The State of Solid State Lighting: What Programs Need to Know

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ABSTRACT

Solid State Lighting (SSL) is commonly recognized as one of the most promising technologies to reduce the energy used for lighting homes and businesses. In order to plan for and promote this technology, efficiency program planners and implementers need to be well informed.

The authors of this paper have provided an independent, third-party assessment of the aspects of SSL that are critical for program planning. The paper starts by reviewing how SSL works and how this source is different from other light sources. Both known and unknown aspects of this new light source are discussed. The authors also highlight promising applications for both residential and commercial lighting.

The paper provides a status of new industry test procedure development and provides details of these test procedures, which enable efficiency programs to compare products. The authors discuss implications for efficiency programs and when the time will be right for wide-spread promotion of this light source. In particular, they share the successes and lessons learned from early pilot programs.

Introduction

Efficiency programs are very excited by the potential of Solid State Lighting (SSL) products but have been proceeding cautiously due to the many unknowns surrounding the technology. There has been a lot of industry and consumer hype regarding SSL, particularly light-emitting diodes (LEDs). While efficiency programs are excited to begin promotion of LED products, they are very concerned with providing consumers with a positive first experience with the technology. Efficiency programs are well aware of the consequences of moving too quickly with a technology as was seen with compact fluorescent lamps (CFLs).

Efficiency programs have indicated that having an ENERGY STAR® label is a key component for allowing programs to move forward with LED promotions. There are a lot of LED products on the market and ENERGY STAR will help identify energy-efficient products that will meet consumers' expectations. In December 2006, DOE released draft ENERGY STAR criteria for SSL luminaires intended for general illumination. Following public review and comment, DOE issued second draft criteria in April 2007. The final draft criteria were released in September 2007 with an effective date of September 30, 2008, contingent on related standards and test procedure finalization.

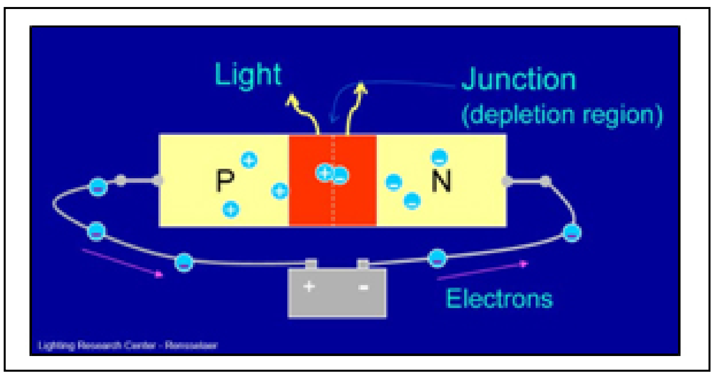
Some efficiency programs are moving forward with programs slightly ahead of the ENERGY STAR label launch, such as the California investor owned utilities (IOUs) and Efficiency Vermont, and the paper discusses their plans for promotion. Both of these programs are very closely tied to the ENERGY STAR specification for LEDs and related work on the development of test procedures. The majority of efficiency programs plan to wait until the ENERGY STAR criteria is in place and they have become more familiar with the technology and the various suitable applications.

Technology Background

Solid-state lighting refers to lighting applications that use LEDs, organic light-emitting diodes (OLEDs), or light-emitting polymers. LEDs differ from traditional light sources in the way they produce light. LEDs consist of semiconductors that convert electricity into light, while incandescent or fluorescent lamps create light with, respectively, filaments and arcs through gases encased in a glass bulb.

An LED consists of a chip of semiconducting material treated to create a structure called a p-n (positive-negative) junction. When connected to a power source, electricity flows in one direction from the p-side (anode) to the n-side (cathode). Electrons and electron holes flow into the junction and when an electron meets a hole, it falls into a lower energy level, releasing energy in the form of a photon or light.

How LEDs work



Lighting Research Center – Rensselaer Polytechnic Institute

There are multiple areas of concern with LEDs when compared to other light sources: color quality, thermal management, and lumen depreciation or lifetime and they all affect the technology's ability to meet market expectations. The efficiency of LEDs is also impacted by the driver and application or environment in which it is used. It is important that efficiency programs understand these differences so that they are able to identify manufacturers that have taken the unique properties of LEDs into consideration and developed quality products. Efficiency programs should also be aware that luminaire manufacturer's efficacy and lifetime claims are often exaggerated. This is largely due to the fact that manufacturers are used to measuring lamp/device efficacy instead of the efficacy of the entire fixture, which is commonly referred to as luminaire efficacy. LEDs must be considered as a system to determine their effectiveness.

