other (that is, the increased savings of sales to non-residential customers may be at least partially offset by leakage) —this protocol recommends excluding these parameter estimates from impact evaluations of upstream residential lighting programs.

For program administrators who are using intercepts for other purposes (including an assessment of program attribution), questions regarding the intended location and business type can be included in surveys. However, the results should be used cautiously with the following adjustments:

- The results should be weighted to reflect the percentage of program bulbs represented by those distribution channels. For example, if intercept surveys are conducted at retailers that represent 75% of program bulbs, the findings should be assumed to reflect 75% of program bulb sales. For those distribution channels that have not received intercept surveys, the evaluator should first assess how the cross-customer class and cross-service area sales might differ and then apply extrapolated values.
- Intercept surveys should be conducted at retailer storefronts that represent a mix of likely leakage (based on the distance to adjacent service territories). Alternatively, the results should be weighted to reflect the actual mix of retailer risk of leakage.

6 Program Evaluation Elements

Residential lighting programs offer a variety of measures through multiple delivery strategies, with the upstream CFL programs currently being the most ubiquitous. Program administrators who offer a variety of measures and rely on a variety of delivery strategies may need to prioritize their evaluation resources based on criteria such as contribution to savings and assessed uncertainty.

Savings should be assessed through a mix of primary and secondary data, using IPMVP Option A (Retrofit Isolation: Key Parameter Estimates). Key areas needing ongoing and additional research are:

- Assumptions regarding baseline wattage as EISA standards take effect and as LEDs become a larger source of program savings (For example, customers who would have installed a CFL, rather than a program-incented LED, in absence of the program).
- Installation trajectories for measures that are not installed in the first year.

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