What are the Next Steps for Lighting Efficiency Policy? Reporting on a Statewide California Study

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ABSTRACT

The California legislature requested recommendations on ways to improve lighting efficiency in the state. An industry advisory committee was set up and a project was funded to study statewide patterns of lighting energy use and provide policy recommendations. This paper reports on the findings and recommendations of that year long study.

Detailed baselines of lighting energy use were created for both residential and commercial lighting, using extensive on-site survey and metering data. This baseline data was used to create a model of lighting energy use that could estimate the impact of various policy scenarios. In addition to the scenarios analysis, the final recommendations were informed by research on market conditions and barriers, and by discussions with the advisory committee. The five recommendations were 1.) update the lighting energy code, 2.) support development of an efficient a-lamp replacement, 3.) adopt a three step approach to residential lighting efficiency, 4.) support lighting education, and 5.) support research on lighting energy use. The first three are discussed in this paper.

The baseline data proved very useful in validating proposed upgrades to the statewide lighting code, which was recently updated. The potential impact of an efficient A-lamp replacement had previously been discussed, but without substantiating data. By combining the impacts in both the commercial and residential markets, this study shows the potential energy impacts to be dramatic. Many of the current barriers to more widespread use of compact fluorescent lamps are addressed in the third recommendation.

Introduction

In 1993 the California Legislature passed Senate Bill SB 639, requesting that the California Energy Commission (CEC) study lighting energy use in California and report back on recommended ways to improve the efficiency of lighting in California. To support this process, the CEC established a lighting efficiency advisory group (LEAGue) composed of about thirty members of the lighting industry. In addition, a contractor was hired to study lighting energy use patterns in the state, and to develop a methodology to assess the energy impacts of proposed policy initiatives. The CEC, the LEAGue and the project contractor worked together to consider policy alternatives, and to develop a set of recommendations for how lighting efficiency might be most effectively be improved in the State.

This paper discusses the results of that year long effort. Baseline energy use patterns for residential and commercial applications were defined using pre-existing survey data collected by various utilities. The study addressed indoor and outdoor lighting in the residential sector, and indoor lighting in the commercial sector. There was not sufficient data available to adequately characterize outdoor commercial lighting, industrial lighting, or street lighting. Once the baseline energy use patterns were established, a computer model of statewide lighting energy use over a 15 year period was created to study alternate policy scenarios, and assess their potential energy impacts.

Methodology

Survey Data

Data to establish a residential baseline lighting energy use in California were taken from two primary sources, a detailed on-site survey of all lighting equipment in 683 households which was conducted for Southern California Edison (SCE) (HBRS, 1993), and a long term monitoring study of 161 houses conducted in the Northwest, lead by Tacoma Public Utilities (TPU) (Lerman, 1996). The SCE survey was done in 1993 for a statistically representative sample of households, including both single family houses and multi-family units. The SCE surveys, conducted by professional auditors, characterized the lighting equipment and operation of every light source inside and outside of the home. The TPU study, although less rigorous in selection and survey methodology, importantly collected cumulative hours of operation for 80% of fixtures in 161 single family homes over a six month to two year period, ending in 1994.

The commercial baseline was based on combined survey data collected in 1992 and 1994 by Southern California Edison, Los Angeles Department of Water and Power, and San Diego Gas and Electric. (CEUS, 1992, 1994) The combined data sets, which used the same survey methodology and data structure, include over 1500 commercial buildings, representing over 50 million square feet, or almost 10% of the commercial building stock in California. Most of the data came from "high resolution surveys", which included detailed inventories of lighting equipment and operation schedules room by room within each building. "Low resolution surveys" were performed primarily for single use buildings, where one use type represented more than 90% of the building. Thus, the data provides extremely detailed information about lighting power densities and operation schedules on a room by room basis.

Data Processing

The two combined data sets, residential and commercial, were analyzed to characterize lighting baseline conditions in California. These baseline characteristics were reported in detail to the California Energy Commission (Heschong Mahone Group, 1997 Vol. I) This baseline data was then used to populate a relational database computer model, called the California Lighting Model (CLM), which could be used to simulate the energy impacts of changes in lighting practices and technology over time using statewide forecasts for new construction over the next 15 years by square foot for commercial buildings, and by dwelling unit for residences. (Kolderup, 1998)

The model was used to study thirty different policy options which could potentially influence lighting efficiency in California. Scenarios were specified according to how changes in lighting practices or technology might occur over time, and at what rate. Changes were made on a lumen-for-lumen basis, so that lighting output for each application was held constant, while efficiency and market share of technologies could be shifted.

