The Super Lamp initiative is a collaborative effort among California utilities (Pacific Gas and Electric, Southern California Edison, San Diego Gas and Electric, and Sacramento Municipal Utility District), the Natural Resources Defense Council and the California Lighting Technology Center (CLTC), to meet California’s goal of reducing residential lighting consumption to 50 percent of 2007 levels by 2018.

The strategy is to foster the development of high-efficacy light sources that achieve, as much as possible, interchangeability with incandescent lighting, in terms of compatibility with electrical infrastructure and with popular lighting expectations. This article is a summary of research performed at the CLTC to achieve required energy performance and develop a technology-neutral Super Lamp specification for replacement of incandescent technologies in the residential sector.

Some recent history helps to explain the initiative. In 2006, California passed the Global Warming Solutions Act of 2006, which mandated reducing greenhouse gas emissions to 1990 levels by 2020. This in turn spurred initiatives to curtail emissions from several activities, including lighting. For residential lighting, in particular, several legislative options were considered in order to address the still prevalent use of incandescent lighting—much less efficacious than other available alternatives such as CFLs. Alternatives included putting in place higher efficacy requirements amounting to an outright ban of incandescent light sources and setting a mandate to reduce energy consumption by 50 percent (relative to a 2007 baseline) by 2018. The latter proposal was signed into law in late 2007.

At the request of the California Energy Commission, the CLTC researched the possible impacts of these and other options under consideration on California’s residential lighting energy consumption in the 2007-2018 period, such as full substitution for higher-efficacy incandescent or reliance on building codes only. Using available data, a mathematical model for projecting the evolution of California residential lighting energy consumption over the following decade was built. Figure 1 shows the projected energy consumption as a percentage of 2007 levels if no actions were taken. Three levels of growth in number of households were considered: continuing the trends from 2000-2005; 50 percent of that trend; and zero growth. Note that in the “zero growth” scenario there is still growth in overall energy consumption, due to accounting for growth in the number of lamps per household, a significant trend observed in the 2000-2005 period. Also shown in Figure 1 is the energy consumption attributed to houses that comply with the more stringent 2005 California building codes. The increase is due not only to new construction but also to retrofits, and therefore the growth rate is higher.

This article is a summary of CLTC research aimed at developing a technology-neutral Super Lamp specification for replacement of incandescent sources in the residential sector.
technologies able to achieve the same levels of efficacy. These alternatives occupied approximately only 20 percent of screw-base sockets in California residences. Efforts then turned to determining how best to address the remaining 80 percent of screw-base sockets with incandescent lamps.

DEVELOPING A SPEC

The list of complete Super Lamp specifications requirements can be found at http://cltc.ucdavis.edu/content/view/652/342/. The first step towards developing the spec was to identify the major obstacles to increased high-efficacy lighting use in California residences. In 2007, high-efficacy lighting for screw-base sockets meant almost exclusively CFLs, but several issues were preventing this technology from being accepted by a larger section of the population. The CLTC specification had to consider the following factors:

- color
- size
- flicker and noise
- run-up time
- frequent lamp failure in enclosed luminaires or downlights
- inability to dim; lamp failure/erratic behavior when operated on electronic switches (e.g., timers)
- mercury content

**Color.** CFLs and LEDs are usually available in a variety of color temperatures. Although this is very well understood by lighting experts, that is rarely the case with the public, which can result in disappointment when lamps of different color temperatures are unintentionally used in the same space. For this reason, the Super Lamp specification focuses only on lamps with a nominal correlated color temperature (CCT) of 2,700K.

As the lamp is dimmed, color temperature can vary along a band centered on the blackbody locus.

Given the tradeoffs between color rendering and efficacy, minimum values were specified for special color rendering indices ($R_i$ to $R_{11}$), as well as for $CR_{14}$ (average of $R_1$ to $R_{11}$) and $CRI_{14}$ (average of $R_1$ to $R_{11}$). These values were determined by estimating, based on efficacy and CRI measurements:

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**Figure 1:** Aggregate lighting energy consumption by California households under current policy (projection).

