RLPNC 17-11 LED Net-to-Gross Consensus Panel Report

FINAL

June 30, 2018

SUBMITTED TO:
Massachusetts Program Administrators and Energy Efficiency Advisory Council Consultants

SUBMITTED BY:
NMR Group, Inc.

NMR Group, Inc.

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ES Executive Summary

The Massachusetts Program Administrators (PAs) and Energy Efficiency Advisory Council Consultants (EEAC consultants) are currently creating the comprehensive three-year program portfolio plan for 2019 to 2021. Part of this process includes the setting of prospective net-to-gross ratios (NTGRs) for light emitting diode (LED) bulbs offered through various residential programs. Given a great deal of uncertainty about the future of lighting standards and the importance of lighting to the residential portfolios, the PAs and EEAC engaged NMR Group, Inc., to lead a consensus process that would yield recommended prospective NTGRs for 2019 to 2021 for the Residential Retail Products Program (note that prospective lighting NTGR for the Home Energy Services Initiative are being explored separately as part of the RLPNC 18-5 Study). The consensus approach rests on the assumption that asking a panel of experts, who represent various stakeholder groups, to review and asses NTGRs will diminish the bias inherent in relying on a single estimate of NTGR or the interpretation of one stakeholder group.

As discussed more fully in Section 2, the process asked PAs, EEAC consultants, and evaluators to review and discuss retrospective and prospective NTGR estimates and market information drawn from various lighting evaluation activities. Market considerations including the future of the second phase of Energy Independence and Security Act of 2007 (EISA), naturally occurring LED adoption rates, and LED price trends.

NMR recommends that the PAs and EEAC consultants use the NTGRs listed in Table 1 for planning the 2019 to 2021 programs. After reviewing various NTGR approaches and estimates, as well as market information, the consensus panel members submitted their own predictions of NTGRs for 2019 to 2021. During a webinar in February 2018, the panel met to discuss predictions and worked together to set prospective NTGRs for standard (A-lamp), reflector (flood lights), and specialty (primarily globes and candelabras/decorative) bulbs supported through the upstream Residential Retail Products Program. The panel also decided that the PAs would map fixture types to the most similar bulb type, and use that bulb type's NTGR for the similar fixture. This mapping exercise is now complete. Table 1 presents the recommended NTGRs for LED bulbs and fixtures.

Table 1: Recommended Prospective NTGRs and Action Items

	2019	2020	2021
Recommended Upstream Bulb NTGRs for Program Planning			
Standard	35%	30%	25%
Reflector	45%	40%	35%
Specialty	45%	40%	35%
Recommended Upstream Fixture NTGRs for Program Planning			
General service fixtures	35%	30%	25%
Reflector fixtures & downlight kits	45%	40%	35%
Specialty fixtures (lumens < 310 or >3300)	45%	40%	35%

1 Section 1 Introduction and Background

This report describes the process by which the Massachusetts Program Administrators (PAs), the Energy Efficiency Advisory Council Consultants (EEAC consultants), and the residential retail lighting evaluation team, led by NMR Group, Inc., developed prospective net-to-gross ratios (NTGRs) for light emitting diode bulbs (LEDs). The PAs and EEAC consultants will use these prospective NTGRs to help plan the 2019 to 2021 Residential Lighting Core Initiative (the program).

Upstream programs, such as the Massachusetts lighting program, make the already difficult task of estimating NTGRs even harder. Because consumers receive the discount automatically without providing any account or contact information, evaluators have few opportunities to find program participants and determine how much the program influenced their purchases. The Massachusetts PAs and EEAC consultants have used a variety of approaches to estimate retrospective NTGRs for the program (i.e., for prior or current years), including comparison areas, statistical modeling, and supplier self-reports. While each approach has strengths, they also have weaknesses that create threats to validity.

The current rules governing the Three-Year Energy Efficiency Plan process state that the PAs and EEAC consultants must set NTGRs prospectively for the next program cycle. In other words, PAs and EEAC consultants, with the assistance of evaluators, need to predict what the market will be like both with and without the program for the next three years. When developing the 2016 to 2018 plan, the PAs, EEAC, and evaluators addressed this challenge by engaging a panel of experts to participate in a consensus process that established the final NTGRs used for three-year program planning and annual filings. Reviewing multiple estimates and drawing on the collective wisdom of a team of individuals familiar with the Massachusetts and other upstream lighting programs helped to limit the bias introduced by any single method or study. Likewise, this current study also relies on a consensus approach to develop prospective LED NTGRs for the 2019 to 2021 program cycle.

1.1 Study Goals

The study relies on a consensus-building process to develop prospective NTGRs for the Residential Retail Initiative for 2019 to 2021 for the following LED types:

- Standard (medium screw base, meant to reflect A-line bulbs)
- Reflector/floods
- Specialty (focused on globe and candelabra bulbs)

The consensus team also identified a strategy for applying the LED bulb NTGRs to LED fixtures. As discussed in Section 2, the panel also considered developing prospective NTGRs

for all LEDs, hard-to-reach (HTR) consumers,[1] and LEDs by retail channel, but decided against setting values due to the lack of information for these categories.[2]

1.2 Research Topics

The study addressed the following research questions:

- What are the recent estimates and trends for LED NTGRs in Massachusetts and other areas?
- What are the strengths and weaknesses of the NTGR estimation methods used in Massachusetts and other areas?
- What do the estimates and NTG trends suggest for prospective NTGRs in Massachusetts for 2019 to 2021?
- What do market trends and recent intelligence suggest for prospective NTGRs in Massachusetts for 2019 to 2021?

1.3 Sources Used to Inform Consensus Process

The consensus process drew on data from seven evaluation efforts conducted between 2016 and 2018. The efforts that provided information for the study and the approaches they informed include the following:

- RLPNC 16-2: Wave 2 Supplier Interviews – Manufacturer and Implementer Market Share Predictions
- RLPNC 16-7 and RLPNC 17-9: Lighting Market Assessment and On-site Saturation – Change in On-site Saturation and Change in LEDs Added to Panel Homes
- RLPNC 16-5 and RLPNC 17-10 Sales Data Analysis and Modeling – LightTracker Sales Data Modeling
- RLPNC 16-3 and RLPNC 17-12: Lighting Decision Making – InfoScout Purchase Comparison

Table 2 summarizes the characteristics of the various approaches to estimating NTGR used in the studies and provides links to their final reports. Note that most of the studies do not contain NTGRs (RLPNC 16-5/17-10 is the exception) as NMR developed the NTGRs separately using data from the original studies. Section 2 addresses the strengths and weaknesses of each approach, as identified by the consensus team, and Appendix A provides more information about the methodologies and the resulting NTGs from each method. The appendix also lists the full citation of the original studies from which we drew the data.