The scenarios could be structured to study changes in residential or commercial buildings, or both; in new construction only, in retrofitting of existing buildings, or both. The scenarios could also shift assumptions about lighting characteristics of buildings at a number of levels: for example, it could increase the number of a given fixture type per room, increase the efficiency of a particular technology, change the lighting power density for a given space type, shift the market penetration of any technology relative to other technologies, or introduce a entirely new technology.

For example, Scenario N1 modeled the energy impacts if fluorescent sources gradually took over the market for outdoor lighting in new homes, such that after a 15 year period, 50% of the currently incandescent sources were replaced with fluorescent sources. Each year, as more new homes are built (based on CEC forecasts for the California housing market), the model assume that the proportion of outdoor fixtures which use high efficiency fluorescents (at 38-58 lumens/Watt) increases at the expense of low efficiency incandescents (at 11-14 lumens/Watt). The cumulative energy impacts of this scenario are then compared to a base case where the number of homes increase over the same time period, but the characteristics of lighting in the homes do not change over time.

Results

Highlights from the scenario analysis are summarized briefly below. (For detailed descriptions and results, see Heschong Mahone Group, 1997, Vol II). All numbers apply only to the state of California. The model considered commercial applications and residential applications separately, then some combined commercial and residential scenarios were studied.

Commercial Scenarios. The analysis shows that it is possible to lower the overall lighting power density for the existing California commercial building stock by an average of 30% using only standard 1996 technologies, and without lowering the lighting levels in any spaces. Reductions averaging up to 0.45 watts/SF for the building stock as a whole are obtainable using only existing technologies and design methods. (These values vary considerably by building type).

Converting all existing fluorescent applications to T8 lamps and electronic ballasts, a change that is already well underway in the marketplace, saves more energy and reduces wattage more than lowering Title 24 by a uniform 20%. This first step (which was generally implemented in the adopted 1999 revisions) to revise the standards based on using T8 lamps and electronic ballasts in fluorescent applications, would save about 2,800 gigawatthours per year.

These savings can be doubled if all commercial lighting were converted to the most efficient alternative which is commercially available in 1996, such as through the use of halogen infrared (HIR) lamps, compact fluorescent lamps (CFLs) and advanced high intensity discharge (HID) lamps, where appropriate, in addition to the more efficient fluorescent technologies. If such an upgrade of the Standards were implemented, it would result in over 1,000 megawatts in electricity demand reduction and 4,300 gigawatthours of energy savings per year for the state. This is equivalent to removing one nuclear power plant from production and saving California businesses about $350 million dollars/year.

An even greater savings, with an additional 19% savings, could be further achieved through including other viable lighting efficiency methods such as careful lighting design, use of automatic controls and daylighting in the Standards. Such use of all commercially viable technologies was found to reduce installed load by almost 2,000 megawatts, and save 7,500 gigawatthours per year.

Residential Scenarios. Interventions which effect the entire residential market, such as marketing campaigns or appliance standards, have a vastly greater impact than policies that only effect new homes, such as Title 24 energy standards requirements. While the new construction residential scenarios have the ability to save from approximately 0.5% to 1.5% of current residential lighting energy use, the "all building" residential scenarios have the potential to effect from 7% to 21% of current residential lighting energy use, or about a 14 times larger impact. Residential lighting in general is operated for very few hours per day (2.3 hrs). In order to achieve significant and cost effective savings, residential lighting efficiency programs should either target those lighting fixtures which operate for the longest hours, or where there are the greatest number of inefficient fixtures.

Outdoor lighting meets both of these criteria. Residential outdoor lighting efficiency measures show the greatest savings for the new construction approaches considered in this study, and almost ten times those savings when applied to all homes through consumer based approaches.