**Figure 2:** Aggregate lighting energy consumption by California households under 2010 incandescent ban (projection).
of 2,700K CFLs of varying CRI, the highest CRI indices—and in particular $R_g$—that would still result in meeting the Energy Star requirements for efficacy. The requirement for $R_g$ (strong red), usually the most challenging special color rendering index for CFLs, is a minimum value of 12, with a minimum of 40 for all other 13 special indices. A minimum average of 70 is required for all 14 indices ($CRI_{14}$), and minimum $CRI_{10}$ is set at 82, a small increase over the Energy Star requirements.  

Size. The specification addresses some of the most common lamp shapes: A19, R30, PAR38 and G30. For some of these, it is difficult to manufacture CFLs that exactly fit the ANSI standard shape, most commonly because the ballast demands more space than allowed. To minimize incompatibilities with existing luminaires, we determined, from physical measurements of available lamps, the smallest deviation possible from the standard that would encompass at least one existing model. Super Lamp space drawings were then developed by making slight modifications to ANSI standard lamp space dimensions. This was not necessary for PAR38 and G30 shapes, since existing CFLs were found that already complied with the standard. Figure 5 shows the Super Lamp requirements for A19 lamps of less than 20 watts.

Run up and starting. Amaigam lamps can take a few minutes to achieve 80 percent of full output, whereas non-amalgam lamps can take around 15 seconds or less. However, non-amalgam lamps perform poorly in high-temperature environments, which is a desirable Super Lamp feature. The Super Lamp requirement for run-up time, 45 seconds, was based on the fastest run-up characteristic observed in the CLTC laboratory with commercially-available amalgam lamps.

Many dimming CFLs are not able to start unless the dimmer is set close to full power. In order to achieve performance closer to that of incandescent lamps, it is required that lamps start at 70 percent power, a value deemed achievable with today's technology by several lamp manufacturers.

Flicker and acoustic noise. Flicker and acoustic noise were some of the original complaints about CFLs. While in some cases this is due to improper use of CFLs, such as operating a non-dimming lamp on a dimmer, it is important to limit the amount of flicker and acoustic
noise produced by Super Lamps. With the aim of ensuring a high degree of satisfaction in residential use, the CLTC is currently investigating measurement procedures and performance requirements for these quantities.

Performance in high temperature environments. Most CFLs aren’t suitable for use in enclosed luminaires and usually carry a warning for installations in such environments. Unfortunately, that warning is sometimes ignored and contributes to a perception of unreliability. For this reason, in the Super Lamp specification it is required that lamps of all shapes meet the elevated temperature requirements that Energy Star at present makes only for reflector lamps, such as life, lumen maintenance and maximum temperature rating. These include lumen maintenance and lamp life.

Dimming and electronic switch compatibility. In 2009, dimmer switches controlled 12 percent of the sockets in California homes. However, most CFLs are not compatible with dimmers. The same happens with electronic switches that require a trickle current to run through the lamp when it is in the off state. As mentioned above, for compatibility with high temperature environments, CFLs usually carry a warning, which is not always considered. For this reason, Super Lamps must be dimmable—a feature available in some of today’s lamps—and also compatible with electronic switches, a feature that several manufacturers deemed to be achievable. Lamps should be dimmable down to 20 percent of full light output.

Mercury. Due to widespread concern with toxic hazards in the home, we sought to specify a mercury level that was as low as possible without jeopardizing lamp life and the ability to dim to low levels. Consultation with lamp manufacturers yielded a value of 3 milligrams as being a reasonable compromise.

STATUS AND NEXT STEPS

The current version of the Super Lamp specification is now publicly available and the CLTC is accepting sample submittals from lamp manufacturers. Meanwhile, the California utilities are in the process of determining their incentive structure for high-efficacy screw-base lamps. At the time of writing, it is expected that incentives for lamps that qualify for the Super Lamp program will be significantly higher than incentives for other lamps.

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