Color Quality

Even though LEDs do not inherently produce white light, with technological advances they have great potential to produce high-quality white light with unmatched energy efficiency. The light LEDs emit in the visible spectrum falls within in a very narrow range of wavelengths, which produces colored light. This is why LEDs have been primarily used in niche colored light applications such as equipment indicator lights, traffic signal lights, and exit signs to date.

In order for LEDs to be used successfully in other general illumination applications, white light needs to be created. There are two main ways in which white light can be achieved with LEDs: phosphor conversion and RGB systems.

The majority of currently available white LED products are created through a phosphor conversion on a blue LED. When a blue LED is combined with a yellow phosphor, the light will appear white to the human eye. Phosphor-converted (PC) chips are produced in large volumes and in various packages, which decreases costs. With the PC LED, the greatest light output and efficacy come from LEDs with high correlated color temperature (CCT). High CCTs mean that the LEDs are cooler or bluer in color. Warmer CCTs (comparable to incandescent color) are generally less available and more expensive to produce because they require more phosphors.

The RGB approach produces white light by mixing the three primary colors - red, green, and blue. The color quality of the resulting light can be enhanced by the addition of amber to "fill in" the yellow region of the spectrum. RGB systems are more often custom designed for use in architectural settings. While RGB systems are generally used to generate changing colors and hues, they are capable of creating different shades of white.

The advancements taking place in the development of white LEDs are critical to delivering a positive consumer experience because as with other light sources, consumers prefer CCTs between 2700 and 3000 K.

Heat Management and Lifetime

There are three main factors that affect the junction temperature of an LED, the drive current, the thermal path, and the ambient temperature. LEDs require supplementary electronics or power supplies, usually referred to as drivers. The driver converts line power to the appropriate voltages and currents required by LEDs. According to the U.S. Department of Energy (DOE)'s fact sheet on thermal management of white LEDs, LEDs convert about 15%-25% of the power into visible light and the remainder is converted to heat. The amount of heat that can be removed is determined by both the ambient temperature and the design of the thermal path from the die to the surroundings.

The short-term effects of excess heat are color shift and reduced light output. The long-term effect of excess heat is reduced lifetime or accelerated lumen depreciation which, is defined as the decrease in lumen output that occurs over the life of the device. This is why the heat management and an awareness of the operating environment are critical considerations to the design and application of LED luminaires for general illumination. Successful products will use superior heat sink designs to dissipate heat, and minimize junction temperature.

Advantages of LEDs

If designed correctly, LED luminaires can have many benefits over traditional light sources, including long life, energy savings, better light output, durability, and smaller flexible light fixtures.

One of the advantages often discussed with LEDs is the potential for longer life. White LEDs can provide 50,000 hours or more of life, which could significantly reduce maintenance costs for the consumer. The Alliance for Solid State Illumination Systems and Technologies

(ASSIST), a group led by the Lighting Research Center (LRC), recommends defining useful life as the point at which light output has declined to 70% of initial lumens (abbreviated as L70) for general lighting. As discussed earlier, the life expectancy of an LED will vary based on steps taken to manage the heat.

The small size and directional light emission of LEDs offer the potential for innovative, low-profile, compact lighting design. The directionality of LEDs needs to be managed by the manufacturer. LEDs are also largely impervious to vibration because they do not have filaments or glass enclosures. This durability may provide added value in applications where broken lamps present a hazard to occupants, such as children's rooms, assisted living facilities, or food preparation industries.

