Compact Fluorescent (CFL) Saturation in the Northeast: Where the Rubber Hits the Road

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Abstract

While there are many metrics of importance to an evaluator assessing a residential lighting program, one could argue that measuring changes in saturation --the ratio of compact fluorescent lamps (CFLs) to sockets -- provides one of the more important indicators of program success. Saturation reflects a broad range of program outcomes including net impacts, sales penetration, product persistence and installation, and usage in the region of interest. In a series of studies involving socket counts in homes throughout New England, we have gathered data that contribute to the body of evidence of regional program achievement via this primary indicator of success.

This paper provides a longitudinal view of CFL market saturation rates that is interesting to consider in the context of barriers that have been encountered during the emergence of CFL technology, the activities that have been undertaken to support its adoption and the unique nature of the challenge to unseat traditional Edison socket incandescent lighting from its ubiquitous place in the American household.

This paper provides some historical context of these issues in the Northeast along with information on how advocates of CFL adoption have structured their support of CFLs in the market place. We also present results of primary data collection efforts to illustrate how the adoption of the CFL technology has grown at the homeowner level over time. This adoption and saturation data is then utilized in multiple ways to show its usefulness in considering remaining potential as well as possible implications in program planning.

Introduction

While there are many metrics of importance to an evaluator assessing a residential lighting program, one could argue that measuring changes in saturation --the ratio of CFLs to sockets -- provides one of the most important indicators of program success. Saturation reflects a broad range of program outcomes including net impacts, sales penetration, product persistence and installation, and usage in the region of interest. In a series of studies involving socket counts in homes throughout New England, we have gathered data that contribute to the body of evidence of regional program achievement by virtue of tracking this primary indicator of success.

A longitudinal view of CFL market saturation rates can also be particularly interesting when considering the history of barriers that have been encountered during the emergence of CFL technology, the activities that have been undertaken by utilities and others to support its adoption during that time and the unique nature of the challenge to unseat traditional Edison socket incandescent lighting from its ubiquitous place in the American household.

Unlike many other markets, the existing CFL lighting market growth is unique in that it can be considered a constrained market. That is, the CFL market is constrained to the extent that all households already have effective lighting products already in use and the growth of CFLs can occur basically as a result of opportunities that arise when incandescent bulbs fail, when there is socket growth due to new construction or renovation, and in instances where reasons for adoption are compelling enough for consumers to displace operational incandescent lights. Additional CFL market dynamics include continuing advances in lighting technology such as solid state lighting and emerging regulatory movements in some regions to ban incandescent lighting.

This paper provides some historical context of these issues as they have evolved in the Northeast along with information on how advocates of CFL adoption have structured their support of CFLs in the market place. We also present results of primary data collection efforts to illustrate how the adoption of the CFL technology has grown at the homeowner level over time. This adoption and saturation data is then utilized in multiple ways to show its usefulness in considering remaining potential as well as possible implications in program planning.

Overview of New England CFL Program Interventions

Compact fluorescent lamps were introduced in the 1970's and acceptance of them in the residential lighting market has been uneven across the United States. Since that time, government and utilities, among other entities, have invested both public and ratepayer funds to promote CFLs due to the dramatic decrease in energy consumption compared to incandescent bulbs[1]. The CFL market in New England in particular has enjoyed support from utility sponsored energy conservation initiatives for many years. This support has taken many forms over the years and is summarized at a high level in Figure 1. The intervention timeline[2] in the top half of the figure shows the general approach the sponsors of lighting programs in New England have taken to encourage the adoption of CFLs among consumers since the late 1980's. At a high level, these activities have generally moved from independent, splintered approaches that focused on the direct installation of CFLs, CFL rebates and consumer driven promotions to interventions that have become more focused on buy-down activities that occur at a state or regional level directly with manufacturers and retailers.

The bottom half of Figure 1 simplifies the market over time via a broad categorization of the primary interventions associated with each era as either a "push" or "pull" marketing strategy. Generally, these can be envisioned as either a marketing strategy in which the activity assists customers in "pulling" or creating a demand for these products, or a strategy in which the activity encourages manufacturers to "push" products toward customers. A good mix of strategies will establish a marketplace over time that encourages the adoption of a product by increasing awareness of the product and its central properties, increasing the willingness to adopt it when opportunities arise, and ensuring the availability of the product for the consumer at the place and time needed.

