Northeast Residential Lighting Hours-of-Use Study

FINAL

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Submitted to:

Connecticut Energy Efficiency Board

Cape Light Compact

Massachusetts Energy Efficiency Advisory Council

National Grid Massachusetts

National Grid Rhode Island

New York State Energy Research and Development Authority

Northeast Utilities

Unitil

Submitted by:

NMR Group, Inc.

DNV GL

50-2 Howard Street, Somerville, MA 02144
Phone: (617) 284-6230 Fax: (617) 284-6239
www.nmrgroupinc.com

Abstract

The purpose of this study was to provide updated information to the Connecticut Energy Efficiency Board, the Massachusetts Program Administrators (Cape Light Compact, National Grid Massachusetts, Northeast Utilities, and Unitil), National Grid Rhode Island, and the New York State Energy Research and Development Authority (hereafter "the Sponsors") to assist in the calculations of demand and energy savings for lighting programs. Specifically, this report presents load shapes, coincidence factors (CFs), and daily hours of use (HOU).

Based on data collected from 4,462 loggers, the evaluators performed a series of regression models to estimate HOU. They concluded that the region comprising Connecticut, Massachusetts, Rhode Island, and Upstate New York had a household daily HOU of 2.7 hours for all bulbs and 3.0 for efficient bulbs, with HOU by room type varying from a low 1.7 in bathrooms to a high of 6.7 on the exterior of homes. Hours of use for Downstate New York exceeded those for the other areas included in the study, with a daily HOU of 4.1 for all bulbs and 5.2 for efficient bulbs for the household; room-specific estimates varied from 3.2 for bathrooms to 7.7 for kitchens.

The evaluators also provide detailed HOU estimates by room type, home type (i.e., single-family or multifamily), and income level for the region overall and for each individual area included in the analysis. Additionally, the report presents load shapes as well as well as coincidence factors for winter and summer peak period and winter and summer peak hours to aid in load planning and the calculation of peak demand savings.

Other topics addressed include comparisons of HOU for efficient and inefficient bulb types and comparisons to other existing HOU studies both in the Northeast region and throughout the United States.

Additional Attachments – Data Tools

Due to the vast amount of data collected for this study, the Team was able to analyze and present HOU data in many different ways. In total, the team created and analyzed over 1700 breakdowns (eight modeled areas by eight room types by eight classifications of home and income, plus a model including all homes, all across three bulb types). While the results of these models are summarized and presented in this report, NMR wanted to provide the Sponsors with access to all of the data. Therefore, as attachments to this report, NMR has provided two Excel-based data viewing tools that the Sponsors can explore on their own or with assistance from NMR. Both tools were designed to be intuitive, and pulling up data breakdowns requires only that the user select the data desired using drop down lists.

HOU Calculator – *Northeast HOU Calculator.xls*

The first tool, the 'Northeast HOU Calculator.xls' provides an efficient way to view, edit, and update HOU estimates by room and bulb type. Instructions for the tool are included within the Excel document.

Load Shape Data Viewer – *Northeast Load Shape Data Viwers.xls*

The second tool, the 'Northeast Load Shape Data Viewer.xls' provides an efficient way to view load shape data generated by the study. As with the HOU calculator, instructions for the tool are included within the Excel document.

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Executive Summary

The purpose of this study was to provide updated information to the Connecticut Energy Efficiency Board, the Massachusetts Program Administrators (Cape Light Compact, National Grid Massachusetts, Northeast Utilities, and Unitil), National Grid Rhode Island, and the New York State Energy Research and Development Authority (hereafter "the Sponsors") to assist in the calculations of demand and energy savings for lighting programs. Specifically, this report presents load shapes, coincidence factors (CFs), and daily hours of use (HOU).

Following are the principal tasks completed as part of this project:

- Sample design
- Recruitment
- Onsite data collection
- Analysis and reporting

To help control costs, the study took advantage of previously planned lighting saturation studies in New York and Massachusetts; the results of the saturation studies are presented under separate cover.[1,2] To complement the Base Study,[3] NYSERDA also funded an oversample of high-rise households in Manhattan. In addition, this study leveraged data collected as part of two additional concurrent studies: the *Massachusetts Low-Income HOU Study* (conducted by Cadmus) and the *National Grid New York EnergyWise Study* (conducted by DNV GL).[4] NMR, Cadmus, and DNV GL coordinated the development of protocols and methods to ensure comparable data.

Methodology

A brief overview of the methodology is presented here in the Executive Summary; for complete details, please refer to Section 2.

Sample Design, Recruitment and Onsite Visits

For this evaluation, the Team collected data through onsite visits to 848 homes located throughout Connecticut, Massachusetts, New York (excluding Nassau and Suffolk Counties), and Rhode Island. All sites required two visits. During the first visit, the Team collected detailed

[1] NMR, *Massachusetts Onsite Lighting Saturation Report.* Delivered to the Massachusetts Program Administrators on June 7, 2013.

[2] NMR, RIA, and Apex, *Draft Market Effects, Market Assessment, Process and Impact Evaluation of the NYSERDA Statewide Residential Point-of-Sale Lighting Program: 2010-2012.* Delivered to NYSERDA on December 13, 2013.

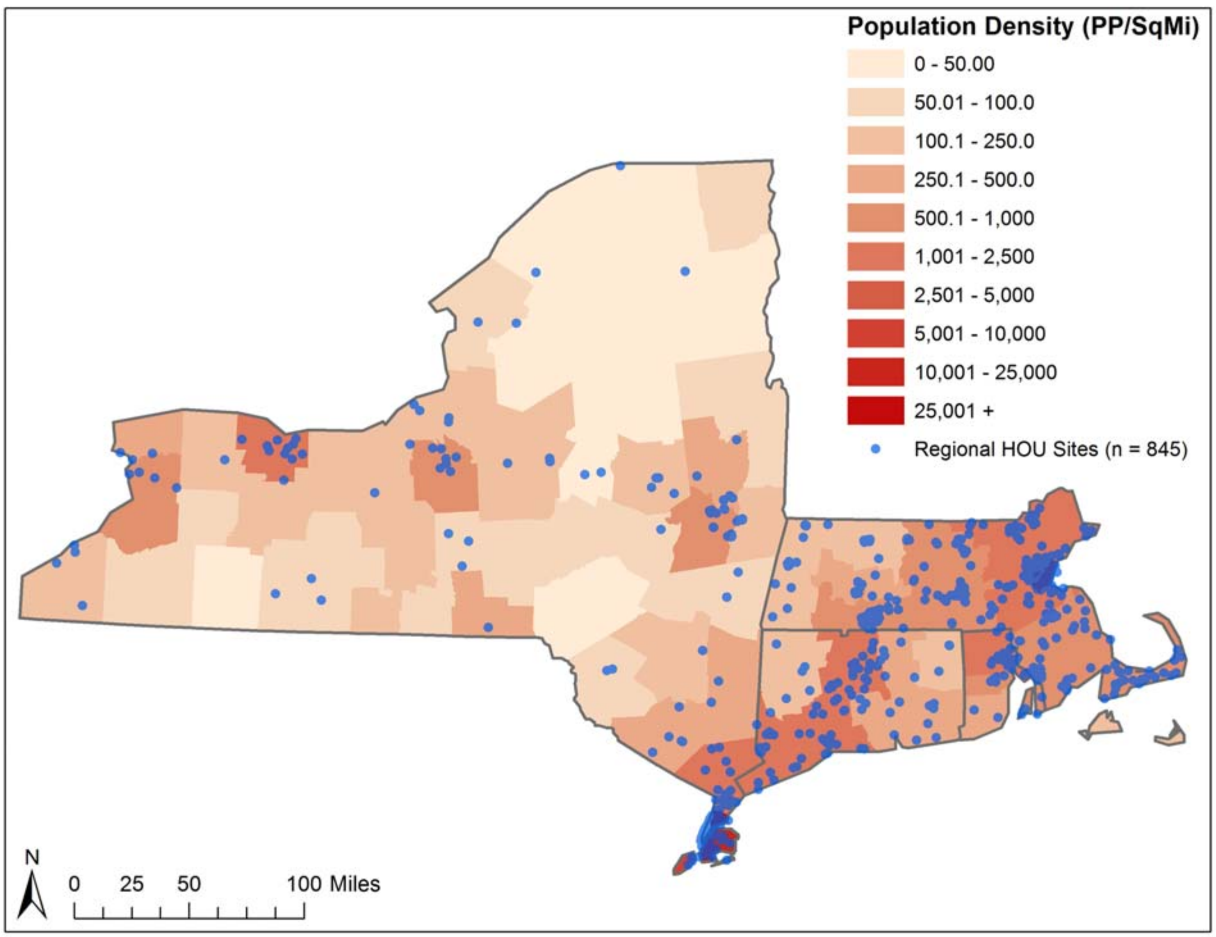
[3] In this report, Base Study refers to all data collection in Connecticut and Rhode Island and to a subset of data collection in Massachusetts and New York excluding: the High-Rise Oversample, the Cadmus Low-Income HOU Study, and the National Grid New York *EnergyWise* Study. Additional details on the breakdown of households and loggers from each study can be found in section 2.3.

[4] Cadmus, *Massachusetts Low Income Metering Study.* Delivered to the Massachusetts program Administrators on March 5, 2014.

lighting inventory data and installed time-of-use light meters (loggers). The second visit consisted of removing loggers installed during the first visit. In New York, NYSERDA funded the inclusion of an additional oversample of high-rise homes located in Manhattan in order to determine if high-rise households in densely populated New York City behave differently in terms of lighting usage.

The Team offered all potential study participants incentives that varied by area and study (that is, the region-wide study in all four states, and the separate study of high-rise apartments in Manhattan). Sections 2.1 and 2.2 provide additional detail on sample design, recruitment methods, and onsite visit protocols. Figure ES-1 provides an overview of the sample included in the final analysis, along with population density.

Figure ES-1: Site Locations with Population Density



Sample Attrition, Data Cleaning, and Treatment of Outliers

Altogether, over 5,730 loggers were installed between December 2012 and March 2013. Logger installations were timed to be as close to the winter solstice as practical, given project constraints and the impact of storms.[5] Logger installation began November 26th in Rhode Island and all of the loggers in Rhode Island were installed prior to December 21, 2012. Logger installation in the other areas began in January 2013 and was completed by the end of March 2013. Logger retrieval began in June 2013 and continued through August 2013. The greatest number of loggers was deployed between February and July 2013 (six months). A substantial number of loggers (greater than 1,500) was deployed in each month from December 2012 through July 2013 (eight months). Attrition due to customers moving, damage to loggers, and lost loggers reduced the sample about 4%.

The Team was very careful in identifying and removing loggers with HOU values that might be considered outliers. While some loggers recorded very high usage over the study period, the percentage of these loggers was small (approximately 1%). In addition, the Team implemented quality assurance and control procedures during logger installation and removal that reduced errors associated with loggers recording incorrect data (described in Section 2.2). Removing outliers and data cleaning (see Section 2.3) reduced the number of loggers included in the final analysis to 4,642. Of the 4,642 loggers included in the final analysis, 84% were installed for at least 121 days and 31% of the loggers were installed for at least 151 days. On average loggers were installed for 143 days.

Coefficient of Variation

Section 2.4 in the main report provides a summary of the coefficients of variation (CV) assumed when calculating the original onsite sample sizes, final sample sizes used in the analysis, the updated CV found by this study, and the sample size required by the updated CV to achieve 90/10 precision.[6] The team utilized a stratified sampling design and room specific CVs throughout the states to ensure adequate sample to model HOU at the room level, a household sample and CV has been calculated and presented for hypothetical purposes. Because the CVs for lighting were unknown during study design, the Team assumed a CV of 0.7 to calculate onsite sample size for specific rooms in which lighting use was expected to be fairly similar across the sample. For the "other" category of rooms, which included a number of miscellaneous rooms with various uses, a CV of 1.0 was used because the Team could not be confident that lighting usage would be consistent across the sample.

After completing the study and estimating HOU, the Team recalculated the observed CVs for each room type. Lighting use within each room type was more variable than the Sponsors and Team members anticipated, with CVs hovering around 1.0 but reaching as high as 1.38 for bathrooms and 1.6 for the "other" room type. Overall, the CV is 1.20. Further discussion of the CVs can be found in Section 2.4.

[5] The study received approval November 14, 2012. There were two notable storms that impacted the completion of onsite visits for this study: Superstorm Sandy and Winter Storm Nemo. Additional details on the impact of these storms on the study schedule can be found in Section 2.2.
[6] The CV is equal to the standard deviation divided by the mean.

Weighting

To account for differences in demographics and lighting inventories in the final sample and the population, the Team relied on a complex weighting scheme. For each logger, the Team applied a premise weight that controlled for home type (single-family or multifamily)[7] and income (low-income or non-low-income). Also at the logger level, the Team used room weights that adjusted for the total number of bulbs in a given room type as well as the total number of logged bulbs in each room type. Room-level weights were further broken out by efficient and inefficient bulb types. For a complete overview of weights, please see Section 2.5.

HOU Modeling

Developing HOU estimates consisted of three modeling steps:

- Creating annual datasets (Section 2.6.1)
- Adjusting HOU estimates (Section 2.6.2)
- Applying a hierarchical model (Section 2.6.3)

A summary of each modeling steps is included here in the Executive Summary. Detailed descriptions of each of the steps are included in Section 2.

Creating Annual Datasets. Since each logger was installed for only a portion of the year—between five and nine months—the Team had to annualize the data. To annualize the data the Team fit a sinusoid model to each logger.[8] The Team drew upon the methods outlined in the KEMA/Cadmus California Upstream Lighting Program Evaluation.[9] The Team fitted separate weekend and weekday models for each logger. For any loggers not conforming well to the sinusoid model, the analysts took additional steps to prepare annualized estimates based on average daily usage over the period logged (described in Section 2.6.1).

Adjusting HOU Estimates. Using the annualized estimates, the Team performed a weighted regression analysis to estimate the adjusted HOU for each room in each area of the study. In this step, only loggers for each individual area were used to develop area-specific estimates, and all loggers were used to develop estimates for the overall region. Based on outputs from this model, it was clear that Connecticut, Massachusetts, Rhode Island, and Upstate New York all had comparable usage patterns and that usage patterns for Downstate New York (including Manhattan) were significantly different.

Applying a Hierarchical Model. Due to the similar use patterns in four of the areas (CT, MA, Upstate NY, and RI), the Team sought a way to leverage data from each of these areas to refine

[7] To align with how the Sponsors define single family and multifamily programs, this study defines single family as: single-family detached, single-family attached, and two-to-four unit properties. Multifamily households are defined as properties with five or more units.

[8] The evaluators will provide an image of this model type in the final report, but a quick Google image search for “sinusoidal model” will show the shape.

[9] KEMA, Inc. and the Cadmus Group, Inc. *Final Evaluation Report: Upstream Lighting Program Volume 1*. Prepared for California Public Utilities Commission, Energy Division. February 8, 2010.

area-specific estimates. To accomplish this, the Team fit a multi-level hierarchical model. The advantage of this type of modeling approach is the ability to use information from all four areas to help inform area-specific estimates. In a hierarchical model, the observations specific to an area form the basis of the estimates for that area, while observations from outside that area also inform and help refine the area-specific estimates.[10,11] The hierarchal model is particularly beneficial for areas where fewer loggers were installed, thereby providing more refined (tighter precision and adjusted means) HOU estimates compared to individual models fit to each area separately.

Throughout this report, eight separate area estimates are presented—five produced by the hierarchical model and three produced by separate standalone models—as described in Section 2.6.3. For the sake of clarity, the team presents below a brief overview of the data informing each of the estimates, and the reader may find it helpful to refer to this overview when reading the summary of results that follows:

Hierarchical Models

Connecticut (CT): A product of the hierarchical model described in Section 2.6.3. The 549 loggers from Connecticut inform the core of Connecticut estimates. The core estimates were then refined through a hierarchical model that drew upon all loggers installed in Massachusetts, Rhode Island, and Upstate New York.

Massachusetts (MA): A product of the hierarchical model described in Section 2.6.3. The 2,175 loggers from Massachusetts inform the core of Massachusetts estimates. The core estimates were then refined through a hierarchical model that draws upon all loggers installed in Connecticut, Rhode Island, and Upstate New York.

Rhode Island (RI): A product of the hierarchical model described in Section 2.6.3. The 232 loggers from Rhode Island inform the core of Rhode Island estimates. The core estimates were then refined through a hierarchical model that drew upon all loggers installed in Connecticut, Massachusetts, and Upstate New York.

Upstate New York (UNY): A product of the hierarchical model described in Section 2.6.3. The 721 loggers from Upstate New York inform the core of Upstate New York estimates. This includes the 299 loggers from the National Grid *EnergyWise* Study. The core estimates were then refined through a hierarchical model that drew upon all loggers installed in Connecticut, Massachusetts, and Rhode Island.

Overall Excluding Downstate New York (Overall): A product of the hierarchical model described in Section 2.6.3, the Overall estimates collapse the modeled data from the four areas described above. The 3,677 loggers from Connecticut, Massachusetts, Rhode Island, and Upstate New York make up the core of Overall estimate. As with the other estimates above, the Overall estimate excludes all loggers from Downstate New York (including Manhattan).

[10] Cnaan, A., Laird, N.M., & Slasor, P. "Tutorial in Biostatistics: Using the Generalized Linear Mixed Model to Analyze Unbalanced Repeated Measure and Longitudinal Data." Statistics in Medicine 16 (1997): 2349-2380.
[11] Fitzmaurice, G.M., Laird, N.M., & Ware, J.H. *Applied Longitudinal Analysis, 2nd Ed*. New York: Wiley, 2011.

<u>Standalone Models</u>

Manhattan (MHT): A product of a standalone model (as described in Section 2.6.3), the 544 loggers from Manhattan inform the Manhattan estimates.

Downstate New York (DNY): A product of a standalone model (as described in Section 2.6.3), the 965 loggers from Downstate New York, including the 544 loggers from Manhattan, inform the Downstate New York estimates.

NYSERDA Service Area (NYSERDA): A product of a standalone model (as described in Section 2.6.3), the 1,686 loggers from New York—the 721 loggers from Upstate New York and the 965 loggers from Downstate New York (including the 544 loggers from Manhattan)—inform the NYSERDA Overall estimates.

Derivation of Load Curves

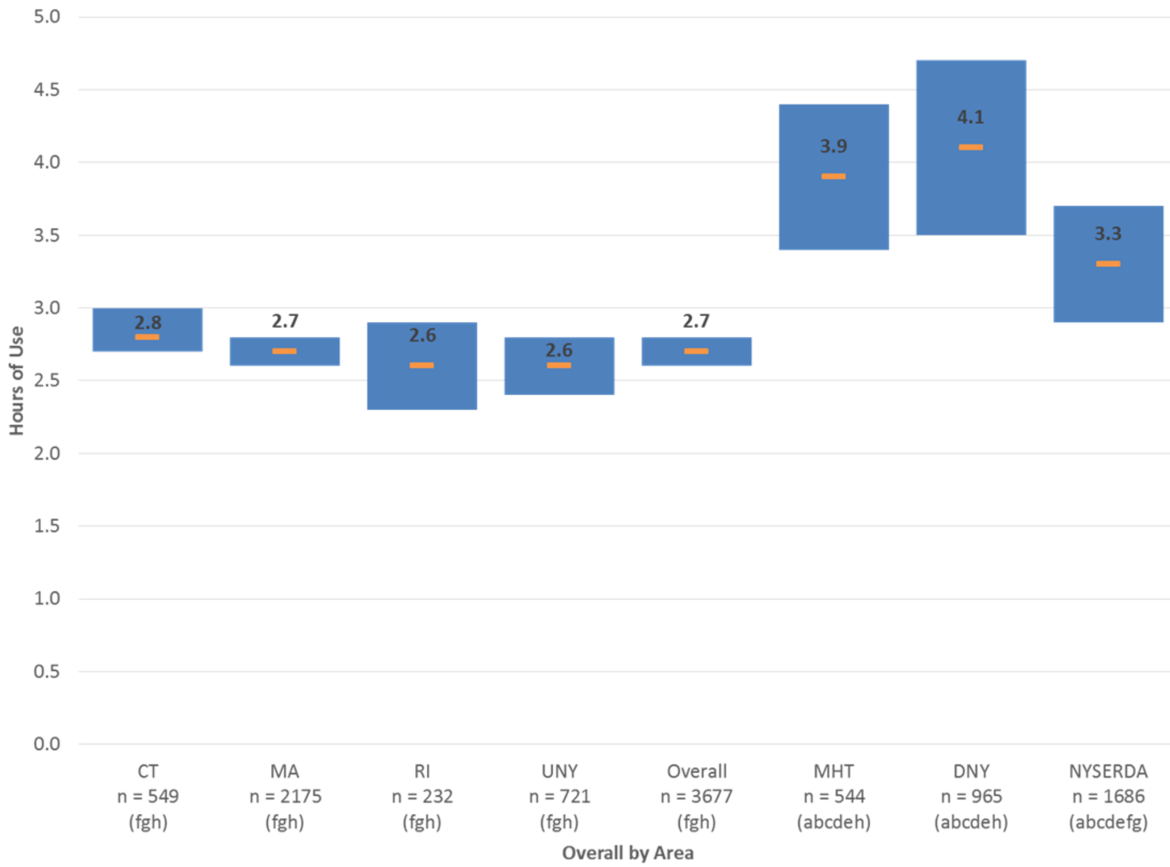
As with the HOU modeling, since each logger was installed for only a portion of the year—between five and nine months—the Team had to annualize the data to generate a full year of monthly load curves for the eight geographies included in the study. In general, adequate actual logged lighting load data were available for February through July for all areas. For any months lacking sufficient data, the Team modeled lighting usage as a function of average hours of daylight. This method relies on the relationship between lighting and average daylight hours. To compare the fit of the model, the Team compared the modeled load curves to actual load curves for months with sufficient data. Comparing the actual versus modeled load curves across 304 combinations of area, home type, and income the overall performance is quite good, with average root mean squared error (MSE) around 0.01. Additional discussion of these methods is included in Section 2.7.

HOU Analysis Results

When the Team began to analyze HOU across areas, it became apparent that the HOU estimates for Connecticut, Massachusetts, Rhode Island, and Upstate New York were all very similar and that the estimates for Manhattan, Downstate New York (which excludes Nassau and Suffolk Counties), and NYSERDA (a combination of Upstate and Downstate New York) diverged from the other areas. For reasons explained in detail in Section 2.6, the similarity of Connecticut, Massachusetts, Rhode Island, and Upstate New York justified their use in a hierarchical model that did *not* include the divergent areas of Manhattan or Downstate New York.

To simplify the discussion in this Executive Summary, the Team will first compare the four similar areas informed by the hierarchical model and then discuss the NYSERDA area standalone models. Figure E-2 below shows the household level daily HOU estimates for each of the eight models as well as the confidence intervals around the point estimates. Each of the five estimates from the hierarchical model is statistically similar to the others. Estimates for Manhattan and Downstate New York are statistically higher compared to the other models.

Figure E-2: Household HOU Estimates by Area[1,2]



[1] – The Overall model includes CT, MA, RI, and UNY. The Overall model excludes MHT and DNY.
[2] – The DNY model includes MHT.
Statistically different at the 90% confidence level from:

[a] – Connecticut
[b] – Massachusetts
[c] – Rhode Island
[d] – Upstate NY
[e] – Overall
[f] – Manhattan
[g] – Downstate NY
[h] – NYSERDA Overall

HOU Analysis Results – Hierarchical Models: All Bulbs

The Team found no significant differences in HOU estimates at the household level between any of the areas included in the hierarchical models. Even at the room level, only nine significant differences exist—discussed in detail in Section 3.2.1—out of 80 comparisons between the five sets of estimates obtained from the hierarchical model.[12] It is important to note that none of the areas are significantly different from each other at the household level, and even at the room level only one significant difference exists between the Overall model and any of the four areas included in the Overall model.

Further, the Team examined HOU estimates in these four areas by the following eight categories of home type and income levels:

[12] That is, the individual model for each of the four areas plus the overall model.

- Single-Family Households (SF)
- Multifamily[13] Households (MF)
- Low-Income Households (LI)
- Non-Low-Income Households (NLI)
- Low-Income Single-Family Households (LI SF)
- Low-Income Multifamily Households (LI MF)
- Non-Low-Income Single-Family Households (NLI SF)
- Non-Low-Income Multifamily Households (NLI MF)

The team then compared models for each category within an individual area. For example, the Team compared Massachusetts single-family household estimates to each of the other seven breakdowns for Massachusetts at the household level (28 separate comparisons for each area). Across the eight categories within a specific area there were only four significant differences. These four differences are discussed in detail in Section 3.3.

The Team also compared each of the eight categories across the five areas (i.e., each area and the Overall model). For example, the Team compared Massachusetts low-income households to low-income households in each of the other four areas (ten comparisons for each of the eight categories of home type and income). Across the areas, there were only three significant differences among the five areas, again discussed in detail in Section 3.3.

With such minor differences in HOU estimates across Connecticut, Massachusetts, Rhode Island, and Upstate New York and with relatively few differences at the home type and income level, ***the Team recommends that the Sponsors consider adopting the HOU room-by-room estimates from the Overall hierarchical model for all households regardless of income or home type***. This approach is echoed by the recently completed Massachusetts Low-Income Study and has the advantage of simplifying reporting and evaluations in the future. Table ES-1 provides the room-by-room estimates by area. Results are presented as *mean (90% CI)*.

[13] To align with how the Sponsors define single family and multifamily programs, this study defines single family as: single-family detached, single-family attached, and two-to-four unit properties. Multifamily households are defined as properties with five or more units.

Table ES-1: HOU Estimates by Area and Room – All Bulbs

Room	CT	MA	RI	UNY	Overall[1]
Bedroom	2.6 (2.2, 3.1) bdefg	2.0 (1.8, 2.3) afgh	2.6 (2.0, 3.3) dg	1.7 (1.3, 2.1) acfgh	2.1 (1.9, 2.3) afgh
Bathroom	1.5 (1.1, 2.0) fgh	1.8 (1.5, 2.0) fgh	1.2 (0.6, 1.8) fgh	1.9 (1.5, 2.4) fgh	1.7 (1.5, 1.9) fgh
Kitchen	4.6 (4.0, 5.1) fgh	4.0 (3.7, 4.3) fgh	3.8 (3.0, 4.5) fgh	4.1 (3.7, 4.6) fgh	4.1 (3.9, 4.3) fgh
Living Space	3.8 (3.3, 4.3) d	3.3 (3.0, 3.6) g	3.4 (2.7, 4.2)	3.1 (2.6, 3.5) afgh	3.3 (3.1, 3.6) g
Dining Room	3.2 (2.6, 3.9) f	2.7 (2.3, 3.1) fg	3.5 (2.6, 4.6)	2.5 (1.9, 3.1) fg	2.8 (2.5, 3.1) fg
Exterior	6.0 (5.6, 6.5) bdegh	5.5 (5.2, 5.8) acg	6.6 (6.0, 7.1) bdegh	5.5 (5.1, 5.8) acg	5.6 (5.3, 5.9) acg
Other	1.7 (1.4, 2.0) fgh	1.7 (1.5, 1.9) fgh	1.6 (1.2, 2.0) fgh	1.7 (1.4, 2.0) fgh	1.7 (1.6, 1.9) fgh
Household	2.8 (2.7, 3.0) fgh	2.7 (2.6, 2.8) fgh	2.6 (2.3, 2.9) fgh	2.6 (2.4, 2.8) fgh	2.7 (2.6, 2.8) fgh

[1] – The Overall model includes CT, MA, RI, and UNY. The Overall model excludes MHT and DNY.
[a] – Statistically different at the 90% confidence level from Connecticut
[b] – Statistically different at the 90% confidence level from Massachusetts
[c] – Statistically different at the 90% confidence level from Rhode Island
[d] – Statistically different at the 90% confidence level from Upstate NY
[e] – Statistically different at the 90% confidence level from the Overall model
[f] – Statistically different at the 90% confidence level from Manhattan
[g] – Statistically different at the 90% confidence level from Downstate NY
[h] – Statistically different at the 90% confidence level from NYSERDA Overall

HOU Analysis Results – Standalone NYSERDA Models: All Bulbs

Comparing Manhattan, Downstate New York, and NYSERDA (i.e., the combined Upstate and Downstate areas) to each other, there were only four statistically significant differences at the household level, the room level, or even among the eight home type and income categories. However, it is important to note that the all NYSERDA households (3.3) at the household level are significantly lower compared to both Manhattan and Downstate New York.

Further, the Team examined HOU estimates in these three areas by the following eight categories of home type and income levels:

- Single-Family Households (SF)
- Multifamily[14] Households (MF)
- Low-Income Households (LI)
- Non-Low-Income Households (NLI)
- Low-Income Single-Family Households (LI SF)
- Low-Income Multifamily Households (LI MF)
- Non-Low-Income Single-Family Households (NLI SF)

[14] To align with how the Sponsors define single family and multifamily programs, this study defines single family as: single-family detached, single-family attached, and two-to-four unit properties. Multifamily households are defined as properties with five or more units.

- Non-Low-Income Multifamily Households (NLI MF)

The team then compared models for each category within an individual area. For example, the Team compared Downstate New York single-family household estimates to each of the other seven breakdowns for Downstate New York at the household level (28 separate comparisons for each area). Across the eight categories within a specific area there were nine significant differences. Additional details on differences are discussed in in Section 3.3. Table ES-3 provides the room-by-room estimates by area. Results are presented as *mean (90% CI)*.