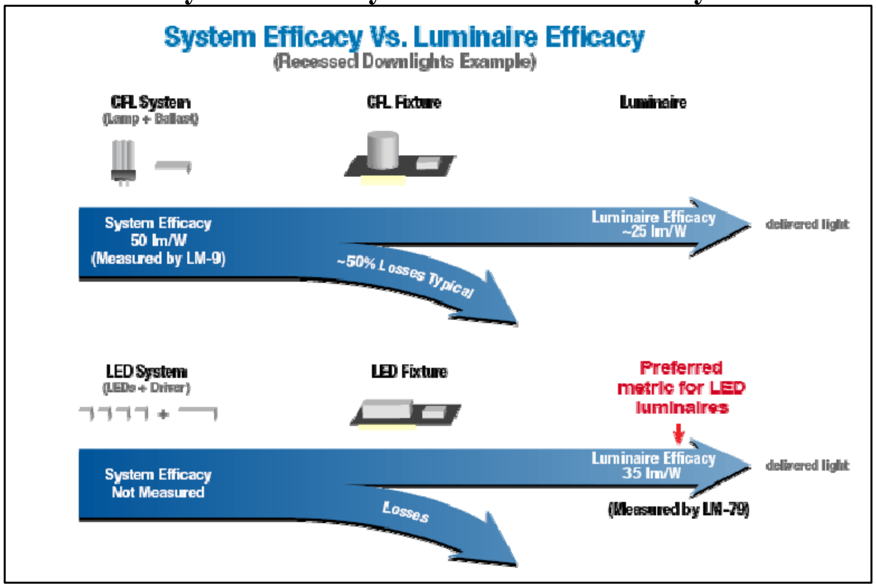
Also, unlike some Compact Fluorescent Lamps (CFL's) and HID lamps, LEDs come on at full brightness almost instantly, with no re-strike delay. In general illumination applications, instant on can be desirable for safety and convenience. Traditional light sources can burn out sooner if switched on and off frequently however with LED life and lumen maintenance is unaffected by rapid cycling.

Another benefit is that some LEDs emit virtually no IR or UV. Excessive heat (IR) from lighting presents a burn hazard to people and materials. UV is extremely damaging to artwork, artifacts, and fabrics and can cause skin and eye burns in people exposed to unshielded sources over time.

Promising Applications – Delivering Energy Savings

While LEDs have been around for more than 40 years, up until recently they have not been used for general illumination. The characteristics of white LEDs allow them to be a promising option for a number of niche general illumination applications. In these applications, LEDs have the potential for higher application efficiency than current light sources. For fixture types such as recessed downlights and under-cabinet fixtures, it is not uncommon for 40-50% of the total lamp light output to be lost in the fixture. Well-designed LED fixtures reduce the need for reflectors and diffusers that can trap light, and can deliver light more efficiently to the intended location.

System Efficacy Vs. Luminaire Efficacy



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Given this, an LED luminaire with lower lm/W might actually be equal to other sources with higher lm/W once losses in fixture efficiency are factored in. For these reasons, well designed LEDs can work well in task and under-shelf fixtures, recessed downlights, and outdoor lighting applications. And as white LEDs become brighter and more efficient, they can be used for other general illumination applications. Some out of the box designs have been proposed where entire walls and ceilings become the lighting system. This section looks at specific applications, both residential and commercial, that take advantage of LEDs' unique characteristics.

Residential Applications

Recessed downlighting. Given the prevalence of downlights in US homes, the potential energy savings from high-performing, energy-efficient downlights is significant. New developments in LED technology and luminaire design in this application have the potential to decrease downlight wattage by 75% or more, as compared to incandescent sources.

There are many issues that need to be considered with downlighting particularly, light loss, high-temperature environments, and glare. LED downlights (both for new installations and retrofits) that have come on the market recently vary widely in both light output and efficacy. However, the latest developments in LED technology and luminaire design appear very promising (DOE).

Comparing Recessed Downlight Performance Using Different Light Sources

Table 1: Examples of Recessed Downlight Performance Using Different Light Sources

	Incandescent*	Fluorescent*		LED**	
	65W BR-30 Flood	13W 4-pin Spiral CFL	15W R-30 CFL	LED 1	LED 2
Rated lamp lumens	725	860	750		
Lamp wattage (nominal W)	65	13	15		
Delivered light output (lumens), initial	652	514	675	300	730
Luminaire wattage (nominal W)	65	12	15	15	12
Luminaire efficacy (lm/W)	**10**	**42**	**45**	**20**	**60**

* Based on photometric and lamp lumen rating data for commonly available products. Actual downlight performance depends on reflectors, trims, lamp positioning, and other factors. Assumptions available from PNNL.
** Results for two commercially-available products tested. LED 1 was tested in Aug 2006. LED 2 was tested in Sep 2007. Lamp level data are not available for the LED downlights, which contain proprietary LED arrays, heat sinks, reflectors, and diffusers.