It should be noted that in the midst of these interventions there has also been the ebb and flow of CFL programs being used by utilities and regulators as a resource acquisition tool (to reduce energy demand and achieve fast savings impacts) and a market transformation activity (to create a sustainable market that compels consumers to buy and retailers to stock energy saving lighting and creates long-term savings opportunities). One might interpret the figure below as suggesting that with the current headlines including several market based forces pushing along the CFL market (retailers, FCM[3], RGGI[4], etc.), that there is strong evidence of market transformation taking hold in the CFL market.

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[1] Compact Fluorescent Lighting in America: Lessons Learned on the Way to Market, Pacific Northwest National Laboratory, June, 2006.

[2] http://www.energystar.gov/ia/partners/downloads/meetings/EfficientLightinginResidentialMarket_Kates_Bonnano.pdf.

[3] Forward Capacity Market.

[4] Regional Greenhouse Gas Initiative.

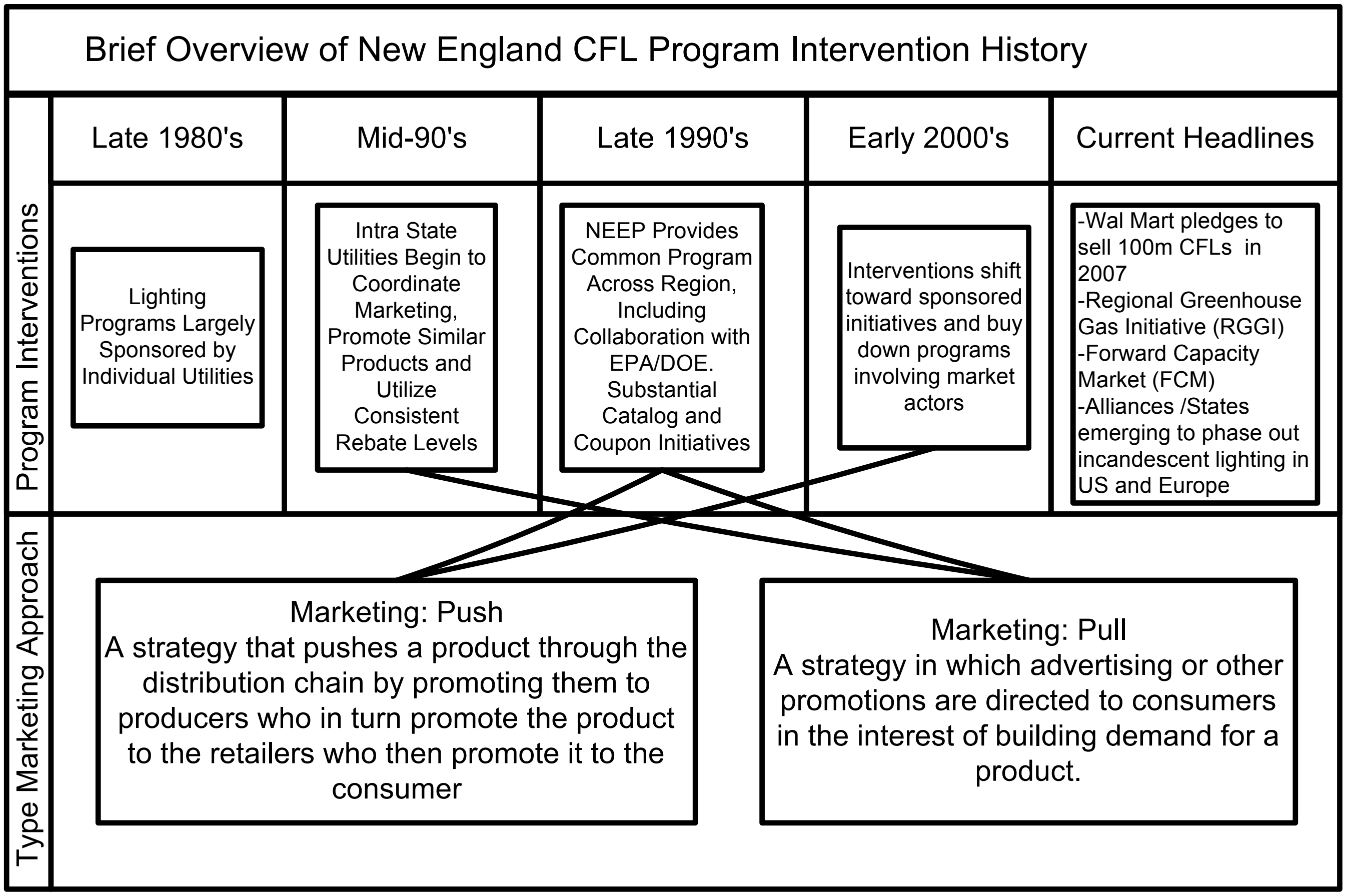


Figure 1: Brief Overview of Northeast CFL Intervention History

Concurrent with these activities in New England, the ENERGY STAR® program, sponsored by the U.S. Department of Energy and the Environmental Protection Agency, has been providing added support for CFLs, including the testing and qualification of many brands and models and national promotion and consumer education efforts. So while it can be surmised that the interventions sponsored by utilities and other organizations in New England have played a key role in encouraging the adoption of CFLs, there are other players and influences that may be also positively contributing to the market.

Under the current headlines portion of the figure, we note several recent activities that suggest that CFLs are picking up significant mass in the marketplace. This includes a pledge by Wal-Mart to sell 100 million CFLs in 2007, the initiation of efforts to control greenhouse gas emissions (e.g., RGGI) and the emergence efforts of some states and alliances to phase out incandescent lighting. These activities present strong evidence of the traction that CFLs are beginning to have as a technology that is succeeding in the marketplace.

Data Availability and Methodology