Table ES-2: HOU Estimates by Area and Room – All Bulbs

Room	MHT	DNY[1]	NYSERDA[2]
Bedroom	3.4 (2.9, 4.0) abde	3.6 (3.1, 4.1) abcdeh	2.8 (2.4, 3.2) bdeg
Bathroom	2.7 (2.2, 3.3) abcde	3.2 (2.4, 4.1) abcde	2.8 (2.2, 3.5) abcde
Kitchen	6.3 (5.6, 7.1) abcde	7.0 (5.8, 8.2) abcde	5.8 (5.0, 6.6) abcde
Living Space	3.9 (3.3, 4.6) d	4.5 (3.5, 5.4) bde	4.0 (3.3, 4.6) d
Dining Room	4.5 (3.6, 5.3) abdeh	4.0 (2.9, 5.0) bde	3.2 (2.5, 3.9) f
Exterior	--	3.6 (2.2, 5.1) abcde	4.7 (3.7, 5.7) ac
Other	3.4 (2.4, 4.5) abcde	3.2 (2.3, 4.1) abcde	2.4 (1.9, 2.9) abcde
Household	3.9 (3.4, 4.4) abcdeh	4.1 (3.5, 4.7) abcdeh	3.3 (2.9, 3.7) abcdefg

[1] – The DNY model includes MHT.
[2] – The NYSERDA model includes UNY and DNY (including MHT)
[a] – Statistically different at the 90% confidence level from Connecticut
[b] – Statistically different at the 90% confidence level from Massachusetts
[c] – Statistically different at the 90% confidence level from Rhode Island
[d] – Statistically different at the 90% confidence level from Upstate NY
[e] – Statistically different at the 90% confidence level from the Overall model
[f] – Statistically different at the 90% confidence level from Manhattan
[g] – Statistically different at the 90% confidence level from Downstate NY
[h] – Statistically different at the 90% confidence level from NYSERDA Overall

HOU Analysis Results – Special Considerations for NYSERDA

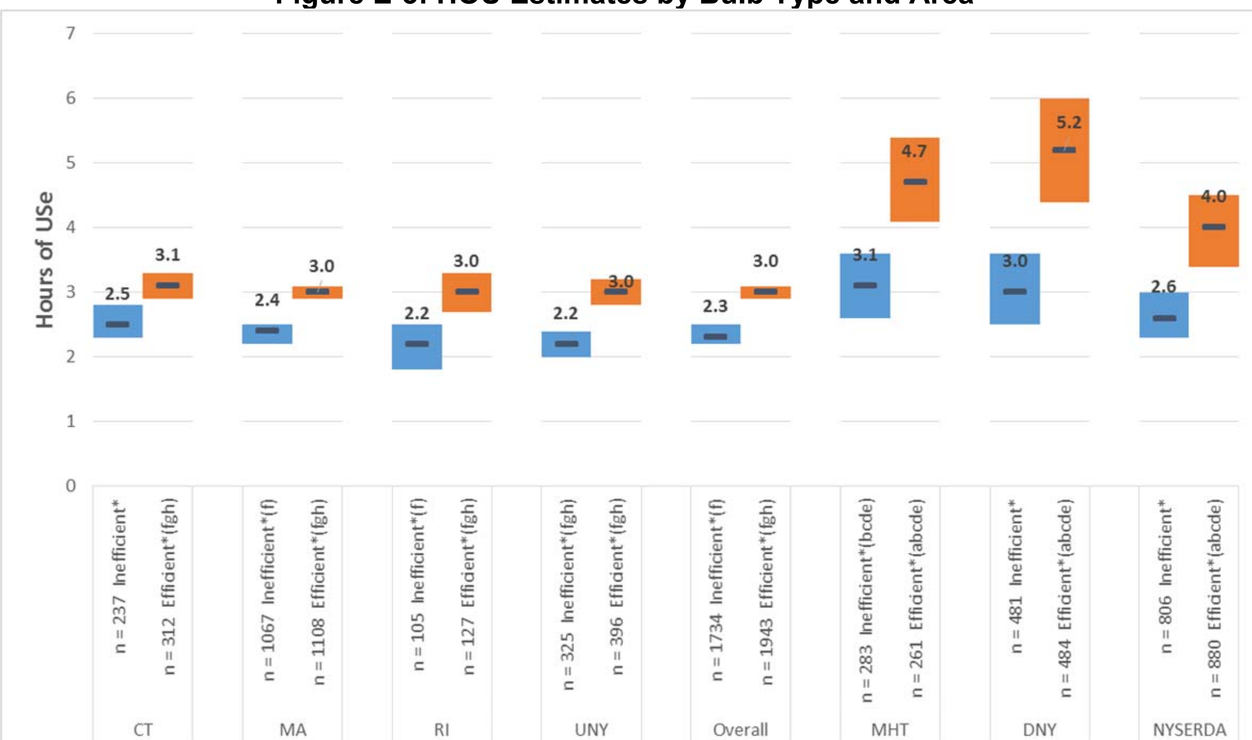
The models show that Downstate New York differs from Upstate New York. In fact, the divergence of Downstate New York is so strong that, when the Team combined both NYSERDA regions and compared the household HOU results between the combined NYSERDA area and Upstate alone, the models showed statistically significant differences. In short, if Downstate is in a model, it differs from Upstate New York—not to mention the other three states also included in this study. The divergence of Upstate New York and Downstate New York estimates and the vastly different housing stock and demographics in each area may help to explain the difference in the NYSERDA service area model. Given the divergence in HOU estimates and the fact that both Upstate and Downstate models are significantly different from the NYSERDA model, ***NYSERDA should consider adopting separate HOU estimates for Upstate New York and***

Downstate New York. The Team recommends that NYSERDA consider adopting the Overall model room-by-room estimates for Upstate New York presented in Table ES-1 and the Downstate New York model estimates presented in Table ES-2 for Downstate New York.

Inefficient versus Efficient Bulbs HOU

While the Team did not find many significant differences between areas, home types, and income types, it did uncover significant differences comparing HOU by bulb efficiency. HOU estimates for efficient bulbs are significantly higher than HOU estimates for inefficient bulbs within each of the eight individual models. Estimates for inefficient and efficient bulbs across the five sets of estimates obtained from the hierarchical model, are all statistically similar, meaning that use of inefficient bulbs does not vary much across the areas, and neither does use of efficient bulbs. Figure E-3 shows the HOU estimates by area broken out by the type of bulb (inefficient vs. efficient). Inefficient bulbs include halogens and incandescent bulbs, and efficient bulbs include CFLs, LEDs, and fluorescent bulbs. For each bulb type, the figure provides the means as well as the confidence intervals around the mean. Results are presented as *mean (90% CI)*.

Figure E-3: HOU Estimates by Bulb Type and Area



Statistically different at the 90% confidence level from:

a – Connecticut	e – Overall
b – Massachusetts	f – Manhattan
c – Rhode Island	g – Downstate NY
d – Upstate NY	h – NYSERDA Overall

The differences in bulb efficiencies may be evidence supporting one of three competing theories put forth by some lighting program implementers and evaluators about how households use efficient bulbs. The first theory, differential socket selection, is that households select higher-use locations for their high-efficiency light bulbs. The second theory, shifting usage, holds that a household installs an efficient bulb in a socket and then begins to use that socket in lieu of sockets containing inefficient bulbs. The third theory, increased usage, asserts that snapback occurs—using an efficient product more than the non-efficient one it replaced. However, this evaluation did not collect any data to determine which of these three theories is correct, or the proportion of the difference between efficient and inefficient HOU that is attributable to each type of behavior. In the absence of clear evidence supporting one theory over the others, the Team suggests assuming that the difference between efficient and all-bulb HOU is caused equally by the behavior posited by all three theories, with each accounting for one-third of the total difference between efficient and all-bulb HOU. The team thinks it would be reasonable for residential lighting programs to claim savings based on two of the three theories—differential socket selection and shifting usage—and reduce savings based on the third theory, increased usage (snapback). Therefore, the Team recommends adjusting efficient HOU by subtracting one-third of the difference between efficient and all-bulb HOU.

Table ES-3 and Table ES-4 present the efficient HOU estimates by room from the hierarchical model and the three standalone models. Table ES-5 and Table ES-6 present the HOU estimates adjusted for snapback. As with the all-bulb HOU estimates, the Team recommends that the Sponsors consider using the Overall model for Connecticut, Massachusetts, Rhode Island, and Upstate New York. NYSERDA should consider using two estimates: one for Upstate New York and one for Downstate New York.

Table ES-3: HOU by Area for Efficient Bulbs—Unadjusted for Snapback

Room	CT	MA	RI	UNY	Overall
Bedroom	2.8 (2.4, 3.3) bdefg	2.3 (2.0, 2.6) acfgh	3.1 (2.4, 3.7) bdefg	2.2 (1.7, 2.6) acfgh	2.4 (2.2, 2.6) acfgh
Bathroom	1.8 (1.3, 2.2) fgh	2.2 (1.9, 2.5) fgh	1.7 (1.0, 2.4) fgh	2.1 (1.7, 2.6) fgh	2.1 (1.8, 2.3) fgh
Kitchen	4.7 (4.2, 5.3) fgh	4.2 (3.9, 4.5) fgh	4.2 (3.4, 5.0) fgh	4.3 (3.9, 4.8) fgh	4.3 (4.1, 4.6) fgh
Living Space	4.0 (3.5, 4.5)	3.6 (3.3, 3.9) fg	3.7 (2.9, 4.5) g	3.3 (2.8, 3.8) fgh	3.6 (3.4, 3.9) fg
Dining Room	3.5 (2.9, 4.2) fg	3.1 (2.6, 3.5) fgh	3.9 (2.8, 5.0)	2.9 (2.3, 3.5) fgh	3.1 (2.8, 3.5) fgh
Exterior	6.7 (6.1, 7.3) bdegh	5.8 (5.5, 6.2) ac	6.7 (6.1, 7.4) bdegh	5.7 (5.2, 6.2) ac	6.0 (5.6, 6.3) ac
Other	2.0 (1.7, 2.3) fgh	2.0 (1.7, 2.2) fgh	1.7 (1.3, 2.1) fgh	2.0 (1.7, 2.3) fgh	2.0 (1.8, 2.1) fgh
Household	3.1 (2.9, 3.3) fgh	3.0 (2.9, 3.1) fgh	3.0 (2.7, 3.3) fgh	3.0 (2.8, 3.2) fgh	3.0 (2.9, 3.1) fgh

[1] – The Overall model includes CT, MA, RI, and UNY. The Overall model excludes MHT and DNY.
[a] – Statistically different at the 90% confidence level from Connecticut
[b] – Statistically different at the 90% confidence level from Massachusetts
[c] – Statistically different at the 90% confidence level from Rhode Island
[d] – Statistically different at the 90% confidence level from Upstate NY
[e] – Statistically different at the 90% confidence level from the Overall model
[f] – Statistically different at the 90% confidence level from Manhattan
[g] – Statistically different at the 90% confidence level from Downstate NY
[h] – Statistically different at the 90% confidence level from NYSERDA Overall

Table ES-4: HOU by Area for Efficient Bulbs—Unadjusted for Snapback

Room	MHT	DNY	NYSERDA
Bedroom	4.2 (3.3, 5.0) abcde	4.4 (3.6, 5.2) abcdeh	3.3 (2.8, 3.8) bdeg
Bathroom	3.5 (2.8, 4.3) abcde	4.6 (3.4, 5.8) abcde	3.6 (2.8, 4.5) abcde
Kitchen	6.7 (5.8, 7.6) abcde	7.7 (6.4, 9.0) abcde	6.3 (5.4, 7.1) abcde
Living Space	4.7 (3.9, 5.5) bde	5.1 (4.1, 6.2) bcde	4.3 (3.5, 5.0) d
Dining Room	5.4 (4.3, 6.4) abde	5.4 (4.1, 6.6) abde	4.1 (3.3, 4.9) bde
Exterior	--	4.8 (3.0, 6.6) ac	5.4 (4.3, 6.5) ac
Other	4.1 (2.9, 5.3) abcde	3.9 (2.8, 5.0) abcde	2.9 (2.2, 3.6) abcde
Overall	4.7 (4.1, 5.4) abcde	5.2 (4.4, 6) abcdeh	4.0 (3.4, 4.5) abcdeg

[1] – The DNY model includes MHT.
[2] – The NYSERDA model includes UNY and DNY (including MHT)
[a] – Statistically different at the 90% confidence level from Connecticut
[b] – Statistically different at the 90% confidence level from Massachusetts
[c] – Statistically different at the 90% confidence level from Rhode Island
[d] – Statistically different at the 90% confidence level from Upstate NY
[e] – Statistically different at the 90% confidence level from the Overall model
[f] – Statistically different at the 90% confidence level from Manhattan
[g] – Statistically different at the 90% confidence level from Downstate NY
[h] – Statistically different at the 90% confidence level from NYSERDA Overall

Table ES-5: HOU by Area Adjusted for Snapback

Room	CT	MA	RI	UNY	Overall
Bedroom	2.8 (2.4, 3.1) bdefg	2.2 (2.0, 2.4) acfgh	2.9 (2.4, 3.4) bdefg	2.0 (1.7, 2.3) acfgh	2.3 (2.1, 2.5) acfgh
Bathroom	1.7 (1.3, 2.0) fgh	2.0 (1.8, 2.3) fgh	1.6 (1.1, 2.1) fgh	2.1 (1.7, 2.4) fgh	2.0 (1.8, 2.1) fgh
Kitchen	4.7 (4.3, 5.1) bfgh	4.2 (3.9, 4.4) afgh	4.1 (3.5, 4.6) fgh	4.3 (3.9, 4.6) fgh	4.2 (4.1, 4.4) fgh
Living Space	3.9 (3.5, 4.3) dg	3.5 (3.3, 3.7) fgh	3.6 (3.0, 4.2) fg	3.2 (2.9, 3.6) afgh	3.5 (3.4, 3.7) fgh
Dining Room	3.4 (2.9, 3.9) fg	3.0 (2.6, 3.3) fgh	3.8 (3.0, 4.6) df	2.8 (2.3, 3.2) cfgh	3.0 (2.8, 3.3) fgh
Exterior	6.5 (6.0, 6.9) bdegh	5.7 (5.5, 6.0) acg	6.7 (6.2, 7.2) bdegh	5.7 (5.3, 6.0) ac	5.8 (5.6, 6.1) acg
Other	1.9 (1.7, 2.1) fgh	1.9 (1.7, 2.0) fgh	1.7 (1.4, 2.0) fgh	1.9 (1.7, 2.1) fgh	1.9 (1.8, 2.0) fgh
Household	3.0 (2.8, 3.2) fgh	2.9 (2.8, 3.0) fgh	2.9 (2.7, 3.1) fgh	2.8 (2.7, 3.0) fgh	2.9 (2.8, 3.0) fgh

[1] – The Overall model includes CT, MA, RI, and UNY. The Overall model excludes MHT and DNY.
[a] – Statistically different at the 90% confidence level from Connecticut
[b] – Statistically different at the 90% confidence level from Massachusetts
[c] – Statistically different at the 90% confidence level from Rhode Island
[d] – Statistically different at the 90% confidence level from Upstate NY
[e] – Statistically different at the 90% confidence level from the Overall model
[f] – Statistically different at the 90% confidence level from Manhattan
[g] – Statistically different at the 90% confidence level from Downstate NY
[h] – Statistically different at the 90% confidence level from NYSERDA Overall

Table ES-6: HOU by Area Adjusted for Snapback

Room	MHT	DNY	NYSERDA
Bedroom	3.9 (3.3, 4.5) abcdeh	4.1 (3.6, 4.7) abcdeh	3.2 (2.8, 3.5) bdefg
Bathroom	3.3 (2.7, 3.8) abcde	4.1 (3.3, 5.0) abcde	3.4 (2.8, 4.0) abcde
Kitchen	6.6 (5.9, 7.2) abcde	7.5 (6.5, 8.4) abcdeh	6.1 (5.4, 6.7) abcdeg
Living Space	4.4 (3.8, 5.0) bcde	4.9 (4.1, 5.7) abcde	4.2 (3.6, 4.7) bde
Dining Room	5.1 (4.3, 5.8) abcdeh	4.9 (4.0, 5.8) abdeh	3.8 (3.2, 4.4) bdefg
Exterior	--	4.4 (3.1, 5.7) abce	5.2 (4.4, 6.0) ac
Other	3.9 (3.0, 4.8) abcdeh	3.7 (2.9, 4.5) abcdeh	2.7 (2.3, 3.2) abcdefg
Overall	4.5 (4.0, 5.0) abcdeh	4.8 (4.3, 5.4) abcdeh	3.7 (3.4, 4.1) abcdefg

[1] – The DNY model includes MHT.
[2] – The NYSERDA model includes UNY and DNY (including MHT)
[a] – Statistically different at the 90% confidence level from Connecticut
[b] – Statistically different at the 90% confidence level from Massachusetts
[c] – Statistically different at the 90% confidence level from Rhode Island
[d] – Statistically different at the 90% confidence level from Upstate NY
[e] – Statistically different at the 90% confidence level from the Overall model
[f] – Statistically different at the 90% confidence level from Manhattan
[g] – Statistically different at the 90% confidence level from Downstate NY
[h] – Statistically different at the 90% confidence level from NYSERDA Overall

Load Shape Analysis

The Team developed hourly load shapes by month for each area based on logger data collected for the study. The Team also calculated coincidence factors (CFs) in two ways for each area:

1. Using the data that informed the monthly load shapes for the three New England states included in the study, the Team calculated CFs during the New England Independent System Operator (ISO-NE) summer and winter on-peak and Seasonal Peak hours. According to ISO-NE, the winter on-peak hours are during non-holiday weekdays from 5:00 to 7:00 PM. The summer on-peak hours are during non-holiday weekdays from 1:00 to 5:00 PM.[15]
2. The Team also prepared estimates based on peak data from the two Independent System Operators covering the area of the Sponsors.

[15] While NYSERDA does not fall within the ISO-NE area and is instead included at the New York Independent System Operator (NYISO), the New York technical manual published by the New York Department of Public Service (DPS) currently provides summer CFs based on the ISO-NE peak period. Therefore, the study provides updated CFs for NYSERDA areas during the same summer and winter peak periods.

a. The Team prepared estimates based on ISO-NE's 2013 Seasonal Peak Data for Connecticut, Massachusetts, and Rhode Island. According to the ISO-NE Seasonal Peak Data Summary, in 2013 the winter peak period occurred on January 24, 2013 at the hour ending 19 and the summer peak hour occurred on July 19, 2013 at the hour ending 17.
b. The Team prepared estimates based on the NYISO's peak hour. Based on NYISO actual load data for 2013, the peak occurred on July 7, 2013 at the hour ending 19.

Figure ES-4 displays one load curve in the Executive Summary as a visual accompaniment to the data presented in Table ES-7. Section 3.4.3 of the main document presents additional load curves for each area. In each load curve, the shaded area represents the relevant summer and winter peak periods (1:00 to 5:00 PM in the summer and 5:00 to 7:00 PM in the winter, based on the hour ending). The average percentage of bulbs turned on during summer and winter peak periods is shown in the upper left, and the calculated confidence interval is displayed for each hour. All of the load curves for each of the areas show a similar pattern of low usage starting around midnight, ramping up beginning in the hour ending at 6:00 AM, building until around noon, and then flattening off. In each area there is also a ramp-up in usage entering the evening hours at around hour ending at 6:00 or 7:00 PM (near the end of the winter peak period). ***As with HOU estimates, the team recommends that the Sponsors consider adopting the Overall load curve and resulting coincidence factors across Connecticut, Massachusetts, Rhode Island, and Upstate New York.*** In addition, unlike with HOU estimates, the all bulb and efficient bulb coincidence factors are statistically similar for the Overall model and as such there is no need to adopt an all bulb estimate and a separate efficient specific estimate. ***Turning to Downstate New York and Manhattan, the Team recommends that NYSERDA adopt the Downstate New York model to represent Downstate New York and Manhattan as the two models are statistically similar.*** Results in Table ES-7 are presented as *mean (90% CI)*.

The Team leaves it up to the Sponsors to decide when it is appropriate to use the winter and summer peak period estimates versus the ISO specific peak hour estimates. Both estimates are presented together in the tables below.

Figure ES-4: Overall Load Curve for Summer and Winter (Weekday) – All Bulbs

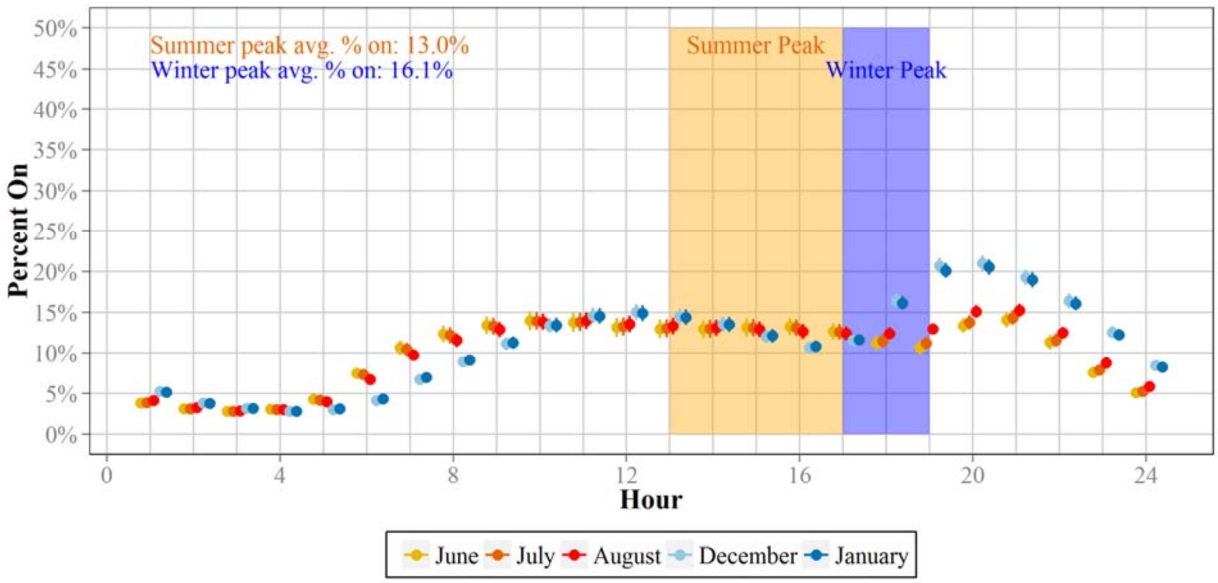


Table ES-7: Peak Period Coincidence Factors and Confidence Intervals – All Bulbs

Region	Winter Peak Period Dec. & Jan. (5 PM – 7PM)	Summer Peak Period June, July and August (1 PM – 5PM)	ISO-NE Seasonal Peak Hour (Winter) January 24, 2013 Hour Ending 19	ISO-NE Seasonal Peak Hour (Summer) July 19, 2013 Hour Ending 17	NYSO Peak Hour July 7, 2013 Hour Ending 19
CT	17% (15%, 19%) d	16% (13%, 18%) bd	22% (19%, 24%)	16% (13%, 18%)	n/a
MA	16% (15%, 17%)	12% (11%, 14%) ac	19% (18%, 20%)	12% (10%, 13%)	n/a
RI	16% (13%, 19%)	19% (15%, 24%) bde	19% (16%, 22%)	17% (13%, 21%)	n/a
UNY	14% (11%, 16%) ae	11% (9%, 13%) acf	n/a	n/a	9% (8%, 11%)
Overall[1]	16% (15%, 17%) d	13% (12%, 14%) c	20% (19%, 21%)	13% (12%, 15%)	n/a
MHT	27% (24%, 30%) h	17% (15%, 19%) h	n/a	n/a	19% (17%, 21%)
DNY	28% (25%, 31%) h	17% (15%, 19%) h	n/a	n/a	19% (17%, 21%)
NYSERDA	22% (19%, 24%) fg	14% (12%, 15%) fg	n/a	n/a	15% (13%, 16%)

[1] – For the ISO-NE Seasonal Peak Hours, the Overall estimates presented include only data from CT, MA, and RI.
[2] – The Overall model includes CT, MA, RI, and UNY. The Overall model excludes MHT and DNY.
[3] – The DNY model includes MHT.
[4] – The NYSERDA model includes UNY and DNY (including MHT)
[5] – In this table, significance testing is limited to comparing CT, MA, RI, UNY and Overall to each other and MHT, DNY, and NYSERDA.
[a] – Statistically different at the 90% confidence level from Connecticut
[b] – Statistically different at the 90% confidence level from Massachusetts
[c] – Statistically different at the 90% confidence level from Rhode Island
[d] – Statistically different at the 90% confidence level from Upstate NY
[e] – Statistically different at the 90% confidence level from the Overall model
[f] – Statistically different at the 90% confidence level from Manhattan
[g] – Statistically different at the 90% confidence level from Downstate NY
[h] – Statistically different at the 90% confidence level from NYSERDA Overall

Considerations

Consider Adopting the Overall model HOU and coincidence factors for CT, MA, RI, and Upstate New York

With such minor differences in HOU estimates across Connecticut, Massachusetts, Rhode Island, and Upstate New York and with relatively few differences at the home type and income level, the Team recommends that the Sponsors consider adopting the HOU room-by-room estimates from the Overall hierarchical model for all households in these four areas. The Overall model has the greatest level of precision owing to the larger sample sizes and is statistically similar to each of the individual area models on a room-by-room basis and by each of the eight categories of home type and income. By adopting room-by-room estimates, the Sponsors will have the flexibility to apply separate estimates based on specific program data. For example, if direct install program data include room type, the Sponsors can apply estimates for specific room types.

Further, room-by-room estimates provide the ability to update and revise HOU estimates periodically for upstream programs based on room-level socket saturation. For example, if saturation data indicate that saturation is increasing more quickly in kitchens relative to other room types, this would results in an increase to household HOU.

Consider Adopting Two Models for NYSERDA Area

Given the divergence of the Upstate New York model from both the Downstate and even the NYSERDA area model, NYSERDA should consider using the Overall hierarchical model (i.e., the four area model discussed above) for Upstate and the stand-alone Downstate New York for Downstate New York and Manhattan. NYSERDA may also want to consider whether or not higher lighting operating hours and coincidence factors among Downstate households may justify programmatic differences for Upstate and Downstate, such as higher incentives in the latter.

1 Introduction

The purpose of this study was to provide updated information to the Connecticut Energy Efficiency Board, the Massachusetts Program Administrators (Cape Light Compact, National Grid Massachusetts, Northeast Utilities, and Unitil), National Grid Rhode Island, and the New York State Energy Research and Development Authority (hereafter "the Sponsors") to assist in the calculations of demand and energy savings for lighting programs. Specifically, this report presents load shapes, coincidence factors (CFs), and daily hours of use (HOU).

The implementation of the Energy Independence and Security Act of 2007 (EISA) and the introduction of new technologies to the market—specifically, light-emitting diode bulbs (LEDs) and EISA-compliant halogens—are two indicators that residential lighting saturation is likely to change rapidly over the coming years. At the same time, changes in the composition of residential lighting means that HOU estimates based on individual bulb types are likely to become obsolete very quickly.

Unlike previous HOU studies, this study provides estimates not for a single technology or bulb type (e.g., compact fluorescent lamps [CFLs]), but by room type. This is based on the assumption that people are likely to use their lights in a given room the same way regardless of the types of bulbs in the room.

The following are the principal tasks completed as part of this project:

- Sample design
- Recruitment
- Onsite data collection
- Analysis and reporting

In addition to the data collected as part of the current study, referred to as the Base Study,[16] in the report the researchers also leveraged data collected as part of two concurrent studies: the *Massachusetts Low-Income HOU Study* (conducted by Cadmus) and the *National Grid New York EnergyWise Study* (conducted by DNV GL). Finally, NYSERDA funded an oversample of high-rise households in Manhattan that added to the comprehensiveness of the study. NMR, Cadmus, and DNV GL coordinated the development of protocols and methods to ensure comparable data. Table 1-1 provides an overview of the number of households included from each study by area. For a more detailed breakdown of households and loggers contributing to the study please see section 2.3.

[16] In this report Base Study refers to all data collection in Connecticut and Rhode Island and to a subset of data collection in Massachusetts and New York excluding: the High-Rise Oversample, the Cadmus Low-Income HOU Study, and the National Grid New York *EnergyWise* Study. Additional details on the breakdown of households and loggers from each study can be found in section 2.3.

Table 1-1: Households by State and Study

Bulb Type	Base Study	Low-Income Study	*EnergyWise* Study	High-Rise Study	Total
Connecticut	90	--	--	--	90
Massachusetts	137	261	--	--	398
New York	138	--	60	121	319
Rhode Island	41	--	--	--	41
Total	**406**	**261**	**60**	**121**	**848**

2 Methodology

This section describes the sample design, recruitment, onsite data collection, data preparation, the coefficient of variation, weighting, HOU modeling, derivation of load curves, and solar shading methodology.

2.1 Sample Design and Recruitment

This study included data collected in four separate states: Connecticut, Massachusetts, Rhode Island, and New York (excluding Nassau and Suffolk Counties). While the Team attempted to keep the sample similar in each area, the strategies differed somewhat both within and across areas. The evaluation team identified households for the onsites in three different ways: random-digit dial (RDD) telephone surveys, customer lists, and an address lookup. The reasons for these differences were primarily due to lack of customer lists for NYSERDA households and the need to maintain comparability to prior efforts in Massachusetts. For all areas except that covered by the Massachusetts Low-Income Study, households were recruited by telephone using Computer Assisted Telephone Interviewing (CATI).[17] The Massachusetts Low-Income Study obtained customer names and addresses from a list of customers receiving the low-income rate and did not have reliable phone numbers. Recruitment for this study was carried out using postcards that explained the study and encouraged customers to call to arrange an appointment.

In New York, NYSERDA funded the inclusion of an additional oversample of high-rise homes located in Manhattan. This sampling approach involved an oversample of high-rise apartments. To recruit the high-rise oversample, the evaluation team developed a list of high-rise buildings in Manhattan using the Primary Land Use Tax Lot Output (PLUTO™) database maintained by the City of New York Department of City Planning. The PLUTO data files contained information for 859,324 building locations across five boroughs in New York City (NYC).[18] Focusing on Manhattan, the evaluators identified 31,092 residential high-rise buildings with 868,942 units in Manhattan.[19] Based on the data contained within the PLUTO database, the evaluation team developed an initial sample stratified by age of building (vintage) and height, with a goal of completing visits to low-income households in proportion to their share of total units. Abt SRBI, NYSERDA's survey contractor, sent samples of addresses from the PLUTO database to Telematch. The Team used matched telephone numbers to conduct a CATI survey to recruit high-rise respondents.

Regardless of identification or recruitment method, the NMR team offered all potential study participants incentives that varied by area and study.

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[17] Massachusetts and New York Base Study households were recruited in conjunction with longer 15 minute consumer telephone surveys (analysis presented under separate cover).
[18] Each location may have multiple buildings.
[19] For the purposes of this study, high-rise buildings were defined as four stories or higher.

