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MEMORANDUM

To: Electric and Natural Gas Program Administrators of Massachusetts

From: The Residential Retrofit and Low Income Evaluation Team

Subject: Status of Ongoing Low Income Lighting and Heating Metering Study

Date: June 28, 2013

In October 2012, the Residential Retrofit and Low Income Evaluation Team (Evaluation Team) began a study of low income households in Massachusetts to assess lighting hours of use and the prevalence of secondary heating on behalf of the Massachusetts Program Administrators (PAs).[1] The study has two overarching objectives:

1. Determine a daily low income-specific lighting hours-of-use (HOU) value to replace the current Low Income Program assumption of 2.8 (hours/day), which was determined through a metering study not specific to low income homes.[2]
2. Determine the prevalence of low income customers who use a secondary heating source to warm their homes and how best to incorporate secondary heating usage into future evaluations (as historical evaluations have exclusively assessed changes only in primary heating).

Study Description

To meet these objectives, the Evaluation Team conducted 261 site visits at randomly sampled low income customer homes across the Commonwealth of Massachusetts. As shown in Table 1, we used a stratified random sampling approach to meter PA customers in a manner that reflected the low income population across the Commonwealth. We adjusted our sample targets by oversampling PAs with fewer total low income customers (relative to the other PAs) to ensure an adequate representation.

[1] The study defined the target population as PA customer on a low income rate (at or below 60% of the area median income). Prior participation in the low income program was not considered as an eligibility criteria for the study.

[2] NMR Group, Inc. 2009. Residential Lighting Markdown Impact Evaluation.

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Table 1. Metering Sample by Program Administrator

Program Administrator	Percent of MA LI Population	Unadjusted Target	Adjusted Target	Metered Homes
Berkshire Gas	<1%	3	12	7
Cape Light Compact	5%	13	13	16
Columbia Gas	5%	13	13	18
National Grid	51%	135	105	101
New England Gas	<1%	3	12	13
NSTAR	24%	63	60	64
Unitil	<1%	3	12	6
WMECO	14%	37	37	36
Total	**100%**	**264**	**264**	**261**

At each home, trained Evaluation Team technicians completed a whole-home lighting inventory and installed up to 10 lighting loggers per home. The technicians also installed a meter that assesses thermostat usage (for both manual and programmable thermostats) and meters that monitored heating equipment.

In total, our team installed more than 2,000 lighting loggers and 800 meters on heating equipment and collected usage information from November 29, 2012, through May 2, 2013.

Since the efficient lighting market is evolving, the PAs and Evaluation Team agreed at the outset of the study that metering of lighting would not be limited to compact fluorescent lights (CFLs) as had been the case in previous studies. Instead, all lighting present in sampled homes qualified for metering. Focusing on all lighting, and determining room type-specific HOUs, will ensure the study's results are applicable regardless of the type of efficient lighting measures (LEDs, etc.) that future low income programs may offer. This approach also aligned the Evaluation Team's low income-specific work in Massachusetts with a concurrent regional metering study lead by NMR Group, Inc.

Collaboration with Regional Study

Shortly after our study launched, NMR initiated a similar lighting-focused metering study that sampled homes across New England. The NMR study, which included a small number of low income customers but primarily targeted non-low income customers, sampled 587 homes in Connecticut (n=90), Massachusetts (n=137), New York (n=319), and Rhode Island (n=41).

The timing of these two studies, as well as their different focus, provided a unique opportunity to directly compare low income and non-low income lighting saturations and usage. To ensure a valid comparison, we collaborated with NMR to develop consistent metering and fixture-selection protocols.

Study Status

As of today, the Evaluation Team has removed all metering equipment and completed our preliminary analysis of lighting and heating usage. However, there has been insufficient time to complete our full internal review of the data and analysis or for the PAs, representatives of the Massachusetts Energy

Efficiency Advisory Council (EEAC), and the Massachusetts Low income Energy Affordability Network (LEAN) to review and comment before finalizing the study.

Timeline for Completing Study

Through discussions with the PAs, EEAC, and LEAN, the Evaluation Team agreed to the following timeline to complete this study. The timelines include multiple review periods for all stakeholders to ensure that the final report addresses all relevant issues or concerns.

