It's Almost the End of the World and We Know It: An Examination of the Future of Residential Lighting Programs

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ABSTRACT

Residential lighting has been the workhorse of energy-efficiency programs ever since the CFL was introduced, historically accounting for the largest share of all residential energy savings. Depending on housing type and size, consumers can expect to replace about seven bulbs each year. No other end use comes close to this level of turnover, which has created an unprecedented opportunity for program intervention. While there is no doubt that residential lighting programs have been hugely successful to date, the future is less certain.

Right now, program administrators across the U.S. are planning the next few years of programs and, as regulators set savings targets, we must have an informed conversation about the future of lighting. The implementation of federal (EISA) and state standards (California CEC standards), as well as the rapid advancement and adoption of LEDs, has program administrators and regulators talking about the end of traditional residential lighting programs.

In this paper, we explore data based on recently completed LED market assessments in a program state and a non-program comparison area – as well as over a decade of LED saturation observations. The authors leverage this data to help paint a picture of the current lighting market and to forecast the future in the program and non-program areas (based on current market conditions). In addition, we explore the potential impact of the second phase of the Energy Independence and Security Act of 2007. This look into the future helps to answer the question, "When is the end for residential lighting programs?"

Introduction

In this paper, we examine long-term trends in residential lighting socket saturation for Massachusetts and a non-program comparison area. We chose portions of New York (comprising Westchester County and 40-mile radiuses around the cities of Albany, Buffalo, Rochester, and Syracuse) as a comparison area because they present a unique opportunity to understand how the residential lighting market has responded to the cessation of standard spiral CFL incentives in 2012 and nearly all upstream incentives in 2014.[1] In addition, the demographic profile of the combined New York comparison area offers a close approximation to that of Massachusetts.

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[1] Note: we refer to the comparison portion of the state as *New York* throughout the paper. The comparison area does not include Long Island or New York City, where some upstream program activity continues.

Prior to 2014, both Massachusetts and New York had upstream lighting program activity and evaluations. However, in 2012, at the direction of the New York Department of Public Service (NY DPS), New York began to exit the residential upstream market with the cessation of standard spiral CFL incentives. In 2014, New York essentially ceased all upstream incentives (for CFLs and LEDs). The NY DPS directive was based on the premise that the residential lighting market would continue to transform without further intervention. At the same time, Massachusetts continued to support CFLs through the end of 2016 and continues to support LEDs.

On-site lighting saturation surveys in the New York comparison area serve as a proxy to help understand what may have happened in Massachusetts had the Massachusetts Program Administrators (PAs) similarly eliminated standard spiral CFL incentives in 2012 or at some point thereafter.

Methodology

Field technicians collected data for this paper were through on-site lighting inventories conducted in both Massachusetts and New York, with on-site participants recruited via consumer surveys. From 2013 through 2018, 2,797 on-site visits were completed in both states combined – 766 in New York and 2,031 in Massachusetts. There were two types of visits: new visits (the first visit to a home) and panel visits (subsequent visits to homes). The 2017-18 Market Assessment relied entirely on visits to panel households (because previous rounds had detected no statistical difference in lighting use between new and panel households).[2]

This paper also presents predicted socket saturation through 2030. We developed and fitted adoption curves to estimate efficiency improvement and acceleration (Buskirk 2012). Using observed changes in LED saturation, we applied a simplified logistic function to forecast LED saturation for Massachusetts (assuming continued program support) and New York (assuming no program support). For both forecasts, we used the following function:

$$f(t) = \frac{M}{1 + e^{-\alpha(t-T)}}$$

Where,

M = **Maximum saturation,** the maximum expected saturation for LEDs.
α = **Alpha**, the rate at which efficiency is increasing over time. A lower alpha results in a flatter curve and a higher alpha results in a steeper curve.
T = **half point,** the point in time where we expect saturation to reach 50%.

For the purposes of our forecast, we assumed that LED saturation would reach a maximum (M) of 90% saturation – with 10% of sockets being ultimately out of reach either due to specialized features or requirements or lack of willingness to adopt LEDs. We manipulated the alpha and half point such that the curve aligned with the observed saturation levels between 2008 and 2018. The section on these forecasts provides additional details.

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[2] Site visits typically occurred in the fall and winter (crossing two calendar years). We label visits by the ending year, as the data reflect the state of the market at that time. Therefore, the 2015-16 visits are labeled 2016 and the 2016-17 visits are labeled 2017.