Table 2-1 provides an overview of the incentive levels and recruitment method and Figure 2-1 shows the locations of the sites included in the analysis overlaid on a population density map of the Northeast. Additional maps showing sites by income, housing type, and logger location are provided in Appendix B. Participants received two separate incentive checks, upon completion of the installation visit and one upon completion for a total incentive ranging from $150 to $250. Each incentive was roughly one-half of the total incentive amount. Finally, Table 2-2 provides the response rates for the recruiting surveys administered for the Base Study and the High-Rise Oversample. The Team provides response rate one and response rate three based on the American Association of Public Opinion Research's (AAPOR) standard response rate definitions.[20] As discussed earlier, the Team offered incentives and set aggressive recruiting goals for low-income and multifamily households to help reduce non-response bias. However, non-response bias is unavoidable and as with all survey efforts, the results of this study are subject to non-response bias.

Table 2-1: Recruitment Method[1]

Bulb Type	Install Incentive	Removal Incentive	Total Incentive	RDD	Customer List	Address Reverse Lookup
Connecticut	$50	$100	$150	✓		
Massachusetts						
Base Study	$150	$100	$250		✓	
Low-Income Study	$50	$100	$150		✓	
New York						
Base Study[2]	$150	$100	$250	✓		
High-Rise Study	$100	$100	$200			✓
EnergyWise Study	$50	$100	$150		✓	
Rhode Island	$50	$100	$150	✓		

[1] Difference in incentive levels were largely due to budgetary considerations and overlap with existing saturation studies in Massachusetts and New York which required longer installation visits.
[2] The same incentive was offered to Upstate and Downstate households. However, a different incentive level was offered to high-rise study participants in Manhattan.

[20] http://www.aapor.org/Standard_Definitions2.htm#.UyCfQIXvgcQ

Figure 2-1: Site Locations with Population Density

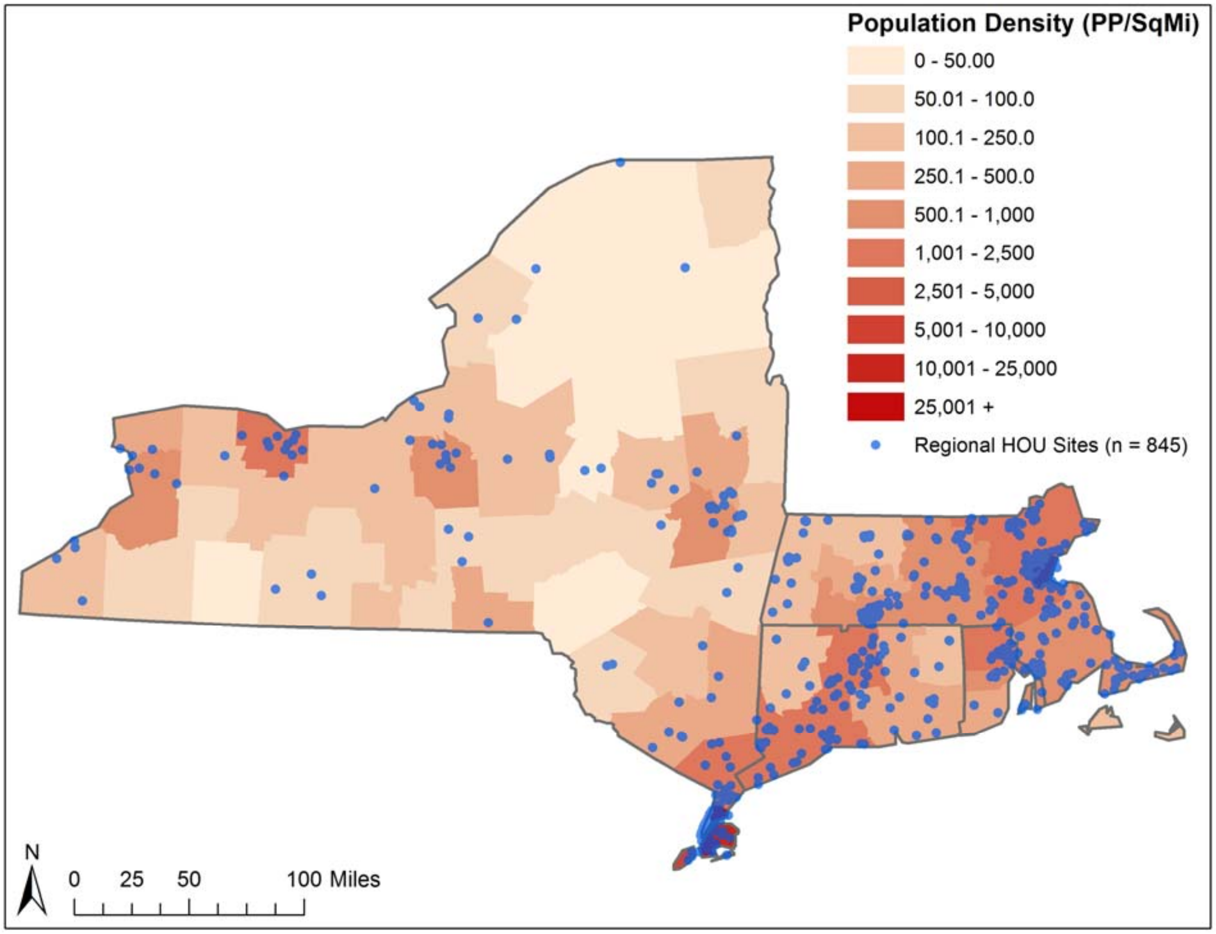


Table 2-2: Response Rates

Area	RR1	RR3
Connecticut	14%	16%
Massachusetts Base Study	47%	47%
New York		
Upstate New York	8%	12%
Downstate New York	7%	10%
Manhattan	8%	10%
Rhode Island	10%	12%

2.2 Onsite Visits

For this evaluation, the Team collected data through onsite visits to 848 homes located throughout Connecticut, Massachusetts, New York, and Rhode Island. All sites visited required two visits. During the first visit, the Team collected detailed lighting inventory data and installed time-of-use light meters (loggers). The second visit consisted of removing the loggers installed during the first visit.

Altogether, over 5,730 loggers were installed between November 2012 and September 2013. Logger installations were timed to be as close to the winter solstice as was practical given project constraints and the impact of winter storms. Additional details on the time period of logging is included in Section 2.2.2.

2.2.1 Impact of Storms

There were two storms that affected logger installation: Superstorm Sandy and Winter Storm Nemo.

Superstorm Sandy

In October 2012, Superstorm Sandy made landfall in the Northeast impacting nearly the entire area of the study. Given the devastation of the storm, especially in areas of Connecticut, Massachusetts, and New York City, the stakeholders decided to delay recruiting and subsequent onsite visits in these areas to allow households sufficient time to recover. This delay would have pushed recruiting into the December holiday period and so the stakeholders elected to delay until January 2013. The Team evaluated the impact of the storm on households in Rhode Island and determined to move forward with recruiting in November.

Winter Storm Nemo

In early February 2013, Winter Storm Nemo brought snow and rain to much of New England and New York. Snow fall was particularly heavy in Connecticut and parts of Massachusetts. In the week following the storm numerous visits were canceled or delayed. However, the majority of onsite visits were completed before the storm and so the storm had only a minor impact on the overall project schedule, extending installation visits by two weeks.

Since most of the loggers were installed before the storm, some stakeholders expressed concern that the storm might impact study results due to power outages (lower HOU) or households staying home from work (higher HOU). Given the relatively short period of recovery (two to three days) and the long period metering (six months or longer) the Team determined that the impact of the storm would be negligible. In addition, weather-related school closures and power outages are common in the Northeast and therefore reflect average lighting usage in any given year.

2.2.2 Logging Period

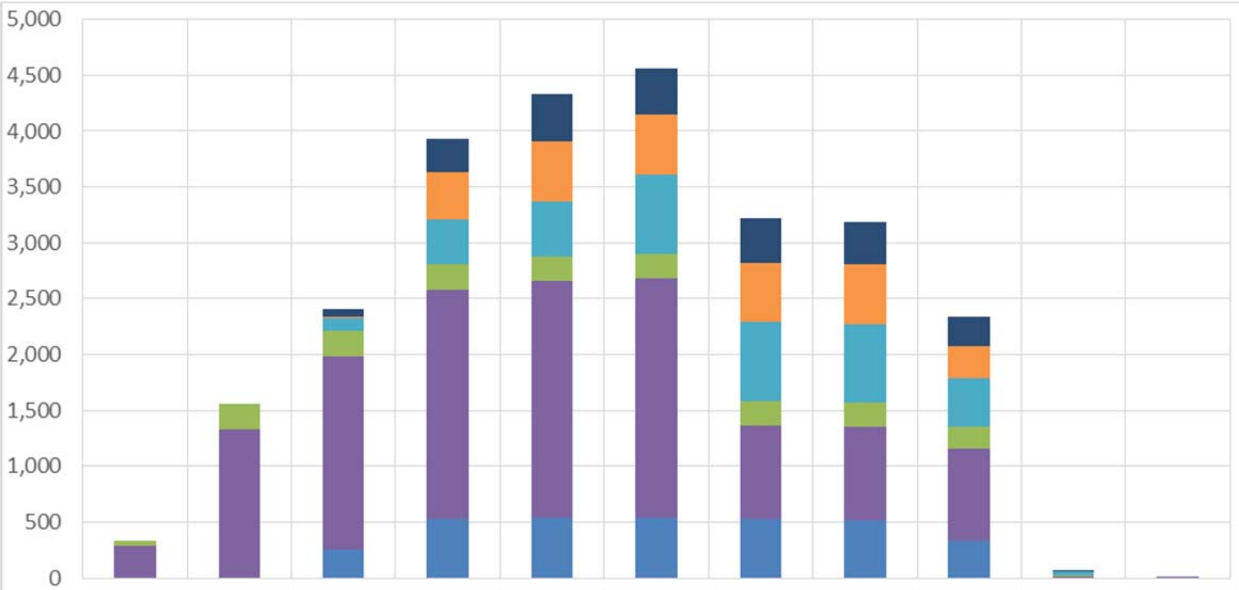
In total, the Team had loggers in the field for a ten month period beginning November 2012 and ending September 2013. However, note that relatively few loggers were in the field in November 2012, August 2013, and September 2013. This approach to logging a partial year is consistent with the guidelines recommended by the Uniform Methods Protocol for upstream lighting programs.[21] According to the protocols, "*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 for at least three months (that is, two waves of three-month metering will attain six months of data). All data should be annualizing techniques such as sinusoidal modeling to reflect a full year of usage.*" Details on annualization technique applied to collected data can be found in section 2.6.1.

Details on loggers installed by month can be found in Figure 2-2. Logger installation began November 26th in Rhode Island and Massachusetts and all of the loggers in Rhode Island were installed prior to December 21, 2012. Logger installation in the other areas began in January 2013 and was completed by April 2013. As the figure below shows, the time period with the greatest number of loggers deployed was between February and July 2013 (six months). A substantial number of loggers (greater than 1,500) were deployed in each month from December 2012 through July 2013 (eight months). As Figure 2-3 shows, of the 4,642 loggers included in the final analysis, 84% were installed for at least 121 days and 31% of the loggers were installed for at least 151 days. On average loggers were installed for 143 days. Loggers were installed on average for the following number of days in each area:

- CT – 147 days
- MA – 145 days
- RI – 216 days
- UNY – 123 days
- DNY – 132 days

[21] The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures. National Renewable Energy Lab. Subcontract Report NREL/SR-7A30-53827. April 2013.

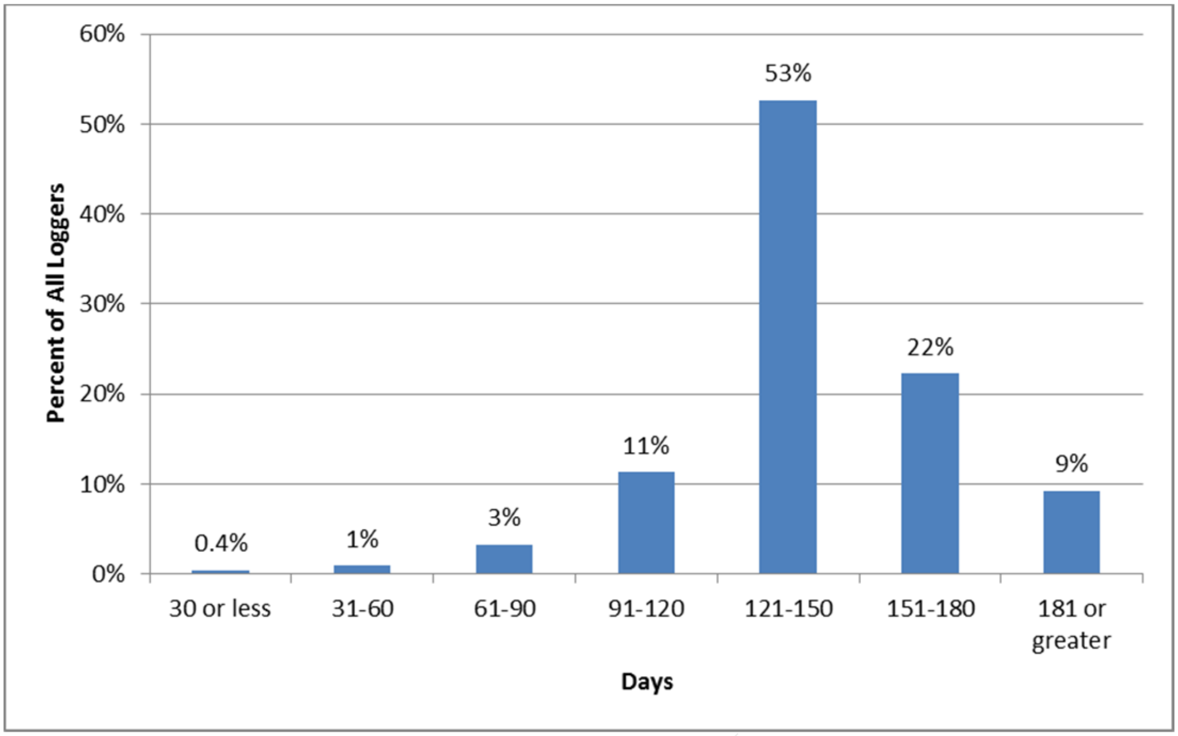
Figure 2-2: Loggers Installed by Month[1,2,3]



	Nov-12	Dec-12	Jan-13	Feb-13	Mar-13	Apr-13	May-13	Jun-13	Jul-13	Aug-13	Sep-13
DNY			73	294	419	410	400	387	270	7	
MHT			16	421	542	536	535	530	281	7	
UNY			108	399	487	710	705	699	431	27	
RI	50	229	230	227	224	222	219	217	200	15	
MA	284	1,335	1,736	2,060	2,110	2,138	831	835	824	13	6
CT			250	524	546	543	534	523	335	2	
Total	334	1,564	2,413	3,925	4,328	4,559	3,224	3,191	2,341	71	6

[1] Includes only those loggers used in the final analysis. Excludes loggers lost to attrition or excluded during cleaning.
[2] The Cadmus Low-Income Study began removing loggers in Massachusetts in April and completed removals by May 2013.

Figure 2-3: Percent of Loggers Installed by Number of Days



2.2.3 Data Collection – Initial Visit

During the initial onsite visits, a trained technician gathered detailed information on each socket in the home. This information differed slightly by area and included the following factors listed in Table 2-3. Note that this study does not include a complete analysis of lighting inventories data and instead focuses on HOU. However, complete analyses of lighting inventory data are presented under separate cover for Massachusetts and New York.[22,23]

[22] NMR, *Massachusetts Onsite Lighting Saturation Report.* Delivered to the Massachusetts Program Administrators on June 7, 2013.

[23] NMR, RIA, and Apex, *Draft Market Effects, Market Assessment, Process and Impact Evaluation of the NYSERDA Statewide Residential Point-of-Sale Lighting Program: 2010-2012.* Delivered to NYSERDA on December 13, 2013.

Table 2-3: Data Collected for Installed Bulbs by Area[1]

	NYSERDA Base Study	MA Base Study	MA Low-Income Study	RI	CT	NY High-Rise Study
Room Location	✔	✔	✔	✔	✔	✔
Primary Room	✔	✔		✔	✔	✔
Control Type/Specialty Features	✔	✔	✔	✔	✔	✔
Wall Mounted Control	✔	✔		✔	✔	✔
Multi Switch	✔				✔	
Fixture Type	✔	✔	✔	✔	✔	✔
Bulb Type	✔	✔	✔	✔	✔	✔
Bulb Shape	✔	✔	✔	✔	✔	✔
Socket Type	✔	✔	✔	✔	✔	✔
Wattage	✔	✔				✔
Manufacturer and model number (CFLs and LEDs only)	✔	✔				✔
Where and When Purchased (CFLs and LEDs only)	✔	✔				✔
What type of bulb was replaced (CFLs and LEDs purchased in past year)	✔	✔				✔

[1] Analysis of these variables is included in the separate lighting saturation studies presented in Massachusetts and New York.

A typical onsite visit proceeded as follows: A trained technician arrived at the home at a pre-scheduled time, introduced him- or herself, and asked for the contact person who had been identified when scheduling the visit. To ensure uniformity in data collection and facilitate quality control checks,[24] the technician walked around the outside of the home in a clockwise direction, recording all information on exterior lighting sockets. Next, the technician proceeded through the inside of the home in a clockwise direction, beginning with the foyer (entryway) and going through each room and part of the home systematically. If the product was a CFL or LED, the technician noted its manufacturer and model number and any specialty features. The technician also asked the respondent to estimate when he or she had purchased that particular CFL or screw-base LED. The technician and householder also examined all light bulbs in storage, again noting similar detailed information on stored LEDs and CFLs and asking the householder the specific reason why he or she had bought the stored bulbs. Lastly, the technician installed lighting loggers on fixtures in targeted room types using a predetermined random selection methodology. The lighting inventory portion of the visits typically took less than two hours.

The Team installed an average of seven loggers per home—eight for single-family homes and six for multifamily homes. Loggers were placed on unique circuits (a circuit is a set of bulbs or

[24] The Team completed quality control revisits on 5% of the sample homes to ensure the reliability and validity of all procedures and data collection. The quality control visits revealed no evidence of systematic errors in data collection.

fixtures operated by the same switch) throughout each home with a goal of installing one logger in each of the following room types for single-family homes: dining rooms, exteriors, living spaces, bedrooms, bathrooms, and kitchens, and two loggers in other room types. Protocols for multifamily homes were similar except for dining rooms and exteriors, which were included in other room types.

Participants were provided with an incentive check for roughly one-half of the total incentive upon completion of the installation visit. Additional details on incentive levels can be found in section 2.1.

2.2.4 Data Collection – Logger Retrieval

During the onsite visits to remove the loggers, the technician was provided with pre-filled forms containing the logger ID number, room, fixture type, bulb type, bulb shape, and socket type for each logger installed at each site. The technician confirmed the characteristics for each bulb and performed a state test to determine whether or not the logger had accurately recorded event data during the time it was installed. Additional information recorded upon retrieval included:

- Total time shown on the logger
- Any changes to the bulb, logger, or fixture during the time the logger was installed as reported by the homeowner
- The homeowner's estimated typical usage for each monitored fixture

Altogether, 5,730 loggers were installed between November 2012 and March 2013. Logger installations were timed to coincide with the winter solstice, and all of the loggers in Rhode Island were installed prior to December 21, 2012. Logger installation in the other areas began in January 2013 and was completed by the end of March 2013. In total, 5,730 loggers were installed. Logger retrieval began in June 2013 and continued through September 2013. Attrition due to customers moving, damage to loggers, and lost loggers reduced the sample by about 4%.

Participants were provided with an incentive check for roughly one-half of the total incentive upon completion of the removal visit. Additional details on incentive levels can be found in section 2.1.

2.2.5 Quality Assurance and Control

In all of our work, NMR endeavors to maintain a high quality work product. The sensitive nature of onsite work means that special precautions must be taken to ensure the quality of data collected and avoid jeopardizing the relationship the Sponsors have with their customers. To that end, the Team employed a number of steps to ensure that onsite technicians performed quality work that reflected well on NMR and our clients.

The Team's quality control and standard operating procedures began well before a field technician ever set foot in a customer's home. All of the field technicians received rigorous project-specific training. Training topics included project background, project-specific data collection protocols, and customer service and interaction training. Scheduling staff were also provided with an overview of this training so that they knew what customers would expect when they agreed to participate and were able to answer any questions the customers had. Every effort was made to ensure that customers were fully informed and that unnecessary surprises were avoided.

Below, is an outline of some of the specific quality control and training measures the Team utilized for the Northeast Residential Lighting HOU Study. Note that for the Massachusetts Low-Income Study, Cadmus performed all site visits and followed their own training protocols. Cadmus and NMR worked closely together to develop protocols that were similar. NMR staff performed all of the visits in Connecticut, Rhode Island and Downstate New York (including Manhattan). NMR and KEMA staff both performed visits in Upstate New York with NMR staff completing the base study visits and KEMA staff completing a separate set of visits with National Grid *EnergyWise* multifamily participants.

Quality Control and Training Measures

- All field staff received training using training materials successfully implemented in similar onsite lighting saturation studies but tailored to the unique needs of the Northeast Residential Lighting HOU Study. Training included instruction on the following:
    - Identify various types and shapes of sockets, light bulbs, and controls
    - Examine light bulbs in a safe manner, including instructions on what equipment to bring to a home, working with covered fixtures, and clean-up of broken lamps (especially for CFLs and fluorescents) and compensation for bulbs and fixtures accidentally damaged during the visit
    - Ensure that they have located and inventoried all light bulbs (including stored bulbs) in the home through such procedures as creating a home schematic, mapping their route through the home, and documenting difficult-to-characterize lighting with pictures.
    - Correctly set up, install, and remove lighting loggers
- Training also included some background on EISA and its requirements so that the field technician could answer questions he or she might receive on this topic while performing the inventory.
- The NMR project manager or a designated team member accompanied each field technician on his or her first day of site visits.
- The NMR project manager or a designated staff member recruited participants and scheduled appointments, assigning them to field staff based on location and work load.
- Each field staff member was required to report his or her progress at the end of each day and input the completed onsite data into a shared document site for the NMR project manager for review.

In addition to reviewing the onsite forms, NMR staff called 20% of participants to ensure that their experience with the field technician was satisfactory. The Team also revisited approximately 5% of the homes in each area of the study, where the NMR project manager or a designated team member, who had not previously visited the home, repeated the data collection and observed logger installation to make sure the technician had performed all tasks in a satisfactory manner.

2.3 Sample Attrition, Data Cleaning, and Outlier Detection

When planning the study, the Team assumed that some attrition would take place due to loggers being damaged, stolen, or being otherwise unrecoverable. As Table 2-5 shows, the Team installed 5,730 loggers and obtained data for 5,494 loggers—2,627 from the base study and 2,867 from the following three studies combined: the Massachusetts Low-Income Study, the National Grid NY *EnergyWise* Study, and the NYSERDA High-Rise Study. For each logger, the HOU for each day of the study period was calculated. NMR performed quality assurance and quality control on the daily logger data. Loggers with extremely frequent on/off records (flickering) or loggers that were on for over three consecutive weeks were identified for potential removal, as were loggers with unusable read data (e.g., dates outside of the study period or corrupt logger IDs). The Team cross-checked loggers with extremely high or extremely low usage with participant self-reported use data as collected by field technicians while onsite during the removal visit.

Self-reported usage data were collected in the Rhode Island, Connecticut, NYSERDA, and Massachusetts Low-Income Study sites. For each logger collected, homeowners were asked to estimate the average daily usage individually for each light metered. Homeowners provided either specific estimated hours of use per day or a general estimation, such as frequent or infrequent use. Table 2-4 shows the self-reported estimate along with the # of loggers for which a specific estimate was provided and the actual average HOU recorded for those loggers. For example, for 191 loggers households said they used the light less than one hour per day and for those same 191 loggers the average recorded usage was 1.03 per day. While respondents were not completely accurate with their estimations, for the most part they were able to describe the relative magnitude of lighting usage by bulb. It is important to note that Massachusetts Base Study households were not asked to provide self-reported estimates. The question was inadvertently left out of the final removal visit protocols.

Table 2-4: Estimated Usage vs. Average HOU Recorded

Self-Reported Estimate	# of Loggers	Avg HOU Recorded
Total # of Loggers	*3,506*	*3.06*
Less than 1 hour per day	191	1.03
1-2 hours per day	392	2.30
3-4 hours per day	274	4.06
5-6 hours per day	333	4.12
7-9 hours per day	59	7.85
10-14 hours per day	63	10.45
15-20 hours per day	29	10.33

24 hours per day/always	45	9.24
Never/Almost never	90	1.23
Infrequent Use	1,294	1.86
Frequent Use	504	4.13
Don't know	232	3.06

The Team was very careful in identifying and removing loggers with HOU values that might be considered outliers. While some loggers did indeed record very high usage over the study period, the percentage of these loggers was small. Using a relatively standard, albeit conservative, cutoff of 3.0 times the interquartile range of HOU (broken out by room type), roughly 2% of all loggers would have been deemed outliers. However, it is also true that different people/households can exhibit very different usage patterns for any number of reasons, and it is not unlikely that the loggers exhibiting higher than ordinary usage represent some small portion of the actual population. Therefore, the Team adopted a very conservative approach, and the only "outliers" removed were those for which it was not reasonable to assume the recorded data were correct—namely, those that exhibited obvious flickering or that were on continuously for over three consecutive weeks *and* whose unexpectedly high observed usage did not agree with self-reported usage for the bulb in question, as discussed above. Ultimately, all preliminary data cleaning resulted in the removal of 364 loggers, leaving 5,130 loggers across all areas.

The Team then created a dataset for analysis by merging logger data with household demographic data that included the following: education, income, home type (single-family and multifamily), tenure, and presence of children under the age of 18 in the home. Loggers that were missing all demographic data or had corrupt IDs were dropped. Of the 5,130 loggers included after Step 1 (cleaning), an additional 488 loggers (most from the Massachusetts Low-Income Study) had to be dropped because they were missing one or more of the variables that contributed to the regression analysis, or because they had corrupt IDs. This left us with a total of 4,642 loggers for analysis.

The Massachusetts Low-Income Study loggers were most affected by data cleaning. Ultimately only 68% of all Low-Income Study loggers installed were included in the analysis presented in this report. Nearly all of the loggers were retrieved (99%)[25] but between missing demographic data and data cleaning nearly one-third of the loggers (31%) were excluded from the final analysis.

[25] The Massachusetts Low-Income Study had a much shorter logging period which led to decreased attrition from customers moving, damaged loggers, or lost loggers.

Table 2-5: Logger Counts with Attrition

Bulb Type	Homes	Loggers Installed	Loggers Retrieved	Retrieved Loggers as a Percent of Installed	Loggers Modeled	Modeled Loggers as a Percent of Installed
Connecticut	90	613	579	94%	549	90%
Massachusetts						
Base Study[1]	137	941	941	100%	837	89%
Low-Income Study	261	2,000	1,975	99%	1,338	67%
New York						
Base Study	138	964	849	88%	843	87%
High-Rise Oversample[2]	121	615	593	96%	544	88%
EnergyWise Study	60	320	299	93%	299	93%
Rhode Island	41	277	258	93%	232	84%
Total	**848**	**5,730**	**5,494**	**96%**	**4,642**	**81%**

[1] The Massachusetts Base Study includes both low-income and non-low-income households. Low-income households included in the Base Study are in addition to those included in the Low-Income Study.
[2] Eleven of the homes included as part of the New York Base Study were located in Manhattan. After attrition nine of these eleven homes remained bringing the total number of Manhattan households to 130.

2.4 Sample and Coefficient of Variation

The Team employed two different coefficients of variation (CVs) when designing the sample for single-family, multifamily, and high-rise homes.[26] Because the CVs for lighting were unknown ahead of time, the Team turned to the Independent System Operator of New England (ISO-NE) for guidance.[27] The ISO-NE suggests using a CV of 0.5 for homogeneous populations (i.e., ones that exhibit similar behavior) and 1.0 for heterogeneous population (i.e., ones that behave differently). After some discussion, the Sponsors and the Team decided to employ a CV of 0.7 to calculate onsite sample size for specific rooms (bedroom, bathroom, kitchen, living room, dining room, and exterior) in which lighting use was expected to be fairly similar across the sample. For the "other" category of rooms, which included a number of miscellaneous rooms with various uses, a CV of 1.0 was used because the Team could not be confident that lighting usage would be consistent across the sample. Utilizing the two CVs, the Team calculated a specific room sample size of 133 loggers and "other" room sample size of 271 loggers based on a 90% confidence level and a 10% acceptable margin of error.

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[26] The CV is equal to the standard deviation divided by the mean.
[27] ISO New England Inc. 2012. *Measurement and Verification of Demand Reduction Value from Demand Resources: Manual M-MVDR*. Revision 4, effective June 1, 2012.

After completing the study and estimating HOU, the Team recalculated the CVs for each room type. As shown in Table 2-6, lighting use within each room type was more variable than the Sponsors and Team members anticipated, with CVs hovering around 1.0 but reaching as high as 1.38 for bathrooms and 1.6 for the "other" room type. Overall, the CV is 1.20. The Team also calculated updated CVs for the sub-groups utilized in the analysis, and they also exhibit a fair amount of heterogeneity in use by room type (Table 2-7). Therefore, moving forward, the Team recommends that evaluators utilize a CV of at least 1.2 for each area of interest (e.g., each room type or each sub-group in the population) and possibly as high as 1.5 to ensure an adequate sample size. In fact, if sampling very specific room types or sub-groups, the CV may need to be even greater.[28]

Table 2-6: Original and Updated Coefficient of Variation

	Original Assumed CV	Final Sample Size Utilized in Analysis (# of Loggers)	Standard Deviation of Average HOU	Mean HOU	Updated CV	Sample Size using Updated CV (# of Loggers)
Bathroom	0.7	700	2.98	2.16	1.38	515
Bedroom	0.7	913	2.78	2.42	1.15	358
Dining Room	0.7	401	3.43	3.13	1.10	327
Exterior	0.7	184	4.52	5.08	0.89	214
Kitchen	0.7	751	4.26	4.59	0.93	233
Living Space	0.7	742	3.59	3.45	1.04	293
Other	1.0	951	2.96	1.85	1.60	693
Total	--	4,642	--	--	--	1,940
Household	1.0	271	2.95	3.54	1.20	390

[28] Sample sizes by room and area are included in the body of the report in Table 3-2.