Targeting residential lighting fixtures which operate for three or more hours per day for replacement with more efficient light sources shows even greater potential savings. Placing HIR lamps in these fixtures can save about 12% of current residential lighting energy use, while using compact fluorescent lamps in these heavily used fixtures has the potential to save 21%.

Targeting table lamps and floor lamps for replacement with more efficient sources also has considerable impact, since there is such a huge number of these portable fixtures. Automatic controls which can reliably eliminate unnecessary hours of operation also have potential to save considerable energy. Current trends in increased energy use for lighting in residences, such as the increased use of high wattage halogen torchiers, could also cancel gains from other efficiency programs.

Potential energy savings from the "'all building" residential scenarios are on a par with those considered for commercial buildings. This similarity in energy savings potential exists in spite of the fact that commercial lighting hours of operation are 4 times longer than residential. The similarity in savings exists primarily because the residential sector is so large, with 3 times as much installed wattage as the commercial sector, and because residential lighting currently uses much less efficient sources than commercial, and thus there is much greater potential for savings from efficiency improvements.

Combined Residential and Commercial Scenarios. We looked at the combined residential and commercial impacts of some scenarios. The most dramatic were replacements of existing incandescent lamps with either a CFL or a HIR replacement. The large number of target fixtures in the residential market and the large amount of energy and demand savings possible in the commercial market make these combined strategies have an impact on par with the most aggressive commercial scenarios. An HIR A-lamp replacement results in about 1,000 megawatts of demand reduction in California, while a CFL replacement results in about 1,500 megawatts of demand reduction. The resulting energy savings are 4,340 gigawatthours and 7,468 gigawatthours per year respectively.

Recommendations

The results of the scenario analysis was combined with market barriers research, (Heschong Mahone Group, 1997, Vol III) and input from members of the LEAGue and project team to develop a set of recommendations put forth to the CEC. Five major recommendations were presented, in order of priority, based on an assessment of their potential benefits and costs:

1. Update the commercial lighting power density standards
2. Support development of an efficient A-lamp replacement
3. Adopt a three step approach to residential lighting efficiency
4. Support lighting education
5. Support research on lighting energy use

The first three recommendations are discussed in this paper, with an assessment of their potential energy impacts, and a brief background and rationale for each.

Update Commercial Title 24 Lighting Standards

Commercial lighting energy efficiency has consistently been shown to be one of the most effective means to reduce energy consumption in buildings. Utility program impact evaluations have demonstrated that, of all building efficiency options, lighting efficiency measures have the largest overall net impact on both energy savings and peak demand reductions. (RLW, 1997)

Revisions to the energy code have the permanent effect of raising the standard level of practice in the entire lighting community. Because of the rate of new construction and renovation in commercial buildings, a revision to building energy standards will generally affect the entire building stock within 15 to 20 years. Lighting energy savings are also amplified by secondary effects in reducing building cooling loads. Lighting efficiency measures for new construction have been found to be especially persistent: once adopted, they tend to stay in place, and to continue saving energy for the life of the lighting system.

California's Title 24 Building Energy Standards have been acknowledged as one of the major driving forces in improving the energy efficiency of the lighting industry. Fixture manufacturers across the country who were interviewed for this study uniformly acknowledged Title 24 as the primary driving force for increased production and marketing of efficient lighting technologies. In the two decades since it was enacted, Title 24 has come to define the basic standard of practice for the California lighting industry. Lighting professionals who interviewed for this study stated that their own lighting installations typically exceed Title 24 requirements, and that exceeding the Standard requirements by 10% is feasible and "easy." Our analysis confirms their view, showing that by 1992-4, on average, the existing commercial building stock had achieved better than 100% average compliance with the lighting standards, exceeding Title 24 lighting power density requirements by a net of 5%. This is a major policy achievement.

Our analysis shows an enormous potential for energy savings and demand reduction that could result by simply bringing the Title 24 lighting standards up-to-date based on the efficient technologies that were commercially available in 1996, without any reductions in existing lighting levels.

Recommendation: Revise LPD Standards Based on Current Efficient Technologies. California should continue to upgrade the lighting power densities required by Title 24 non-residential lighting standards based on commercially available and cost effective efficient lighting technologies for all applications. (Potential impacts are discussed in "Commercial Scenarios" section above).