Evidence of Historical Program Effect

Figure 1 provides saturation by bulb types over time in Massachusetts. To aid in understanding trends, we have interpolated data to represent 2011, a year when a study was not completed. As the data show, after a brief period of stagnation (2009 to 2012) efficient bulb saturation has grown steadily, while inefficient bulb saturation has decreased.

Between 2003 and 2014, gains in efficient bulb saturation were driven largely by CFL adoption. However, after 2014, we observed a modest but steady decline in CFL saturation. At the same time, LED adoption (and resulting saturation) began to increase rapidly. This pattern mirrors program activity in Massachusetts, which heavily supported CFLs between 2003 and 2013 and then began to transition program support to LEDs in 2013, virtually ending program support for CFLs as of December 31, 2016.
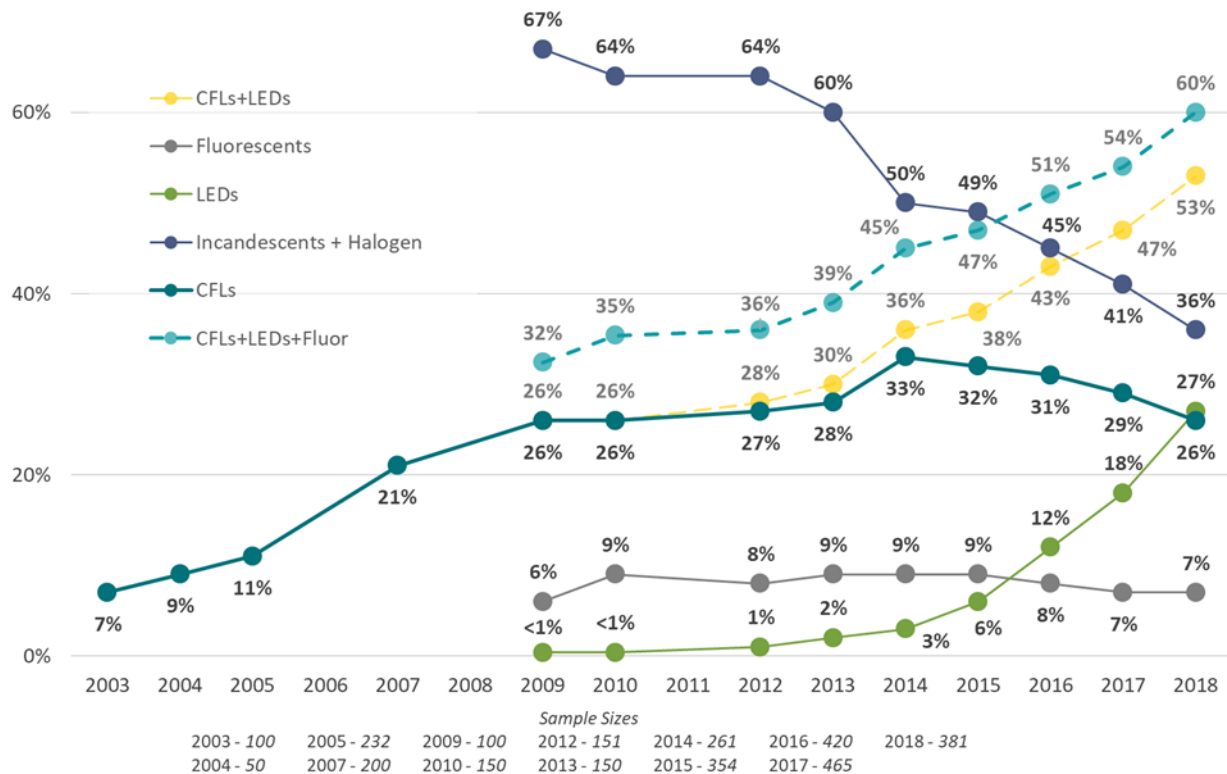

Figure 1 Massachusetts saturation over time

Figure 2 provides an overview of efficient and inefficient saturation trends from 2009 to 2018 in both Massachusetts and the New York comparison area.[3] In this figure, we exclude linear fluorescent lamps and focus on LEDs and CFLs because linear fluorescent socket saturation has remained relatively unchanged in both areas since 2009.

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[3] Prior to 2013, the New York data was collected in a broader area in New York – representing the full state. Starting in 2013, the data shown are limited to visits conducted in a 40-mile radius around Buffalo, Rochester, Syracuse, and Albany, and all of Westchester County.