[1] HTR customers are generally considered to have lower incomes or educational attainment, or to primarily speak a language other than English. The program currently operationalizes HTR through sales in discount stores, second-hand (thrift) shops, and certain grocery, convenience, and neighborhood stores.

[2] The panel briefly discussed ENERGY STAR® qualified LEDs and low-lumen LEDs, but quickly decided they lacked evidence to set NTGRs for these bulb breakdowns. All NTG estimates assume non-ENERGY STAR and low lumen LEDs are included in the baseline. This report does not discuss them further.

Table 2: Characteristics of Approaches

	Manufacturer / Implementer Market Share Predictions	Change in On-site Saturation	Change in LEDs Added to Panel Homes	LightTracker Sales Data Modeling	InfoScout Purchase Comparison
Evaluation Studies (hyperlinked)	RLPNC 16-2	RLPNC 16-7, 17-9	RLPNC 16-7, 17-9	RLPNC 16-5, 17-10	RLPNC 16-2, 17-12
Bulb Types	Standard (A-line), Reflector, Other Specialty	Standard (A-line), Reflector, Other Specialty	Standard (A-line), Reflector, Other Specialty	All LEDs	Standard (A-line), Reflector, Other Specialty, Retail Channels
Data type	Predicted market share	Change in saturation and storage and program supported sales	Newly added LEDs and program-supported sales	Modeled market-level sales and program-supported sales	LED purchases and program supported sales
Prospective or Retrospective	Prospective	Retrospective	Retrospective	Retrospective	Retrospective
Baseline	Prediction w/o program market share	Portions of New York, weighted to MA	Portions of New York, weighted to MA	Modeled w/o program market share, drawing on data from 31 states	Portions of New York, weighted to MA
Observed or Self-reported	Self-reported	Mix	Observed	Observed (retailer sales, customer scanned UPCs of purchases)	Observed (scanned receipts)

2 Section 2 Consensus Process and Results

The LED NTG Consensus Process seeks to integrate the lessons learned from multiple efforts to estimate retrospective and prospective NTGRs, as well as recent market intelligence, to set LED NTGRs for the next three-year planning cycle. This task carries a great deal of weight. On the one hand, NTGRs that overstate program importance could lead the PAs to place too much support behind LEDs, diverting ratepayer funds from other efforts. On the other hand, understating NTGRs could lead the PAs to prematurely reduce or remove support, causing them to miss out on substantial energy savings.[3] Rapid change and high levels of uncertainty in the market increase the challenges of setting prospective NTGRs and planning for the program's future. Foremost among these challenges is understanding the natural occurring market adoption for LEDs and continued uncertainty regarding federal implementation of a second phase of the Energy Independence and Security Act of 2007 (EISA). Regarding EISA. The questions center around how rapidly the market would shift to LED dominance without program incentives, whether the federal government will implement or repeal a 45 lumens-per-watt requirement for general service bulbs, which bulbs would be considered general service, and whether they would allow a sell-through period for non-compliant bulbs.

The consensus process operates under the assumption that a team of experts who review the available evidence, consider market trends and sources of uncertainty, and have an open conversation about the strengths and weaknesses of the estimation approaches and market intelligence will yield thoughtful, informed prospective NTGRs that limit the bias of any one approach or any single individual's interpretation of the results. This section describes the consensus process, summarizes the main points of the discussion of strengths and weaknesses, presents the recommended prospective NTGRs, and explains the final reasoning behind the recommendations.

2.1 Steps in the Consensus Process

The consensus process involved the following steps.

Step 1 Confirmation of Methods to Inform Process: The first step was to confirm the studies and methods that will feed into the consensus-building process.

[3] Barclay, D, M. Coen, K. von Trapp, M. Meek and S. Walker. 2017. *Keep Calm and Carry On: Why Upstream Lighting Programs are Still Important*. http://www.iepec.org/2017-proceedings/65243-iepec-1.3717521/t003-1.3717945/f003-1.3717946/a035-1.3717965/an133-1.3717968.html

Step 2 Identification and Recruitment of Experts: The PAs, EEAC consultants, and evaluators discussed whether EEAC and PA planners, as well as PA implementers and implementation contractors, should be involved in the consensus process. They decided that planners should not be involved in the process, and that implementers could provide estimates of market share with and without the program, but should not be directly involved in the NTGR consensus process.

Step 3 Compilation of Study Results: After completion of the preliminary NTGR estimates, NMR prepared a memorandum and accompanying spreadsheet that summarized the approaches and results, and reported recent LED NTG results from other jurisdictions. The consensus panelists reviewed the memo, calculations, and results. The panel met via webinar in January 2018 and discussed the strengths and weaknesses of the various approaches and suggested items for NMR to examine more closely.

Step 4 Solicitation of Initial Responses: NMR followed the panel's guidance for items to examine more closely, and subjected the preliminary NTGRs to additional quality control review. NMR finalized the NTGR estimates, compiled them into a revised memo and spreadsheet, and distributed these to the panel. Panelists reviewed the methods and results again, but this time they submitted their own assessment of strengths and weaknesses and rated which approach they found to be the strongest and weakest (Section 2.2). They then gave their own predictions of NTGRs for various LED bulb styles for 2019, 2020, and 2021 (Section 2.3).

Step 5 Setting Consensus Recommended NTGRs: NMR compiled the panelists' final assessments of strengths and weaknesses, as well as the individual NTGR predictions and reasons behind them from Step 4, into a webinar presentation for the second consensus panel meeting, held in February 2018. Having reviewed the methods and thought about the approaches, the panel engaged in a conversation about the evaluated results and individual predictions of NTGR and the future of the market. They reached consensus regarding the recommended NTGRs for standard, reflector, and specialty LEDs for 2019 to 2021. They also suggested a strategy for assigning NTGRs to fixtures. Section 2.4 describes this step in more detail.