Support Development of Efficient A-Lamp Replacement

Our analysis shows great promise for a lamp which would be a more efficient, direct screw-in replacement for standard incandescent light bulbs. For example, a tungsten halogen infrared reflecting (HIR) lamp, which could be used in both residential and commercial applications, has the potential to reduce demand and save as much energy per year as upgrading the Commercial Title 24 Lighting Standards, discussed above. Such a product could reduce statewide demand by 1,000 megawatts and save approximately 4,000 gigawatthours per year. This is a huge potential for energy savings.

While compact fluorescent lamps can be cost effective replacements for those incandescent lamps in applications with long hours of operation, CFLs also face a wide range of market barriers and operating characteristics that make them unsuitable or uneconomical for many applications. If an efficient A-lamp should be manufactured with similar photometric properties as standard incandescent lamps, and have the same operating characteristics, such as dimming capability, instant on, and lack of temperature sensitivity, and be marketed in a price range of $3 to $6 per lamp, so that it is within the price range expected for products at consumer outlets such as grocery stores, it is likely to have wide applicability and acceptance.

There are other innovative technologies which may eventually be able to improve the efficiency of the A-lamp, but at this point, the infrared reflecting technology is the nearest to commercialization.

Our analysis assumes a direct screw-in replacement for existing standard incandescent lamps which operates at 22 lumens per watt at smaller sizes, and 25 lumens per watt for larger sizes.

Recommendation*:* Support R&D of A-Lamp Replacement An efficient replacement for the screw-in incandescent lamp has enormous energy saving potential. The development of an HIR A-lamp uses a very near-term technology, and seems poised on the verge of commercialization. Some targeted research to resolve performance optimization, manufacturing, or marketing issues may be necessary to take it the last step to commercialization. We recommend that the CEC identify key areas that will benefit from public support to move this promising technology forward. For example, technical specifications could be developed that embody the "drop-in" replacement product vision expressed above. Development of commercially produced prototype lamps may be an important next step.

Recommendation: Join in Procurement Efforts. Efforts to spur manufacturers to create such a lamp have recently revolved around procurement initiatives, initiated by the federal government and international agencies. The intention is to create a large enough market to make it worthwhile for a manufacturer to initiate production of an efficient A-lamp replacement. The appropriate price point and efficacy level of the product remain controversial. A necessary next step may be identifying a larger, more stable market or agreeing upon lower specifications for the initial procurement.

Adopt a Three Step Approach for Residential Lighting Efficiency

Residential lighting energy use has been shown to be significant: about 2/3 the size of commercial lighting energy use, and 8% of overall statewide electricity use. Residential installed lighting wattage is three times the commercial level, and residential lighting loads on electric utilities are equivalent to 83% of commercial lighting loads in the early evening peak demand period (6 PM). However, residential lighting remains vastly less efficient than commercial lighting, and has not benefited from the many recent improvements in lighting technology. Even though residential hours of operation are short, there is still significant potential to save energy and reduce utility demand with efficiency measures because of the huge installed load, and because of its inefficiency.

Residential lighting has a very different market structure than commercial lighting. Energy codes have a much smaller, and slower impact on residential lighting than on commercial lighting because a smaller percentage of installed lighting is effected, and changes to installed lighting is less frequent. Residential lighting is driven by the diffuse consumer market, rather than more concentrated wholesale purchasing. Fixtures are most often selected for aesthetics, and lamps are most often purchased as a commodity, based on price and convenience. A large portion (18%) of residential lighting is portable, such as table and floor lamps, and moves with the homeowner. Retailing of energy efficient lighting products is constrained by the demands of the mass merchandising system. A large portion of residential fixtures are manufactured overseas, and sold at discount prices, creating a very competitive market where quality and performance are usually at a price disadvantage.

For all of these reasons, it has been difficult to develop an effective strategy to promote efficiency in the residential lighting market. To reach this complex market, the Commission should take a three step approach:

- Maintain the existing energy standards for new construction, and gradually expand the requirements for efficient lighting sources which are permanently wired into new homes.
- Promote commercialization of compact fluorescent lamps through public service advertising and promotion of greater standardization in manufacturing.

- Participate in labeling programs and encourage development of appliance standards for residential lighting fixtures that improve their efficiency and performance.