Table 2-7: Updated Coefficient of Variation by Sub-sample

	SF	MF	Low Income	Non-low Income	SF Low Income	SF Non-low Income	MF Low Income	MF Non-low Income	Efficient Lighting	Non-efficient Lighting
Bathroom	1.36	1.36	1.32	1.45	1.28	1.40	1.35	1.36	1.34	1.36
Bedroom	1.23	1.05	1.15	1.15	1.18	1.33	1.10	1.01	1.15	1.12
Dining Room	1.16	1.00	1.12	1.08	1.13	1.19	1.12	0.92	1.02	1.14
Exterior	0.87	1.31	0.95	0.80	0.93	0.80	1.82	0.39	0.87	0.91
Kitchen	0.95	0.90	1.01	0.84	1.01	0.85	0.99	0.82	0.91	0.96
Living Space	1.06	1.01	1.03	1.05	1.03	1.07	1.00	1.02	0.97	1.10
Other	1.63	1.52	1.63	1.55	1.63	1.62	1.60	1.44	1.59	1.58

2.5 Weighting

The Team applied a fairly complex weighting scheme to accommodate the four states and to control for home type and income level. The following weighting factors were developed:

Premise weights are based on four demographic characteristics collected during recruitment:

- Home type: single-family (one-to-four units) or multifamily (five or more units)[29]
- Income: low-income or non-low-income

Multifamily and low-income households are two groups that are often underrepresented in lighting evaluations. To ensure an adequate sample of households and loggers were included in the study, the Team oversampled both multifamily and low-income households.

Room weights are based on the total number of bulbs in each room as well as the total number of logged bulbs in each room type. The weights include breakdowns for the following room types and are further broken out by room type and whether the bulb is an LED, CFL, or fluorescent tube ("efficient bulb" versus an incandescent or halogen ("inefficient bulb"):

- Single-family homes: bathroom, bedroom, dining room, exterior, kitchen, living room, and all other rooms.
- Multifamily homes: bathroom, bedroom, kitchen, living room, and all other rooms.

The Team created separate weights for Connecticut, Massachusetts, and Rhode Island. For New York, separate weights for Upstate New York, Downstate New York, and Manhattan, were developed, as well as an overall NYSERDA service-area weight that includes Manhattan.

For single-family homes, HOU estimates are based on only those loggers installed in single-family homes, and similarly multifamily estimates are based on only loggers installed in multifamily homes. Because the evaluators made a point of ensuring adequate representation from multifamily and low-income households when creating the sample, it was also necessary to develop a premise weight that incorporates home type as well as income status. The premise weight is based on demographic data specific to each individual state or area.

In addition to the individual state weights described above, the Team prepared a combined overall Northeast weight that incorporates the combined demographic characteristics of all states included in the study.

Below, is an example to illustrate the various components of the weighting scheme:

[29] To align with how the Sponsors define single family and multifamily programs, this study defines single family as: single-family detached, single-family attached, and two-to-four unit properties. Multifamily households are defined as properties with five or more units.

Example: In New York the sampled included 306 homes—90 single-family and 216 multifamily. The bulb and logger counts for New York multifamily and all multifamily properties included in the study are included in Table 2-8.

Table 2-8: Weighting Example

	New York Multifamily: All Rooms		New York Multifamily: Bathrooms		All Multifamily All Areas: All Rooms[1]		All Multifamily All Areas: Bathrooms[1]	
Area	**All**	**Metered (TB)**	**All**	**Metered (TRB)**	**All**	**Metered (TM)**	**All**	**Metered (TRM)**
Total Bulbs	5,201	1,198	849	237	9,342	2,526	1,526	433
Efficient Bulbs	1,749	660	252	130	3,484	1,370	482	222
Inefficient Bulbs	3,452	538	597	107	5,858	1,156	1,044	211

[1] Includes all multifamily homes in the entire study across all states, except the *EnergyWise* Multifamily homes were excluded from weighting because they were program participants and had higher relative efficient saturation levels.

To calculate the bathroom weight for multifamily homes in New York, the following formula was applied:

Efficient bulb weight: $\frac{TRB/TB}{TRM/TM} = \frac{130/660}{222/1{,}370} = 1.215534 \frac{\mathrm{TRB/TB}}{\mathrm{TRM/TM}} \frac{252/1749}{140/880} = 0.90566$

Inefficient bulb weight: $\frac{TRB/TB}{TRM/TM} = \frac{107/538}{211/1{,}156} = 1.089625 \frac{597/3452}{164/825} = 0.869989$

Where:

TRB = total bulbs in a given room type (specific to a given state)

TB = total bulbs in all rooms (specific to a given state)

TRM = total bulbs metered in a room (based on all homes across four states)

TM = total metered bulbs in all rooms (based on all homes across four states)

This process was repeated for each room type among multifamily homes and then again among single-family homes. To combine single-family and multifamily HOU estimates, the Team prepared premise weights based on the Census data specific to each individual state or area included in the study.

During the course of the analysis, it became apparent to the evaluators that the Downstate New York and Manhattan High-Rise sample behaved differently than the rest of the sample; for this reason, the Downstate New York and Manhattan weights were consistently treated differently than the rest of the areas. The Downstate New York and Manhattan samples are not included in other areas' premise or room weight calculations and the Downstate New York and Manhattan room weights are not leveraged against the entire sample and only refer to Downstate New York and Manhattan in the weighting formula. The detailed weighting tables are included in Appendix D.

2.6 HOU Modeling

2.6.1 Annualized HOU Estimates

Since each logger was installed for only a portion of the year—143 days on average—the Team had to annualize the data. This was accomplished by fitting a sinusoid model individually to each logger.[30] The Team drew upon the methods outlined in the KEMA/Cadmus California Upstream Lighting Program Evaluation,[31] which are summarized here. Separate weekend and weekday models were fitted for each logger. For any loggers not conforming well to the sinusoid model, the analysts took additional steps to prepare annualized estimates based on average daily usage over the period logged (described below). The sinusoid model for each logger took the following form:

$$h_d = \alpha + \beta\sin(\theta_d) + \varepsilon_d$$

Where

h_d = hours of use on day d,

θ_d = angle for day d, where θ_d is 0 and the spring and fall equinox, $\pi/2$ for d = December 21, and $-\pi/2$ for d = June 21,

α and β are regression coefficients,

ε_d is the residual from the regression.

In each model, α represents the average weekday (or weekend day) use for a given logger. Because a weekday model and a weekend model were fitted for each logger, the Team calculated the overall average usage for the year for each logger as a weighted average of the α from the weekday model and the α from the weekend model (see below for more detail).

As in the KEMA/Cadmus CA Upstream Lighting report,[31] model fits with an estimated β coefficient having absolute value greater than 10 and those whose standard error for β was greater than one were classified as "poor." Additionally, The Team classified as "poor" any fits yielding an annual average (α) less than or equal to zero or greater than 24. A summary and discussion of the results from the annualization models fitted to each logger can be found in Appendix E.

In both the weekday and weekend models, the average yearly weekday/weekend value for each poor-fitting logger was set to the average daily weekday/weekend usage over the period for which the logger had data available rather than the estimated intercept (α) from the corresponding regression model. The Team then calculated the overall average annual daily

[30] Additional details on the logging period are included in Section 2.2.2.
[31] KEMA, Inc. and the Cadmus Group, Inc. *Final Evaluation Report: Upstream Lighting Program Volume 1*. Prepared for California Public Utilities Commission, Energy Division. February 8, 2010.

hours of use for each logger by averaging the weekend and weekday specific averages in proportion to the number of weekend/weekday days over the course of the year. Specifically:

$$avg.hou_i = \frac{(n_{wd}\alpha_{wd,i} + n_{we}\alpha_{we,i})}{n_{wd} + n_{we}}$$

Where i indexes each logger, n_{wd} is the number of weekdays over the year, n_{we} is the number of weekend days over the year, $\alpha_{wd,I}$ is the average weekday usage for logger i, and $\alpha_{we,I}$ is the average weekend usage for logger i.

After annualizing the data for each logger, NMR merged logger data with household demographic data. Household demographic data included information on education level, income, single- or multifamily status, own/rent status, and whether there was anyone under 18 years of age in the household.

2.6.2 Adjusted HOU

Next, the Team used the annualized estimates as the dependent variable in a weighted regression analysis to estimate the adjusted average HOU for each room in each area of the study. Table 2-9 describes the variables that contributed to the regression analysis as predictors.

Table 2-9: Variables Used as Predictors in HOU Regression Models

Variable	Description	Levels
Room Type	Room/location the bulb was located.	Bedroom
		Bathroom
		Kitchen
		Living Space
		Dining Room
		Exterior
		Other
Efficient Bulb	Whether the bulb was efficient or non-efficient.	Yes
		No
Income	Household income.	Low Income
		Non-Low Income
Education	Education level of the respondent.	Less than High School
		High School or GED
		Some College
		Bachelor's Degree
		Advanced or Graduate Degree
Rent/Own	Whether household is owned or rented	Rent
		Own
Under 18	Anyone under 18 years of age in the household	Yes
		No
Home Type	Single or multi-family residence	Multi Family
		Single Family

Variables were retained in the model if they were statistically significant at 90% confidence, allowing for a more parsimonious model. The lone exceptions to this rule were income level and housing type – these were retained despite not being statistically significant, as one of the goals of this study was to quantify the association between usage and income/housing type.

Additional variables considered for inclusion in the model that did not prove to be statistically significant included saturation, fixture type, bulb shape, socket type, and control type. While there were some differences in usage across different levels of these variables, other variables in the model performed better in explaining those differences.

In this first step, the model used only loggers for each individual area to develop area-specific estimates, and all loggers were used to develop estimates for the overall region. Based on outputs from this model, the results are clear that Connecticut, Massachusetts, Rhode Island, and Upstate New York all had comparable usage patterns, while usage patterns for Downstate New York (including Manhattan) households differed from the other areas. Table 2-10 presents the HOU estimates from these separate area-specific regressions.

Table 2-10: Overall Estimated HOU from Preliminary Models

Area	Estimated Overall HOU	90% Confidence Interval
Connecticut	2.9	(2.5, 3.2)
Massachusetts	2.6	(2.4, 2.8)
Rhode Island	2.9	(2.2, 3.5)
Upstate New York	2.4	(2.1, 2.8)
Downstate New York	4.1	(3.5, 4.7)
Manhattan	3.9	(3.4, 4.4)

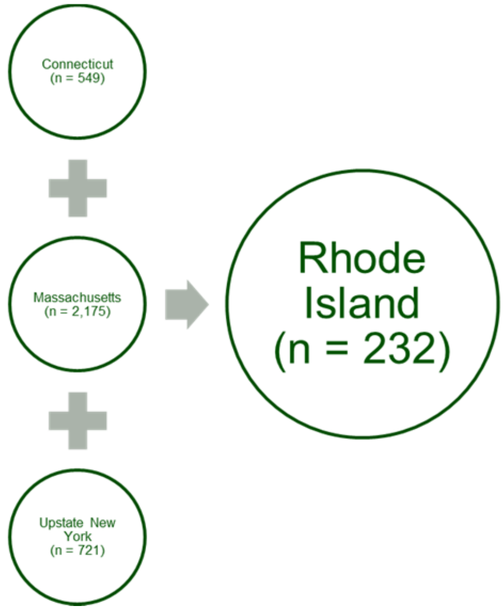
2.6.3 Hierarchical Model

Due to the similar use patterns in four of the areas (CT, MA, Upstate NY, and RI), the Team sought a way to leverage data from all of these areas to refine area-specific estimates. The structure of the data—loggers nested in homes, nested in areas—is well suited for a multi-level hierarchical model. The advantage of this type of modeling approach is the ability to use information from all four areas to help inform area-specific estimates. In a hierarchical model, the observations specific to an area form the basis of the estimates for that area, while observations from outside that area also inform and help refine the area-specific estimates.[32,33] For example, Figure 2-4 below provides a visual representation of how the estimate for Rhode Island is informed by loggers in Connecticut, Massachusetts, and Upstate New York. The hierarchal model is particularly beneficial for areas where fewer loggers were installed, thus providing more refined (tighter precision and adjusted means) HOU estimates compared to individual models fit to each area separately.

[32] Cnaan, A., Laird, N.M., & Slasor, P. "Tutorial in Biostatistics: Using the Generalized Linear Mixed Model to Analyze Unbalanced Repeated Measure and Longitudinal Data." Statistics in Medicine 16 (1997): 2349-2380. Fitzmaurice, G.M., Laird, N.M., & Ware, J.H. *Applied Longitudinal Analysis, 2nd Ed*. New York: Wiley, 2011.

[33] More technically, the estimate from each area is a weighted average of the adjusted population-averaged mean HOU (across all areas in the model) and that particular area's adjusted HOU profile.

Figure 2-4: Overview of Hierarchical Model



To account for potential correlation among loggers in the same household/area, the model included a random intercept term at the site ID level, which is dependent on the area that site ID is nested in. This dependence is established at another level in the modeling framework. Additionally, to estimate area-specific HOU estimates for all rooms, the model included random area-specific regression coefficients for the room type variable, allowing for information from other areas to help inform the area-specific HOU estimate of each room. Premise and room weights were applied directly in the likelihood of the model.[34,35] The exact form of the hierarchical model is presented below.

[34] Rabe-Hesketh, S. & Skrondal A. "Multilevel Modeling of Complex Survey Data." Journal of the Royal Statistical Society, Series A 169 (2006): 805-827.
[35] Graubard, B.I. & Korn E.L. "Modeling the Sampling Design in the Analysis of Health Surveys." Statistical Methods in Medical Research 5 (1996): 263-281.

$$
\begin{aligned}
E(hou_{ijk}) = {} & (\beta_0 + b_{0,j}) + (\beta_1 + b_{1,k}) \times I(Room_{ijk} = Bathroom) + (\beta_2 + b_{2,k}) \\
& \times I(Room_{ijk} = Bedroom) + (\beta_3 + b_{3,k}) \times I(Room_{ijk} = Dining) + (\beta_4 \\
& + b_{4,k}) \times I(Room_{ijk} = Kitchen) + (\beta_5 + b_{5,k}) \times I(Room_{ijk} = Living) + (\beta_6 \\
& + b_{6,k}) \times I(Room_{ijk} = Other) + I(Bulb.type_{ijk} = Efficient) \\
& + \beta_8 I(Income_{ijk} = LI) + \beta_9 I(Education_{ijk} = HS) \\
& + \beta_{10} I(Education_{ijk} = Some\ college) + \beta_{11} I(Education_{ijk} = Bach.) \\
& + \beta_{12} I(Education_{ijk} = Adv/Grad\ Deg.) + \beta_{13} I(Own/Rent_{ijk} = Rent) \\
& + \beta_{14} I(Under18_{ijk} = yes) + \beta_{15} I(Home.type_{ijk} = MF)
\end{aligned}
$$

where i indexes the loggers, j indexes the homes, k indexes the areas, and:

$$b_{0,j} \sim N(b_k, \sigma_{b_k}^2), \ \ \forall site_j \in region_k \ \forall k,$$

$$b_k \sim N(0, \sigma_{reg}^2), \ \ for\ k = 1, \ldots, n_{regions},$$

$$b_{l,k} \sim N(0, \sigma_l^2), \ \ for\ l = 1, \ldots, 6\ and\ \forall k,$$

Note that $n_{regions} = 4$, as the hierarchical model includes only loggers from Connecticut, Massachusetts, Rhode Island, and Upstate New York.

Table 2-10 shows that Downstate New York (including Manhattan) and Manhattan by itself had different usage patterns—specifically, higher HOU—than the other four areas in the study.[36] Thus, separate robust linear regression models were fit for Downstate New York, for the subset of Downstate New York in Manhattan, and for all of the NYSERDA area (all of Upstate and Downstate combined). Downstate regression models incorporated the same variables listed in Section 2.6.2. After fitting the regression models, the Team used the fitted values of the appropriate regression to calculate adjusted HOU estimates by area and room.

Separate models were also fitted for each of the following eight sub-categories:

- Single-Family Households (SF)
- Multifamily Households (MF)
- Low-Income Households (LI)
- Non-Low-Income Households (NLI)
- Low-Income Single-Family Households (LI SF)
- Low-Income Multifamily Households (LI MF)
- Non-Low-Income Single-Family Households (NLI SF)
- Non-Low-Income Multifamily Households (NLI MF)

[36] The Team does not present Downstate New York minus Manhattan due to the NYSERDA program structure. They treat Downstate—comprising all of New York City, most of Westchester County, and a few towns in other counties—as one unit in their program planning and implementation.

As with modeling at the overall level, a hierarchical model was fitted using data from only Connecticut, Massachusetts, Rhode Island, and Upstate New York within each sub-category listed above, while separate stand-alone models for each of Downstate New York, Manhattan, and all of NYSERDA were also fitted within each sub-category.

2.6.4 Overall Regression Model Coefficients

Table 2-11 shows the overall regression coefficients from the hierarchical model fitted to all loggers in Connecticut, Massachusetts, Rhode Island, and Upstate New York. These coefficients were relatively consistent across models, so only for the overall hierarchical model coefficients are presented here. Not only does the hierarchical model allow information from across regions to help inform each region-specific estimate, it also performs better than its non-hierarchical counterpart. The pseudo-R^2 for the overall hierarchical regression model, as calculated according to Xu (2003),[37] is 0.26, compared to an R^2 value of 0.14 for the stand-alone regression model fit at the overall level, suggesting a nearly two-fold improvement in the amount of explained variance from fitting a standard linear regression model to this data. Table 2-11 excludes the room-by-room estimates, as those are presented in Section 3 as adjusted means rather than as regression coefficients. Blank cells in this table represent the baseline level of each variable in the model, and all coefficients should be interpreted as relative to the corresponding baseline level for each variable.

For example, this model estimates that, holding all other variables constant, households in which the respondent had a bachelor's degree use about 0.6 hours of light less than those where the respondent had less than a high school degree, while households paying rent use roughly 0.5 more hours of light than do home owners. These findings are consistent with long-held beliefs among lighting program implementers and evaluators who have often speculated that education and tenure are two important factors in determining lighting usage. The team speculates that renters may use more lighting because the number of occupants per room compared to home owners who typically live in larger homes. Unfortunately, the Team has insufficient demographic data to test this hypothesis fully as part of this study. However, the Team examined census data on occupants per room and found that the areas with fewer occupants per room on average were found to have lower HOU estimates by this study, as summarized in Table 2-12. This may suggest that future studies should collect data on total occupants per household.

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[37] Xu R. "Measuring Explained Variance in Linear Mixed Effects Models." Statistics in Medicine 22 (2003):3527-3541.

Table 2-11: Overall Regression Coefficients from Hierarchical Model

Variable	Level	Coefficient	90% Confidence Interval*
Efficient Bulb	Yes	0.631	(0.455, 0.806)
	No		
Income	Low Income	0.007	(-0.261, 0.273)
	Non-Low Income		
Education	Grad/Adv. Degree	-0.635	(-1.288, -0.082)
	Bachelor's Degree	-0.587	(-1.253, -0.019)
	Some College	-0.778	(-1.420, -0.248)
	HS or GED	-0.728	(-1.362, -0.176)
	Less than HS		
Own/Rent	Rent	0.532	(0.249, 0.821)
	Own		
Under 18	Yes	0.598	(0.362, 0.824)
	No		
Home Type	Multi Family	-0.157	(-0.470, 0.154)
	Single Family		

*Intervals that do not contain zero correspond to statistical significance at 90% confidence.

Table 2-12: Occupants per Room

Area	Estimated Household HOU	Total Occupied Housing Units	Occupants per Room			
			0.5 or fewer	0.51 to 1.0	1.01 to 1.50	1.51 or greater
CT	2.8	1,360,184	73%	26	1	<1
MA	2.7	2,525,694	72%	26	1	<1
RI	2.6	410,639	72%	26	1	<1
UNY	2.6	2,883,410	77%	22	1	<1
Overall	2.7	7,918,058	73%	25	1	1
MHT	3.9	738,131	57%	38	3	2
DNY	4.1	3,408,268	53%	38	5	3
NYSERDA	3.3	7,029,809	63%	32	3	2

2.7 Derivation of Load Curves

The Team generated load curves that describe the weekday lighting usage by hour of the day for each of the eight geographic categories (Connecticut, Massachusetts, Rhode Island, Upstate New York, Overall, Manhattan, Downstate New York, and NYSERDA service area) included in the study. Besides the area-specific curves that describe each of the different areas at the overall household level, the Team also generated load curves for multiple sub-samples of the data including single-family, multifamily, low-income, non-low-income, single-family low-income, single-family non-low-income, multifamily low-income, and multifamily non-low-income. The majority of the data collected for this analysis was gathered in the first half of 2013, with most of the logger installations occurring in mid-to-late January; because a full year's worth of data was not available, the Team utilized three separate methods for generating load curves.

For the months with adequate data (February through July), evaluators generated the average amount of lighting usage for each hour of the study period along with a 90% confidence interval for each hour of the study period.

However, due to the timing of metering, the loggers yielded sparse lighting usage data for August, December, and January, and no data for September, October, or November. In order to address the fact that the Team had sparse or non-existent data for these months, to generate load shapes for the months of November, December, and January, the Team modeled lighting usage as a function of average hours of daylight (daylight hours from United States Naval Observatory for the Northeast region)[38] by hour of the day clustered by logger. Predicted lighting usage generated by the model was then used to generate load shapes and confidence intervals for the months of August, November, December, and January. The Team also generated load shapes for the other seven months of the year and compared these modeled load shapes to the actual load data logged to determine how good of a fit the model was providing. To check the fit evaluators calculated the root mean square error (MSE) using the following formula:

root-MSE $=\sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(y_i-\hat{y}_i\right)^2}$

Where:

y_i is the actual value,

$\hat{y}_i$ is the corresponding predicted value from our model, and

N is the total number of loggers.

This results indicate, on average, how far the predictions from the model are from the actual values.[39] As shown in Table 2-13, the overall performance is quite good, with average root MSE around 0.01, indicating that our predictions are, on average within +/- 0.01 of the actual observed value. Figure 2-5 and Figure 2-6 provide a visual comparisons between the modeled load curves and actual load curves for Connecticut in February for all homes and low-income multifamily homes (respectively). As these figures show, the modeled and actual load curves are nearly identical.

[38] See http://www.usno.navy.mil/USNO

[39] Modeled data compared to actual data from February 2013 through June 2013. NA indicates insufficient data was available during the period to provide an estimate.

Table 2-13: Root Mean Squared Error for Load Models

Model (Income, Home Type, Efficiency)	CT	MA	RI	UNY	Overall	MHT	DNY	NYSERDA
Avg. Across All Models	**0.009**	**0.009**	**0.015**	**0.011**	**0.006**	**0.013**	**0.013**	**0.010**
All, All, All	0.008	0.009	0.014	0.008	0.008	0.011	0.011	0.008
All, All, Eff	0.009	0.009	0.015	0.008	0.008	0.016	0.015	0.011
All, All, Ineff	0.009	0.010	0.017	0.009	0.009	0.010	0.010	0.007
LI, All, All	0.009	0.010	0.016	0.008	0.010	0.017	0.021	0.015
LI, All, Eff	0.010	0.011	0.016	0.010	0.010	0.021	0.026	0.022
LI, All, Ineff	0.012	0.012	0.020	0.009	0.010	0.024	0.019	0.013
LI, MF, All	0.012	0.013	0.033	0.026	0.009	0.018	0.016	0.017
LI, SF, All	0.013	0.011	0.016	0.010	0.011	NA	0.025	0.009
NLI, All, All	0.009	0.008	0.014	0.008	0.007	0.011	0.010	0.007
NLI, All, Eff	0.010	0.009	0.015	0.008	0.007	0.016	0.014	0.009
NLI, All, Ineff	0.010	0.009	0.019	0.010	0.008	0.009	0.010	0.007
NLI, MF, All	0.011	0.011	0.013	NA	0.006	0.010	0.011	0.010
NLI, SF, All	0.010	0.008	0.014	0.008	0.007	NA	0.010	0.007
All, MF, All	0.009	0.010	0.015	0.018	0.008	0.011	0.011	0.011
All, MF, Eff	0.011	0.014	0.020	0.042	0.010	0.016	0.015	0.016
All, MF, Ineff	0.012	0.009	0.017	0.016	0.008	0.010	0.011	0.011
All, SF, All	0.009	0.009	0.015	0.007	0.009	NA	0.012	0.007
All, SF, Eff	0.010	0.009	0.016	0.007	0.008	NA	0.012	0.007
All, SF, Ineff	0.010	0.011	0.017	0.009	0.010	NA	0.018	0.009

Figure 2-5: Actual vs. Modeled Load Shape – Connecticut February Weekday, All Homes and All Bulbs

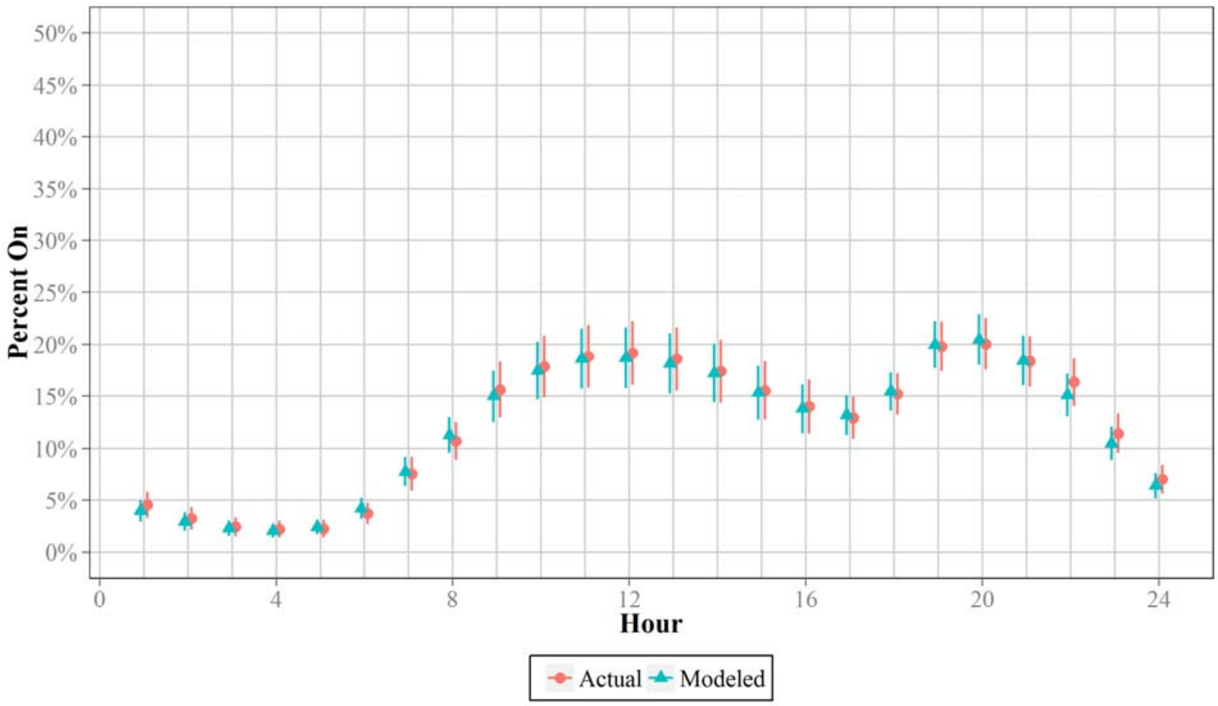
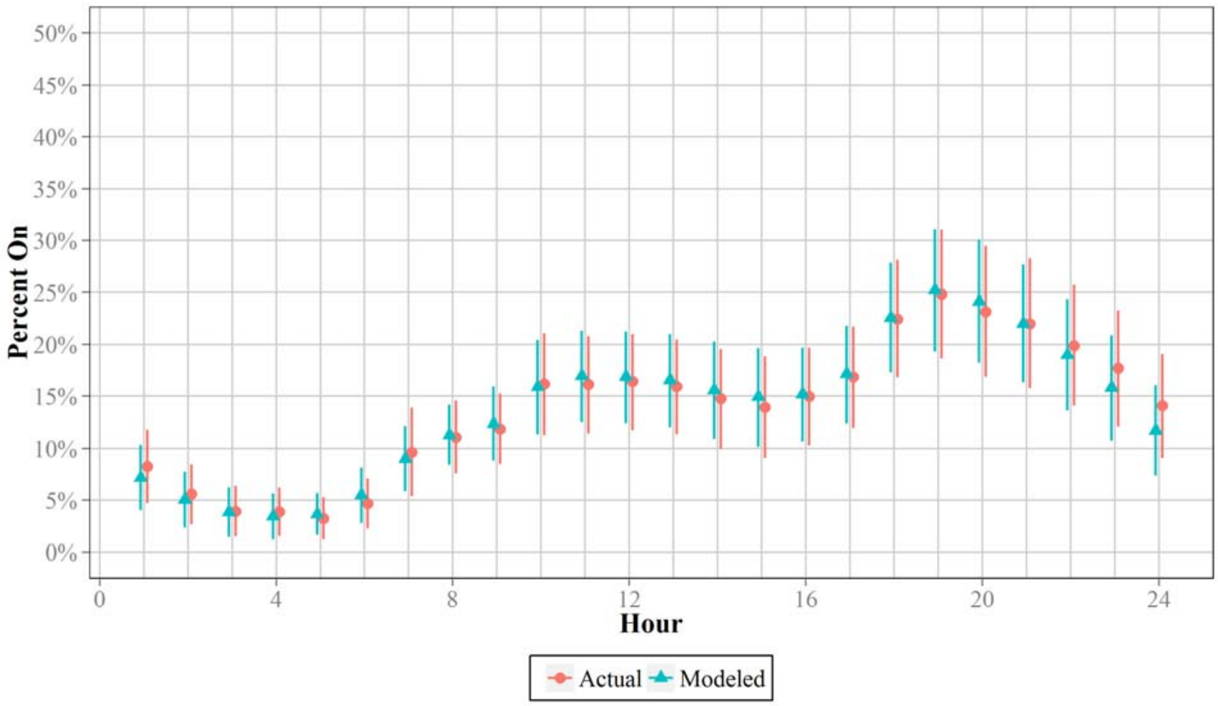


Figure 2-6: Actual vs. Modeled Load Shape – Connecticut February Weekday, Low-Income Multi-family, All Bulbs



3 HOU Analysis Results

Throughout this section and in the appendices, evaluators present the five sets of estimates from the hierarchical model first, in the leftmost portion of each table, followed by the estimates for Manhattan, Downstate New York, and NYSERDA Overall. Unless otherwise specified, all data presented are weighted as described in Section 2.4 and all sample sizes (n) reflect logger counts. Results are presented as *mean (90% CI)*. Significant differences across areas are denoted with a letter *a* through *h*:

a. Statistically different at the 90% confidence level from Connecticut
b. Statistically different at the 90% confidence level from Massachusetts
c. Statistically different at the 90% confidence level from Rhode Island
d. Statistically different at the 90% confidence level from Upstate New York
e. Statistically different at the 90% confidence level from Overall
f. Statistically different at the 90% confidence level from Manhattan
g. Statistically different at the 90% confidence level from Downstate New York
h. Statistically different at the 90% confidence level from NYSERDA

3.1 Analysis Organization

Throughout this report, evaluators refer to eight separate area estimates—five produced by the hierarchical model and three produced by separate standalone models—as described in Section 2.6.3. For the sake of clarity, before presenting the estimates a brief overview of the data informing each of the estimates is provided.