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Undercabinet / shelf-mounted task lighting. LEDs are also a natural fit for undercabinet lighting. The ability to string LEDs in a linear arrangement or to group them together provides lighting designers with options and allows them to reproduce the form factor of linear fluorescent lamps or the single lamps of a halogen or xenon fixture. This application also takes advantage of the inherent directionality of LEDs, which allows a larger proportion of the available light to be directed on the work surface and not lost within the fixture. Near-field photometry measurements of these fixtures provide a good indication of the amount of lumens that reach the task (DOE).

Portable desk / task lighting. Portable desk and task lighting is a promising general illumination application for white LEDs. The small size and directionality of LEDs make a variety of innovative task light designs possible. Through careful designing manufacturers can produce even, shadow-free light distribution over the full task area and eliminate glare.

One important item to note is that many portable desk/task luminaires continue drawing power even when they are turned off. This occurs for fixtures that use a power supply and also have an on-off and/or dimming switch located ahead of the power supply. The LED luminaires that have been tested by US DOE to date have measured off-state power use of 0.5 watt to 2.5 watts. As a result, the efficacy of the fixture drops when the additional power consumption is considered. This problem can be fixed by designing a fixture where the switch is between the plug and the power supply or plug load management devices (DOE).

Outdoor lighting. Because LED performance increases as the operating temperature drops, they are a natural fit for cold-temperature outdoor applications. In addition, the rapid cycling capability of LEDs makes them well-suited to use with occupancy sensors or daylight sensors. Path and step lighting in particular can take advantage of the inherent directionality of LEDs.

Commercial Applications

Refrigerator display case lighting. As previously mentioned, LED performance increases as operating temperatures decline. LEDs can also provide improved light quality for merchandise while reducing the amount of heat introduced to the cold space and required maintenance, at a lower level of power. LEDs efficiently directs the light where it is truly needed eliminating wasteful glare, light that spills out onto the floor and are able to deliver a more uniform profile to the shelf due to the direct nature of the light source. Additionally the LED is a very robust device that is not as likely to be damaged or break during stocking of the shelves. All of these reasons make LEDs a natural fit for grocery store refrigerated and freezer cases.

Street lighting. As indicated above LEDs work well in outdoor applications due to their enhanced performance in cooler temperatures. With fewer limitations on the size and form factor of the fixture, manufacturers can incorporate additional heat sinking into fixture designs that might not be possible in other applications. Currently, most streets are illuminated with high pressure sodium (HPS), which are used primarily because of their long rated life and high efficiency relative to other conventional options. The LEDs offer competitive efficiency and the potential for longer life, which can provide municipalities and utilities with desired maintenance savings. Additionally, the use of LED's provides luminaire manufacturers with the ability to design for precise light cut-off angles and increased uniformity, as demonstrated by an assessment of LED street lighting demonstration in Oakland, CA.

While all these applications appear to be promising, DOE's Commercially Available LED Product Evaluation and Reporting (CALiPER) test results in these applications show performance varies widely and cannot be generalized. These results underscore the fact that products must be evaluated on an individual basis to check color quality, light output, and energy efficiency.

ENERGY STAR®

With so many LED products on the market and different manufacturer claims, it is difficult for efficiency programs to provide guidance to their consumers on how to identify high-quality fixtures. Because the ENERGY STAR label is a highly valued and widely recognized mark of energy efficiency for consumers, many programs feel it is essential that the ENERGY STAR program for SSL in place before they begin the promotion of LEDs for general illumination. Efficiency programs trust ENERGY STAR to ensure the consumer's first experience with LEDs is positive. For this reason, DOE is proceeding cautiously with ENERGY STAR and starting by qualifying products where SSL technology can be appropriately applied.

DOE has developed a transitional two-category approach for SSL general illumination products. Category A covers near-term applications such as under-cabinet kitchen lighting and shelf-mounted task lighting, portable desk/task lighting, recessed downlighting and outdoor wall-mounted porch, step and pathway lighting. Category B establishes efficacy targets for a wider range of future applications, which will take effect once SSL technology is more mature. This transitional approach allows for the early participation of a limited range of products in the promising lighting applications previously discussed. While the effective date for the ENERGY STAR SSL specification is September 30, 2008, it is contingent on the necessary test procedures being final.