Over the last several years, the sponsors of lighting initiatives in New England and primarily in Southeast New England have performed home lighting inventories as part of their ongoing evaluation efforts and market progress tracking activities. Program sponsors have conducted six primary studies among the general population of residential utility customers. These studies are presented in Table 1 and represent 648 on-site surveys in Massachusetts, Rhode Island and Vermont. These inventories included gathering information on the number of sockets inside and outside the home and for each socket, the bulb type, wattage, and socket type (pin, screw, candelabra).

Table 1: Studies with Lighting Inventory Data

Year Performed	State	Sample Size	Method
2002[5]	VT	83	On sites
2003[6]	MA	100	On sites
2004[7]	MA	50	On sites
2005[4]	MA	232	On sites
2005[8]	RI	100	On sites
2005[9]	VT	83	On sites

The data collected as part of these studies allowed us to perform various analyses of CFLs in homes, including saturation rates, by determining the proportion of standard screw-in incandescent bulbs that can be replaced with a standard CFL. This was typically done by counting all sockets with standard incandescent bulbs in them, including those installed on the exterior, in garages, basements, etc. However, CFLs are not suitable for every application, such as cases where the socket requires a candelabra screw-in base[10], where there are dimmable controls[11], for nightlights, the size of the CFL prohibits a good fit, or other instances in which the incandescent is not considered replaceable. Sometimes, it is difficult to assess whether or not a CFL is technologically suitable for a given application. Understanding these situations makes it challenging to estimate the maximum share of sockets that can take a CFL, although we believe the data represented in these studies are comparable and accurate enough to trend meaningfully.

In the studies performed by RLW and NMR cited in this paper, we attempted to reduce bias in the recruitment of households for the surveys through the use of customer incentives and rigorous screening procedures. However, it is still possible that some self selection bias may be introduced in these analyses. Generally, it is likely that customers who are willing to allow visits to their home for these studies may be interested in energy efficiency and so may not reflect the general population of residential consumers. It can also be noted that there is a potential for social desirability bias in the various independent analyses. Some respondents who desire a visit to their home may be more conscientiousness about efficient lighting usage than the general population. However, this would suggest that there is not a bias across the samples, but rather that the surveys may not be fully representative of the general population.