As the figure shows, Massachusetts and the New York comparison area had similar levels of efficient lamp saturation between 2009 and 2013. It was not until New York began to exit the upstream lighting market that we began to observe differences in saturation between the two states. Over a relatively short period, we see that continued program support in Massachusetts created a substantial gap in saturation between the two areas.
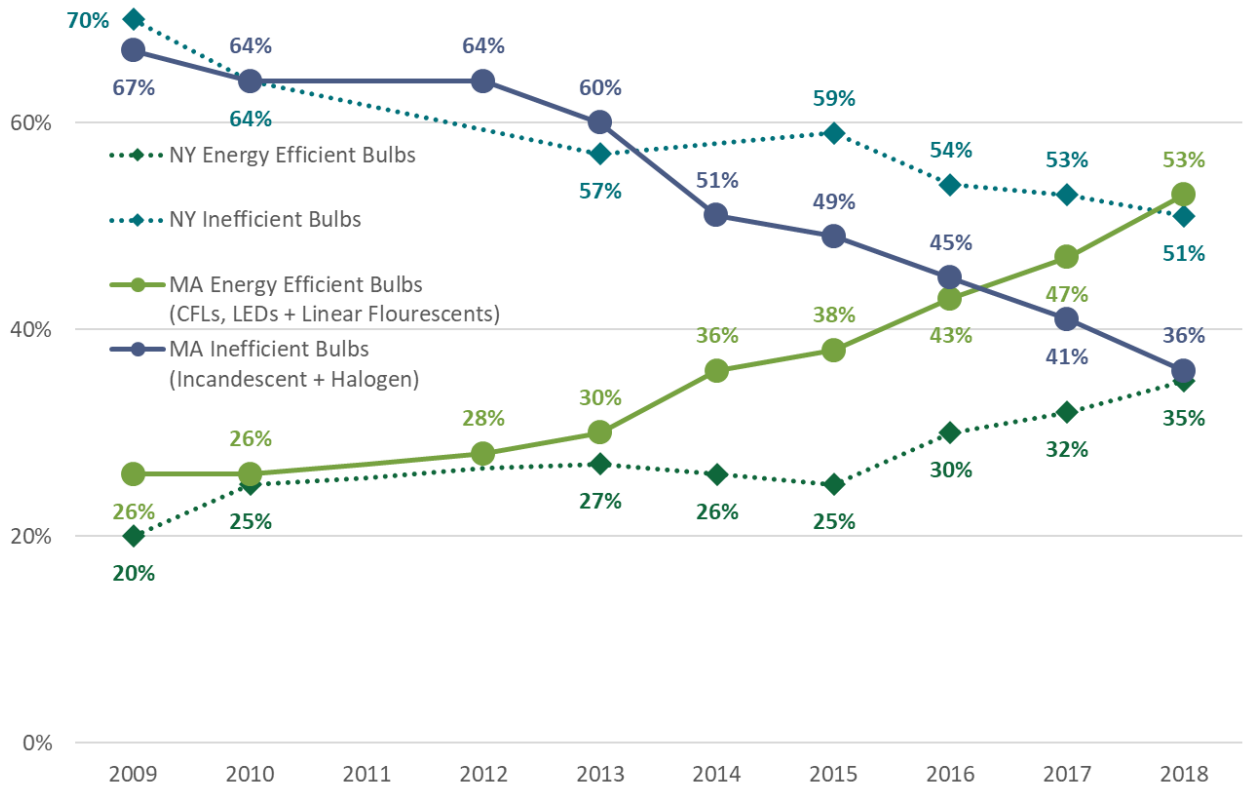

Figure 2 Efficient and inefficient saturation (MA vs. NY)

Starting with the 2016 Market Assessment, technicians collected model numbers for all screw-base LED bulbs (but not for integrated LED fixtures) while on site. Using these model numbers and the list of ENERGY STAR®-qualified LED bulbs, we determined whether LEDs observed during on-site visits were ENERGY STAR qualified. Figure 3 provides the results of this analysis for each area, as well as LED saturation overall from 2009 to 2018. In the figure, we separate LED saturation into three distinct categories: ENERGY STAR qualified, non-ENERGY STAR qualified, and integrated LED fixtures.