Hierarchical Models

Connecticut (CT): A product of the hierarchical model described in Section 2.6.3. The 549 loggers from Connecticut inform the core of Connecticut estimates. The core estimates were then refined through a hierarchical model that drew upon all loggers installed in Massachusetts, Rhode Island, and Upstate New York.

Massachusetts (MA): A product of the hierarchical model described in Section 2.6.3. The 2,175 loggers from Massachusetts inform the core of Massachusetts estimates. The core estimates were then refined through a hierarchical model that draws upon all loggers installed in Connecticut, Rhode Island, and Upstate New York.

Rhode Island (RI): A product of the hierarchical model described in Section 2.6.3. The 232 loggers from Rhode Island inform the core of Rhode Island estimates. The core estimates were then refined through a hierarchical model that drew upon all loggers installed in Connecticut, Massachusetts, and Upstate New York.

Upstate New York (UNY): A product of the hierarchical model described in Section 2.6.3. The 721 loggers from Upstate New York inform the core of Upstate New York estimates. This includes the 299 loggers from the National Grid *EnergyWise* Study. The core estimates were then refined through a hierarchical model that drew upon all loggers installed in Connecticut, Massachusetts, and Rhode Island.

Overall Excluding Downstate New York (Overall): A product of the hierarchical model described in

Section 2.6.3, the Overall estimates collapse the modeled data from the four areas described above. The 3,677 loggers from Connecticut, Massachusetts, Rhode Island, and Upstate New York make up the core of Overall estimate. As with the other estimates above, the Overall estimate excludes all loggers from Downstate New York (including Manhattan).

Standalone Models

Manhattan (MHT): A product of a standalone model (as described in Section 2.6.3), the 544 loggers from Manhattan inform the Manhattan estimates.

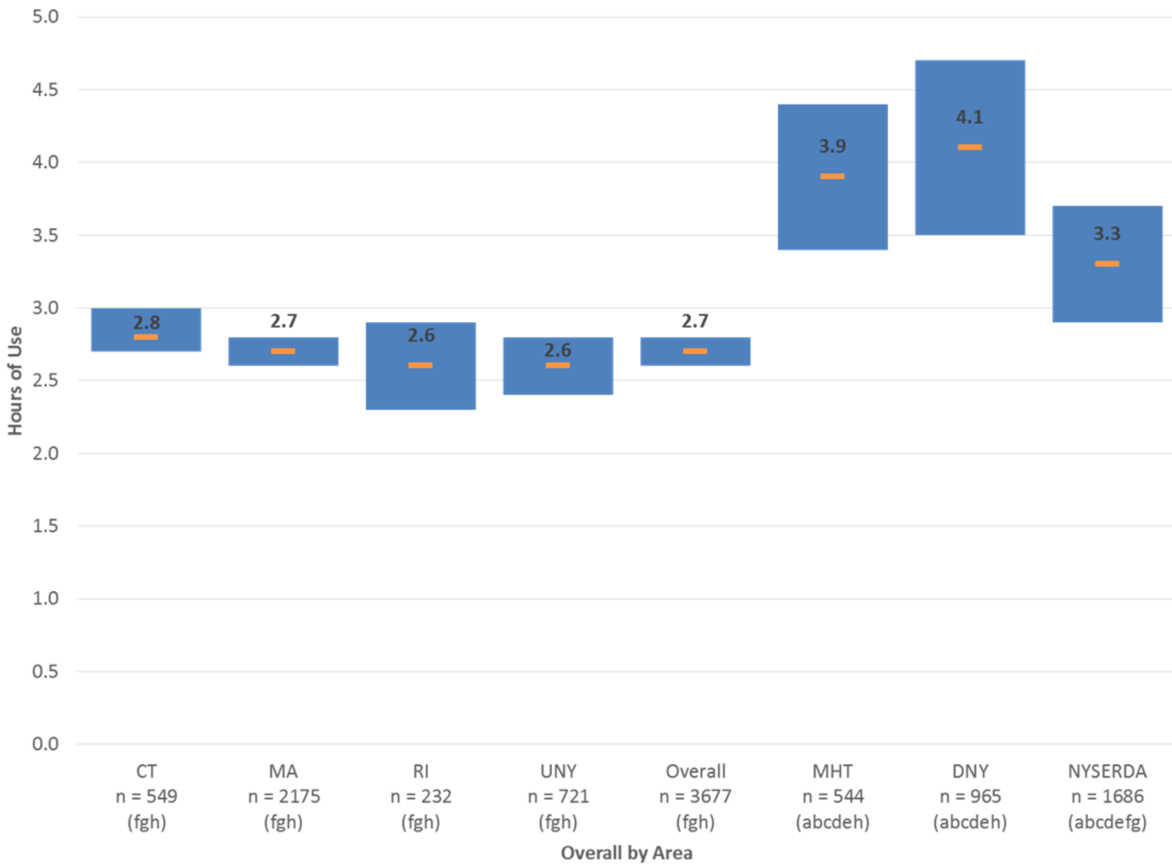
Downstate New York (DNY): A product of a standalone model (as described in Section 2.6.3), the 965 loggers from Downstate New York, including the 544 loggers from Manhattan, inform the Downstate New York estimates.

NYSERDA Service Area (NYSERDA): A product of a standalone model (as described in Section 2.6.3), the 1,686 loggers from New York—the 721 loggers from Upstate New York and the 965 loggers from Downstate New York (including the 544 loggers from Manhattan)—inform the NYSERDA Overall estimates.

3.2 Household HOU Estimates

Figure 3-1 below shows the household level daily HOU estimates for each of the eight models as well as the confidence intervals around the point estimates. Each of the five estimates from the hierarchical model is statistically similar to the others. The confidence interval around the Overall estimate is the narrowest (2.6 to 2.8 HOU); each tenth represents just six minutes. Therefore, it can be said with 90% confidence that actual HOU fall within a twelve-minute range. The Rhode Island estimate has the widest confidence interval (2.4 to 2.8 HOU, a 24-minute range) because Rhode Island had the fewest loggers. Compared to each of the hierarchical models, the Manhattan and Downstate New York HOU estimates are significantly higher (3.9 and 4.1, respectively). Further, these estimates have much wider confidence intervals than those from the hierarchical model; this is true across all models for Downstate New York, Manhattan, and NYSERDA Overall. As discussed in Section 2.6.3, the higher level of precision in the estimates for CT, MA, RI, and Upstate NY is one of the main benefits of the hierarchical modeling approach. The standalone models for Downstate NY, Manhattan, and NYSERDA Overall do not benefit from the ability to borrow information from other areas, thus yielding less precision and wider confidence intervals. The NYSERDA Overall model HOU estimate is significantly higher than the Massachusetts, Rhode Island, Upstate New York, and Overall model estimates, but is statistically similar to the Connecticut model estimate. It is important to note that the estimates from the hierarchical Upstate New York model are significantly different from the estimates from the Downstate New York model and the NYSERDA standalone model that includes Upstate New York. Given the divergence of the Upstate New York model from both the Downstate and, perhaps more importantly, the NYSERDA Overall model, NYSERDA should consider using separate estimates for Upstate and Downstate New York instead of using one NYSERDA-wide estimate.

Figure 3-1: Household HOU Estimates by Area[1,2]



Statistically different at the 90% confidence level from:
[1] – The Overall model includes CT, MA, RI, and UNY. The Overall model excludes MHT and DNY.
[2] – The DNY model includes MHT.

[a] – Connecticut
[b] – Massachusetts
[c] – Rhode Island
[d] – Upstate NY
[e] – Overall
[f] – Manhattan
[g] – Downstate NY
[h] – NYSERDA Overall

3.2.1 Overall HOU Estimates – Room-by-Room

Turning to the room-by-room analysis presented in Table 3-1, out of 80 comparisons between the five sets of estimates obtained from the hierarchical model, there are only nine statistically significant differences:

- Bedroom: HOU estimates for Upstate New York are significantly lower compared to those for Connecticut and Rhode Island.
- Bedroom: HOU estimates for Connecticut are significantly higher compared to those for Massachusetts, Upstate New York, and Overall.
- Kitchen: All HOU estimates are statistically similar across CT, MA, RI, UNY, and Overall.
- Living Space: HOU estimates for Upstate New York are significantly lower compared to Connecticut.
- Dining Room: All HOU estimates are statistically similar across CT, MA, RI, UNY, and Overall.
- Exterior: HOU estimates are significantly lower in Massachusetts, Upstate New York, and Overall compared to those for Connecticut and Rhode Island.
- Other: All HOU estimates are statistically similar across CT, MA, RI, UNY, and Overall.

In contrast, the three NYSERDA standalone models exhibit a greater number of statistical differences at the room level when compared to the estimates from the hierarchical model. Table 3-2 provides the sample sizes (number of loggers) for each area and room type presented in Table 3-1. A summary of the number of differences by models presented below and complete significance testing is included in the table below.

- **Manhattan:** There are 31 significant differences between Manhattan and the other seven models (out of 56 comparisons). Comparing Manhattan to Downstate New York and NYSERDA (16 comparisons), there are only two significant differences (Dining Room and Household).
- **Downstate New York:** There are 38 significant differences between Downstate New York and the other seven models (out of 56 comparisons). Comparing Downstate New York to Manhattan and NYSERDA (16 comparisons), there are only two significant differences (Bedroom and Household).

  NYSERDA: There are 29 significant differences between NYSERDA and the other seven models (out of 56 comparisons). Comparing NYSERDA to Manhattan and Downstate New York (16 comparisons), there are four significant differences (Bedroom, Dining Room, and Household).

Table 3-1: Overall HOU Estimates by Area and Room

Room	CT	MA	RI	UNY	Overall	MHT	DNY	NYSERDA
Bedroom	2.6 (2.2, 3.1) [bdefg]	2.0 (1.8, 2.3) [afgh]	2.6 (2.0, 3.3) [dg]	1.7 (1.3, 2.1) [acfgh]	2.1 (1.9, 2.3) [afgh]	3.4 (2.9, 4.0) [abde]	3.6 (3.1, 4.1) [abbcdeh]	2.8 (2.4, 3.2) [bdeg]
Bathroom	1.5 (1.1, 2.0) [fgh]	1.8 (1.5, 2.0) [fgh]	1.2 (0.6, 1.8) [fgh]	1.9 (1.5, 2.4) [fgh]	1.7 (1.5, 1.9) [fgh]	2.7 (2.2, 3.3) [abcde]	3.2 (2.4, 4.1) [abcde]	2.8 (2.2, 3.5) [abcde]
Kitchen	4.6 (4.0, 5.1) [fgh]	4.0 (3.7, 4.3) [fgh]	3.8 (3.0, 4.5) [fgh]	4.1 (3.7, 4.6) [fgh]	4.1 (3.9, 4.3) [fgh]	6.3 (5.6, 7.1) [abcde]	7.0 (5.8, 8.2) [abcde]	5.8 (5.0, 6.6) [abcde]
Living Space	3.8 (3.3, 4.3) [d]	3.3 (3.0, 3.6) [g]	3.4 (2.7, 4.2)	3.1 (2.6, 3.5) [afgh]	3.3 (3.1, 3.6) [g]	3.9 (3.3, 4.6) [d]	4.5 (3.5, 5.4) [bde]	4.0 (3.3, 4.6) [d]
Dining Room	3.2 (2.6, 3.9) [f]	2.7 (2.3, 3.1) [fg]	3.5 (2.6, 4.6)	2.5 (1.9, 3.1) [fg]	2.8 (2.5, 3.1) [fg]	4.5 (3.6, 5.3) [abdeh]	4.0 (2.9, 5.0) [bde]	3.2 (2.5, 3.9) [f]
Exterior	6.0 (5.6, 6.5) [bdegh]	5.5 (5.2, 5.8) [acg]	6.6 (6.0, 7.1) [bdegh]	5.5 (5.1, 5.8) [acg]	5.6 (5.3, 5.9) [acg]	--	3.6 (2.2, 5.1) [abcde]	4.7 (3.7, 5.7) [ac]
Other	1.7 (1.4, 2.0) [fgh]	1.7 (1.5, 1.9) [fgh]	1.6 (1.2, 2.0) [fgh]	1.7 (1.4, 2.0) [fgh]	1.7 (1.6, 1.9) [fgh]	3.4 (2.4, 4.5) [abcde]	3.2 (2.3, 4.1) [abcde]	2.4 (1.9, 2.9) [abcde]
Household	2.8 (2.7, 3.0) [fgh]	2.7 (2.6, 2.8) [fgh]	2.6 (2.3, 2.9) [fgh]	2.6 (2.4, 2.8) [fgh]	2.7 (2.6, 2.8) [fgh]	3.9 (3.4, 4.4) [abcdeh]	4.1 (3.5, 4.7) [abcdeh]	3.3 (2.9, 3.7) [abcdefg]

[1] – The Overall model includes CT, MA, RI, and UNY. The Overall model excludes MHT and DNY.
[2] – The DNY model includes MHT.

[a] – Statistically different at the 90% confidence level from Connecticut
[b] – Statistically different at the 90% confidence level from Massachusetts
[c] – Statistically different at the 90% confidence level from Rhode Island
[d] – Statistically different at the 90% confidence level from Upstate NY
[e] – Statistically different at the 90% confidence level from Overall
[f] – Statistically different at the 90% confidence level from Manhattan
[g] – Statistically different at the 90% confidence level from Downstate NY
[h] – Statistically different at the 90% confidence level from NYSERDA Overall

Table 3-2: Sample Sizes, Overall HOU Estimates by Area and Room

Room	CT	MA	RI	UNY	Overall	MHT	DNY	NYSERDA
Bedroom	100	451	47	127	725	108	188	315
Bathroom	79	292	37	107	515	119	185	292
Kitchen	79	351	33	120	583	104	168	288
Living Space	85	349	35	113	582	102	160	273
Dining Room	52	171	16	72	311	51	90	162
Exterior	14	114	7	33	168	1	16	49
Other	140	447	57	149	793	59	158	307
Household	549	2175	232	721	3677	544	965	1686

3.3 HOU Estimates by Home Type and Income Level

To further identify any differences by area, evaluators looked at a breakdown of household HOU by different factors. In this section HOU at the household level is compared across eight categories for each area:

- Single-Family Households (SF)
- Multifamily Households (MF)
- Low-Income Households (LI)
- Non-Low-Income Households (NLI)
- Low-Income Single-Family Households (LI SF)
- Low-Income Multifamily Households (LI MF)
- Non-Low-Income Single-Family Households (NLI SF)
- Non-Low-Income Multifamily Households (NLI MF)

Figure 3-2 and Figure 3-3 show the overall daily HOU estimates by category in each area as well as the confidence intervals. In the figures, significant differences are denoted across areas with a letter designation *a* through *h*, found in the legend along with sample sizes (n).

Figure 3-2 presents a comparison of the five hierarchical model estimates for each category, and Figure 3-3 presents a comparison of the Overall model and the three standalone New York models (Manhattan, Downstate New York, and NYSERDA). Additional detailed room-by-room tables using the same eight categories can be found in Appendix A.

First, Figure 3-2 presents a comparison of the estimates from the hierarchical models for each of the eight categories. Among individual areas there are relatively few significant differences:

- **Massachusetts**: HOU estimates for non-low-income multifamily households in Massachusetts are significantly lower compared to those for single-family, low-income, and low-income single-family households in Massachusetts.
- **Rhode Island:** HOU estimates for low-income households are significantly higher compared to those for non-low-income households in Rhode Island.
- **Overall**: HOU estimates for low-income multifamily households are significantly higher compared to those for non-low-income multifamily households in the Overall model.

Similarly, across the five area groupings corresponding to each of the eight hierarchical models, there are relatively few significant differences:

- **Connecticut:** HOU estimates for low-income households are significantly higher compared to those for low-income households in Massachusetts, Rhode Island, and Overall.
- **Rhode Island**: HOU estimates for low-income single-family households are significantly lower compared to those for low-income single-family households in Connecticut, Massachusetts, and the Overall model.

Turning to Figure 3-3, it is apparent that the Overall model estimates are significantly lower for several categories compared to those from each of the standalone models:

- **Overall:**
    - HOU estimates for multifamily households, low-income households, and low-income multifamily households are significantly lower compared to those for Manhattan, Downstate, and NYSERDA.
    - HOU estimates for non-low-income households and non-low-income multifamily households are significantly lower compared to those for Manhattan and Downstate.

It is worth noting that the Overall estimate for single-family homes is statistically similar to the estimates for single-family homes from the Downstate and NYSERDA models. Combined with the significant differences among multifamily households, it is safe to conclude that the differences between the multifamily households in the Downstate New York and NYSERDA models account for the differences between the Overall models.

Across the three standalone models, there are no significant differences, although it is worth noting that the confidence intervals for these models are wider compared to the hierarchical models. As mentioned in Section 3.2, this is mainly a product of these standalone models not being able to benefit from the increased precision the other areas gained through their ability to borrow information across areas in the hierarchical modeling framework.

Among individual standalone models, there are several statistical differences:

- **Downstate:** HOU estimates for low-income households are significantly higher compared to those for single-family, non-low-income, non-low-income single-family, and non-low-income multifamily households.
- **NYSERDA:**
    - HOU estimates for single-family households are significant lower compared to those for multifamily, low-income, and low-income multifamily households.
    - HOU estimates for non-low-income households are significantly lower compared to those for low-income and low-income multifamily.

Figure 3-2: HOU Estimates by Home Type and Income Level – Hierarchical Models

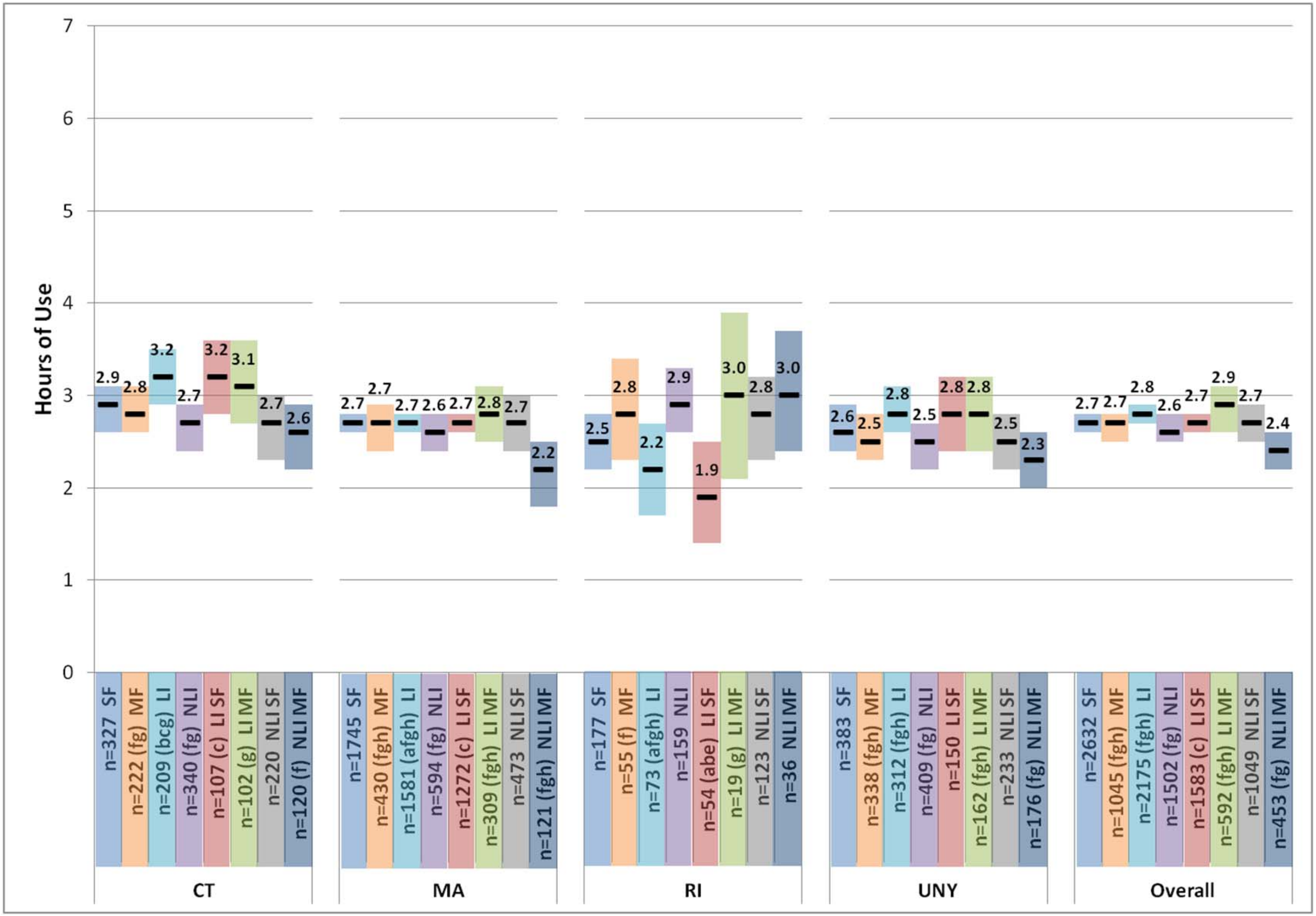
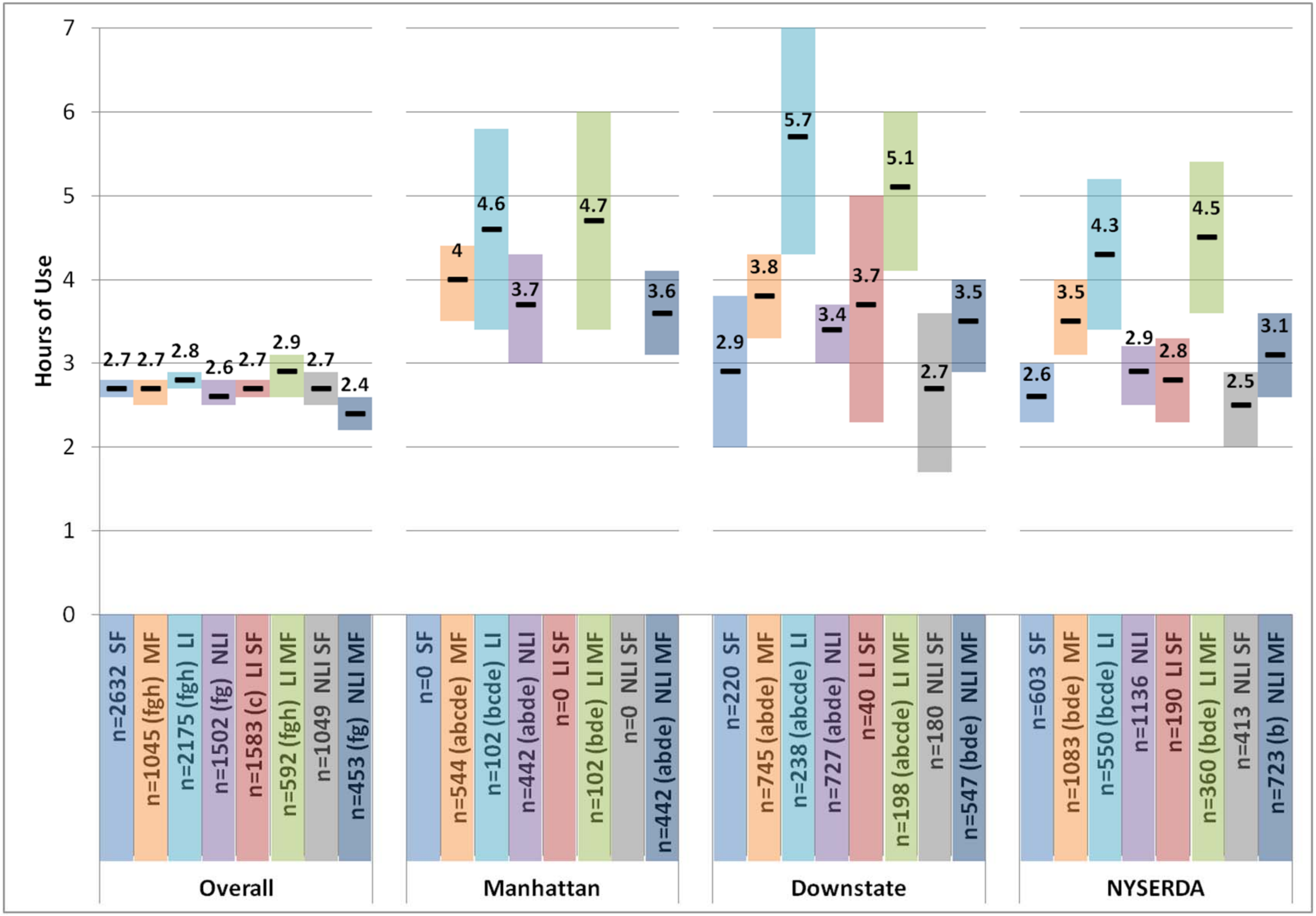


Figure 3-3: HOU Estimates by Home Type and Income Level – Standalone Models

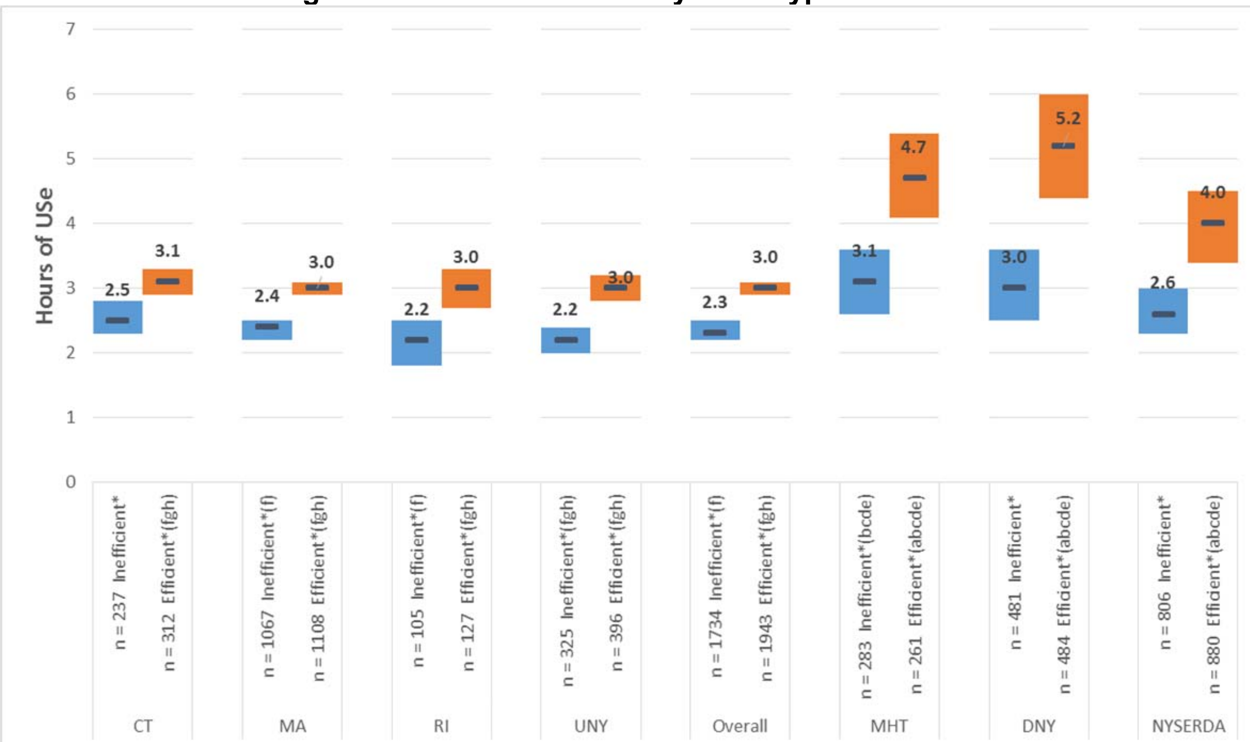


3.4 Efficient and Inefficient Bulb Types

Figure 3-4 shows the HOU estimates by area broken out by the type of bulb (inefficient vs. efficient). Inefficient bulbs include halogens and incandescent bulbs, and efficient bulbs include CFLs, LEDs, and fluorescent bulbs. For each bulb type, the figure provides the means as well as the confidence intervals. Significant differences within an area are denoted with an asterisk (*) and significant differences across areas are labeled with a letter *a* through *h*, found in the legend along with sample size (n).

Among all eight areas, efficient bulb HOU estimates are universally significantly higher compared to inefficient bulb HOU estimates. Similar to all bulb HOU estimates, estimates for inefficient and efficient bulbs, respectively, across each of the estimates obtained from a hierarchical model are all statistically similar ranging from 3.0 to 3.1. In contrast, when compared to the Manhattan, Downstate New York, and the NYSERDA model estimates, there are a number of significant differences. HOU estimates for efficient bulbs are universally lower among the five sets of estimates from the hierarchical model compared to the three standalone model estimates, and HOU estimates for inefficient bulbs are significantly lower for four out of the five hierarchical model estimates compared to those for Manhattan. (Those for Connecticut are statistically similar.) Estimates for inefficient and efficient bulbs, respectively, across Manhattan, Downstate New York, and NYSERDA are statistically similar.