Step 6 Reporting: This report represents the last step in the consensus process.

2.2 Discussion of Strengths and Weaknesses

The evaluation team pursued five evaluation approaches that yielded NTGR estimates because of prior positive experiences using the approach for assessing the net impacts of residential lighting, data availability, or both. However, each of the approaches has strengths and weaknesses. Table 3 lists the strengths and weaknesses identified by the consensus panelists (including evaluation team members who worked on the approaches).[4] This section describes the main strengths and weaknesses raised by the evaluation team and panelists.

[4] Consensus panelists provided numerous strengths and weaknesses and their reasons for their opinions. We believe Table 3 captures the main points, although we recognize the summary loses some of the nuance in individual responses.

2.2.1 Overarching Strengths and Weaknesses

While the approaches each have individual strengths and weaknesses, they share some common ones. The methods' biggest strength is that they each draw on data collected from Massachusetts market actors – either as predicted by persons knowledgeable with the market or collected directly from consumers and retailers in the state. They have all been subjected to data review and vetting processes. At the same time, the data also consider the experiences of areas outside of Massachusetts, using comparison areas, examinations of state-level data across the nation, or understandings of how markets behave without program intervention. Collectively, the data span the universe of market actors – from manufacturers to retailers to end users.

The methods' biggest weakness stems from the continued inability of each of the data sources (except the Manufacturer / Implementer Interviews, which use percentages) to provide a realistic estimate of market-level LED sales. The reasons include the following:

- Retailers who report to LightTracker do so voluntarily, participation varies by retail channel, and there is little way to assess if the reporting retailers submit all of their sales across the nation.[5]
- The consumers who report purchases to InfoScout and to the third-party source that sells data to LightTracker do so voluntarily.[6] While they pledge to scan all receipts or purchases, respectively, consumers likely vary in their diligence in doing so.
- The on-site visits use systematic methods to identify newly added bulbs and assess saturation, but the sample sizes for individual bulb types are small, making them prone to the influence of a few low and high users.

The challenges in determining market-level sales creates an issue: when we compare program-supported LED sales for 2016 and 2017 – all of which are ENERGY STAR bulbs – to predicted market-level LED sales (not limited to ENERGY STAR) in the other methods, program-supported sales rivals or exceeds market-level LED sales. **This biases NTGRs downward** because it overstates the proportion of bulbs in the market directly supported by the program (which understates spillover effects).

Another challenge with each of the methods is that they either did not provide estimates for HTR consumers or retail channel-specific results, or the estimates they provided were unreliable.[7] They also did not address integrated LED fixtures and downlight retrofit kits. We return to these issues in Section 2.4.2.

[5] That is, while the retailers likely submit all the sales they have vetted at the time of delivery to the third-party source, data from individual store locations could be missing.
[6] LightTracker includes both retail sales data and consumer panel data (this panel is separate from the on-site panel NMR runs).
[7] The results for these breakdowns were not stable across similar methods over time or data sources, which violates both the statistical and practical understanding of reliability.

Table 3: Characteristics of Approaches

	Manufacturer / Implementer Market Share Predictions	Change in On-site Saturation	Change in LEDs Added to Panel Homes	LightTracker Sales Data Modeling	InfoScout Purchase Comparison
Strengths					
Votes for Strongest [1]	***2***	***0***	***5***	***0***	***0***
Data	Represents the whole MA lighting market	Multiple sources; direct measurement; market-level adjustment for direct install participation	Panel data is more reliable/consistent; direct measurement; Household-level adjustment for confirmed direct install participation	Robust dataset for both program and non-program states; based on actual sales and purchase data	Based on actual purchase data
Methodology	Predictions made by market actors who are very familiar with effects of presence/absence of program rebates on sales; Market actors don't think in terms of energy savings	The on-site methods are based on a naturally occurring experiment, with good granularity, and suggest a consistent and coherent story over time	The on-site methods are based on a naturally occurring experiment, with good granularity, and suggest a consistent and coherent story over time	Controls for intervening factors, including program age	In theory, similar strengths to the LightTracker work (purchase / sales-based)
Results	Consistent with other NTG results; prospective estimates; provides a narrative in addition to numbers			Plausible results	

	Manufacturer / Implementer Market Share Predictions	Change in On-site Saturation	Change in LEDs Added to Panel Homes	LightTracker Sales Data Modeling	InfoScout Purchase Comparison
Weaknesses					
Votes for Weakest[2]	***0***	***2***	***0***	***0***	***3***
Data	Asked for MA-market level but responses likely reflect their company's place in the market; weighting issues	Not enough detail, too much noise; purchase numbers small by bulb type	Not enough detail, too much noise; purchase numbers small by bulb type	Concerns about completeness of data in representing full lighting market; no 2017 data; combined LEDs; sales data noisy at state level	Concerns about comparability b/w MA and NY; concerns about representativeness of panel; differences in channels across states
Methodology	Potential for gaming bias; using LED sales only is conservative; uncertainty in market lends less confidence in predictions	Potential for Hawthorne effect[3]	Potential for Hawthorne effect	Some issues of comparability b/w program and non-program states; even with program age, prior saturation not explicitly considered	
Results		NTG results all over the map; contradicts other NTG results	Unreliable when examined by style; Inconsistent with other results		Inconsistencies with other NTG results and across channels; data appear to provide outlier estimates.

[1] One panelist cast a vote for prospective and retrospective separately as the strongest approach.
[2] One panelist declined to name a weakest method.
[3] The Hawthorne effect occurs when the act of being studied affects an individual's behavior. In the case of panelists, the concern is that being a part of a study on lighting will lead them to act differently about lighting than the general population. NMR has found no evidence of the Hawthorne effect among on-site panelists. Likewise, we have no evidence of gaming or socially desirable responses among manufacturers.

2.2.2 Approach-specific Strengths and Weaknesses

The strengths and weaknesses that panelist named for individual approaches fell into three broad categories: data, methods, and results. Table 3 above lists the strengths and weaknesses by approach, and we discuss the key points below.