As the data show, ENERGY STAR LED saturation was significantly higher among Massachusetts households than New York households each year between 2016 and 2018. Interestingly, since 2016, the two states have had nearly the same saturation levels for non-ENERGY STAR LEDs (6% in Massachusetts and 7% in New York) and integrated LED fixtures (4% in Massachusetts and 2% in New York). ENERGY STAR models account for the entire LED saturation difference between the two states. Since the Massachusetts PAs' programs provide incentives only for ENERGY STAR LEDs, this is compelling evidence that the Massachusetts programs are directly leading to increased adoption of ENERGY STAR LEDs.
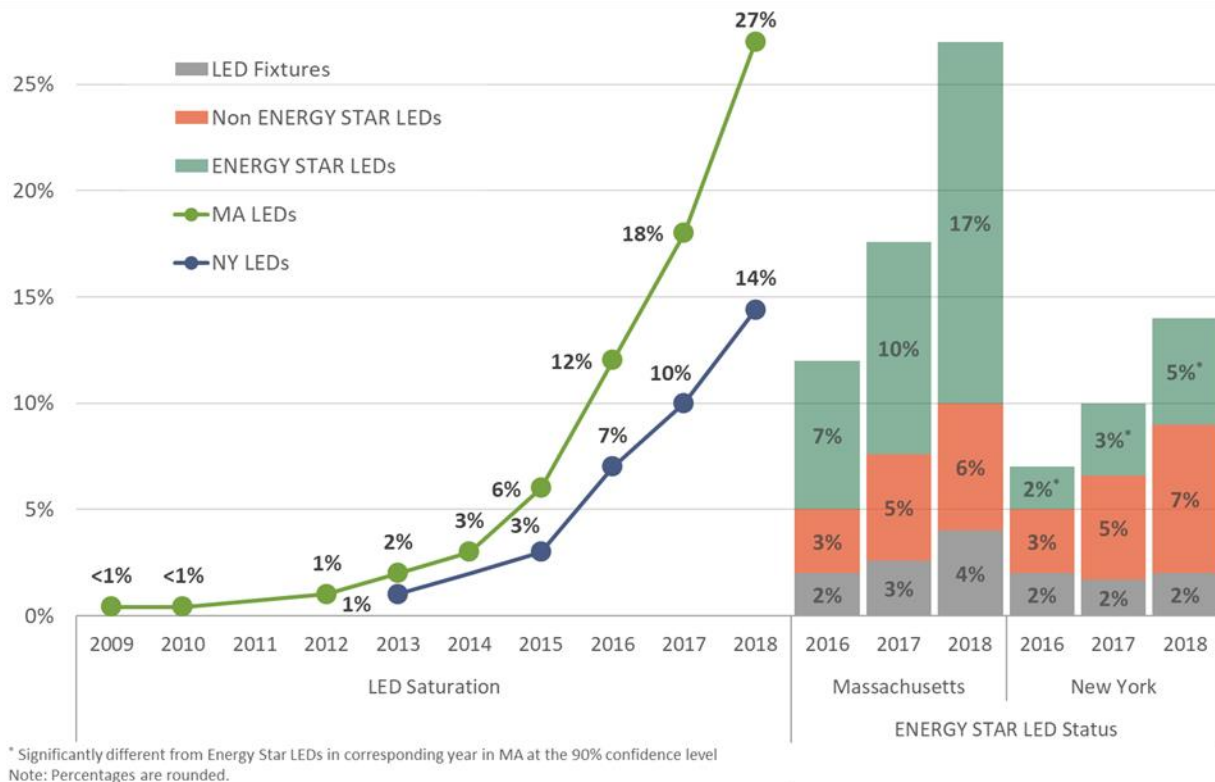
Figure 3 LED bulb saturation MA vs. NY

Estimating LED Saturation Growth

The first residential LED screw-base light bulb became available in 2008, but 60-watt equivalent omni-directional LEDs did not become readily available until about three years later (2011). In just seven years, we have witnessed LEDs being installed in 27% of the sockets in Massachusetts and 14% in the New York comparison area. Naturally, the question facing program administrators is, "to what extent can we expect LED saturation to continue to grow with and without program support?" To answer this question, we sought to create a forecast of market adoption through a market adoption curve.