Examination of Metrics

Figure 2 contains the percent of homes observed to have at least one CFL in them over the last several years. The bottom bar of the figure presents, in linear form, a standard product or behavior adoption

[5] http://publicservice.vermont.gov/energy-efficiency/ee_files/efficiency/eval/res_efficient_products/epp_complete.pdf.
[6] Market Progress and Evaluation Report (MPER) for the 2005 Massachusetts ENERGY STAR® Lighting Program Final September 29, 2006, volume 1, Nexus Market Research, RLW Analytics, Inc, Dorothy Conant, Shel Feldman.
[7] http://www.capelightcompact.org/pdfs/compact-2004-annual-report-07-01.pdf.
[8] Memo, 2006 residential socket counts in Rhode Island, RLW Analytics, Inc for National Grid USA, February 28, 2006.
[9] http://publicservice.vermont.gov/index/VT%20Res%20.pdf.
[10] The ENERGY STAR program is currently developing a specification v.4.0 that includes CFLs with candelabra bases, which may open up the field of eligible sockets in the future.
[11] Dimmable ENERGY STAR CFL products exist, but technologically they are inferior to incandescent bulbs because the dimming range is shorter, color shifts, and shut-off points are inconsistent (a problem when multiple bulbs are on a single dimmable control).

curve as formalized by Everett Rogers.[12] While some argue this adoption curve is over-simplified, it does present a means of assessing progress in a market such as CFLs in the Northeast. In considering the proportion of homes with at least one CFL over time, we have an estimate of the adoption of CFLs in the general residential home population. In each bar, the adoption rate (or the proportion of homes observed with a CFL in them) is shown, extending from the innovator segments to the laggard segments. The definitions as presented by Rogers are bulleted below[13]. The threshold of each adoption phase is provided. Each group classified in this figure represents a particular mindset toward adopting a new technology or behavior, from Early Adopters who are most apt to embrace a change to Laggards, who are best characterized as individuals who only accept a change after it has been fully tried and true in the mainstream.

- Innovators - Venturesome people, greater propensity to take risk
- Early Adopters - Social leaders, educated, try out new ideas, but in a careful way.
- Early Majority - Deliberate, thoughtful people who are careful but accept change more quickly than the average person.
- Late Majority - Skeptic people, will use new ideas or products only when the majority is using it.
- Laggards - Traditional people, caring for the "old ways", are critical towards new ideas and will only accept it if the new idea has become mainstream or even tradition.

In interpreting Figure 2, it can be observed that in 1998, 30% of homes in the general residential Northeast population had at least one CFL installed. This suggests that individuals in the 'Innovator' and 'Early Adopter' classifications, who are more prone to adaptation than others, had already made the decision to try and install CFLs. By 2003, the Early Majority had adopted CFLs and in 2006, many individuals are characterized as in Late Majority – skeptics who use new products or ideas after the majority has tried it – are beginning to use the CFL technology in their homes.

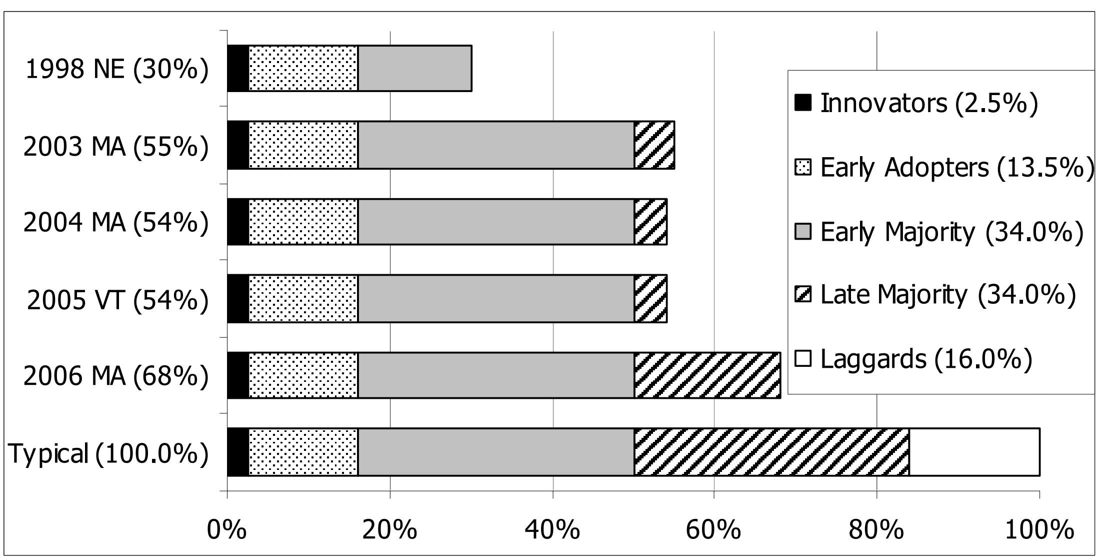


Figure 2: CFL Adoption Curve in Northeast

[12] Rogers, Everett. (1995). Diffusion of innovations. Fourth edition. New York, NY: The Free Press.
[13] http://en.wikipedia.org/wiki/Diffusion_of_innovations, http://www.12manage.com/methods_rogers_innovation_adoption_curve.html.