Table 2. Timeline

Event	Date
Evaluation Team attends Low Income Best Practices Meeting	7/12/2013
Evaluation Team submits draft report to PAs/EEAC/LEAN	8/2/2013
PAs/EEAC/LEAN offers initial feedback via conference call	8/9/2013
Comments on draft report due	8/16/2013
Evaluation Team submits revised draft report to PAs/EEAC/LEAN	8/23/2013
Comments on revised draft report due	8/30/2013
Evaluation Team submits final report	9/6/2013

High-Level Methodology

The following sub-sections provide a high-level summary of the five key methodological elements:

1. Sampling
2. Recruitment
3. Data Collection
4. Weighting
5. Annualization

Sampling

At the outset of the study, each PA provided contact information for every customer currently on a low income rate code. Collectively these customers compose the population of low income households (as defined by rate codes) in Massachusetts. The Evaluation Team reviewed the contact lists and selected a stratified random sample of these households. The stratification was by PA as shown in Table 1 above. The Evaluation Team over-sampled PAs with fewer low income customers to increase their representation in the study.

Recruitment

To obtain an unbiased sample, the Evaluation Team mailed postcards to the sampled low income customers. The postcard briefly explained the study, offered a $150 incentive, and encouraged customers to call to arrange an appointment for a site visit. The postcard also informed customers that our team would schedule site visits on a first-come, first-served basis.

The Evaluation Team grouped the responding customers by geographic location to create efficient driving routes. Technicians (who worked in teams of two) were scheduled to visit approximately four to five sites per day (depending on the PA's service territory).

After establishing the preliminary schedule, we contacted customers and matched their availability and the open spots. We gave customers additional details about the project and what would happen during the initial site visit and in the subsequent months.

Data Collection

The Evaluation Team called customers the day before their appointment to confirm the date and time. During the site visit, which lasted approximately 90 minutes, our technicians conducted the lighting inventory and installed the loggers. The technicians provided leave-behind letters with helpful information about the project, the loggers, the project's timeline and schedule, and contact information should the customers have any questions or concerns. At the time of installation, customers also received a $50 gift card for their time.

A small number of customers (19) contacted us to request we remove the loggers before the end of the metering period (as they were moving or for other reasons). We met each customer's request within a few days of the call.

Two weeks before logger removal, we contacted customers to finalize dates and times to visit. As with installation scheduling, we grouped site visits by geographic location to maximize efficiency and keep evaluation costs low. We contacted each customer again the day before to confirm their scheduled appointment. In most cases, our technicians completed five removals per day, spending about one hour at each customer's site. After the loggers were successfully removed, customers received an additional $100 (a total of $150) for their study participation. Several customers received an additional $25 due to extended timelines.

For the collection of specific data during the site visits and from the metering equipment, the Evaluation team developed and used two sets of protocols—one for lighting and one for the heating audit. Copies of the protocols are provided as separate documents. These protocols established considerable detail about how rooms were classified, which fixtures or equipment were selected for metering, and the type of meters used.

Weighting

The Evaluation Team calculated room and demographic weights for the HOU analysis.

Applying room weights corrects for the fact that the total number of medium screw-based (MSB) bulbs and metered (or sampled) MSB bulbs varies by room type across all inventoried households. The equation below shows the necessary inputs used to calculate individual room weights.

$$Room\ weight = \frac{\left(\frac{total\ MSB\ bulbs\ by\ room\ type}{total\ MSB\ bulbs\ in\ all\ room\ types}\right)}{\left(\frac{total\ metered\ MSB\ bulbs\ by\ room\ type}{total\ metered\ MSB\ bulbs\ in\ all\ room\ types}\right)}$$

An example makes this clearer. We calculated the bedroom room weight calculation using the following inputs:

- Total MSB bulbs in bedrooms = 2,390
- Total MSB bulbs in all rooms and households = 10,511
- Total metered MSB bulbs in bedrooms = 729
- Total metered MSB bulbs in all rooms and households = 3,373

$$Bedroom\ weight = \frac{\left(\frac{total\ MSB\ bulbs\ by\ room\ type}{total\ MSB\ bulbs\ in\ all\ room\ types}\right)}{\left(\frac{total\ metered\ MSB\ bulbs\ by\ room\ type}{total\ metered\ MSB\ bulbs\ in\ all\ room\ types}\right)} = \frac{\left(\frac{2{,}309}{10{,}511}\right)}{\left(\frac{729}{3{,}373}\right)} = 1.02$$

The resulting bedroom-weight of 1.02 means that our metering study slightly under-sampled bedroom lights. By applying a room weight of 1.02 to each light metered in a bedroom, our analysis accounts for this slight disparity and aligns our sample of metered lights with the population of total lights determined through the whole-house lighting inventory.