As mentioned above, we used observed data to forecast socket saturation using the following simplified logistic function, setting *M* to 90% and manipulating *a* and *T* to match observed 2009 to 2018 data for each state:

$$f(t) = \frac{M}{1 + e^{-\alpha(t-T)}}$$

Figure 4 below provides an overview of the final fitted curves. For both areas, an *alpha* of 0.28 fit the data best. The curves fit observed data best with the assumption that Massachusetts would reach its half point in mid-2019 (assuming continued program support) and New York would reach its half point at the start of 2021 – about one and a half years later. In the figure, the solid green line represents observed LED saturation in Massachusetts from 2009 through 2018, and the solid blue line represents observed LED saturation in the New York comparison area over the same period. The dotted lines represent forecasted saturation.
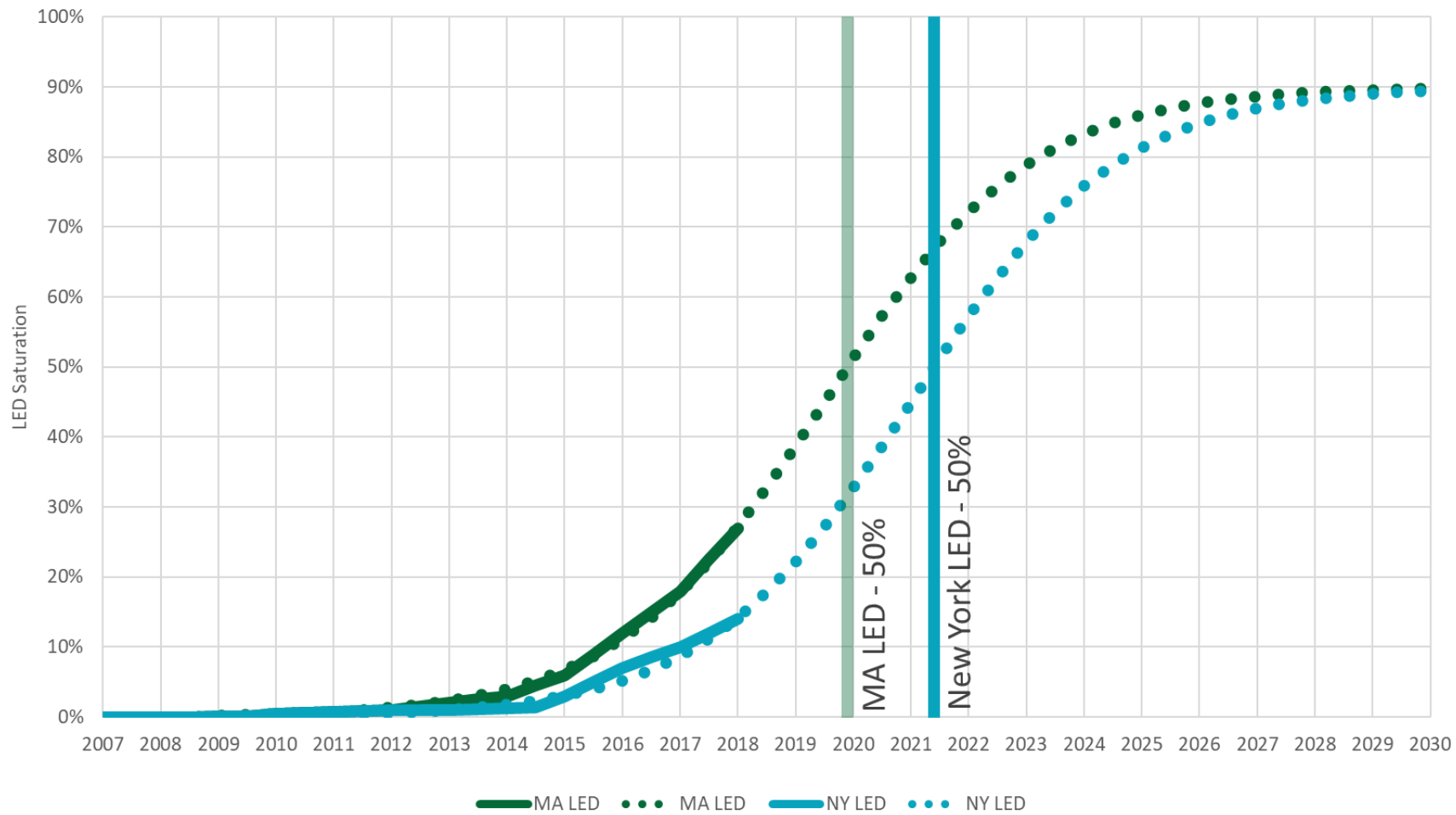
Figure 4 LED adoption curves

Based on these two adoption curves, if Massachusetts continues to support LEDs between 2018 and 2020, we expect that the existing gap in LED saturation between Massachusetts and New York will continue to widen – reaching a peak difference of 19 percentage points in 2020. In addition, while the gap between the two curves begins to diminish in 2021, a substantial gap (>10%) remains until after 2023. This is important because, during this period, electric customers in Massachusetts will continue to benefit from increased saturation of LEDs and lower energy costs.