Data: Discussions about data focused on how much of the market the method covered and the confidence panelists had in the data. Data stemming from direct observation by a trained technician (e.g., as in change in LEDs added to homes), lighting manufacturers (given their in-depth understanding of the market), and retailer-reported sales sparked the greatest confidence. Those that required consumers to report data voluntarily instilled less confidence. Panelists also discussed market coverage, discussing whether the data captured the entire lighting market, a sizable portion of it, or a single company's share. Likewise, panelist commented on small sample sizes and *data noise* (particularly for individual bulb types).

Methods: Discussion of the strengths and weaknesses of methods focused on respondents' knowledge of the market, bias in their responses (gaming, social desirability, reactive [Hawthorne] effects), ability to control for intervening factors (including prior efficient bulb saturation), consistency in results over time, comparability across areas/states, and the degree to which the method takes actual sales/purchases into account.

Results: Panelists mentioned only a few strengths and weaknesses regarding the results. Suppliers had the clear strength of being the only method to provide prospective NTGR estimates. Panelists also felt that LightTracker supplied plausible results, albeit for all LEDs only. Concerns centered on the inconsistencies within and across methods, especially when examining methods by bulb type.

2.2.3 Panelist Assessment of Strongest and Weakest Methods

After considering the strengths and weaknesses on their own (i.e., prior to the final consensus meeting), consensus panelists named which methods they found the strongest and weakest overall (Table 3, blue-shaded rows). The change in newly added bulbs garnered the most votes (five) for the strongest method. Consensus panelists cited the direct observation of changes in Massachusetts and New York as compelling evidence for their choice. Two others (one voted twice) selected manufacturer / implementer interviews because the approach provided prospective predictions of NTGR.

In contrast, the InfoScout data approach (three votes) edged out the change in on-site saturation (two votes) for the weakest method. For both methods, consensus panelist argued that the results were inconsistent and implausible across time and bulb types.

2.3 Expert Panel Predictions

Step 4 of the consensus process culminated in consensus panelists offering their own predictions of NTGRs. NMR received five different sets of predictions, including one from the EEAC consultants (but two sets of reasons), one from the PAs, and three from evaluators (representing NMR and two of the subcontractors working on Massachusetts and other lighting evaluation studies across the nation). Table 4 shows the average, low, and high

prediction for each year and bulb type, while Figure 1 presents the same averages graphically. Evaluator responses have been combined so as not to exhibit undue influence on the values. We show the descriptive statistics for information only as the consensus process relies on reaching agreement on prospective NTGRs through discussion rather than using an average of submitted values.

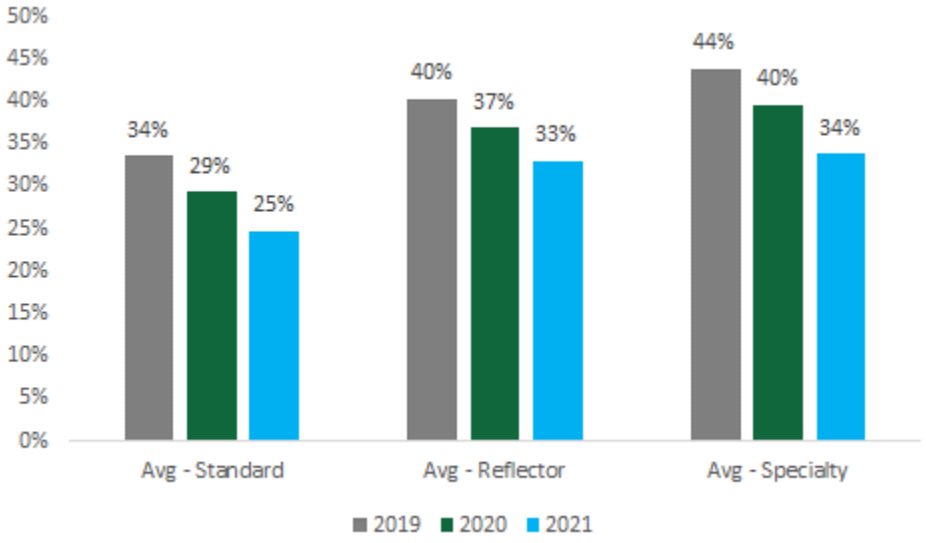
Within bulb types, consensus panelists expected NTGRs to decline between 2019 and 2021, from an average of 34% to 25% for standards, 40% to 33% for reflectors, and 44% to 33% for specialties. The range between highest and lowest prediction converged over time for all three bulb types, from 15% in 2019 to 9% in 2021 for standards, 16% to 10% for reflectors, and 12% to only 2% for specialty bulbs. This suggests that panelists show less agreement about the current program impact on the lighting market than they do about the future impact.

Across bulb types, for all respondents and years, consensus panelists predicted standard NTGRs to fall below those of reflector and specialty bulbs. The difference was an average of about six to eight percentage points per year between standard and reflector and nine to eleven percentage points per year between standard and specialty. In contrast, panelists predicted the NTGRs of reflector and specialty bulbs to be very similar, deviating by only one to four percentage points on average.

Table 4: Panelists' Low, Average, and High Predictions of NTGRs (n=3)

	2019			2020			2021		
Product	Ave.	Low	High	Ave.	Low	High	Ave.	Low	High
Standard	34%	30%	45%	29%	25%	33%	25%	20%	29%
Reflector	40%	34%	50%	37%	33%	45%	33%	30%	40%
Specialty	44%	38%	50%	40%	36%	45%	34%	33%	35%

Figure 1: Panelists' Average Predictions of NTGR (n=5)



2.4 PROSPECTIVE NTGR DISCUSSION[8]

To prepare for Step 5, the setting of prospective NTGRs by consensus, NMR compiled the assessments of strengths and weaknesses, various predicted NTGRs, and the reasons underlying the predictions. The consensus panel met on February 28, 2018, to review the compiled information, discuss which NTGRs to set (bulb and product types, program delivery modes, specific consumer groups or retail channels), and reach consensus on the recommended values for 2019, 2020, and 2021.