To the extent that the above information provides a sense of the number of homes in which CFLs 'have their foot in the door', it becomes interesting to begin considering how many sockets are populated with the CFL technology in those homes. As discussed earlier, aside from the number of homes with CFL's, another important metric of success is change in saturation (the ratio of CFLs to sockets). Saturation reflects the final result of a broad range of program outcomes that might be planned or unplanned. These outcomes include net impacts, sales penetration, usage in the region of interest, and product persistence and installation. While sales figures can also be used to track program activity and success, they can be difficult to quantify and may be impacted by things that occur in the home – such as CFLs burning out, CFLs that are never installed and sometimes CFLs that are given away. The only real way of knowing how CFLs are being used is to be in the field observing them in people's homes.

Figure 3 presents the results of several saturation studies performed in the Northeast since 2003 and California since 2000 in which saturation was calculated. Each state has its own trend line. The studies performed in California have been included to illustrate what saturation may have looked like in 2000 to the extent that California can be considered a proxy for what early saturation may have looked like in the Northeast. There is a 2005 California study also included in the graph for purposes of further supporting the idea that California maybe a good proxy for early saturation estimates given apparent convergence between the California and Northeast 2005 saturation rates. In considering the saturation from these California touchstones, over the five year period between 2000 and 2005 California saturation has experienced a tenfold increase.

The general trend evident in the figure is a steady increase in saturation among Northeastern States over the last several years. In two years time, Massachusetts residential CFL saturation has increased nearly 62% from 7.0% in 2003 to 11.3% in 2005. In 2002, Vermont was estimated to have a saturation rate of 4.4% and has increased nearly fourfold to an estimated 16.0% rate in 2005. Vermont has aggressively encouraged the adoption of CFLs for the past several years and this high saturation level may be suggestive of future saturation increases that may be experienced in Massachusetts.