While room weights relate to the selection of specific lights for metering, demographic weights account for differences in the characteristics of the metered households relative to the population of low income households. The Evaluation Team used two demographic weights based on: 1) the number of occupants in the home and 2) the age of occupants (seniors versus non-seniors).[3] Accounting for these two factors, which directly impact total household lighting usage, by applying demographic weights corrects for any differences in the homes in our sample of low income customers and in the subset that participates in the Low Income program.

To compute the occupant per home weight, the Evaluation Team relied on data about 988 Low Income program participants that we gathered during site visits to 21 Community Action Agencies (CAA) in 2012. We compared occupancy information to assess any differences between these program participants and the low income customers sampled for our metering study. This comparison showed that our metering sample and the program participants generally had similar distributions; the primary difference was that there were more families (three or four occupants) present in our sample. Table 3 provides the comparison and weights applied for adjust for differences between our sample and the program.

[3] To be consistent with data provided by the Department of Housing and Community Development for American Recovery and Reinvestment Act funded low income weatherization activity, the Evaluation Team defined seniors at age 60 or above.

Table 3. Occupants per Home – Low Income Program Population and Metered Sample

Occupants/Home	LIWx Population	Metering Sample	Weight
One	37%	28%	134%
Two	28%	27%	105%
Three	14%	20%	71%
Four	12%	16%	74%
Five	6%	6%	105%
Six	3%	2%	171%
Seven or more	1%	1%	76%

Since the program serves a large number of seniors (who are often retired and home during the workday), we also assessed for a difference in the proportion of sampled homes with at least one senior occupant and the proportion of program homes with at least one senior occupant. As the Evaluation Team did not collect age information as part of the previous CAA site visits, we developed the age weights using data provided by the Department of Housing and Community Development (DHCD).

To be consistent with the DHCD data, the Evaluation Team defined senior households as those in which at least one occupant is 60 years old or older. Table 4 shows the senior and non-senior household distribution for the Low Income program population and the metering sample and their weights. As evident in the table, the metering sample included a lesser proportion of senior homes than the program. As a result, each senior household in our sample received a weight between 105% and 194% (depending on the number of seniors in the home). Because the value is greater than 100%, these weights mean senior households within the metering sample are given greater influence during the analysis.

Table 4. Age of Occupants per Home – Program Population and Metered Sample

Occupant Ages	LIWX Population*	Metering Sample	Weight Range
Under 60	70%	84%	83%
Age 60 and older	30%	16%	105-194%

The final joint probability weight applied to each home in the study for the HOU regression analysis is the product of the room weight and the two demographic weights.

Annualization

The Evaluation Team first calculated the total “time-on” (in seconds) per logger per hour per day of the metering period. We then calculated the total daily HOU for each logger per day by summing the time-on across each hour of each day. We then prepared the data for panel regression modeling by merging the summarized lighting usage records with information about the household (the number of occupants and the presence of seniors).

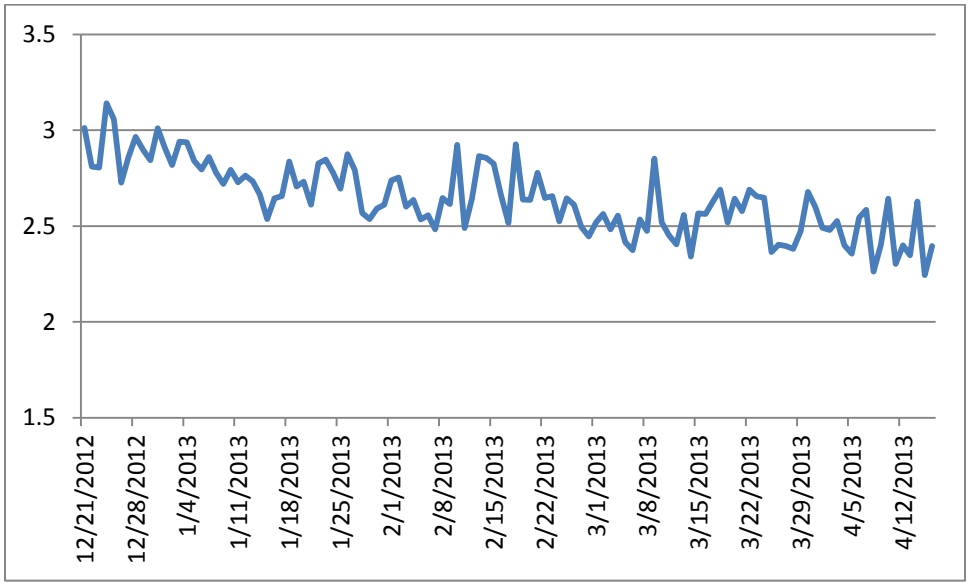
We used a fixed effects model to predict HOU. The fixed effects approach allows the regression model to calculate different average HOU intercepts at the individual logger level. The fixed effects model also captures all of the explained and unexplained variation associated with a specific logger into the regression and out of the error term. The dummy variable approach accounts for potential influences and behaviors that affect HOU but are not explicitly captured by the model's independent variables. The resulting models therefore have a high degree of explanatory power.