While the panelists did not always agree on all points, as their individual predictions would suggest, their opinions already had converged on the magnitude and direction of NTGs over time within and across bulb types. This facilitated the process, and consensus was easily reached for the topics below.

2.4.1 All, Standard, Reflector, and Specialty LEDs

In their individual predictions, some panelists believed that the retrospective results for individual bulb types lacked consistency and reliability. One argued in favor of setting NTGRs for all LEDs and using the single value for all bulb types because the evaluated results did not provide strong enough evidence of a difference in NTGRs across type. While other panelists agreed that the retrospective NTGRs for individual bulb types lacked consistency, they held that market intelligence, coupled with the variation in manufacturer and implementer predicted NTGRs, argued for separate NTGRs by bulb type. They also noted that, while the reflector and specialty markets were changing rapidly, with LEDs gaining a strong foothold, market share for reflector and specialty still lagged standard LEDs. The panelists reviewed 2016 and 2017 program-supported sales by bulb type (Table 5), noting that the PAs increased their support for standard LEDs in 2017 in response to dropping CFLs from the program (because most CFLs lost ENERGY STAR status after a specification change). In the end, all agreed that the market evidence pointed to differences across bulb types.

Table 5: Program-supported LEDs by Bulb Types, 2016 and 2017

	2016	2017
Total Sales	**4,080,673**	**8,720,868**
Standard	56%	70%
Reflector	30%	22%
Specialty	14%	9%

[8] As noted earlier, the consensus panel briefly discussed setting prospective LED NTGRs for single-family direct install programs, but ultimately decided to address this topic in the RLPNC 18-5 Home Energy Assessment LED NTG study, to be delivered separately.

To set the recommended values, the consensus team started with the average values presented in Table 4 and, in real time, reviewed how adjusting the predictions of individual panelists would affect the NTGRs. ***In the end, the panel recommended NTGRs for standard bulbs that fell slightly below the averages (Table 6). They set the NTGRs for reflector and specialty bulbs at the same values, which fell slightly above the original averages.***

Table 6: Average and Panelist Recommended Predicted NTGRs

Product	2019		2020		2021	
	Ave.	Rec.	Ave.	Rec.	Ave.	Rec.
Standard	34%	35%	29%	30%	25%	25%
Reflector	40%	45%	37%	40%	33%	35%
Specialty	44%	45%	40%	40%	34%	35%

2.4.2 Hard-to-Reach, Retail Channels, and Fixtures

The team also discussed potentially setting NTGRs by retail channel – as a proxy for HTR customers. The program currently considers sales in discount stores; second-hand (thrift) shops; and certain grocery, convenience, and corner stores as reaching HTR customers. While the program's channel-based approach to boosting sales among HTR consumers aligns with the practical needs of manufacturers and retailers,[9] it does not align with the behavior of consumers. Both HTR and non-HTR consumers frequently shop at the same types of stores, with many shoppers in both groups frequenting home improvement, mass merchandise, and discount stores. Therefore, the panelists concluded that applying a NTGR for HTR would not match the program design or shopper behavior.

The panel also considered whether to set channel-specific NTGRs. Prior program research has documented varying NTGRs by retail channel.[10] Although that prior research occurred when the program still supported more CFLs than LEDs, panelists generally believed that home improvement (especially), mass merchandise, and membership clubs (so called *big box* stores) may be transformed, and are now able to sustain high LED sales and market share without program support. Some argued that NTGRs in other channels likely remained higher than big box stores, but the research methods used to estimate NTGR did not provide conclusive evidence. The consensus team decided not to set channel-specific NTGRs. Subsequently, while the PAs and EEAC consultants considered sponsoring a channel-specific NTGR effort, they ultimately agreed that, even if current NTGRs differed by channel,

[9] Some commentators have suggested that the program consider sales in certain neighborhoods or zip codes as HTR. In this model, some locations of Retailer A would be considered HTR and others would not. However, manufacturers and retailers want the flexibility to move stock from underperforming stores to stores meeting or exceeding their sales targets. Because the program sets specific sales targets for HTR LEDs, moving stock between HTR and non-HTR stores creates logistic programs for tracking and claiming sales. Thus, for practical reasons, the program implementer has decided on a channel-based model for HTR implementation.

[10] For example, NMR Group and KEMA. 2013. *Lighting Retailer, Supplier Perspectives on the Massachusetts ENERGY STAR® Lighting Program.* http://ma-eeac.org/wordpress/wp-content/uploads/Lighting-Retailer-Supplier-Perspectives-on-the-Massachusetts-Energy-Star-Lighting-Program-Final-Report-June-2013.pdf

they were converging over time. Thus, any channel-specific differences would likely diminish (and possibly disappear) during the 2019 to 2021 program cycle. For these reasons they decided not to pursue additional research on channel-specific NTGRs.

Finally, the consensus panel noted that the process did not yield NTGRs for LED fixtures, including integrated fixtures and downlight retrofit kits. The program supports three main types of fixtures: downlight retrofit kits; hardwired fixtures; and portable desk, table, and floor lamps. The panel settled on a strategy by which the PAs would examine the types of fixtures supported through the programs and map them to the NTGR for the most appropriate bulb type. **The PAs have completed this mapping and report that they consider downlight kits to be like reflector bulbs and other fixtures to be like general service bulbs. NMR analysis also revealed that about 94,000 fixtures (7%) emitted more than 3,300 or less than 310 lumens. We argue that these should be treated similarly to specialty bulbs.**

2.5 Summary of Recommended NTGRs and Action Items

Table 7 summarizes the consensus panel's recommended NTGRs for LED bulbs and fixtures. **NMR recommends that the PAs and EEAC consultants use these NTGRs for planning the 2019 to 2021 programs.**

Table 7: Recommended Prospective NTGRs and Action Items

	2019	2020	2021
Recommended Upstream Bulb NTGRs for Program Planning			
Standard	35%	30%	25%
Reflector	45%	40%	35%
Specialty	45%	40%	35%
Recommended Upstream Fixture NTGRs for Program Planning			
General service fixtures	35%	30%	25%
Reflector fixtures & downlight kits	45%	40%	35%
Specialty fixtures (lumens < 310 or >3300)	45%	40%	35%

Appendix A Estimation Approaches

This study draws on data from seven evaluation efforts conducted between 2016 and 2018. Most of them provided data that was later used to calculate NTGRs, while one study had the objective of estimating NTGRs.