Market momentum leaves little doubt that both areas will reach high levels of LED saturation. However, our adoption models suggest that Massachusetts will reach 80% saturation in 2023, eighteen months earlier than New York. The big-ticket question is whether residential lighting programs still have a role in energy-efficient portfolios, knowing that the lighting market will transform at some point regardless of intervention. Massachusetts' continued residential lighting program has accelerated the pace of LED adoption and this method of estimation shows that those efforts will bear fruit at least through 2021, and possibly through 2023. However, the adoption curves estimate that the gap between program and counterfactual will begin to diminish starting in 2022, and will be reduced to just 5% by 2025.

Other Factors Impacting Residential Lighting

Impact of CFLs

Note that the adoption curve focuses exclusively on LEDs. As shown in Figure 1 above, CFLs currently occupy about one-quarter of sockets in Massachusetts. However, CFL saturation peaked in 2014 and has been steadily declining ever since. In addition, recent studies of sales data show that CFLs accounted for less than 10% of all lamp purchases in 2017. Given the rapid exit of CFLs from the market, and an assumed expected life of approximately seven years, we anticipate that the majority of CFLs will burn out by 2020 or 2021 (NMR 2018a). In addition, we expect that the swapping of CFLs for LEDs will hasten the decline of CFL saturation, given long-standing dissatisfaction with certain CFL characteristics, including flickering, mercury, warm-up time, and light quality (Barclay et al. 2016).

Impact of Federal Standards

The residential lighting market has been and will continue to be impacted by not just voluntary energy-efficiency incentive programs, but also by changes in federal regulations. The Energy Independence and Security Act (EISA) of 2007[4] has had, and will continue to have, a profound impact on the residential lighting market. While EISA encompassed a wide variety of energy-related standards, for the purposes of this paper, we concentrate on the General Service Lighting (GSL) standards.

EISA laid out initial standards to be implemented between 2012 and 2014 (Phase I) and a schedule of events that would lead to increased standards in 2020 (Phase II) and 2025 (Phase III). The act envisioned the Department of Energy (DOE) issuing rulemakings that would take effect in 2020 and 2025. However, it also included a provision (backstop) that would go into effect in those years should the DOE fail to complete a rulemaking in accordance with the act or

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[4] https://www.gpo.gov/fdsys/pkg/PLAW-110publ140/html/PLAW-110publ140.htm

if the final DOE rulemaking did not produce savings greater than or equal to the savings of the backstop provision.

Phase I of EISA went into effect in a staged process from 2012 through 2014. Phase I increased the efficacy requirements of the most common GSLs by about 28-30%. The standards essentially required that all GSLs provide the same efficacy as common halogen lamps. Despite the standards taking effect up to five years ago, there is evidence of a long sell-through period – lamps covered by 2012 standards were still being purchased by consumers in 2017. The impact of Phase I of EISA is incorporated in observed saturation.

On January 19, 2017, the DOE issued two rulemakings[5,6] related to Phase II of EISA and indicated that the rules would go into effect as scheduled in January of 2020. The rules specifically cited an efficacy standard of 45 lumens per Watt (equivalent to the backstop provision).[7] In addition, the rules redefined GSL to include seven previously exempt categories of lamps and expanded the covered lumen range. Since Phase II of EISA has yet to go into effect, the saturation based adoption curves presented in this paper do not incorporate any influence it may have on the market. When Phase II goes into effect, it will lead to increases in LED saturation in both areas and will likely reduce the gap between Massachusetts and the New York comparison area at an earlier date. However, there is much uncertainty about the implementation of Phase II of EISA.

Enforcement

In the January 2017 rules, the DOE explicitly stated that they may not enforce the standards for all lamp types beginning in 2020. Instead, they may delay enforcement based on an ongoing dialog with lighting industry stakeholders – delaying enforcement for lamp categories without suitable LEDs (NMR 2018b).

Sell Through Period

While the final rules say that manufacture and sale of lamps are covered, the DOE further clarified in a footnote that the DOE would likely allow manufacturers to sell through non-compliant lamps manufactured before the backstop goes into effect (NMR 2018b).