After estimating the individual models and intercepts for each logger, the Evaluation Team calculated overall HOU as the mean of all individual logger intercepts.

Since the metering period did not span the entire year, we annualized the results using a sinusoidal curve representing the available daylight per day. This approach is recommended by the U.S. Department of Energy's Uniform Methods Protocol for lighting impact evaluations due to the strong relationship between daylight hours and lighting usage observed through a multitude of studies.[4]

A review of the unadjusted meter data (average daily time-on across all loggers, shown in Figure 1) supports the sinusoidal approach and shows a gradual decrease in lighting usage over the course of the metering period. This trend corroborates the assumption that lighting usage will generally decrease from the winter solstice to the summer solstice as daylight increases.

Figure 1. Observed Unadjusted MSB Lighting Usage



Preliminary Results

While the study is ongoing, the Evaluation Team can offer the following preliminary results at this time.

[4] http://www1.eere.energy.gov/wip/pdfs/53827-6.pdf, page 15.

Hours-of-Use

The Evaluation Team estimated a preliminary average weighted (room and demographics) HOU of 2.66 hours per day for light bulbs installed in MSB sockets. At 90% confidence, the precision of this estimate is 5.96%. This results in a 90% confidence interval of 2.50 and 2.82 that includes the program's current assumption of 2.8 hours/day.

At the room level, our preliminary findings (Table 5) show that the highest average annual HOU—not surprisingly—occur in room types with high levels of traffic, such as kitchens, dining rooms, and living rooms. Exterior fixtures also showed higher lighting usage on average, which is consistent with anticipated night-time use of these fixtures. Bedrooms and bathrooms showed lower average annual lighting usage relative to the aforementioned room types. Again, these preliminary findings are also consistent with expectations that bedrooms and bathrooms may not be frequented by occupants as often as high-traffic rooms during a given day.

Table 5. HOU, Overall and by Room Type

Room Type	Weighted HOU/day	Relative Precision at 90% Confidence (±)	90% Confidence Interval
Overall	**2.66**	**6%**	**2.50 – 2.82**
Kitchen	4.16	13%	3.62 – 4.70
Dining Room	3.85	26%	2.84 – 4.86
Exterior	3.30	31%	2.29 – 4.31
Living Space	3.45	12%	3.05 – 3.86
Bedroom	2.42	10%	2.17 – 2.67
Bathroom	1.89	17%	1.57 – 2.22

The relative precision estimates are a function of both sample size (that is, loggers) and variance in light usage across room types and households. For some rooms (kitchens, living space, bedrooms, and bathrooms) room type-specific precision estimates are close to the 10%.

The Evaluation Team also estimated average annual HOU for senior and non-senior households to test the assumption that the presence of a senior impacts lighting usage (and, therefore, that the application of a senior-based weight is appropriate). On average, we found that homes with at least one senior use MSB lights for 2.12 hours per day, while non-senior households use their MSB lights 2.88 hours per day (26% more), as shown in Table 6.