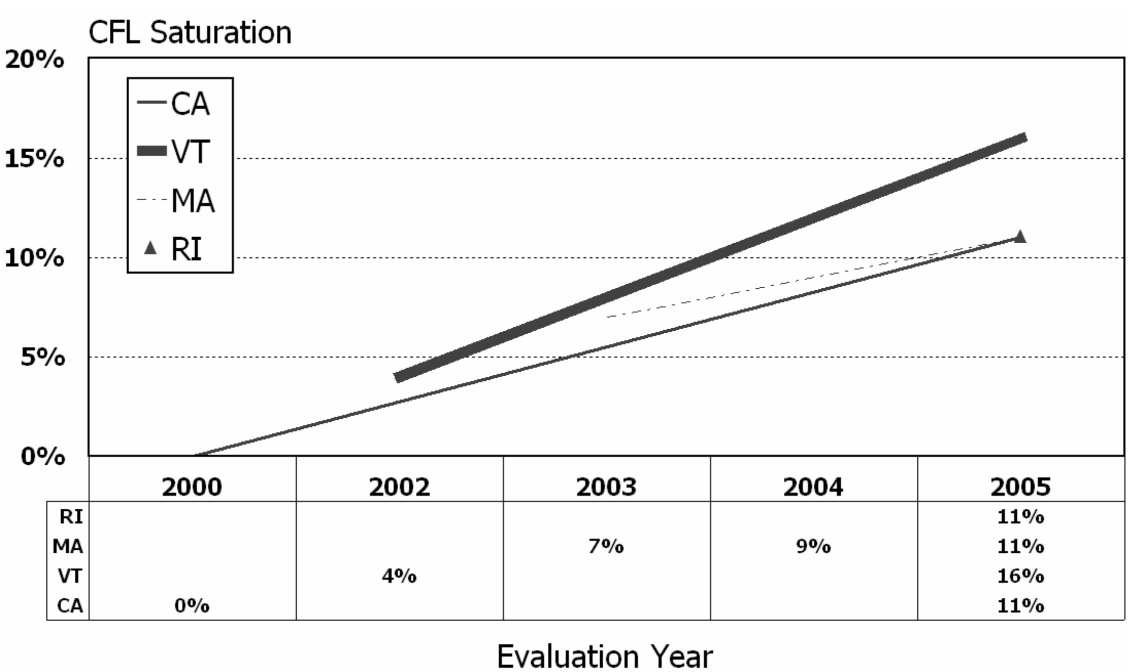
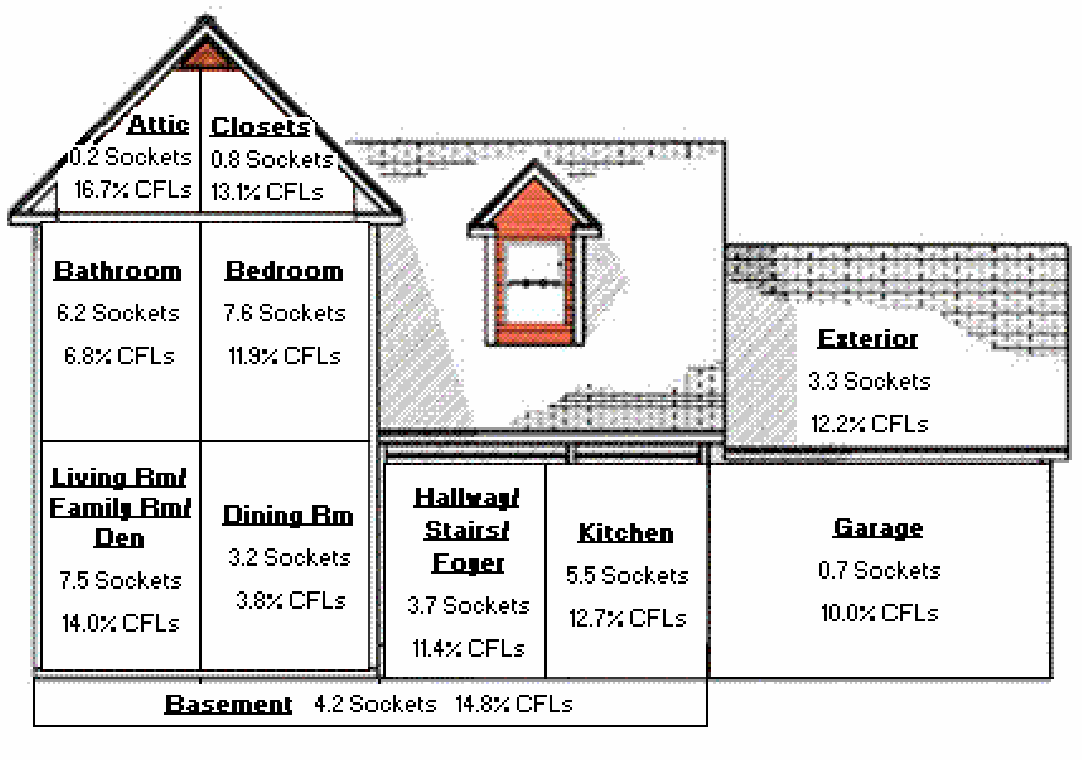


Figure 3: Saturation Rates from Recent Studies in the Northeast

Figure 4 provides an illustration of a home showing the average number of sockets and the percent of sockets occupied by CFLs from a recent study in Massachusetts. (Some of the room socket counts are less than one because some homes do not have those types of rooms.) Home locations with the highest saturation of CFLs are the attic, basement, living/family rooms, and closets. Bathrooms and dining rooms have the lowest CFL saturation levels, perhaps due to the desire to have traditional lighting above mirrors in bathrooms and the lighting aesthetics and dimmable nature of many dining room lighting fixtures.

Figure 4: Where are the CFLs?