NEMA Settlement

In March of 2017, the National Electrical Manufacturers Association (NEMA) filed a petition to review the DOE rulemakings. On July 7, 2017, the DOE and NEMA reached a settlement; NEMA agreed to withdraw its petition and the DOE agreed to complete the GSL rulemaking and other associated regulatory activities. This settlement agreement essentially re-opened the rulemakings and may delay enforcement by two or more years. While we have been

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[5] https://www.gpo.gov/fdsys/pkg/FR-2017-01-19/pdf/2016-32012.pdf
[6] https://www.gpo.gov/fdsys/pkg/FR-2017-01-19/pdf/2016-32013.pdf
[7] Importantly, EISA directed the DOE to undertake a standards rulemaking for GSLs, to be completed by January 1, 2017. According to EISA, if the rulemaking was not complete or if the rulemaking did not produce savings greater than or equal to the savings from a minimum efficacy standard of 45 lumens per watt, a statutory provision (backstop) would take effect.

unable to obtain a copy of any settlement agreement, our understanding is that the DOE agreed to do the following:

1. Issue a Notice of Data Availability (NODA), requesting market data for GSL incandescent lamps and other incandescent lamps. This NODA was issued in August of 2017.
2. Based on a review of data provided through the NODA, issue final rules for vibration and rough service lamps re: the backstop. These rules were initially estimated to be delivered by September of 2017, but have not yet been issued.
3. Issue a Supplemental Notice of Proposed Rulemaking (SNOPR) for GSL lamps. This would be expected to include standards for GSL LEDs. This SNOPR was initially estimated to be issued in the first quarter of 2018, but has yet not been issued.

Next Steps

While an entire industry awaits the outcome of this process, the DOE remains silent on the proceedings. No one knows what the outcome of the DOE's review will be, but it stands to reason that one of three scenarios are likely (for brevity, we have greatly simplified the scenarios).

Scenario One: The January 2017 rulemakings stand as written.	• Backstop goes into effect January 1, 2020 • Nearly all lamp categories are covered (15 exemptions for minor categories continue) • Sunset years for all covered lamps: 2022 or 2023
Scenario Two: The definition of GSL is amended from the January 2017 rulemakings and most of the exemptions are restored.	• Backstop goes into effect January 1, 2020 • Original exemptions (aside from vibration and rough service) are restored • A-lamps between 29 W and 100 W (equivalent) are covered • Sunset years for covered lamps: 2022 or 2023 • Sunset years for non-covered lamps: 2025 or 2026
Scenario Three: The backstop is pushed back by one or two years (2021 or 2022).	• Backstop goes into effect January 1, 2021 or January 1, 2022 • Exemptions are modified as in Scenario One or Scenario Two • Sunset years for covered lamps: 2023 or 2024 • Sunset years for non-covered lamps: 2026 or 2027

Based on interviews with a variety of stakeholders, including manufacturers, retailers, and advocacy groups, the authors believe that Scenario Two is the most likely, though we believe all possible outcomes result in opportunities for continued program savings through at least 2020.

Assessing the Benefit of Future Program Effects

Based on the adoption curve forecasts, we conclude that the cumulative program effects are essentially placing Massachusetts about one to two years ahead of New York in terms of LED adoption. If our forecasts are correct, the question becomes whether continued program intervention is worthwhile, or whether the Program Administrators should exit the market and

allow naturally occurring market adoption (evidence of which has been observed in the New York comparison area) to take over. To answer this question, we examined the projected savings that ratepayers in Massachusetts would be expected to accrue due to continued program intervention. Figure 5 provides an overview of LED saturation by year in Massachusetts and the counterfactual area, the difference in saturation, and the monetary savings from energy reduction alone at the household level and statewide.[8]

As the figure shows, between 2019 and 2021, as the gap between Massachusetts and the counterfactual grows, ratepayers in Massachusetts are projected to save $200 million or more each year.[9] For context, in 2016, the Program Administrators spent $42 million on the Residential Lighting Initiative. While EISA Phase II may truncate savings opportunities beginning in 2021 or 2022, there are substantial opportunities to generate savings for ratepayers in the near-term. Looking at the cumulative savings between 2013 and 2030, we would expect ratepayers to save upwards of 1.5 billion dollars – with two-thirds of those savings coming from annual savings between 2013 and 2021.