An important part of the ENERGY STAR program requirement is being able to verify performance through third-party testing of devices. Currently there is a list of five labs that have been pre-qualified to do product testing and DOE is working to add more. The labs include Gamma Scientific in San Diego, CA, Independent Testing Laboratories, Inc. in Boulder, CO, the Lighting Research Center; Rensselaer Polytechnic Institute in Troy, NY, Lighting Sciences, Inc. in Scottsdale, AZ, and Luminaire Testing Laboratory, Inc. in Allentown, PA. However there has been somewhat of a back-log with the CALiPER testing and more labs will be needed to keep pace with all the testing for ENERGY STAR and efficiency programs.

Test Procedures

The SSL test procedures that are of particular relevance to ENERGY STAR, efficiency programs and market transformation involve color, lifetime, and ability to measure to efficacy. There are three main test procedures that address these topics and they are being developed by American National Standards Institute (ANSI) and Illuminating Engineering Society of North America (IESNA). The test procedure numbers are ANSI standard C78.377, IESNA LM-79 and LM-80. There are also test procedures for in situ temperature measurement and power factor, Underwriter's Laboratories (UL) 1598 and ANSI C82.77 respectively.

Chromaticity. ANSI standard C78.377 provides specifications for the chromaticity of SSL products. In particular, it specifies the recommended color ranges for white light LEDs through various CCTs and ensures communication of color to consumers. ANSI standard C78.377 is finalized and available to the public.

Efficacy. IESNA standard LM-79 is the approved method for the electrical and photometric measurements of SSL products. It identifies the procedures for measuring total light output, electrical power, luminaire efficacy and color quality (including CCT, CRI, color spatial uniformity and color maintenance) of SSL luminaires and replacement lamps. LM-79 was completed and made public in May 2008. The majority of these tests must be performed by a third party DOE verified lab but the test for color spatial uniformity and maintenance are measured through self certification by the manufacturer.

Lifetime. LM-80 is the approved method for measuring lumen depreciation of LED light sources. It specifies procedures for determining lumen depreciation and useful life of LEDs. However, it does not address lumen depreciation within a luminaire.

This test procedure was created because life testing for LEDs is impractical due to the long expected lifetimes. Even with constant operation, testing an LED for 50,000 hours would take 5.7 years. Because the technology continues to develop and evolve so quickly, products would be obsolete by the time they finished life testing. The proposed method is based on the idea of useful life, the time it takes for the device's light output to decline to a level that no longer meet the needs of the application. For general ambient lighting, useful life is the average number of hours that the LED would operate before depreciating to 70% of initial lumens. Because of this, LM-80 is slightly more problematic and also still in committee. It is projected to be completed and made public in the summer of 2008.

The good news is that the delay with LM-80 shouldn't postpone ENERGY STAR qualification of products. Once LM-80 is public, the burden will be placed on the device manufacturers to prove lifetime. The device manufacturers can obtain necessary data through temperature measurement tests, and so essentially the day after the LM-80 is complete they will be able to generate an LM-80 test report.

Efficiency Program Pilots

Pacific Gas and Electric Company Program

Pacific Gas and Electric (PG&E) Company shares the growing enthusiasm for LEDs and believes LED lighting has the potential to help customers save energy as well as contribute to protecting the environment. PG&E's emerging technologies and incentive program staff are working closely with the LED industry, DOE, and the standards and testing community. This work will provide both IOUs and manufacturers the opportunity to evaluate new products with customer feedback on performance and satisfaction.

As with many efficiency programs, PG&E has offered incentives for LED exit signs and channel letter signage, and in late 2007, created a new incentive for LED refrigerated case lighting. Even so, PG&E is taking a cautious stance toward offering incentives for LED in general illumination due to performance concerns and the lack of test procedures.

While ENERGY STAR labeling procedures and industry-adopted testing standards are being finalized, PG&E, along with the other California investor-owned utilities (IOUs) Southern California Edison and San Diego Gas & Electric, is working to develop new statewide rebate programs for LEDs in specific applications.

The program will involve the development of a list of products that meet specific product qualification criteria for the following applications: refrigerator display case lights, recessed downlights, street and area lights, parking garage lights and MR16s. These applications were selected based on energy savings potential and the results of demonstration projects. In the case of the one Category A application (downlights) the qualification criteria will mirror the ENERGY STAR criteria. For the other applications that are not currently included in Category A of ENERGY STAR new product qualification criteria will be developed in collaboration with the DOE ENERGY STAR staff. This effort will result in a database of LED qualified products. Once a product is qualified and listed in the approved product database, customers will be eligible to receive incentives for installing the products.