Below, we summarize the approaches to estimating NTGRs from data provided by each evaluation effort and summarize the resulting NTGRs for standard, reflector, and specialty LEDs. We provide a link to the original studies when introducing a method; full citations are available in Section A.3.

A.1.1 Manufacturer and Implementer Predicted Market Share

Manufacturer and Implementer market-share predictions is the only estimation approach that predicted prospective NTGRs, which is the primary objective of the consensus approach. The evaluation team asked manufacturers and retailers (during in-depth interviews), as well as PA implementers and the implementation contractor (via email), to predict market share with and without the PA lighting program for 2018, 2020, and 2022. We received usable market share predictions from 17 manufacturers, accounting for 93% of the lighting program sales. We also received usable predictions from three retailers, but they accounted for only 18% of sales, and their sales were not mutually exclusive of those of manufactures. Therefore, we only used the manufacturer estimates to predict prospective NTGRs. The PA implementers and the implementation contractor decided to submit one set of combined predictions. We used the following equation to predict market share NTGRs:

$$NTGR = \frac{(LED\ market\ share\ with\ program - LED\ market\ share\ without\ program)}{LED\ market\ share\ with\ program}$$

NMR calculated unweighted manufacturer and implementer NTGR predictions and weighted manufacturer predictions. The need to weight the data is due to program sales varying widely across manufacturers. For example, as shown in Table 8, Respondent 015 accounted for only 0.01% of program standard LED sales, while Respondent 012 manufactured 27% of the program standard LEDs. Lacking total market-level sales across all bulb types by manufacturer, no clear weighting scheme presented itself.[11] Therefore, the evaluators used the data available to create an imperfect but workable weight scheme. The weighting scheme applies the percentage of program LED sales represented by each manufacturer to all bulb sales as reported by LightTracker. This yielded an approximation of each manufacturer's total market sales. We then multiplied each respondent's predicted LED market share with and without the program by their estimated total market sales. This gave the number of LEDs sold by that specific manufacturer according to their own predictions. We summed these and converted the total number of LEDs back to a market share estimate. These were then used

[11] For this reason, the 16-2 Supplier Interview Report reports unweighted market share estimates only.

within the market share NTGR equation provided above. We produced separate weights for each of the three bulb types; as an example, Table 8 displays the scheme for standard bulbs for 2018 with and without the program.

Table 8: Standard Bulb Manufacturer Weighting Scheme Example

1	2	3	4	5	6	7
Respond ID[1]	%LED 2018 w/ program	%LED 2018 w/o program	% of Standard LED Program Sales	% of Standard LightTracker Sales[2] (Col 4 x 4,260,274)	#2018 bulb sales w/ program (Col 2 x Col 5)	#2018 bulb sales w/ program (Col 3 x Col 5)
001	54%	47%	0.3%	11,783	6,363	5,538
003	70%	40%	24.0%	1,021,027	714,719	408,411
005	60%	40%	5.4%	231,541	138,925	92,616
007	54%	27%	6.1%	258,400	139,536	69,768
008	35%	25%	8.8%	375,103	131,286	93,776
010	33%	15%	10.7%	456,832	150,754	68,525
011	40%	38%	6.8%	289,400	115,760	109,972
012	60%	40%	27.2%	1,159,626	695,775	463,850
014	84%	60%	0.1%	5,411	4,546	3,247
015	35%	35%	0.01%	517	181	181
017	45%	25%	6.5%	277,979	125,090	69,495
019	65%	30%	3.1%	130,550	84,857	39,165
020	50%	25%	0.4%	15,177	7,589	3,794
021	30%	24%	0.6%	26,928	8,078	6,463
Total	**N/A**	**N/A**	**100%**	**4,260,274**	**2,323,460**	**1,434,801**
Weighted Market Share					55%	34%

[1] Missing IDs were assigned to suppliers excluded from the analysis because they were retailers or because they did not sell Standard LEDs through the program.
[2] This is estimated based on point-of-sale data, which include mass merchandise, dollar, discount, grocery, drug, and some membership stores, representing 40% of lighting sales in Massachusetts.

One concern with the Supplier and Implementer Market-share approach is the implicit assumption that the PAs provide direct market support for the entire program lift by using the with-program market share prediction in both the numerator and denominator of the equation. This contrasts with the market-sales approach (see equations below, with pertinent inputs highlighted), in which market-level sales (analogous to with program market-share) appears in the numerator, while program sales – a subset of market-level sales – appears in the denominator. In the second equation, the difference between program sales and with-program market sales is spillover. This difference does not exist in the market-share equation

(on top); therefore, the market-share approach does not adequately account for the spillover implicit in the manufacturers' with-program predictions.

$$NTGR = \frac{(LED\ market\ share\ with\ program - LED\ market\ share\ without\ program)}{LED\ market\ share\ with\ program}$$

$$NTGR = \frac{(LED\ market\ sales\ with\ program - LED\ market\ sales\ without\ program)}{LED\ program\ sales}$$

NMR conducted a sensitivity analysis to show how the NTGRs would change if direct program sales accounted for only 90% of the market lift (with the remaining 10% being spillover) (Table 9). This approach translates the market share predictions into sales predictions and then enters the results into the market share equation above. Although the scenario is unlikely, we also provide the opposite example – if the PAs support 110% of lift, meaning they supported too many bulbs, dipping into baseline sales. Table 9 provides an example of the sensitivity analysis for Standard LEDs based on weighted manufacturer NTGR predictions. This example relies on a hypothetical sale of 1,000,000 bulbs.