		Year	MA	Counter-factual	Diff.	Annual Monetary Savings Based on Energy Reduction	
						Household	Statewide
	History	2013	2%	1%	1%	$4	$12 M
		2014	3%	1%	2%	$8	$24 M
		2015	6%	3%	3%	$13	$35 M
		2016	12%	7%	5%	$21	$59 M
		2017	18%	10%	8%	$34	$94 M
		2018	27%	14%	13%	$55	$153 M
Near-term Program		**2019**	**39%**	**22%**	**17%**	**$72**	**$200 M**
		2020	**51%**	**33%**	**18%**	**$76**	**$212 M**
		2021	**63%**	**45%**	**18%**	**$76**	**$212 M**
EISA Phase II Impacts		2022	72%	57%	15%	$64	$177 M
		2023	79%	68%	11%	$47	$130 M
		2024	83%	76%	7%	$30	$82 M
		2025	86%	81%	5%	$21	$59 M
		2026	88%	85%	3%	$13	$35 M
		2027	89%	87%	2%	$8	$24 M
		2028	89%	88%	1%	$4	$12 M
		2029	90%	89%	1%	$4	$12 M
		2030	90%	89%	1%	$4	$12 M
		Cumulative First-Year Savings				*$556*	*$1543 M*

Figure 5 First year savings over time

[8] Not accounting for non-energy impacts (NEIs), including operation and maintenance savings from not having to replace shorter-life incandescent and halogen lamps – valued at upwards of $3 per bulb over the life of an LED.
[9] Savings were calculated by multiplying the difference in saturation by the average number of sockets per home in Massachusetts (58), the average assumed cost of electricity (16.5 cents per kWh), the average all bulb hours-of-use at the household level (2.7), and an average delta watt of 45. To extrapolate to statewide savings, we multiplied by the number of occupied households in Massachusetts (2,776,061) based on the Census.

Conclusions

Evidence to date and forecasts of future adoption clearly show that residential lighting programs are making a difference, increasing adoption of LEDs, and moving the market forward at a faster pace. In fact, the saturation gap between Massachusetts and the New York comparison area has widened in each of the last three years – indicating that LED sales growth in Massachusetts has yet to level off. If Massachusetts continues to support LEDs, we expect that the existing gap in LED saturation between Massachusetts and New York will continue to widen, reaching a peak difference of 18 percentage points in 2020.

Still, naturally occurring market adoption and federal standards (EISA) are likely to diminish the effectiveness of traditional upstream programs in the long term. Based on the market adoption curves presented in this paper, the authors conclude that the effects the Massachusetts upstream program are likely to continue to accelerate the pace of LED adoption through 2021. Beginning in 2022, we expect program effects to begin to diminish. This timing also aligns with the expected impact of the Phase II of EISA. This may mean that 2022 or 2023 is the answer to the question posed by this paper: "When is the end for residential lighting programs?"

However, in the near term, this paper provides strong evidence that program administrators should consider continued support for LEDs as the savings opportunities are enormous. Capitalizing on available residential lighting opportunities has already resulted in millions of dollars in savings for ratepayers, and continued support will result in millions more. While the data from this paper is specific to Massachusetts, the authors believe other program administrators can leverage this research to help make informed decisions about the future of their own programs.

Key Findings

- As the gap between Massachusetts and the counterfactual grows, ratepayers in Massachusetts are projected to save $200 million or more annually. For context, in 2016, the Program Administrators spent $42 million on the Residential Lighting initiative.
- In Massachusetts, LED saturation has increased nine-fold since 2014; in 2018, more than one in four sockets (27%) were filled with an LED.
- While the New York comparison area has also experienced growth in LED saturation, in the absence of program support, the pace of LED adoption has been slower than that observed in Massachusetts.
- Massachusetts households had significantly higher saturation of ENERGY STAR® LEDs compared to New York households (17% vs. 5%), representing nearly the entire difference in LED saturation between the two areas (27% and 14%, respectively).
- Based on the program and non-program adoption curves, if Massachusetts continues to support LEDs between 2018 and 2020, we expect that the existing gap in LED saturation between Massachusetts and New York will continue to widen, reaching a peak difference of 18 percentage points in 2020. In addition, while the gap between the two curves begins to diminish in 2021, a substantial gap (>10%) remains until after 2023.
- Market momentum leaves little doubt that both areas will reach high levels of LED saturation. However, our adoption models suggest that Massachusetts will reach 80% saturation in 2023, eighteen months earlier than New York.

- While EISA Phase II is expected to have a large impact on the lighting market, we anticipate a sell-through period, and it is not clear if the DOE will immediately enforce the standards.
  - While EISA Phase II may truncate savings opportunities beginning in 2021 or 2022, there are substantial opportunities to generate savings for ratepayers in the near term. Looking at the cumulative savings between 2013 and 2030, we would expect ratepayers to save upwards of 1.5 billion dollars – with two-thirds of those savings coming from annual savings between 2013 and 2021.

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