The first step in creating the list will be to require manufacturers to submit independent test results based on the procedures being developed by the testing community. These test results will be reviewed to verify the products meet the required product qualification criteria. Manufacturers will be allowed to submit test reports as a result of DOE's CALIPER testing. The California IOUs plan to accept manufacturer information as long as it has been tested by a DOE-verified independent testing lab.

P&E Lessons Learned

As PG&E and the California IOUs develop and implement this pilot LED rebate program, they anticipate several issues will be of key concern. LED lighting is a rapidly advancing technology. Strategies and processes will need to be put in place to ensure that product qualifying specifications keep up with technology advances and that they are consistent with changes to ENERGY STAR specifications. Additionally, the qualified product database will require ongoing updates and support as manufacturers change their product lines to take advantage of these advancements. Even if a product qualifies under the incentive program criteria or as ENERGY STAR, there is no guarantee that quality products will be consistently delivered to customers. This emphasizes the need for a quality assurance process, such as the existing "Program for the Evaluation and Analysis of Residential Lighting" (PEARL) program for CFLs.

Product life is likely to be the most difficult product characteristic to validate through a product qualification procedure. This is of particular concern since excessive heat is so detrimental to LED longevity. Even a well-designed LED lighting product, when used in the wrong application and exposed to high heat conditions, may not perform to its rated life. Requiring long warranty periods can help to address the product life issue. However, it will also be important to track reports of premature failures and develop methods to address these promptly.

Setting appropriate incentive levels and meeting regulatory program cost effectiveness targets are additional concerns for successful program implementation. Obviously, the higher the incentive level, the more effective the incentive will be in reducing the first cost and support the adoption of LED lighting. However, utilities need to establish incentive levels for LED lighting that are cost effective within the broader context of their portfolio of energy efficiency incentives.

PG&E is quick to point out that LED lighting is new and different than other lighting technologies. Therefore, it is important not to rush to conclusions when considering LED lighting. Education, coordination and communication are critical both internally and externally. Lessons learned as programs are implemented and as issues are addressed will be applied to expanding and improving the incentive programs in the future for LED lighting.

Efficiency Vermont Program

Vermont has a long tradition of leading the nation with its energy efficiency programs and services. The first energy efficient CFL programs were implemented in the early 1990s by the investor owned, municipal, and cooperative electric utilities as part of their Demand Side Management programs. Responsibility for these services was assumed by Efficiency Vermont with its creation in 2000. However, aggressive CFL promotion in Vermont will soon be winding down as the CFL lighting market is near saturation and transformation. In 2007, participation in Efficiency Vermont's CFL promotions averaged over 2 CFLs per household.

Due to this maturity in the Vermont CFL market, Efficiency Vermont believes that now is the time to begin promoting LEDs in order to continue to have a viable energy efficient lighting promotion, and achieve real energy savings. LEDs hold the promise of being even more energy efficient than equivalent compact fluorescent lighting products, and to be better suited technologically for certain applications such as down-lighting. Efficiency Vermont also believes it is important to provide Vermont consumers with education and guidance so that they can understand the best applications for LED lighting products and avoid purchasing poor quality lighting products.

To achieve this, Efficiency Vermont has been providing a $30 rebate LED Downlight Instant Lighting Coupon for the LED Lighting Fixtures (LLF)'s LR6 downlight since April 1, 2008. This product has been selected because of its superior light quality and because it has passed CALiPER testing. Efficiency Vermont is also leaving the door open for additional products to be eligible for this Instant Coupon promotion. Efficiency Vermont will require that in order for other LED Downlight products to be eligible for this promotion, the products must have been 3rd party tested, either by CALiPER (IESNA LM-79, IESNA LM-80) or equivalent, and these additional products must have the pre-approval of Efficiency Vermont. Efficiency Vermont feels comfortable implementing this promotion ahead of the ENERGY STAR LED specification because it believes that the CALiPER test results provide a good indication of the product's quality.