Given space constraints for this paper, we will focus on the rationale for first two initiatives. The third, labeling programs and appliance standards have been discussed and promoted by others.

Residential Title 24 Lighting Standards

The time of construction represents the most cost effective opportunity to integrate efficient lighting into homes. New construction standards steadily improve the overall efficiency of housing stock. California was the first state to adopt lighting measures into its residential energy standards. An efficient (i.e. fluorescent) lighting fixture is currently required in kitchen and bathrooms. The Title 24 requirement is very simply stated, requiring only a few lines of text.

As a result of Title 24, fluorescent lighting very clearly increased in California homes. Our analysis shows that the percentage of fluorescent lighting installed in single family homes took a dramatic jump upwards after the Standards were instituted in 1978. That level appears to have remained steady since, and is higher than comparable homes surveyed in other states. However, after an initial dip around 1978, the amount of incandescent lighting in California homes has also steadily risen. The average installed watts per home has increased by an average of 100 Watts per decade. Most of this is attributable to a steady increase in the size of homes, with a corresponding lack of improvement of the efficiency of lighting sources. Combined with the incessant increase in California's population, this growth in residential lighting energy use is clearly an unsustainable trend.

Our analysis suggests that simply achieving full compliance with the current Title 24 provisions would result in an additional 200 gigawatthours of energy savings per year, and would reduce the statewide installed residential wattage by 240 megawatts. Abandoning the residential lighting standards would result in a corresponding increase in energy use.

Since there is no limit on the total amount or wattage of lighting provided, builders have often simply added more fixtures to the kitchen and bathrooms, increasing the overall lighting power density. This is often cited as a symptom of failure of the Title 24 provision. However, our analysis shows that homeowners tend to make more intensive use of fluorescent fixtures. Fluorescent fixtures in kitchens are operated for an hour more per day on average than incandescent fixtures. Thus, a higher rate of installation does not necessarily mean a higher rate of use. Provision of a fluorescent fixture clearly gives the homeowner an option to choose a more efficient source.

Assertions that there was very low compliance with the Title 24 bathroom provisions were not confirmed in our study. California was found to have a higher proportion of fluorescent lighting in bathrooms than other states, and one third of all lighting (lumens) in bathrooms in new single family homes was found to be provided by fluorescent lighting. In our modest survey of contractors who do both remodels and new construction, 81% responded that they install fluorescent lighting in most bathrooms, which was actually higher than the rate they reported for kitchens.

Fixture manufactures reported that they have found a significant market for residential fluorescent fixtures in California because of the Title 24 requirements. A CFL fixture manufacturer reported that while five years ago they had no competitors in the California market, now they have a half dozen aggressive competitors. As a result, their CFL fixture prices have dropped by 30%. Fixture manufacturers are counting on Title 24 to be a continuing force in driving the market for these fixtures. Thus, the problem of lack of selection of appropriate fixtures is being resolved as the market develops.

While compliance with the Title 24 lighting requirement may be imperfect, it is having an impact. Some home builders have been very vocal in expressing their dislike of the provision, but the evidence is that the majority of new homes in the state have some fluorescent lighting, and that most contractors now accept the requirement. The provision was clearly ahead of its time when it was instituted, and has received a lot of criticism because of that. But the lamp and fixture market has gradually been catching up and is now within hailing distance of being able to meet the needs of contractors.

Recommendation: Simplify Kitchen and Bathroom Compliance. The current Title 24 language is quite straight forward. Interpretations of the language have, however, multiplied. Allowing subtle interpretations and multiple substitutions complicates the compliance process enormously, and variation in interpretations between jurisdictions can aggravate discontent among builders who complain about unfair enforcement. Agreeing on one simple interpretation will greatly assist the code officials who enforce the Standards and provide clear direction to the building community.

Outdoor Lighting. In order to achieve significant and cost effective energy savings, lighting efficiency programs should target either those lighting fixtures which operate for the longest hours, or those applications which have the greatest number of inefficient fixtures. Outdoor lighting meets both of these criteria. Outdoor lighting constitutes 15% of residential lighting energy use, 12% of installed wattage and 13% of fixtures. The hours of operation for outdoor lighting is above the average for residential fixtures, averaging close to 3 hours per day.