Now that we have a sense of where and how many CFLs are installed in the home, one can consider the remaining technical potential on a per home basis. Assuming an annual per CFL savings estimate of 42.8 kWh[14], one can estimate the potential savings per home based upon the current saturation and socket counts. This is strictly a rough estimate, which should be refined with per room hour and delta watt assumptions. But at a high level, assuming 100% of incandescent in a home were to be converted to a CFL, the average home would save about 1,589 kWh per year or 7,945 kWh over a CFL lifetime that is assumed to be five years. This amounts to an estimated air pollution reduction of 2,272[15] lbs of CO2 per year or 11,361 lbs over an assumed five year CFL lifetime. As a point of reference, the ENERGYSTAR.gov website estimates that an "average" passenger car has an estimated CO2 emission of 11,560 lbs per year.

[14] Assumes a 60 watt incandescent is replaced with a 13 watt CFL and operates 2.5 hours a day.
[15] Uses a factor of 1.43 lbs CO2/kWh as gathered from http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CFLs.xls.

Table 2: Estimating Remaining Average Home Savings Technical Potential

Location	Avg Sockets per Home	Saturation	Potential (kWh)
Bathroom	6.2	7%	247.82
Bedroom	7.6	12%	287.16
Living/family Room	7.5	14%	276.62
Dining Room	3.2	4%	132.02
Hallway/Foyer	3.7	11%	140.59
Kitchen	5.5	13%	205.92
Exterior	3.3	12%	145.41
Basement	4.2	15%	153.47
		Total Home	1,589

Combining saturation results by room with approximated operating hours[16] per room can provide an interesting matrix that can be used to consider future CFL activity and potential CFL program directions. The figure below maps rooms type in a typical home with saturation rates and estimated hours of operation. Generally, one can consider the horizontal and vertical arrow directions as providing the greatest CFL efficacy. That is, rooms that have low current saturations have greater opportunity for CFL installations and rooms with higher general hours of use will generally provide the greatest return in energy and dollars in the near term. As indicated in Figure 4 above, some locations have more sockets than others, which might be considered in interpreting this figure and it should be noted that some non-CFL sockets may contain a certain type of bulb that is difficult to find or may be under a particular control strategy – dimmable – that currently does not have a CFL equivalent. This may suggest an opportunity for the production of such a bulb or perhaps an opportunity to increase awareness of new bulb technologies.

	Approximate Annual Hours		
Saturation	0-1,000	1,000-2,000	2,000-3,000
16-20%	Attic	N/A	N/A
11-15%	Basement, Bedroom, Closet, Lr/FR	Exterior	Kitchen
6-10%	Bathroom, Garage	N/A	N/A
0-5%	N/A	Dining Room	N/A

Figure 5: Mapping Room Saturation to Annual Operating Hours

Conclusions

In the Northeast, many CFL initiatives have been sponsored by utilities, states and other organizations since the late 1980's. While the goal and interventions of these initiatives have shifted over time, the support of residential CFL adoption has always been present in some form or other since that time. During the last several years, in-field studies of CFL saturation have shown an ever increasing number of residential lighting sockets are populated with CFLs. While attribution of this increase is difficult to link to

[16] Operating hour bins in this table are estimated based upon RLW's evaluation experience.

any one cause, there is ample evidence that suggests the interventions designed and executed by utilities and other initiative sponsors have played a role in this change. Considering recent headlines in which other marketplace forces are beginning to push CFL adoption and recent saturation data, CFL sales and installation appear to be on the cusp of increasing substantively. The 18seconds.org website, a repository and reporting of CFL sales data as gathered from select retailers, suggests that significant sales are beginning to occur across the United States, further supporting the idea that CFLs are quickly gaining traction as a serious alternative to traditional incandescent lighting.

The gathering of saturation data from homes in the general population can provide an empirical means of tracking the success of CFL adoption. Combined with inventories of homes in regions or states bereft of initiatives similar to the Northeast, a comparison of CFL saturations may provide a sense of attribution to particular program interventions. Over time, field informed CFL saturation estimates in a region can provide persuasive evidence of goal progress and can be used to enlighten other programmatic challenges including an understanding of the current and future market cohorts adopting CFLs, setting new program directions, and assessing remaining CFL potential. In short, quantitatively determining the saturation of a product such as CFLs can be a powerful tool for understanding the most fundamental level of market progress and additionally provides ancillary information and analysis for guiding program resources and targeting future CFL market growth.