Figure 3-4: HOU Estimates by Bulb Type and Area



Statistically different at the 90% confidence level from:

a – Connecticut	e – Overall
b – Massachusetts	f – Manhattan
c – Rhode Island	g – Downstate NY
d – Upstate NY	h – NYSERDA Overall

3.4.1 Efficient and Inefficient Bulb Types – Room by Room

The trend seen at the household level continues when room-by-room estimates are examined. Table 3-3 provides the inefficient bulb estimates room by room, and Table 3-5 contains the efficient bulb estimates room by room. Table 3-4 and Table 3-6 provide the sample sizes (number of loggers) for each area and room type.

Inefficient Bulbs:

- Bedroom: Upstate New York estimates are significantly lower compared to those for Connecticut, Manhattan, Downstate New York, and NYSERDA.
- Bedroom: Manhattan and Downstate New York estimates are significantly higher compared to those for Massachusetts, Upstate New York, and Overall.
- Kitchen: Manhattan estimates are significantly higher compared to those for Massachusetts, Rhode Island, Upstate New York, and Overall.
- Kitchen: Downstate New York estimates are significantly higher compared to those for Rhode Island.
- Dining Room: Manhattan estimates are significantly higher compared to those for Upstate New York and Overall.
- Exterior: Downstate New York estimates are significantly lower compared to those from the regional and overall estimates from hierarchical model.

- Exterior: NYSERDA estimates are significantly lower compared to those for Rhode Island.
- Other: Manhattan estimates are significantly higher compared to those for Massachusetts, Rhode Island, Upstate New York, and Overall.

Efficient Bulbs:

- Bedroom: Manhattan, Downstate New York, and NYSERDA estimates are significantly higher compared to those for Massachusetts, Upstate New York, and Overall.
- Bedroom: Downstate New York estimates are also significantly higher compared to those for Connecticut.
- Kitchen: Manhattan, Downstate New York, and NYSERDA estimates are significantly higher compared to all five estimates obtained from the hierarchical model.
- Living space: Manhattan and Downstate New York estimates are significantly higher compared to those for Upstate New York.
- Living space: Downstate New York estimates are also significantly higher compared to those for Massachusetts and Overall.
- Dining Room: Manhattan and Downstate New York estimates are significantly higher compared to those for Massachusetts, Upstate New York, and Overall.
- Dining Room: Manhattan estimates are also significantly higher compared to those for Connecticut.
- Other: Manhattan and Downstate New York estimates are significantly higher compared to all five estimates obtained from the hierarchical model.
- Other: NYSERDA estimates are significantly higher compared to those for Rhode Island and Overall.

Table 3-3: HOU by Area for Inefficient Bulbs

Room	CT	MA	RI	UNY	Overall	MHT	DNY	NYSERDA
Bedroom	2.4 (1.9, 2.9) [bde]	1.8 (1.5, 2.0) [afgh]	2.2 (1.5, 2.9) [d]	1.4 (0.9, 1.8) [acefgh]	1.8 (1.6, 2.0) [adfgh]	2.8 (2.2, 3.3) [bde]	3.1 (2.4, 3.7) [bde]	2.5 (2.0, 3.0) [bde]
Bathroom	1.2 (0.7, 1.7) [f]	1.5 (1.2, 1.8) [f]	0.8 (0.2, 1.5) [fgh]	1.4 (0.9, 1.9) [f]	1.4 (1.1, 1.6) [f]	2.3 (1.7, 2.8) [abcde]	2 (1.3, 2.7) [c]	1.9 (1.3, 2.4) [c]
Kitchen	4.3 (3.7, 4.9) [cef]	3.7 (3.4, 4.0) [fg]	3.0 (2.2, 3.8) [afgh]	3.5 (3.0, 4.0) [fgh]	3.7 (3.4, 4.0) [afgh]	5.6 (4.8, 6.4) [abcde]	5.3 (4.0, 6.6) [bcde]	4.6 (3.8, 5.4) [cde]
Living Space	3.5 (3.0, 4.1) [de]	3.0 (2.6, 3.3)	2.9 (2.1, 3.7)	2.8 (2.3, 3.2) [agh]	3.0 (2.8, 3.2) [a]	3.3 (2.5, 4.0)	4.0 (2.9, 5.0) [d]	3.7 (2.9, 4.5) [d]
Dining Room	3.0 (2.4, 3.7) [d]	2.5 (2.1, 2.9) [f]	3.3 (2.3, 4.4) [d]	2.1 (1.5, 2.7) [acf]	2.5 (2.2, 2.8) [f]	3.7 (2.9, 4.5) [bdeh]	2.9 (1.9, 3.9)	2.5 (1.9, 3.1) [f]
Exterior	5.4 (4.8, 5.9) [cg]	5.3 (4.9, 5.6) [cg]	6.3 (5.6, 7.0) [abdegh]	5.3 (4.9, 5.7) [cg]	5.3 (5.0, 5.6) [cg]	--	3.1 (1.7, 4.6) [abcde]	4.4 (3.4, 5.3) [c]
Other	1.3 (1.0, 1.7) [fg]	1.4 (1.2, 1.7) [f]	1.5 (1.1, 2.0) [f]	1.4 (1.1, 1.7) [f]	1.4 (1.2, 1.6) [f]	2.7 (1.7, 3.7) [abcde]	2.4 (1.4, 3.4) [a]	1.9 (1.3, 2.4)
Household	2.5 (2.3, 2.8) [cd]	2.4 (2.2, 2.5) [dfg]	2.2 (1.8, 2.5) [afg]	2.2 (2.0, 2.4) [abefgh]	2.3 (2.2, 2.5) [dfg]	3.1 (2.6, 3.6) [bcde]	3.0 (2.5, 3.6) [bcde]	2.6 (2.3, 3.0) [d]

[a] – Statistically different at the 90% confidence level from Connecticut
[b] – Statistically different at the 90% confidence level from Massachusetts
[c] – Statistically different at the 90% confidence level from Rhode Island
[d] – Statistically different at the 90% confidence level from Upstate NY
[e] – Statistically different at the 90% confidence level from Overall
[f] – Statistically different at the 90% confidence level from Manhattan
[g] – Statistically different at the 90% confidence level from Downstate NY
[h] – Statistically different at the 90% confidence level from NYSERDA Overall

Table 3-4: Sample Sizes, Inefficient Bulbs

Room	CT	MA	RI	UNY	Overall	MHT	DNY	NYSERDA
Bedroom	47	228	24	75	374	60	103	178
Bathroom	35	171	21	33	260	77	107	140
Kitchen	25	132	12	29	198	33	53	82
Living Space	40	174	11	56	281	54	85	141
Dining Room	30	101	10	37	178	30	49	86
Exterior	7	66	3	21	97	1	11	32
Other	53	195	24	74	346	28	73	147
Household	237	1067	105	325	1734	283	481	806

Table 3-5: HOU by Area for Efficient Bulbs

Room	CT	MA	RI	UNY	Overall	MHT	DNY	NYSERDA
Bedroom	2.8 (2.4, 3.3) bdefg	2.3 (2.0, 2.6) acfgh	3.1 (2.4, 3.7) bdefg	2.2 (1.7, 2.6) acfgh	2.4 (2.2, 2.6) acfgh	4.2 (3.3, 5.0) abcde	4.4 (3.6, 5.2) abcdeh	3.3 (2.8, 3.8) bdeg
Bathroom	1.8 (1.3, 2.2) fgh	2.2 (1.9, 2.5) fgh	1.7 (1.0, 2.4) fgh	2.1 (1.7, 2.6) fgh	2.1 (1.8, 2.3) fgh	3.5 (2.8, 4.3) abcde	4.6 (3.4, 5.8) abcde	3.6 (2.8, 4.5) abcde
Kitchen	4.7 (4.2, 5.3) fgh	4.2 (3.9, 4.5) fgh	4.2 (3.4, 5.0) fgh	4.3 (3.9, 4.8) fgh	4.3 (4.1, 4.6) fgh	6.7 (5.8, 7.6) abcde	7.7 (6.4, 9.0) abcde	6.3 (5.4, 7.1) abcde
Living Space	4.0 (3.5, 4.5)	3.6 (3.3, 3.9) fg	3.7 (2.9, 4.5) g	3.3 (2.8, 3.8) fgh	3.6 (3.4, 3.9) fg	4.7 (3.9, 5.5) bde	5.1 (4.1, 6.2) bcde	4.3 (3.5, 5.0) d
Dining Room	3.5 (2.9, 4.2) fg	3.1 (2.6, 3.5) fgh	3.9 (2.8, 5.0)	2.9 (2.3, 3.5) fgh	3.1 (2.8, 3.5) fgh	5.4 (4.3, 6.4) abde	5.4 (4.1, 6.6) abde	4.1 (3.3, 4.9) bde
Exterior	6.7 (6.1, 7.3) bdegh	5.8 (5.5, 6.2) ac	6.7 (6.1, 7.4) bdegh	5.7 (5.2, 6.2) ac	6.0 (5.6, 6.3) ac	--	4.8 (3.0, 6.6) ac	5.4 (4.3, 6.5) ac
Other	2.0 (1.7, 2.3) fgh	2.0 (1.7, 2.2) fgh	1.7 (1.3, 2.1) fgh	2.0 (1.7, 2.3) fgh	2.0 (1.8, 2.1) fgh	4.1 (2.9, 5.3) abcde	3.9 (2.8, 5.0) abcde	2.9 (2.2, 3.6) abcde
Household	3.1 (2.9, 3.3) fgh	3.0 (2.9, 3.1) fgh	3.0 (2.7, 3.3) fgh	3.0 (2.8, 3.2) fgh	3.0 (2.9, 3.1) fgh	4.7 (4.1, 5.4) abcde	5.2 (4.4, 6) abcdeh	4.0 (3.4, 4.5) abcdeg

[a] – Statistically different at the 90% confidence level from Connecticut
[b] – Statistically different at the 90% confidence level from Massachusetts
[c] – Statistically different at the 90% confidence level from Rhode Island
[d] – Statistically different at the 90% confidence level from Upstate NY
[e] – Statistically different at the 90% confidence level from Overall
[f] – Statistically different at the 90% confidence level from Manhattan
[g] – Statistically different at the 90% confidence level from Downstate NY
[h] – Statistically different at the 90% confidence level from NYSERDA Overall

Table 3-6: Sample Sizes, Efficient Bulbs

Room	CT	MA	RI	UNY	Overall	MHT	DNY	NYSERDA
Bedroom	53	223	23	52	351	48	85	137
Bathroom	44	121	16	74	255	42	78	152
Kitchen	54	219	21	91	385	71	115	206
Living Space	45	175	24	57	301	48	75	132
Dining Room	22	70	6	35	133	21	41	76
Exterior	7	48	4	12	71	0	5	17
Other	87	252	33	75	447	31	85	160
Household	312	1108	127	396	1943	261	484	880

3.4.2 Efficient and Inefficient Bulb Types – Unweighted Analyses

To further explore the root causes of differences in HOU estimates for inefficient and efficient bulbs, the Team turned to unweighted and unadjusted analyses of HOU estimates. As Table 3-7 shows, CFLs and fluorescent HOU estimates are significantly higher compared to both incandescent and halogen estimates. Unfortunately, LEDs have not yet been adopted in high enough quantities to comprise a significant amount of our sample, and the resulting confidence interval surrounding LED HOU estimates is quite wide.

Table 3-7: Daily Average HOU Overall by Type of Bulb (Unweighted)

Bulb Type	n	All Households	90% Confidence Interval
All	4,642	2.95	± 0.12
Efficient[1]	2,427	3.35	± 0.17
Inefficient[2]	2,215	2.51	± 0.14
Incandescent	*2,109*	*2.49*	*± 0.14*
CFL	*1,922*	*3.16*	*± 0.17*
Fluorescent	*475*	*4.04*	*± 0.40*
Halogen	*106*	*2.86*	*± 0.52*
LED	*30*	*4.30*	*± 1.74*

[1] Includes CFL, fluorescent, and LED bulbs.
[2] Includes incandescent and halogen bulbs.

Next, the Team evaluated usage by fixture, room, and number of bulbs unweighted. Within each chart, an asterisk (*) denotes a statistically significant difference at the 90% confidence level within a category (inefficient vs. efficient).

Figure 3-5 illustrates significant differences between inefficient and efficient bulbs in seven room types: bathrooms, bedrooms, closets, dining rooms, hallways, kitchens, and living spaces. Five of these room types (bathrooms, bedrooms, kitchens, living spaces, and dining rooms) comprise the top five room types by socket count among Northeast homes, accounting for over three-fifths of household sockets.

Figure 3-6 shows the HOU estimates by bulb type and fixture type for all households in the study. Four fixture categories demonstrate significant differences between inefficient and efficient bulbs: floor lamps, flush mounts, table lamps, and wall mounts.

Figure 3-5: HOU Estimates by Bulb Type and Room Type (unweighted)

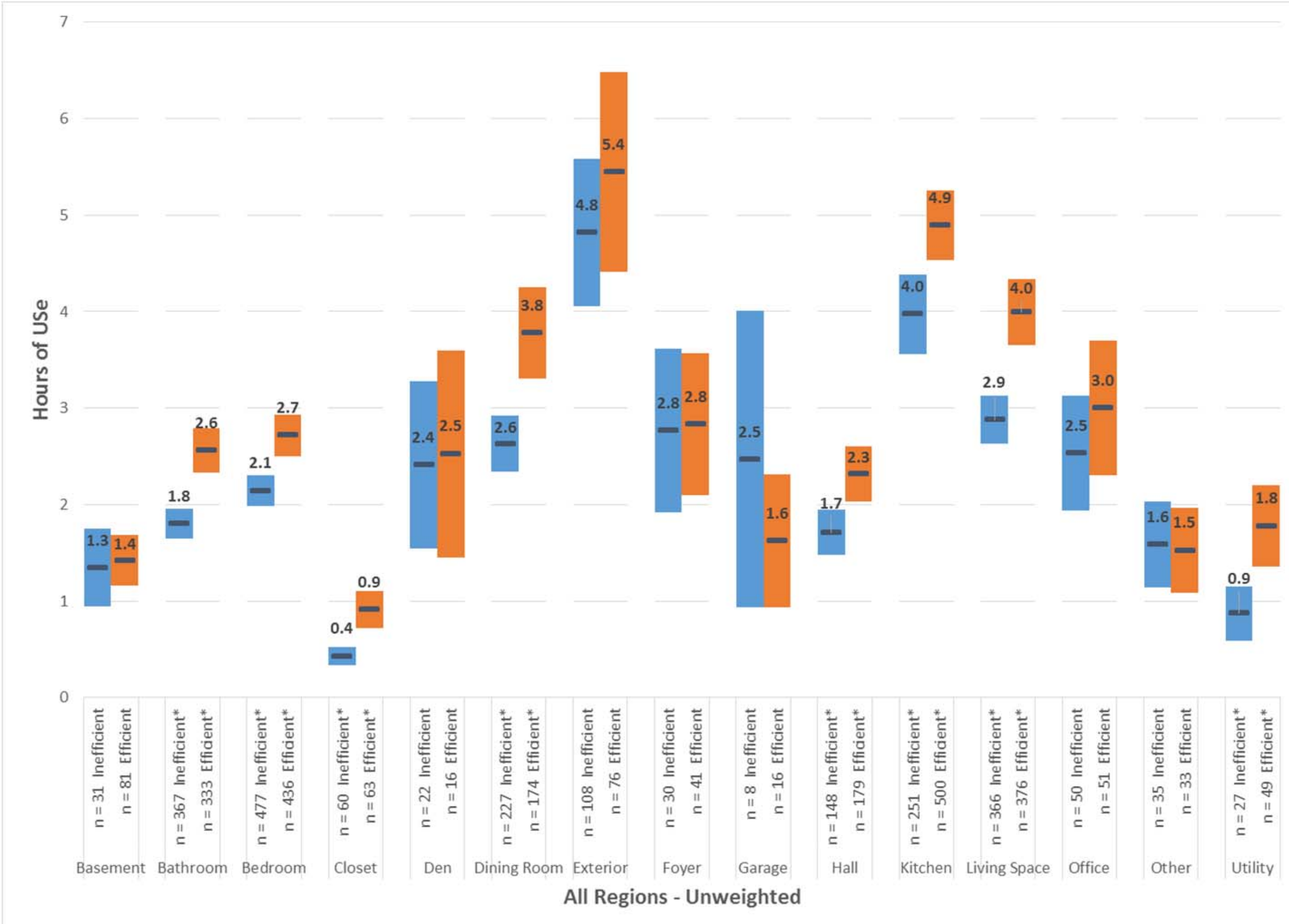
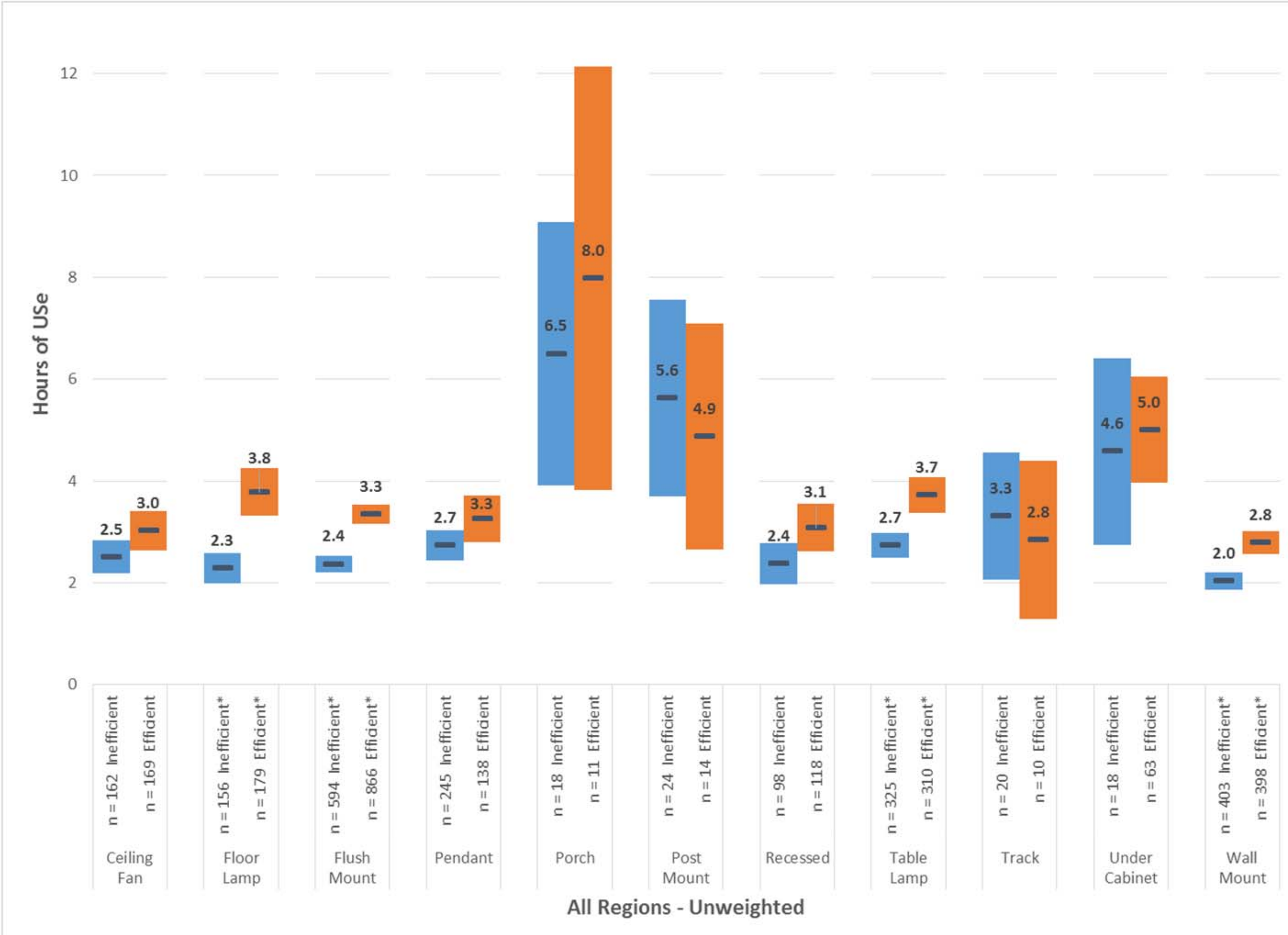


Figure 3-6: HOU Estimates by Bulb Type and Fixture Type (unweighted)



3.4.3 HOU by Saturation of Efficient Bulbs

While the difference in HOU between efficient and inefficient bulbs is persistent across all regions and room types, the reason for this difference remains unclear. To investigate, the Team also calculated unweighted HOU for several breakdowns by CFL saturation and 1) total number of sockets in the home; 2) total number of rooms in the home; and 3) total number of fixtures in the home. Each of the variables considered was broken into quartiles of the distribution at the household level. For example, in Table 3-10 below, roughly 25% of all households in the overall region (excluding Downstate New York) had saturation less than or equal to 20%, 25% of all homes had saturation between 21% and 35%, 25% of all homes had saturation between 36% and 54%, and 25% had saturation greater than 54%. Similarly, roughly 25% had no more than 17 sockets, 25% had 18 to 25 sockets, 25% had 26 to 49 sockets, and 25% over 49 sockets.

Table 3-10 to Table 3-21 below present the results for all these breakdowns. The Team created separate tables for the overall region excluding Downstate New York, and for Downstate New York exclusively. While some patterns may appear within any one efficient bulb table, similar patterns (but at lower levels) will appear in the corresponding inefficient bulb table. In other words, the patterns of HOU for efficient and inefficient bulbs appear to mirror each other, except that the efficient HOU are always a bit higher. This suggests that, for some reason, efficient bulbs simply have a universally higher level of usage than inefficient bulbs across the Overall region.

Another factor apparent in the tables below is the lack of association between saturation and efficient bulb HOU—that is, no consistent pattern emerges between the percentage of sockets filled with efficient bulbs and the HOU for those bulbs. This was also true across all bulb types in our regression models, as household saturation was consistently not a significant predictor of HOU. Figure 3-8 and Figure 3-9 below summarize the overall relationship between efficient bulb HOU and saturation for the overall region excluding Downstate New York and exclusively for Downstate New York, respectively. Consistent with previous work by NMR, the relationship is virtually non-existent.[40]

The differences in bulb efficiencies may be evidence supporting one of three competing theories among some lighting program implementers and evaluators about how households use efficient bulbs. The three theories are:

- **Differential socket selection**, which occurs when a household targets installing efficient bulbs in the fixtures that are used most frequently in any given room. In this scenario household lighting preferences are static. The Team believes it would be reasonable for the Sponsors to claim higher HOU caused by differential socket selection because the efficient bulbs are operating for the same HOU as the inefficient bulbs replaced.

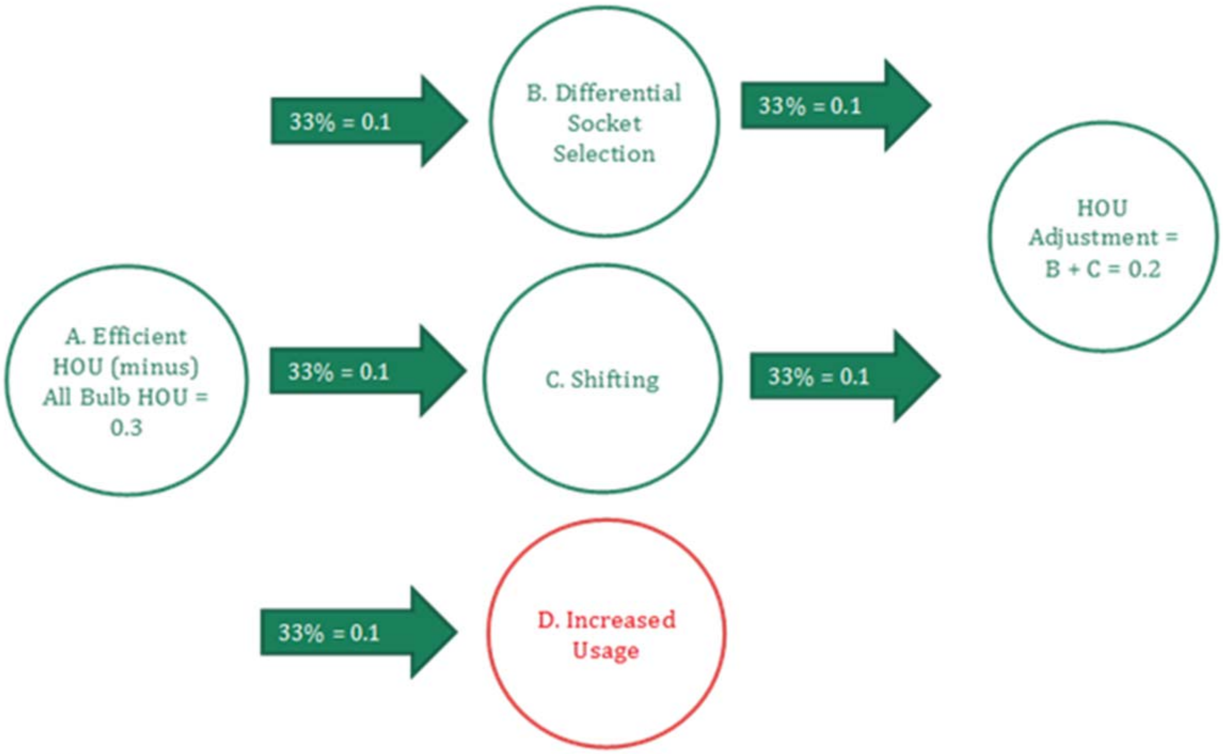
[40] NMR, RLW, GDS. *Residential Lighting Markdown Impact Evaluation.* January 20, 2009.

- **Shifting usage**, which occurs when a household installs an efficient bulb in a socket and then begins to use that socket in lieu of sockets containing inefficient bulbs. In this scenario, the Team believes it would be reasonable for the Sponsors to claim savings for the shift in usage because HOU for the fixture that is used more frequently offset usage from inefficient fixtures. This theory does not discount the possibility that the fixture selected was already the most frequently used fixture in a given room.
- **Increased usage (snapback)**, which occurs when a household installs an efficient bulb in a socket and begins using that socket more because the cost to operate that light is lower. Any increased HOU that occurs as a result of snapback should be excluded when the Sponsors claim energy savings.[41]

In the absence of clear evidence supporting one theory over the others, the Team suggests assuming that the difference between efficient and all-bulb HOU is caused equally by the behavior posited by all three theories. Figure 3-7 provides an illustration giving each of the three possible scenarios equal weight. As explained above, only one of the three scenarios (increased usage) should be excluded when the Sponsors calculate energy savings. Table 3-8 and Table 3-9 provide HOU estimates by area and room adjusted to exclude increased HOU resulting from snapback.

[41] More specifically, snapback or rebound effects refer to changes in patterns of usage that occur after energy-efficient products are installed and result in reduced overall energy savings. In the case of residential lighting, snapback would result in households using an energy-efficient light bulb for more hours per day than they used the replaced inefficient bulb, without any corresponding reduction in the HOU of other inefficient bulbs in the room.