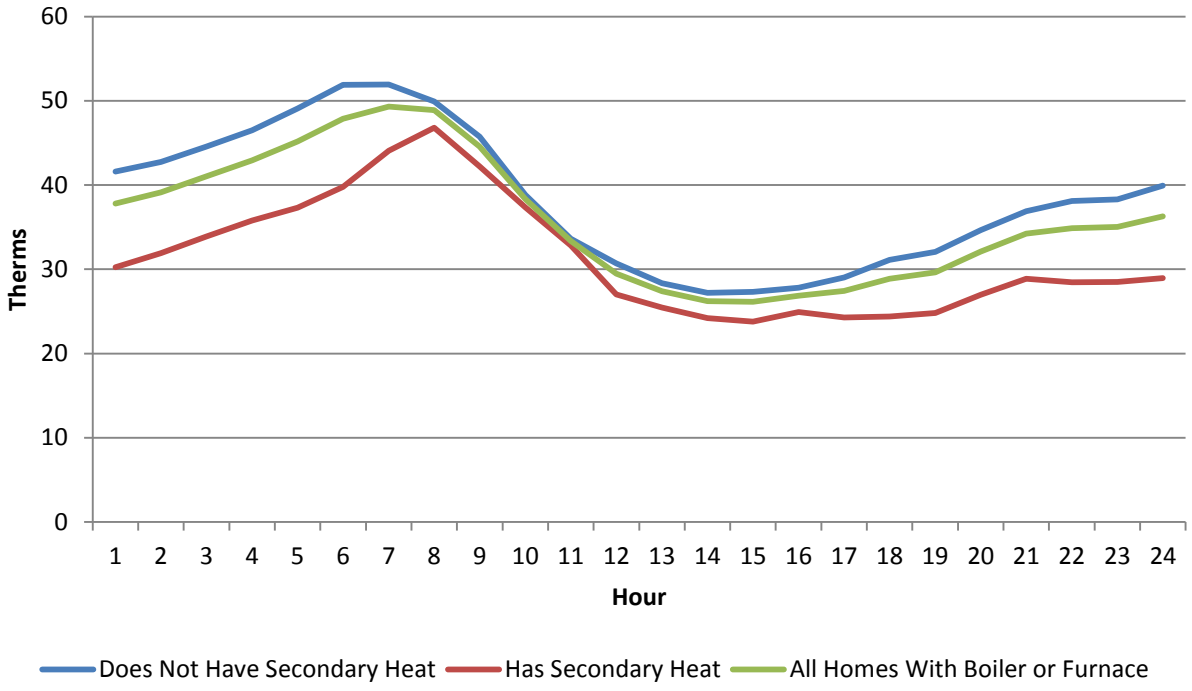
Table 6. HOU for Senior and Non-senior Households

Household	Weighted HOU/day	Relative Precision at 90% Confidence (±)	90% Confidence Interval
Senior	2.12	12%	1.86 – 2.37
Non-senior	2.88	7%	2.68 – 3.07

Secondary Heating Use

While much of this memo has focused on the lighting methodology and preliminary results, the Evaluation Team has developed some initial findings related to secondary heating usage. First, our site visits determined that 34% of low income homes employ secondary heating. Second, a comparison of homes with and without secondary heating sources reveals that there is less primary heating usage in homes with secondary heating options (Figure 2).

Figure 2. Comparison of Annual Natural Gas Fuel Consumption of Primary Heat Source When Secondary Heat Source is Present



This preliminary finding, while intuitive, potentially has important ramifications on future evaluations. It means that impact evaluations that focus exclusively on primary heating impacts may underestimate the program's true energy savings. For example, if a participant with secondary heating receives insulation through the program, it is likely the usage of their primary and secondary heating will decline. To date, the reduction of secondary heating for these types of customers has not been accounted for.

Preliminary Conclusions

As noted, this study is ongoing and the Evaluation Team, PAs, EEAC and LEAN will collaboratively review, update as necessary, and finalize this study by early September. However, the preliminary results described above allow the Evaluation Team to offer the following preliminary conclusions, which are subject to change as the study is completed.

- The preliminary low income-specific HOU of 2.66 is slightly less than the current program assumption of 2.8 hours/day.
- Low income seniors use their lights less (2.12 hours per day) than low income non-senior (2.88).

- Homes with secondary heating sources appear to supplement their primary heating when heating their home. As a result, future evaluations should consider the impact of program measures on both primary and secondary heating.

Caveats

- The Evaluation Team analysis is ongoing and all preliminary findings are subject to change. We do not anticipate significant changes to the key results presented in this memo, but acknowledge these results may shift slightly following the complete internal (our team) and external (PAs/EEAC/LEAN) review process.

- The Evaluation Team is attending the Low Income program's Best Practices meeting on July 12 to discuss CAA's bulb installation practices. Discussions to date indicate that some CAAs may install efficient lighting in any available MSB sockets, while others may target specific high-use room or fixture types. The CAA's collective installation practices have ramifications on the appropriateness of the preliminary HOU of 2.66, which represents average usage across all MSB sockets in low income homes.