Table 9: Market-Share Approach – Standard LED Sensitivity Analysis

Row	Approach	2018	2020	2022
1	Estimated Bulb Sales		1,000,000	
2	Weighted with Program Market Share	55%	65%	52%
3	Weighted without Program Market Share	34%	44%	34%
4	With Program Sales	545,378	654,233	519,740
5	Without Program Sales	336,786	439,313	339,818
6	Denominator = 100% with Program Market Share	545,378	654,233	519,740
7	Denominator = 90% with Program Market Share	490,840	588,810	467,766
8	Denominator = 110% with Program Market Share	599,916	719,657	571,714
9	NTGR 100% with Program Market Share	38%	33%	35%
10	NTGR 90% with Program Market Share	42%	37%	38%
11	NTGR 110% with Program Market Share	35%	30%	31%

A.1.2 Change in On-site Saturation

The change in on-site saturation approaches uses data collected for the 2017 and 2018 market assessment studies. These assessments compare on-site saturation and other bulb characteristics for Massachusetts and a portion of Upstate New York, plus Westchester County. The New York State Energy Research and Development Authority (NYSERDA) and the New York electric utilities stopped offering incentives on CFLs in 2012 and most lighting

products in 2014. The electric utilities in New York supported energy-efficient lighting only through direct install or online programs.[12] The similarities between Massachusetts and the portion of New York created a natural experiment in which to compare LED adoption rates in Massachusetts, which continues to run an extensive upstream lighting program, and New York, which does not. The evaluation team weights data from New York to the education and home ownership rates of Massachusetts households to create *counterfactual Massachusetts* – what Massachusetts may have been like had they stopped upstream lighting programs like NYSERDA did. The on-site visits include two groups: those visited for the first time in a given year and those who have been visited at least twice for on-site saturation inventories. For the 2018 study, the team only visited panelists.

This method uses changes in LED socket saturation, stored LEDs, and replaced LEDs in Massachusetts and counterfactual Massachusetts to estimate newly added LEDs. We adjust for PA direct installations, yielding an estimate of purchases. We then use these data to calculate a NTGR. We use data collected for the 2016 study as the baseline and then calculate NTGRs that coincide with the 2017 (for all on-site visits and for panelists alone) and 2018 studies (for panelists only). This approach uses the following equation:

$$NTGR = \frac{MA\ market\ purchases\ -\ MA\ market\ purchases\ T_1\ and\ T_2\ assuming\ a\ similar\ change\ in\ Installations\ and\ Storage\ as\ in\ NY\ from\ T_1\ and\ T_2}{MA\ Program\ Sales\ between\ T_1\ and\ T_2}$$

Table 10 presents an example of the full calculations using standard LEDs.

[12] NMR has recently learned that ConEdison, which serves Westchester County, implemented an upstream program; we are currently reaching out to ConEdison to learn when the program began and the size of the program.

Table 10: Standard LED Change in Saturation Approach

A	B	C	D
1	**Starting Numbers**	**Standard**	**Source/comment**
2	MA All Bulbs Installed 2016	68,265,744	On-site saturation studies
3	MA All Bulbs Installed 2017	66,786,240	On-site saturation studies
4	MA Stored LEDs 2016 (wtd to 2017)	997,785	On-site saturation studies
5	MA Stored LEDs 2017	2,527,788	On-site saturation studies
6	MA Installed LEDs 2016 (wtd to 2017)	3,354,479	On-site saturation studies
7	MA Installed LEDs 2017	5,165,035	On-site saturation studies
8	MA Market-level Sales 2016	4,844,470	On-site saturation studies
9	MA Program Sales 2016	2,268,595	Program Tracking Data
10	MA DI Bulbs 2016	1,764,450	Mass Save Data Dashboard
11	**Calculated Numbers**		
12	MA Installed LEDs 2016 (wtd to 2017)	3,354,479	On-site saturation studies (same as Row 6)
13	Counterfactual Installed LEDs 2017	4,822,752	On-site saturation studies
14	MA Stored LEDs 2016 (wtd to 2017)	997,785	On-site saturation studies (same as Row 4)
15	Counterfactual Stored LEDs 2017	1,699,814	On-site saturation studies
16	Counterfactual Installed/Storage Difference 2016 vs. 2017	2,170,303	Row12+Row14-Row13-Row15
17	LED Replacement Rate	356,152	On-site saturation studies, panelists
18	Counterfactual Market-level Sales 2017	2,526,454	Row18+Row19
19	**NTG**	**24.4%**	**(Row8-Row10-Row18)/Row9**

A.1.3 Change in LEDs Added to Panel Homes

For the on-site panelists in the same market assessments cited above, NMR has designed protocols that allow us to identify newly added LEDs to all participating homes. Adjusting for verified PA direct installations produces an estimate of bulbs purchased between visits. As with the on-site saturation approach, the team compares per-household purchases in Massachusetts to New York (weighted to the demographics of Massachusetts) to yield estimated NTGR based on the following equation:

$$NTGR = \frac{(MA\ LED\ purchases\ per\ household - NY\ LED\ purchases\ per\ household)}{Program\ LED\ sales\ per\ household}$$

For example, the 2016 All LED NTGR estimate is as follows:

$$NTGR = \frac{(2.4 - 1.5)}{1.7} = 53\%$$

A.1.4 LightTracker Sales Data

As explained in more detail in the full sales data modeling report, the approach uses full-category lighting sales data (all retail channels) from 38 states to model the impact of program intensity (defined as state-level lighting program spending per household) on LED market share. The model also controls for other factors that may affect lighting sales. The model equation follows:

$$LED\ Market\ Share i = \beta_0 + \beta_1 * Program\ Spending\ per\ HH + \beta_2 * Program\ Age + \sum_{A=1}^{3} \beta_A * Channel\ Variables + \sum_{B=1}^{4} \beta_B * Demographic\ Variables$$

Where:

LED Market Share$_i$ = Proportion of total bulb sales in state ‘i' that are LEDs. Equal to [LED sales/total bulb sales]

β_0 = The model intercept

β_1 = The primary coefficient of interest. This represents the marginal effect of program intensity, or the expected increase in the market share of LEDs for each $1 in additional program spending per household.

β_2 = Another coefficient of interest. This represents the marginal effect in additional program years since inception.

Program Spending per HH$_i$ = The number of 2016 retail lighting program dollars per household in state ‘i.' Equal to total retail lighting program expenditures in state ‘i' (incentive and non-incentive) divided by the number of households in state ‘i.'

Program Age = The number of years state ‘i’ has been running an upstream lighting program.

β_A *and* β_B = Array of regression coefficients for the channel variables and demographic variables.

Table 11 lists the variables in the final equation, while Table 12 presents the model coefficients and p-values.