Figure 3-7: Adjusting for Differences between Efficient and All-Bulb HOU



	HOU		
	3.0	Efficient HOU	
	2.7	All bulb HOU	
A.	0.3	Difference	
B.	0.1	Differential Socket Selection	= one-third of difference
C.	0.1	Shifting	= one-third of difference
D.	0.1	Increased Usage	= one-third of difference
	2.90	Adjusted Efficient HOU	= all bulb HOU + differential socket selection + shifting (2.7 + 0.1 + 0.1) OR = efficient bulb HOU - increased usage (3.0 - 0.1)

Table 3-8: HOU by Area Adjusted for Snapback

Room	CT	MA	RI	UNY	Overall
Bedroom	2.8 (2.4, 3.1) bdefg	2.2 (2.0, 2.4) acfgh	2.9 (2.4, 3.4) bdefg	2.0 (1.7, 2.3) acfgh	2.3 (2.1, 2.5) acfgh
Bathroom	1.7 (1.3, 2.0) fgh	2.0 (1.8, 2.3) fgh	1.6 (1.1, 2.1) fgh	2.1 (1.7, 2.4) fgh	2.0 (1.8, 2.1) fgh
Kitchen	4.7 (4.3, 5.1) bfgh	4.2 (3.9, 4.4) afgh	4.1 (3.5, 4.6) fgh	4.3 (3.9, 4.6) fgh	4.2 (4.1, 4.4) fgh
Living Space	3.9 (3.5, 4.3) dg	3.5 (3.3, 3.7) fgh	3.6 (3.0, 4.2) fg	3.2 (2.9, 3.6) afgh	3.5 (3.4, 3.7) fgh
Dining Room	3.4 (2.9, 3.9) fg	3.0 (2.6, 3.3) fgh	3.8 (3.0, 4.6) df	2.8 (2.3, 3.2) cfgh	3.0 (2.8, 3.3) fgh
Exterior	6.5 (6.0, 6.9) bdegh	5.7 (5.5, 6.0) acg	6.7 (6.2, 7.2) bdegh	5.7 (5.3, 6.0) ac	5.8 (5.6, 6.1) acg
Other	1.9 (1.7, 2.1) fgh	1.9 (1.7, 2.0) fgh	1.7 (1.4, 2.0) fgh	1.9 (1.7, 2.1) fgh	1.9 (1.8, 2.0) fgh
Household	3.0 (2.8, 3.2) fgh	2.9 (2.8, 3.0) fgh	2.9 (2.7, 3.1) fgh	2.8 (2.7, 3.0) fgh	2.9 (2.8, 3.0) fgh

[1] – The Overall model includes CT, MA, RI, and UNY. The Overall model excludes MHT and DNY.
[a] – Statistically different at the 90% confidence level from Connecticut
[b] – Statistically different at the 90% confidence level from Massachusetts
[c] – Statistically different at the 90% confidence level from Rhode Island
[d] – Statistically different at the 90% confidence level from Upstate NY
[e] – Statistically different at the 90% confidence level from the Overall model
[f] – Statistically different at the 90% confidence level from Manhattan
[g] – Statistically different at the 90% confidence level from Downstate NY
[h] – Statistically different at the 90% confidence level from NYSERDA Overall

Table 3-9: HOU by Area Adjusted for Snapback

Room	MHT	DNY	NYSERDA
Bedroom	3.9 (3.3, 4.5) abcdeh	4.1 (3.6, 4.7) abcdeh	3.2 (2.8, 3.5) bdefg
Bathroom	3.3 (2.7, 3.8) abcde	4.1 (3.3, 5.0) abcde	3.4 (2.8, 4.0) abcde
Kitchen	6.6 (5.9, 7.2) abcde	7.5 (6.5, 8.4) abcdeh	6.1 (5.4, 6.7) abcdeg
Living Space	4.4 (3.8, 5.0) bcde	4.9 (4.1, 5.7) abcde	4.2 (3.6, 4.7) bde
Dining Room	5.1 (4.3, 5.8) abcdeh	4.9 (4.0, 5.8) abdeh	3.8 (3.2, 4.4) bdefg
Exterior	--	4.4 (3.1, 5.7) abce	5.2 (4.4, 6.0) ac
Other	3.9 (3.0, 4.8) abcdeh	3.7 (2.9, 4.5) abcdeh	2.7 (2.3, 3.2) abcdefg
Overall	4.5 (4.0, 5.0) abcdeh	4.8 (4.3, 5.4) abcdeh	3.7 (3.4, 4.1) abcdefg

[1] – The DNY model includes MHT.
[2] – The NYSERDA model includes UNY and DNY (including MHT)
[a] – Statistically different at the 90% confidence level from Connecticut
[b] – Statistically different at the 90% confidence level from Massachusetts
[c] – Statistically different at the 90% confidence level from Rhode Island
[d] – Statistically different at the 90% confidence level from Upstate NY
[e] – Statistically different at the 90% confidence level from the Overall model
[f] – Statistically different at the 90% confidence level from Manhattan
[g] – Statistically different at the 90% confidence level from Downstate NY
[h] – Statistically different at the 90% confidence level from NYSERDA Overall

Table 3-10 Efficient Bulb HOU by Saturation by #Sockets – Overall excluding DNY

Saturation	# Sockets	HOU	90% CI
<= 20%	<= 17	3.6	(2.6, 4.6)
	18 to 25	2.8	(1.8, 3.8)
	26 to 49	3.1	(2.5, 3.6)
	> 49	2.5	(1.9, 3.1)
21% to 35%	<= 17	3.8	(3.0, 4.6)
	18 to 25	5.1	(3.8, 6.4)
	26 to 49	2.3	(1.9, 2.7)
	> 49	2.7	(2.3, 3.1)
36% to 54%	<= 17	3.4	(2.6, 4.3)
	18 to 25	2.3	(1.7, 2.9)
	26 to 49	3.2	(2.6, 3.9)
	> 49	3.4	(2.6, 4.3)
>54%	<= 17	2.9	(2.5, 3.3)
	18 to 25	2.8	(2.4, 3.2)
	26 to 49	2.7	(2.2, 3.3)
	> 49	3.4	(2.6, 4.2)

Table 3-11 Inefficient Bulb HOU by Saturation by #Sockets – Overall excluding DNY

Saturation	# Sockets	HOU	90% CI
<= 20%	<= 17	2.7	(2.2, 3.2)
	18 to 25	2.7	(2.0, 3.4)
	26 to 49	2.4	(2.0, 2.7)
	> 49	2.2	(1.9, 2.5)
21% to 35%	<= 17	2.0	(1.6, 2.4)
	18 to 25	2.3	(1.9, 2.8)
	26 to 49	2.1	(1.6, 2.5)
	> 49	2.2	(1.8, 2.7)
36% to 54%	<= 17	2.1	(1.5, 2.7)
	18 to 25	2.5	(1.7, 3.4)
	26 to 49	2.6	(1.9, 3.3)
	> 49	2.4	(1.9, 3.3)
>54%	<= 17	2.4	(1.7, 3.1)
	18 to 25	1.6	(1.2, 2.1)
	26 to 49	1.9	(1.3, 2.6)
	> 49	3.2	(2.2, 4.2)

Table 3-12 Efficient Bulb HOU by Saturation by #Sockets – DNY

Saturation	# Sockets	HOU	90% CI
<= 10%	<= 10	6.7	(4.1, 9.4)
	11 to 14	4.7	(3.0, 6.4)
	15 to 23	4.7	(2.2, 7.1)
	> 23	5.3	(2.7, 8.0)
10% to 25%	<= 10	5.0	(2.4, 7.6)
	11 to 14	6.1	(4.3, 7.8)
	15 to 23	4.3	(2.8, 5.7)
	> 23	5.9	(4.3, 7.5)
26% to 49%	<= 10	4.8	(2.6, 7.1)
	11 to 14	4.0	(2.9, 5.0)
	15 to 23	4.4	(2.2, 6.5)
	> 23	3.7	(2.2, 5.2)
>49%	<= 10	4.8	(3.2, 6.3)
	11 to 14	5.1	(3.8, 6.5)
	15 to 23	5.3	(2.7, 8.0)
	> 23	3.2	(2.3, 4.2)

Table 3-13 Inefficient Bulb HOU by Saturation by #Sockets – DNY

Saturation	# Sockets	HOU	90% CI
<= 10%	<= 10	3.9	(2.6, 5.3)
	11 to 14	4.2	(2.8, 5.6)
	15 to 23	3.0	(2.1, 3.9)
	> 23	3.1	(2.4, 3.8)
10% to 25%	<= 10	1.9	(0.9, 2.9)
	11 to 14	3.5	(2.2, 4.8)
	15 to 23	2.1	(1.6, 2.6)
	> 23	2.7	(1.9, 3.6)
26% to 49%	<= 10	2.3	(1.0, 3.6)
	11 to 14	2.1	(1.6, 2.6)
	15 to 23	3.4	(2.5, 4.3)
	> 23	1.9	(1.1, 2.7)
>49%	<= 10	2.2	(0.8, 3.6)
	11 to 14	0.6	(0.4, 0.8)
	15 to 23	5.7	(-1.2, 12.6)
	> 23	3.6	(1.2, 5.9)

Table 3-14 Efficient Bulb HOU by Saturation by #Rooms – Overall excluding DNY

Saturation	# Rooms	HOU	90% CI
<= 20%	<= 7	3.3	(2.5, 4.1)
	8 to 9	2.7	(1.9, 3.6)
	10 to 12	3.1	(2.5, 3.7)
	> 12	2.9	(2.0, 3.7)
21% to 35%	<= 7	3.5	(2.8, 4.1)
	8 to 9	3.5	(2.3, 4.7)
	10 to 12	2.9	(2.2, 3.7)
	> 12	2.8	(2.3, 3.3)
36% to 54%	<= 7	3.4	(2.7, 4.1)
	8 to 9	2.7	(2.1, 3.3)
	10 to 12	3.6	(2.6, 4.7)
	> 12	2.6	(2.0, 3.2)
>54%	<= 7	2.8	(2.5, 3.1)
	8 to 9	3.1	(2.4, 3.7)
	10 to 12	2.7	(2.2, 3.3)
	> 12	3.1	(2.4, 3.8)

Table 3-15 Inefficient Bulb HOU by Saturation by #Rooms – Overall excluding DNY

Saturation	# Rooms	HOU	90% CI
<= 20%	<= 7	2.6	(2.2, 3.0)
	8 to 9	2.3	(1.9, 2.8)
	10 to 12	2.7	(2.1, 3.2)
	> 12	2.1	(1.7, 2.6)
21% to 35%	<= 7	1.9	(1.5, 2.2)
	8 to 9	2.0	(1.5, 2.6)
	10 to 12	2.5	(2.0, 2.9)
	> 12	2.3	(1.9, 2.8)
36% to 54%	<= 7	2.1	(1.7, 2.5)
	8 to 9	2.3	(1.5, 3.2)
	10 to 12	2.5	(1.5, 3.4)
	> 12	2.7	(2.0, 3.4)
>54%	<= 7	2.0	(1.5, 2.4)
	8 to 9	2.2	(1.5, 2.9)
	10 to 12	2.0	(1.1, 2.9)
	> 12	2.2	(1.3, 3.1)

Table 3-16 Efficient Bulb HOU by Saturation by #Rooms – DNY

Saturation	# Rooms	HOU	90% CI
<= 10%	<= 7	6.1	(4.1, 8.1)
	8 to 9	4.8	(2.6, 7.0)
	10 to 12	5.4	(3.7, 7.2)
	> 12	5.7	(0.5, 10.9)
10% to 25%	<= 7	4.8	(2.7, 7.0)
	8 to 9	4.4	(3.0, 5.8)
	10 to 12	6.3	(5.3, 7.3)
	> 12	4.8	(1.8, 7.9)
26% to 49%	<= 7	4.0	(2.5, 5.4)
	8 to 9	4.8	(3.1, 6.5)
	10 to 12	4.6	(3.2, 6.1)
	> 12	2.9	(1.8, 4.1)
>49%	<= 7	4.5	(3.0, 6.0)
	8 to 9	5.2	(2.8, 7.6)
	10 to 12	5.5	(4.1, 6.9)
	> 12	3.2	(2.3, 4.2)

Table 3-17 Inefficient Bulb HOU by Saturation by #Rooms – DNY

Saturation	# Rooms	HOU	90% CI
<= 10%	<= 7	3.6	(2.4, 4.8)
	8 to 9	3.7	(2.5, 4.8)
	10 to 12	3.6	(2.9, 4.4)
	> 12	3.1	(2.0, 4.1)
10% to 25%	<= 7	2.0	(1.2, 2.9)
	8 to 9	2.8	(1.7, 4.0)
	10 to 12	2.4	(2.0, 2.8)
	> 12	2.8	(1.8, 3.9)
26% to 49%	<= 7	2.1	(1.5, 2.8)
	8 to 9	2.0	(0.4, 3.5)
	10 to 12	3.0	(2.3, 3.7)
	> 12	1.8	(0.7, 3.0)
>49%	<= 7	0.9	(0.6, 1.3)
	8 to 9	4.0	(-0.1, 8.0)
	10 to 12	3.9	(-0.6, 8.4)
	> 12	3.6	(1.2, 5.9)

Table 3-18 Efficient Bulb HOU by Saturation by #Fixtures – Overall excluding DNY

Saturation	# Fixtures	HOU	90% CI
<= 20%	<= 12	3.3	(2.4, 4.2)
	12 to 19	3.3	(2.4, 4.3)
	20 to 34	3.2	(2.6, 3.7)
	> 34	2.6	(1.9, 3.2)
21% to 35%	<= 12	4.1	(3.3, 4.9)
	12 to 19	4.5	(3.3, 5.6)
	20 to 34	2.5	(1.9, 3.1)
	> 34	2.6	(2.2, 2.9)
36% to 54%	<= 12	3.8	(3.0, 4.6)
	12 to 19	2.5	(1.8, 3.1)
	20 to 34	2.4	(1.9, 2.9)
	> 34	3.8	(2.9, 4.7)
>54%	<= 12	2.8	(2.4, 3.1)
	12 to 19	2.9	(2.4, 3.3)
	20 to 34	3.0	(2.4, 3.6)
	> 34	3.4	(2.5, 4.3)

Table 3-19 Inefficient Bulb HOU by Saturation by #Fixtures – Overall excluding DNY

Saturation	# Fixtures	HOU	90% CI
<= 20%	<= 12	2.6	(2.1, 3.0)
	12 to 19	2.6	(2.1, 3.1)
	20 to 34	2.5	(1.9, 3.1)
	> 34	2.2	(1.9, 2.6)
21% to 35%	<= 12	2.1	(1.6, 2.5)
	12 to 19	2.1	(1.6, 2.6)
	20 to 34	2.2	(1.7, 2.7)
	> 34	2.4	(1.9, 2.8)
36% to 54%	<= 12	2.3	(1.8, 2.8)
	12 to 19	2.1	(1.4, 2.8)
	20 to 34	2.6	(1.8, 3.3)
	> 34	2.4	(1.7, 3.2)
>54%	<= 12	1.9	(1.4, 2.3)
	12 to 19	2.0	(1.5, 2.6)
	20 to 34	1.8	(1.0, 2.6)
	> 34	3.2	(2.4, 4.1)

Table 3-20 Efficient Bulb HOU by Saturation by #Fixtures – DNY

Saturation	# Fixtures	HOU	90% CI
<= 10%	<= 10	5.5	(3.3, 7.8)
	11 to 14	5.7	(3.3, 8.1)
	15 to 23	5.2	(3.3, 7.0)
	> 23	5.2	(2.6, 7.8)
10% to 25%	<= 10	4.2	(1.9, 6.5)
	11 to 14	7.6	(6.1, 9.1)
	15 to 23	4.7	(3.7, 5.7)
	> 23	5.4	(3.5, 7.3)
26% to 49%	<= 10	3.8	(2.3, 5.3)
	11 to 14	4.8	(2.9, 6.7)
	15 to 23	3.5	(2.5, 4.5)
	> 23	4.7	(2.3, 7.2)
>49%	<= 10	5.0	(3.6, 6.3)
	11 to 14	5.4	(3.8, 7.1)
	15 to 23	4.4	(1.9, 7.0)
	> 23	3.2	(2.3, 4.2)

Table 3-21 Inefficient Bulb HOU by Saturation by #Fixtures - DNY

Saturation	# Fixtures	HOU	90% CI
<= 10%	<= 10	4.2	(3.1, 5.3)
	11 to 14	2.7	(1.3, 4.0)
	15 to 23	3.3	(2.4, 4.2)
	> 23	3.2	(2.4, 4.0)
10% to 25%	<= 10	1.9	(1.2, 2.6)
	11 to 14	3.2	(1.2, 5.2)
	15 to 23	2.5	(1.8, 3,1)
	> 23	2.8	(1.9, 3.6)
26% to 49%	<= 10	2.0	(1.0, 3.0)
	11 to 14	2.2	(1.7, 2.7)
	15 to 23	3.1	(2.1, 4.1)
	> 23	2.1	(1.2, 3.1)
>49%	<= 10	2.2	(0.8, 3.6)
	11 to 14	0.6	(0.4, 0.9)
	15 to 23	3.1	(-0.7, 7.0)
	> 23	3.6	(1.2, 5,9)

Figure 3-8 Efficient HOU vs. Saturation – Overall excluding DNY

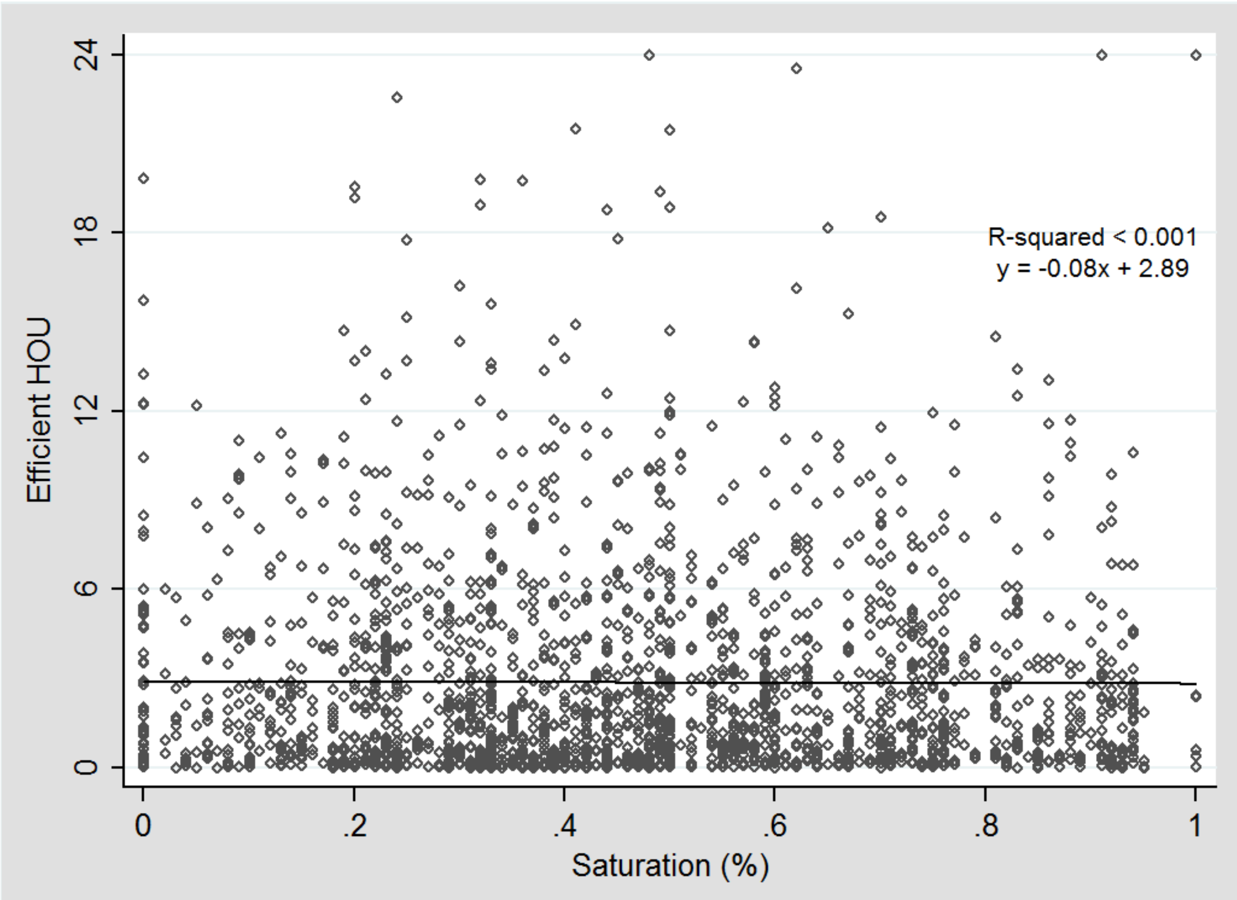
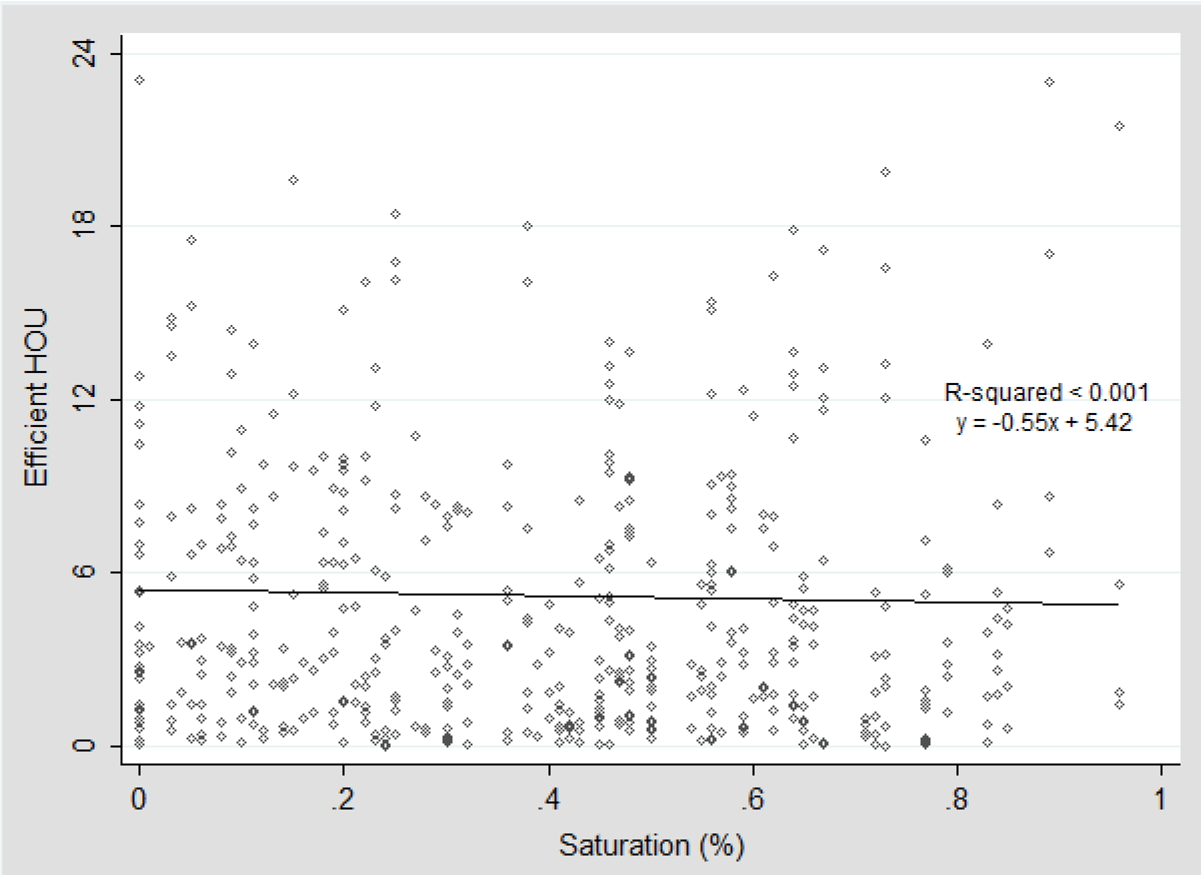


Figure 3-9 Efficient HOU vs Saturation - Downstate NY



4 Load Shape Analysis

This chapter describes the analysis of the monthly load shapes for December and January (winter peak period) and for June, July, and August (summer peak period) as well as the calculation of coincidence factors. The development of monthly load shapes is discussed in Section 2.7.

4.1 Summer and Winter Load Shapes

Figure 4-1 through Figure 4-8 present the summer and winter weekday load shapes for the eight area models (Connecticut, Massachusetts, Rhode Island, Upstate New York, Overall, Manhattan, Downstate New York, and NYSERDA). Additional load curves broken down by home type and income as well as load curves with weekend data can be found in Appendix C. In each load curve, the relevant summer and winter peak periods (1 P.M. to 5 P.M. in the summer and 5 P.M. to 7 P.M. in the winter, based on the hour ending) are shaded. Average percent on during summer and winter peak periods is shown in the upper left, and the calculated confidence interval is displayed for each hour. All of the load curves for each of the areas show a similar pattern of low usage starting around midnight, ramping up beginning in the hour ending at 6

P.M., building until around noon, and then flattening off. In each area there is also a slight ramp up in usage entering the evening hours around the hour ending at 6 P.M. or 7 P.M. (near the end of the winter peak period).

Figure 4-1: Connecticut Load Curve for Summer and Winter (Weekday)

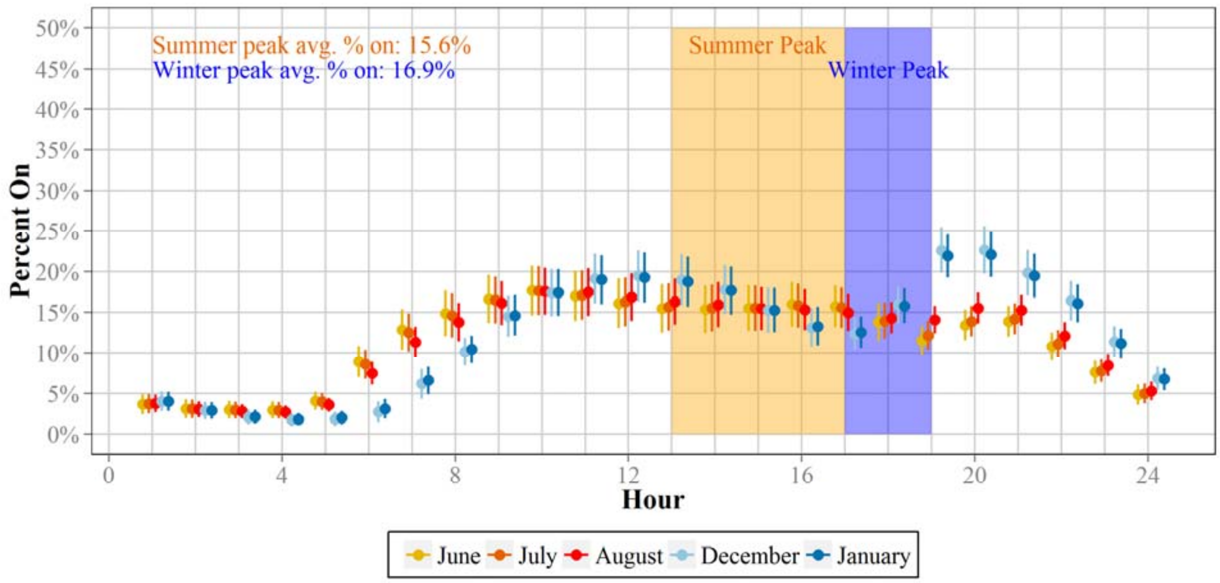


Figure 4-2: Massachusetts Load Curve for Summer and Winter (Weekday)

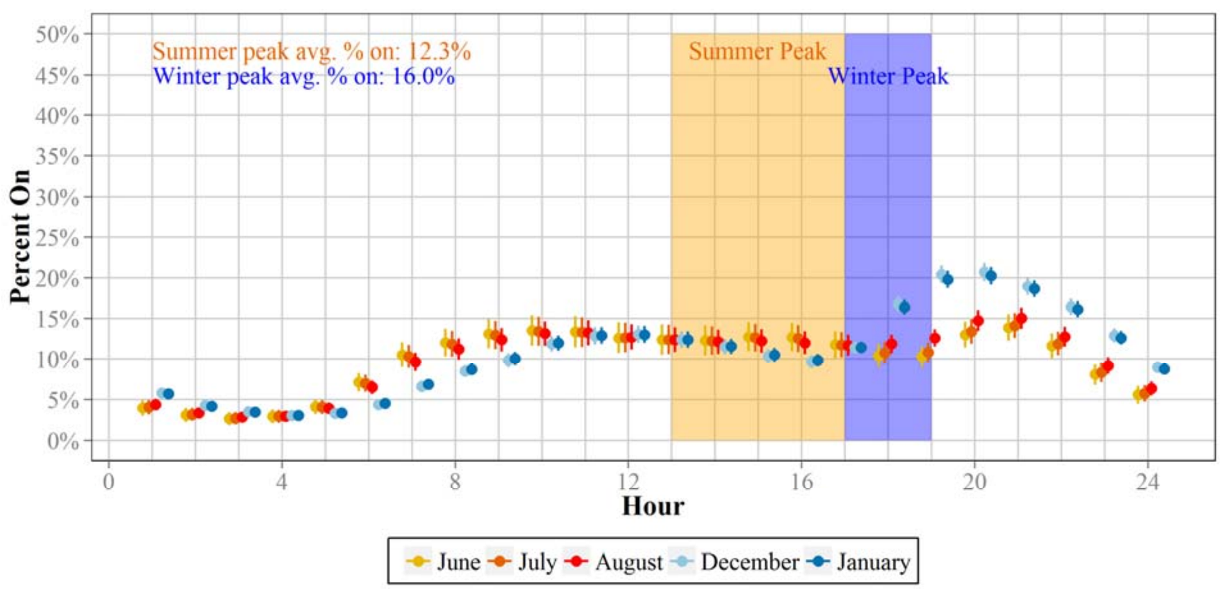


Figure 4-3: Rhode Island Load Curve for Summer and Winter (Weekday)

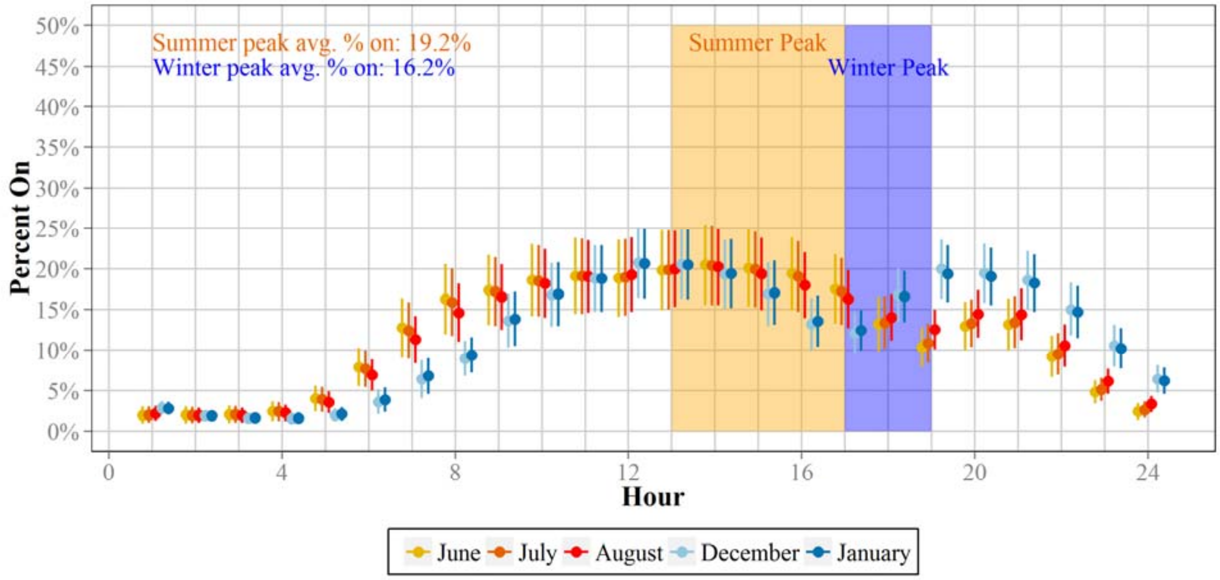


Figure 4-4: Upstate New York Load Curve for Summer and Winter (Weekday)