Outdoor lighting is also considered one of the primary "growth" areas in the residential lighting market. The amount of outdoor lighting installed statewide is expected to continue growing for the foreseeable future. Homeowners are eager to make improvements to their yards, extend the hours of use, and provide decorative and security lighting for their homes.

There are a number of simple, commercially available options for improving the efficiency of outdoor lighting. Our analysis, based on substituting fluorescent for incandescent sources, suggests that implementing these efficiency options for outdoor lighting in new homes could save between 150 and 340 gigawatthours per year, and reduce installed lighting wattage by 130 to 240 megawatts.

Recommendation: Adopt Outdoor Lighting Standards. Outdoor lighting is a strong candidate for future inclusion in the lighting provisions of Title 24.

Indoor Fixtures. Indoor fixtures hardwired to the wall or ceiling of a home are the most common residential fixture type, and account for about 2/3 of all residential lighting energy use.

The National Electric Code (NEC) provides a good definition of the minimum number of fixtures that must be provided in a residence. This list includes those fixtures with the longest hours of operation, such as kitchen, garage and utility room ceiling fixtures, and outdoor fixtures at entrances, those fixtures which are often used for security or night lighting, such as bathrooms, hallways and stairways, and those fixtures already covered in Title 24, i.e. general lighting for kitchens and bathrooms. Thus, the NEC provides a very convenient, comprehensive and simple way to define those fixtures which could be targeted for higher efficiency.

Recommendation: Consider Efficiency Standards for Other Fixtures. The Commission should consider the potential for using the National Electric Code definition of required fixtures for inclusion in the lighting provisions of Title 24. Such a measure should be ear marked for future implementation, if and when, economic or market conditions change so as to make it cost effective.

Promote Commercialization of CFL Technology

California utility companies have aggressively promoted the use of screw based CFLs in both commercial buildings and residences with rebates and discount coupons. They have even given away millions of CFLs for installation in low income homes. Fixture manufacturers across the country report that a preponderance of their fixtures designed to use CFLs are sold in California. However, the penetration of CFLs still remains trivial in comparison to other lighting technologies. In 1992-4, CFLs represented 0.1% of commercial indoor lighting energy use statewide and 0.4% of residential lighting energy use. Of the 20% of homes which had any CFLs installed, they averaged only two CFLs per home. Utilization of the technology has undoubtedly increased since then, but remains far below its potential.

There are a number of significant market barriers that are preventing CFLs from achieving their market potential. These can be addressed in two general categories: negative consumer attitudes, and the need for standardization.

Screw Based vs. Pin Based CFLs. There are two basic types of CFLs, screw based and pin based. It is important to keep the differences between these two types in mind when evaluating the effect of various market barriers. Screw based CFLs come in a number of configurations and sizes, but all use the same medium-based screw-in socket of standard incandescent A-lamps. They also all have an integral ballast, either magnetic or electronic, which is part of the lamp, but is limited by the shorter life span of the phosphors in the bulb. Because the ballast must be discarded with the bulb, there is pressure to keep the ballast cost as low as possible, which has often resulted in manufacturers using poorly performing magnetic ballasts.

The screw based CFLs are intended to be retrofitted directly into fixtures designed for incandescent lamps. Consumer convenience from this ease of retrofit is seen to be one of their primary assets. Because they come in a variety of sizes and shapes, they do not, however, always fit into the fixture. And, importantly, these CFLs do not have the same photometric properties as incandescent lamps they replace, and so the light output patterns of the fixtures inevitably changes when a CFL is substituted for an incandescent.

Pin based CFLs, on the other hand, are comprised of only the glass lamp portion of the fluorescent system. A highly specialized pin-based socket connects the disposable glass lamp component to a ballast, which is typically permanently mounted to the fixture. The configuration of the pin based socket is designed to insure that mismatches of lamp and ballast characteristics cannot occur. Pin based CFLs, thus, do not have the universal retrofit convenience of the screw based CFLs, but they do have other significant advantages. The disposable pin-based lamp can be significantly less expensive than the screw-in CFL with its integral ballast. The more expensive ballast is a part of the fixture, and so the cost of a higher quality ballast is more easily justified. Furthermore, since the fixture is specifically designed to receive a particular size and configuration of CFL (and limited to receiving only that lamp by it's pin-based socket), the photometric distribution of light from the fixture is more likely to be optimized.