Table 11: Sales Data NTG Model Variable Descriptions

Type of Variable	Description
Dependent Variable	
LED Market Share	Proportion of total bulb sales in state 'i' that are LEDs. Equal to [LED sales/total bulb sales].
Program Activity Variables	
Program Spending per HH (sq rt)	Square root of the number of 2016 retail lighting program dollars per housing unit in state 'i.' Equal to total retail lighting program expenditures in state 'i' (incentive and non-incentive) divided by the number of housing units in state 'i.'
Program Age	The number of years state 'i' has been running an upstream lighting program.
Channel Variables	
Sqft NonPOS per HH$_i$	The average non-POS retail square footage per housing unit in state 'i.' Equal to non-POS square footage divided by the number of housing units in state 'i.'
Demographic Variables	
Political Index$_i$	A state-level partisan voter index developed by Cook Political Report (used for 2015 index) and Gallup (used for 2016 index) that uses presidential election voting results as a state-level partisan proxy. A higher than 1.0 value represents greater democratic influence and a value less than 1.0 indicates greater republican influence.
Median Income$_i$	State-level as reported by the American Community Survey.

Table 12: Model Summary Statistics (n=38 States)

Independent Variable	Model Coefficient	*p*-value of Coefficient
Intercept	-0.908	0.013
Program Spending per Household (Sqrt)	0.029	0.001
Political Index	0.010	0.005
Median Income	<0.001	0.007
Political Index * Median Income	<-0.001	0.006
Non-POS sqft per HH	0.011	0.187
Program Age	0.002	0.068
Model Adjusted R^2	**0.677**	

Table 13 shows the NTGR calculations. The LightTracker team developed the NTGR using a "modeled:modeled" calculation as opposed to a "modeled:actual." This means that the counterfactual scenario (which can only be modeled as it never actually happened) was compared to a *modeled* LED market share rather than the actual LED market share for Massachusetts in the data set. This allows for a more comparable calculation.

For estimating the NTGR, the evaluation team presented two options for treating the program age counterfactual:

1) Programs have never existed (Program Age is set to 0); or
2) Programs existed through 2015 (Subtract one year from the Program Age).

Table 13: Massachusetts NTGR Calculations

	Counterfactual	
Calculation Term	**No Massachusetts Programs Ever**	**No Massachusetts Program in 2016**
Total Massachusetts Bulbs 2016 (A)	19,460,804	19,460,804
Program $ per HH Actual (B)	$11.31	$11.31
Program $ per HH Counterfactual (C)	$0.00	$0.00
Program Age Actual (D)	18	18
Program Age Counterfactual (E)	0	17
LED Market Share Counterfactual (F)	17.5%	21.7%
LED Market Share Modeled (G)	31.8%	31.8%
LED Qty Modeled (H=A*G)	6,188,536	6,188,536
LED Qty Counterfactual (I= A*F)	3,405,641	4,222,994
Net LEDs Modeled (J=H-I)	2,782,895	1,965,541
Program LED Bulbs 2016 (K)	5,096,082	5,096,082
NTGR Modeled (L=J/K)	55%	39%

A.1.5 InfoScout Purchases

InfoScout data tracks light bulb purchases for the consumers in their panel, who agree to scan receipts of all purchases they make. In the 16-3 and 17-2 evaluation projects, NMR obtained InfoScout light bulb purchase data for Massachusetts and Upstate and Westchester County New York. The two evaluation projects have data that cover two periods: August 2015 to August 2016 and July 2016 to August 2017. NMR used program data from the same periods to develop a set of NTGRs. We estimated NTGR using the following equation:

$$NTGR = \frac{(MA\ LED\ purchases\ per\ household - NY\ LED\ purchases\ per\ household)}{Program\ LED\ sales\ per\ household}$$

A.2 EVALUATED NTGR ESTIMATES

Table 14 below presents the evaluated NTGRs for standard, reflector, and specialty LEDs. For each bulb type, the estimates ranged widely across methods and sometimes within methods. Differences among the methodologies and calculations explain variation across types, but, within types, the main culprits appear to be small and fluctuating sample sizes, composition of the sample, and no strong estimate of market-level sales (many estimates fall below program supported sales).

Table 14: Evaluated NTGRs by Bulb Type and Approach

Approach	Type	2016	2017	2018	2020	2022
Manufacturers Unweighted	Standard			34%	27%	26%
Manufacturers Weighted	Standard			38%	33%	35%
Manufacturers Weighted (90% of lift)[1]	Standard			42%	37%	38%
Implementers	Standard			38%	36%	23%
LightTracker (Program Age = 0)	All	55%				
LightTracker (Program Age = T - 1)	All	39%				
Onsite Saturation (All Visits)	Standard	24%				
Onsite Saturation (Panel Only)	Standard	-11%[2]	27%			
Onsite Panel Purchase	Standard	47%	33%			
InfoScout Purchase	Standard	34%	17%			
Manufacturers Unweighted	Reflector			35%	36%	33%
Manufacturers Weighted	Reflector			47%	43%	43%
Manufacturers Weighted (90% of lift)[1]	Reflector			52%	48%	48%
Implementers	Reflector			40%	38%	36%
Onsite Saturation (All Visits)	Reflector	135%[3]				
Onsite Saturation (Panel Only)	Reflector	137%	96%[3]			
Onsite Panel Purchase	Reflector	42%	63%			
InfoScout Purchase	Reflector	41%	-3%			
Manufacturers Unweighted	Specialty			34%	32%	31%
Manufacturers Weighted	Specialty			39%	39%	38%
Manufacturers Weighted (90% of lift)[1]	Specialty			42%	43%	42%
Implementers	Specialty			40%	38%	36%
Onsite Saturation (All Visits)	Specialty	143%				
Onsite Saturation (Panel Only)	Specialty	321%	288%			
Onsite Panel Purchase	Specialty	123%	132%			
InfoScout Purchase	Specialty	4%	4%			

[1] From the sensitivity analysis described in Table 9.
[2] Negative values occur when counterfactual/baseline sales exceed Massachusetts sales.
[3] Method predicted no counterfactual reflector sales.

A.3 STUDY CITATIONS

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