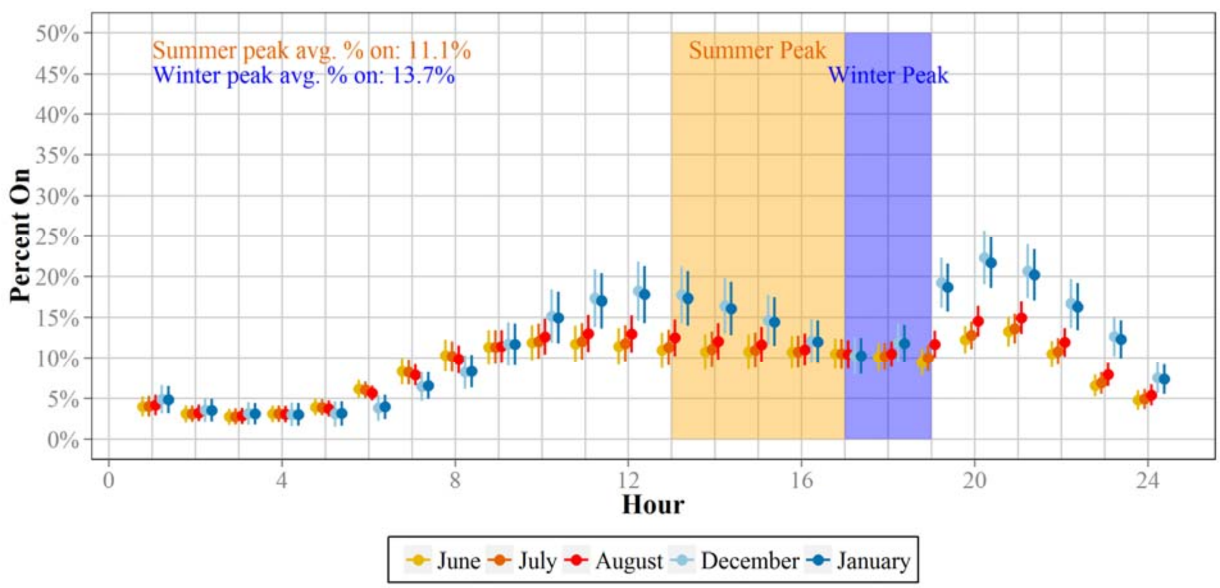


Figure 4-5: Overall Load Curve for Summer and Winter (Weekday)

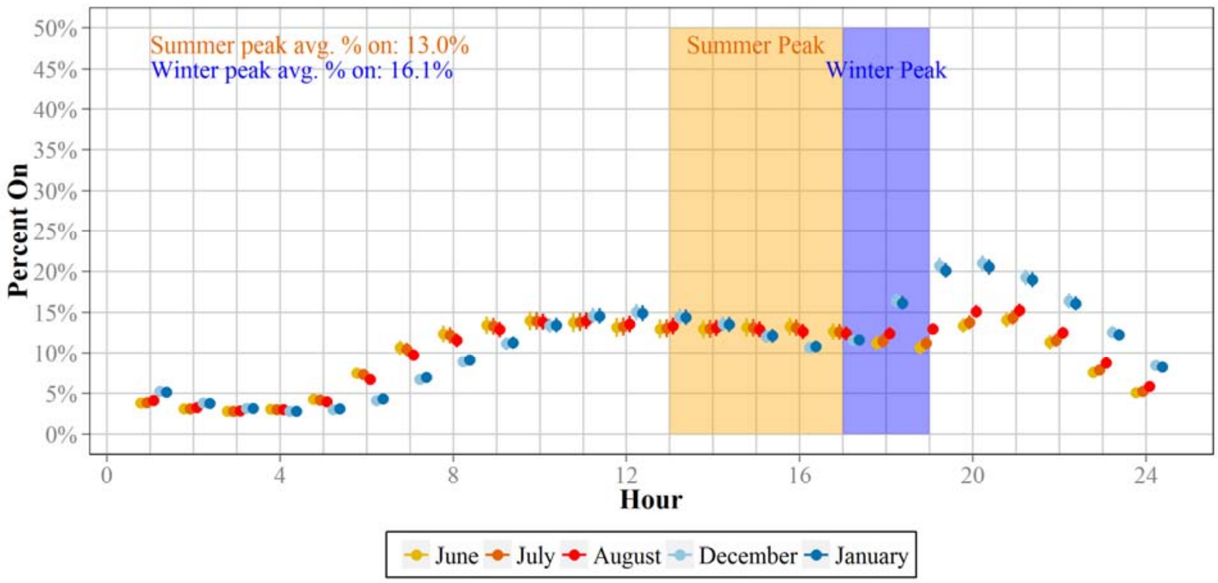


Figure 4-6: Manhattan Load Curve for Summer and Winter (Weekday)

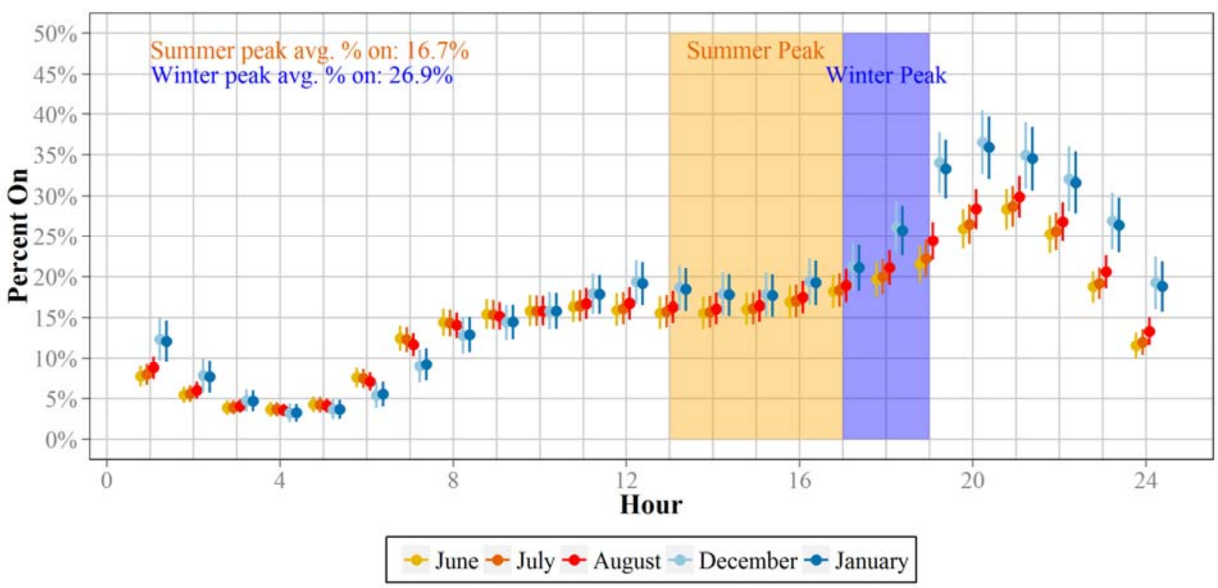


Figure 4-7: Downstate New York Load Curve for Summer and Winter (Weekday)

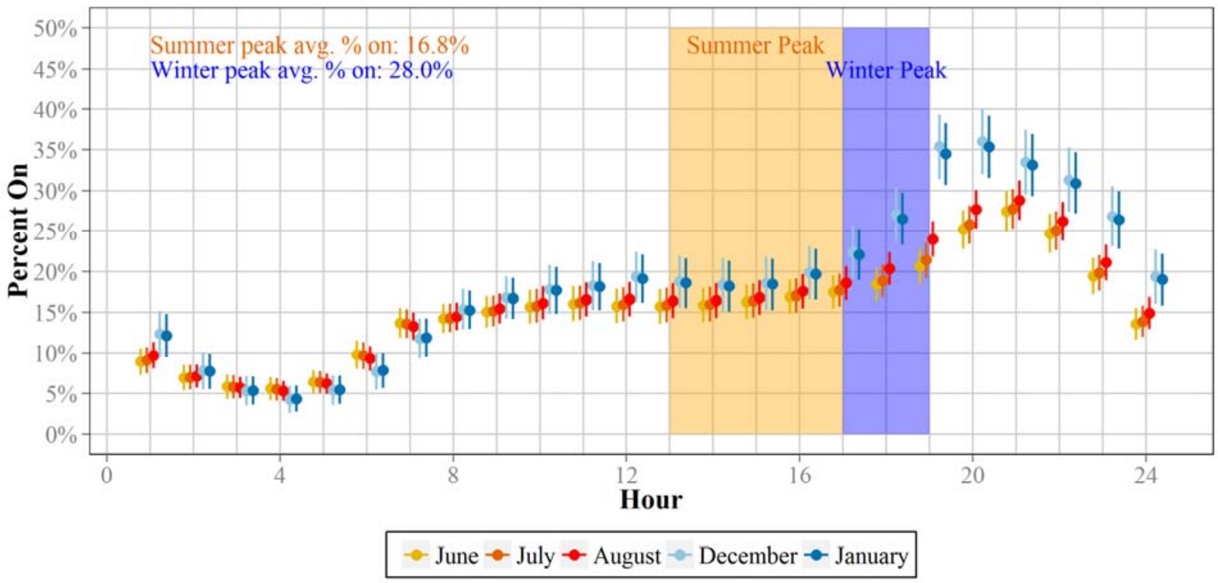
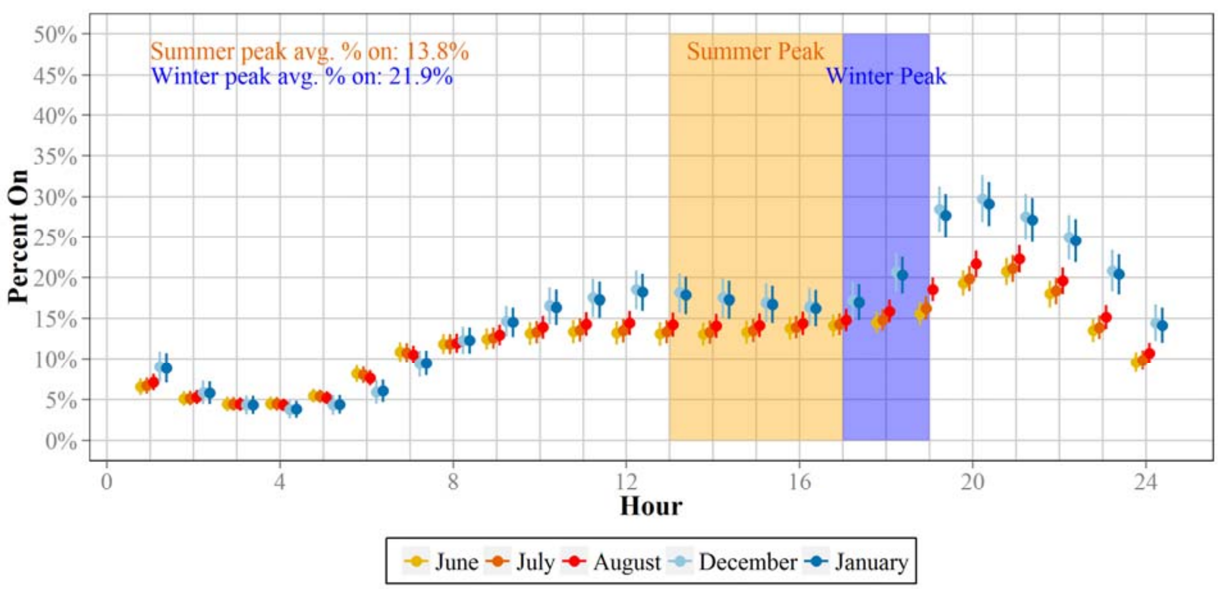


Figure 4-8: NYSERDA Load Curve for Summer and Winter (Weekday)



4.2 Calculating Coincidence Factors for Peak Periods

Using the data that informed the monthly load shapes for the three New England states included in the study, the Team calculated coincidence factors (CFs) during the New England Independent System Operator (ISO-NE) summer and winter on-peak and Seasonal Peak hours. CFs are ratios that represent the percentage of light bulbs in operation during a period of interest and are used in calculating demand reductions. According to ISO-NE, the winter on-peak hours are during non-holiday weekdays from 5 P.M. to 7 P.M. The summer on-peak hours are during non-holiday weekdays from 1 P.M. to 5 P.M.

While NYSERDA does not fall within the ISO-NE area and is instead included at the New York Independent System Operator (NYISO), the New York technical manual published by the New York Department of Public Service (DPS) currently provides summer CFs based on the ISO-NE peak period.[42] Therefore, the study provides updated CFs for NYSERDA areas during the same summer and winter peak periods.

Table 4-1: Peak Period Coincidence Factors and Confidence Intervals – All Bulbs

Month	CT Percent On	MA Percent On	RI Percent On	UNY Percent On	Overall Percent On
December	17% (15%, 19%)	16% (15%, 17%)	16% (13%, 19%)	14% (11%, 16%)	16% (15%, 17%)
January	17% (15%, 19%)	16% (15%, 17%)	16% (13%, 19%)	14% (11%, 16%)	16% (15%, 17%)
Average Winter	**17% (15%, 19%)** [d]	**16% (15%, 17%)**	**16% (13%, 19%)**	**14% (11%, 16%)** [ae]	**16% (15%, 17%)** [d]
June	16% (13%, 18%)	12% (11%, 14%)	19% (15%, 24%)	11% (9%, 13%)	13% (12%, 14%)
July	16% (13%, 18%)	12% (11%, 14%)	19% (15%, 24%)	11% (9%, 13%)	13% (12%, 14%)
August	16% (13%, 18%)	12% (11%, 14%)	19% (14%, 23%)	12% (9%, 14%)	13% (12%, 14%)
Average Summer	**16% (13%, 18%)** [bd]	**12% (11%, 14%)** [ac]	**19% (15%, 24%)** [bde]	**11% (9%, 13%)** [ac]	**13% (12%, 14%)** [c]

[1] – The Overall model includes CT, MA, RI, and UNY. The Overall model excludes MHT and DNY.
[2] – In this table, significance testing is limited to the average winter and summer periods.
[a] – Statistically different at the 90% confidence level from Connecticut
[b] – Statistically different at the 90% confidence level from Massachusetts
[c] – Statistically different at the 90% confidence level from Rhode Island
[d] – Statistically different at the 90% confidence level from Upstate NY
[e] – Statistically different at the 90% confidence level from the Overall model

[42] New York Evaluation Advisory Contractor Team. *New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs: Residential, Multi-family, and Commercial/Industrial Measures*. Submitted October 15, 2010 Current Technical Manual).

Table 4-2: Peak Period Coincidence Factors and Confidence Intervals – All Bulbs

Month	MHT Percent On	DNY Percent On	NYSERDA Percent On
December	27% (24%, 30%)	28% (25%, 32%)	22% (20%, 25%)
January	27% (24%, 30%)	28% (24%, 31%)	22% (19%, 24%)
Average Winter	**27% (24%, 30%)** h	**28% (25%, 31%)** h	**22% (19%, 24%)** fg
June	16% (14%, 18%)	16% (14%, 19%)	13% (12%, 15%)
July	17% (15%, 19%)	17% (15%, 19%)	14% (12%, 15%)
August	17% (15%, 19%)	17% (15%, 19%)	14% (13%, 16%)
Average Summer	**17% (15%, 19%)** h	**17% (15%, 19%)** h	**14% (12%, 15%)** fg

[1] – The DNY model includes MHT.
[2] – The NYSERDA model includes UNY and DNY (including MHT)
[3] – In this table, significance testing is limited to the average winter and summer periods.
[f] – Statistically different at the 90% confidence level from Manhattan
[g] – Statistically different at the 90% confidence level from Downstate NY
[h] – Statistically different at the 90% confidence level from NYSERDA Overall

Table 4-3: Peak Period Coincidence Factors and Confidence Intervals – Efficient Bulbs

Month	CT Percent On	MA Percent On	RI Percent On	UNY Percent On	Overall Percent On
December	19% (16%, 22%)	17% (16%, 19%)	18% (13%, 22%)	19% (14%, 24%)	18% (17%, 19%)
January	19% (16%, 22%)	17% (16%, 19%)	17% (13%, 21%)	18% (14%, 23%)	18% (17%, 19%)
Average Winter	**19% (16%, 22%)**	**17% (16%, 19%)**	**18% (13%, 22%)**	**19% (14%, 23%)**	**18% (17%, 19%)**
June	18% (14%, 22%)	14% (11%, 16%)	18% (12%, 24%)	10% (8%, 13%)	14% (13%, 16%)
July	18% (14%, 22%)	14% (11%, 16%)	18% (12%, 24%)	11% (8%, 13%)	14% (13%, 16%)
August	18% (14%, 21%)	13% (11%, 15%)	18% (12%, 23%)	11% (9%, 14%)	14% (13%, 15%)
Average Summer	**18% (16%, 22%)** d	**14% (13%, 16%)** d	**18% (16%, 23%)** d	**11% (10%, 13%)** abce	**14% (14%, 16%)** d

[1] – The Overall model includes CT, MA, RI, and UNY. The Overall model excludes MHT and DNY.
[2] – In this table, significance testing is limited to the average winter and summer periods.
[a] – Statistically different at the 90% confidence level from Connecticut
[b] – Statistically different at the 90% confidence level from Massachusetts
[c] – Statistically different at the 90% confidence level from Rhode Island
[d] – Statistically different at the 90% confidence level from Upstate NY
[e] – Statistically different at the 90% confidence level from the Overall model

Table 4-4: Peak Period Coincidence Factors and Confidence Intervals – Efficient Bulbs

Month	MHT Percent On	DNY Percent On	NYSERDA Percent On
December	34% (30%, 39%)	34% (29%, 39%)	27% (24%, 31%)
January	34% (29%, 38%)	33% (28%, 38%)	27% (23%, 31%)
Average Winter	**34% (29%, 38%) h**	**34% (29%, 38%) h**	**27% (23%, 31%) fg**
June	20% (17%, 23%)	21% (17%, 24%)	16% (14%, 18%)
July	21% (17%, 24%)	21% (18%, 24%)	16% (14%, 18%)
August	21% (18%, 25%)	22% (18%, 25%)	17% (15%, 19%)
Average Summer	**21% (20%, 24%) h**	**21% (20%, 24%) h**	**16% (15%, 18%) fg**

[1] – The DNY model includes MHT.
[2] – The NYSERDA model includes UNY and DNY (including MHT)
[3] – In this table, significance testing is limited to the average winter and summer periods.
[f] – Statistically different at the 90% confidence level from Manhattan
[g] – Statistically different at the 90% confidence level from Downstate NY
[h] – Statistically different at the 90% confidence level from NYSERDA Overall

4.2.1 ISO-NE Seasonal Peak Hours

In addition to calculating average coincidence factors based on the ISO-NE peak periods, the Team prepared estimates based on ISO-NE's 2013 Seasonal Peak Data for Connecticut, Massachusetts, and Rhode Island. According to the ISO NE Seasonal Peak Data Summary, in 2013 the winter peak period occurred on January 24, 2013 at the hour ending 19, and the summer peak hour occurred on July 19, 2013 at the hour ending 17. Figure 4-9 and Figure 4-10 provide a visual depiction of the peak days for winter and summer, respectively.

Table 4-5: ISO New England Seasonal Peak Period Coincidence Factor

Month	CT Percent On	MA Percent On	RI Percent On
1/24/2013 Hour Ending 19	22% (19%, 24%)	19% (18%, 20%)	19% (16%, 22%)
7/19/2013 Hour Ending 17	16% (13%, 18%)	12% (10%, 13%)	17% (13%, 21%)

Figure 4-9: ISO New England Seasonal Peak Period – HOU Load Shape (Winter)

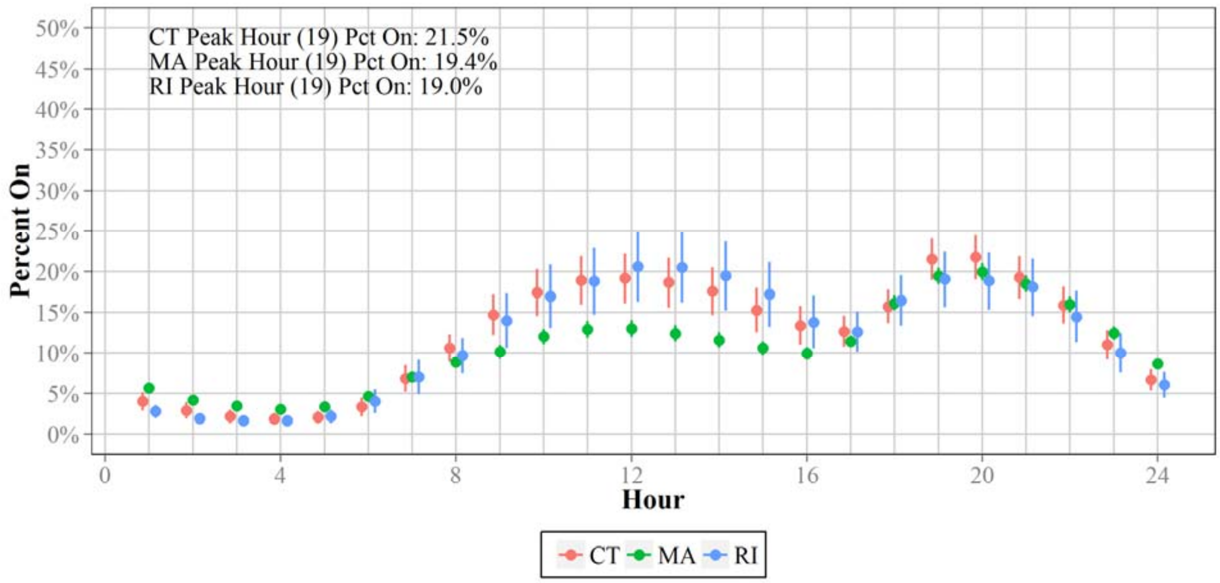
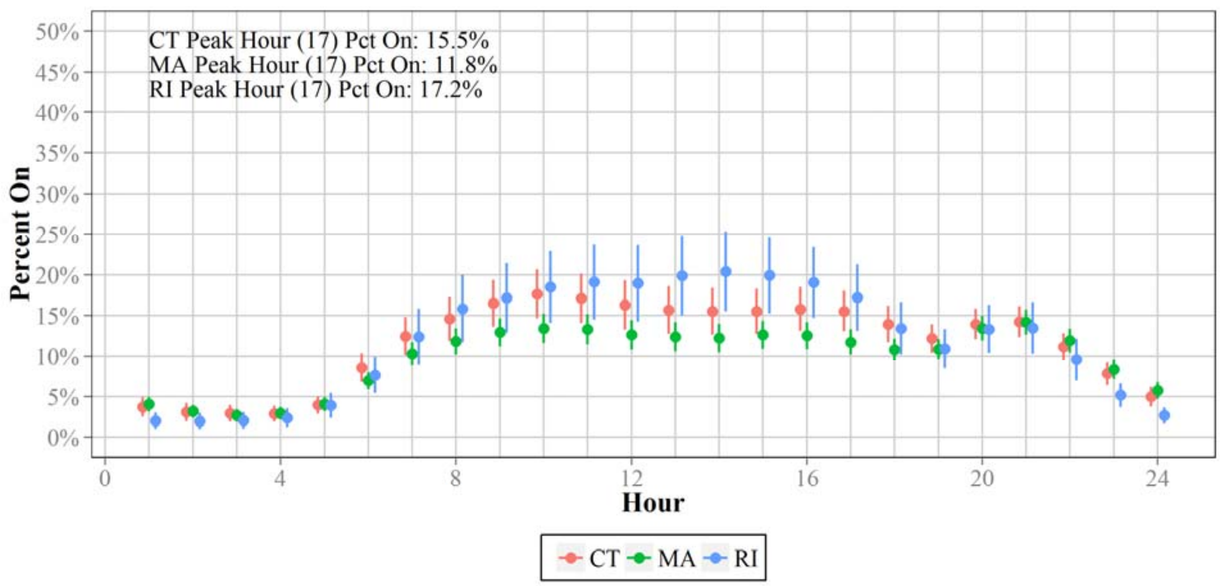


Figure 4-10: ISO New England Seasonal Peak Period – HOU Load Shape (Summer)



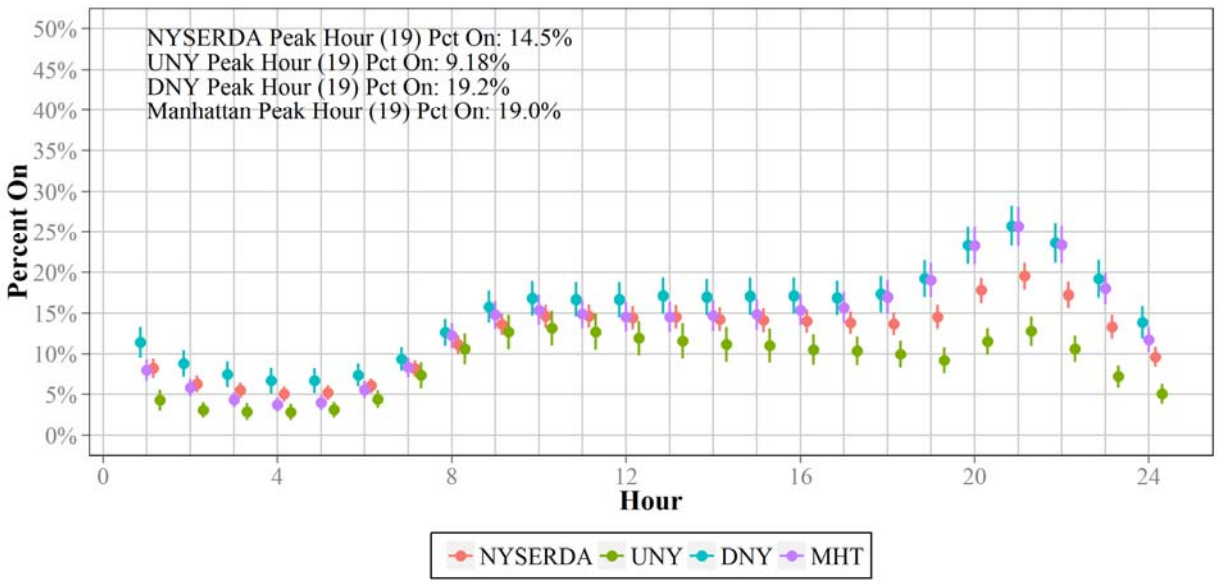
4.2.2 NYISO Seasonal Peak Hours

Finally, the Team prepared estimates based on the NYSIO's peak hour. Based on NYISO actual load data for 2013, the peak occurred on July 7, 2013 at the hour ending 19. Table 4-6 provides the percent on during this hour for each of the four NYSERDA-area models. Figure 4-11 provides a visual depiction of the peak day of July 7.

Table 4-6: Peak Period Coincidence Factors and Confidence Intervals

Month	UNY Percent On	MHT Percent On	DNY Percent On	NYSERDA Percent On
7/7/2013 Hour Ending 19	9% (8%, 11%)	19% (17%, 21%)	19% (17%, 21%)	15% (13%, 16%)

Figure 4-11: NY ISO Peak Hour – HOU Load Shape for July 7, 2013



5 Conclusions

Based on the data collected and analyzed for this study, the Team reached the following conclusions. Considerations and other key findings are included in the Executive Summary.

Lighting HOU are very similar across Connecticut, Massachusetts, Rhode Island, and Upstate New York. Examining data across households in Connecticut, Massachusetts, Rhode Island, and Upstate New York there are no statistical differences in lighting HOU at the household level. Even examining the data for these four areas on a room-by-room basis yields relatively few significant differences (eight in total). Based on this the Team concludes that each of the four areas should consider adopting a single Overall model that combines data from the four areas. Supporting this conclusion, only one significant difference exists between the Overall model and Connecticut, Massachusetts, Rhode Island, and Upstate New York models.[43]

Lighting HOU in Downstate New York (including Manhattan) and Manhattan alone are significantly higher compared to the other areas included in this study. Comparing HOU estimates for Downstate New York and Manhattan to the Overall model and the individual models for Connecticut, Massachusetts, Rhode Island, and Upstate New York, there are a great number of differences both at the household and room level. Out of 56 comparisons, there are 38 significant differences between Downstate New York and the other seven models included in this study (CT, MA, RI, UNY, Overall, MHT, and NYSERDA) and there are 31 significant differences between Manhattan and the other seven models included in this study. Based on this, the Team concludes that Downstate New York (including Manhattan) and Manhattan alone should be treated separately from the other areas and is treated separately in this report.

The NYSERDA service area contains two regions with disparate residential lighting HOU. NYSERDA's current program assumptions as detailed in the New York Technical Manual, apply the same HOU to the entire NYSERDA service area (Upstate and Downstate combined). To help support updates to the New York Technical Manual, the Team prepared a NYSERDA service area HOU estimate, however, the NYSERDA service area household level estimate is statistically different from both the Upstate, Downstate, and Manhattan estimates. Based on this and the conclusion above, the team concludes that NYSERDA should adopt two models and present separate estimates for Upstate and Downstate New York. Given that the Downstate New York and Manhattan estimates are statistically similar, the Team recommends simply using the Downstate New York estimates to represent all of Downstate New York (including Manhattan).

Within areas, relatively few statistical difference exist between households with different home type and income levels. The Team examined HOU estimates across the eight models for eight categories of home type and income level. Focusing on the Overall model, out of 28 comparisons based on home type and income levels, only one significant difference exists.

[43] Bedroom HOU estimates for Connecticut (2.6) are significantly higher compared to the Overall model (2.1). However, the household level estimates for Connecticut are statistically similar to the Overall model.

Examining the Downstate New York model, again out of 28 comparisons, there are only four significant differences (low-income household estimates are significantly higher compared to: single family (all income), non-low-income (all home types), non-low-income single family, and non-low-income multifamily). Based on the relatively low number of significant differences, the Team concludes that adopting separate HOU estimates for different home type and income levels is unnecessary.

HOU estimates for efficient bulbs are significantly higher compared to those for inefficient bulbs. Estimates for inefficient and efficient bulbs across the five sets of estimates obtained from the hierarchical model are all statistically similar, meaning that use of inefficient bulbs does not vary much across the areas, and neither does use of efficient bulbs. While the difference in HOU between efficient and inefficient bulbs is consistent and very clear across all regions and room types, the reason for this consistency is unclear. Three competing theories could help explain the differences: differential socket selection, shifting usage, and increased usage (snapback). However, this evaluation did not collect any data to support one theory over the others. The authors of the Uniform Methods Protocol suggest that measuring snapback for residential lighting programs is not typically possible as it requires both pre- and post-metering of energy-efficient lighting. The Uniform Method Protocols do not recommend adjusting for snapback effects in hours-of-use estimates. However, as differences in usage are observable in the data collected for this evaluation, the Team suggests assuming that the behavior posited by the three theories are equally responsible for the difference observed (i.e. each accounts for one-third of the difference). The difference between the Overall model HOU estimate for efficient and all bulbs is 0.3 hours per day or 110 hours per years (11% difference). Therefore, the adjusted HOU would be efficient HOU minus 0.1 (increased usage caused by snapback). For the Downstate New York Model, the difference is more pronounced 1.1 hours per day or 401 hours per year (27%). Therefore, the adjusted HOU would be efficient HOU minus 0.37 (increased usage caused by snapback). A complete table of adjusted HOU estimates with room-by-room estimates is included in the Executive Summary.