The LED Downlight Instant Rebate Coupon is very similar to the Efficiency Vermont ENERGY STAR CFL Instant Lighting Coupon. As on the existing Instant CFL Coupons, the consumer is required to indicate whether they will be using the product in a residential or commercial application. This will allow Efficiency Vermont to use different hours of use assumptions depending on whether the product is used for residential or commercial applications to measure the energy savings. Efficiency Vermont's ultimate plan is to transition this promotion into an ENERGY STAR LED Downlight Instant Coupon promotion once the ENERGY STAR LED criteria become effective.

The purpose of promoting LED Downlights prior to effective date of September 30, 2008 of the ENERGY STAR LED specification was to provide assistance to Vermont ratepayers that are seeking direction and financial assistance in purchasing LED lighting products and to gain experience in the promotion of these products so as to be prepared for aggressive promotion once the ENERGY STAR LED specification becomes effective.

Efficiency Vermont Lessons Learned

In the short time since Efficiency Vermont launched this promotion they have learned some very important lessons regarding communications, purchasing limits, participation and consumer satisfaction.

Communications. Careful communications with vendors and sales representatives regarding rebate amounts, timing, and product eligibility is important to consider when launching a program. Efficiency Vermont developed and implemented the LED Downlight promotion partially in response to heavy market demand for LED products eligible for rebates. In the process of developing this promotion Efficiency Vermont representatives spoke with customers (Vermont ratepayers), lighting showrooms, and commercial electrical suppliers. With so much excitement in the market for these technologies, these conversations unfortunately resulted in the start of rumors and misconceptions of what the final promotion would be. In the future, Efficiency Vermont will make it clearly understood that these early conversations are to be held in strict confidence.

Purchase limits. Carried over from their CFL program, the LED coupon has stated purchase limits, with directions that, if the purchaser has a need for a larger number of lighting products they should contact Efficiency Vermont. These purchase limits are 6 and 25 product packages for residential electric accounts and commercial accounts respectively. Efficiency Vermont has found itself in the position of screening many requests for purchases beyond the stated limits for the LED Downlights. It appears that the limits worked for CFLs but not so well for LED Downlights due to the differences in application. While CFLs are great for installation in discrete locations around a home or business, downlights are typically installed in clusters or groupings that necessitate changing out many lights at one time to maintain consistency in light quality, and avoid conflict between different types of light sources in the same application and/or space.

Participation. The largest segment of participants seems to be in the residential new construction and renovation markets. It is a guess, but this may be due to the high first cost of these LED downlights. The ability to finance the purchase with a home improvement loan or mortgage may make the first cost more palatable. This first cost issue bears further investigation by Efficiency Vermont if they hope to make this a successful mainstream promotion with wide appeal.

Consumer satisfaction. There have been high levels of customer interest and participant satisfaction. Efficiency Vermont and one of its retail lighting partner showrooms have displayed and demonstrated the LLF LR6 LED Downlight product at several home shows. The interest in this product has been fantastic. Additionally, Efficiency Vermont has yet to receive any negative feedback, either about the LLF LR6 LED downlight or the Efficiency Vermont LED Downlight promotion.

Conclusion

SSL has great potential in certain general illumination applications, the majority of which have been identified in Category A of the ENERGY STAR specification. Given uncertainties surrounding the quality of these products and test procedures, the majority of efficiency programs have decided to wait for the ENERGY STAR label before beginning promotion. It is likely that more program administrators will begin considering programs once LED products start to be labeled, which is anticipated to occur in September 2008.

The early work being done by the California IOUs and Efficiency Vermont prior to the ENERGY STAR program has been mostly in the careful selection of products, third-party verification of performance and determining how to set their incentive levels. Both programs considered offsetting the first cost of the product as well as the potential energy savings within the broader context of their portfolio of energy efficiency incentives.

Efficiency Vermont's early success in promoting a product that has been third-party tested underlines the need for robust quality assurance for Category A applications and demonstrates a need for third-party testing for all other applications. To meet this need, DOE is actively pursuing other testing facilities to add to their list of verified labs. In addition, LRC's National Lighting Product Information Program (NLPIP) is looking to test products for efficiency programs. It is very promising that once the LED test procedures are finalized that there will be a number of organizations and testing facilities that efficiency programs can rely on to help support the development LED programs. These testing facilities will be critical in weeding out poor quality LED products and helping efficiency programs protect the consumer from having negative experiences with this technology.

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