Consumer Attitudes. The term "fluorescent" has powerful negative connotations for most consumers, based on their past experience of fluorescent lighting in offices and utility spaces. Many have also had unsatisfactory experience with early CFL products. People have long memories for unpleasant experiences. Presented with a product that they associate with unacceptable properties--hum, flicker, poor color rendition, unpleasant light quality, insufficient light output, early failure—they are resistant to reevaluating their assessment.

Lighting retailers who were asked by our study if customers had any complaints about CFL fixtures most often cited low light output, poor color, hum and flicker as the primary complaints. However, none of these problems are inherent in the technology any longer. More advanced CFL technology has solved all of these problems. Other desirable features such as instant on and dimming are also becoming available. But, this is news for consumers, and most retailers, who have yet to see these products reach the consumer market. Information about the positive new features of CFLs is not widely available to the residential consumer.

While energy efficiency may be a social good, it is not generally the prime criterion by which people choose their lighting. Lighting has many other aspects which are more prominent—pleasant ambiance, aesthetics, sparkle, safety, security, ease of replacement, etc. CFL lighting must succeed on many levels if we are to see its energy benefits adopted in the residential sector.

Recommendation*:* Support Public Service Advertising. The CEC should support public service advertising that helps educate consumers on efficient lighting options. The Commission could help form a statewide advertising consortium which would fund general advertising that would benefit all members of the industry. For example, there are CFL ballast and fixture manufacturers whose primary market is in California, and who would benefit from a joint advertising effort. Such a public service advertising effort would best be undertaken in support of other residential lighting efficiency policies, such as the adoption of appliance standards or expanded Title 24 standards discussed elsewhere in this report.

Public service advertising can raise the importance of efficiency as a lighting selection criterion. However, efficiency and life cycle costs are not likely to ever be prime criteria for most consumers in their selection of lighting products. Thus, advertising should also focus on non-energy benefits of CFLs that may be more appealing to consumers, such as their long life or cool, safe operation.

How Many Consumers Does It Take to Change a Light Bulb? Consumers are often faced with a insurmountable challenge in simply trying to replace a compact fluorescent lamp, especially pin-based CFLs. Selecting the right lumen output and light color options and matching the base configuration, lamp configuration, and lamp wattage with the fixture shape or ballast capabilities requires an advanced knowledge of technical lighting terminology. Given the variety of options available, it is not very likely that the local hardware or office supply store will carry the right product. It is almost certain that the local grocery store, dependent on rapid turn-over of products, will not stock it. A specialty CFL would only take up shelf space while waiting for just the right customer, who then won't need another one for years. Instead, grocery stores can use the same shelf space to stock standard incandescent A-lamps as commodity items that work in 90% of all home fixtures, and that are purchased multiple times per year.

Residential consumers are not the only ones who suffer from the excessive variability of CFL products. Retail and wholesale outlets have found it prohibitive to stock a complete line of replacement lamps or ballasts. Lighting specifiers cannot get competitive bids because not enough products are "equivalent." Fixture manufacturers, with so many new products coming on line, cannot develop a line of fixtures that will achieve a stable market share and long term profitability. All these problems contribute to raising the cost of using CFLs.

Thus, we believe that, until there is more standardization of the product, compact fluorescents will not achieve widespread consumer acceptance, and will not realize the potential economies of scale available from mass production and mass marketing.

Industry Standards. Over the last decade, compact fluorescent lamps and ballasts options have multiplied and their performance characteristics have improved dramatically, however, sales of any one product have not proven a clear winner in the market place. Indeed, the pace of innovation has outpaced the capability of the lighting industry to adjust to the changes. One of the greatest concerns of the CFL fixture manufacturers interviewed was the cost of constantly re-engineering their fixtures to match new lamp technologies. Lamp-ballast incompatibility problems also caused them extensive field troubleshooting costs, raising their risks from using new lamps and generating considerable customer ill will. As a result, fixtures designed specifically for CFLs remain a premium item, with most products limited to high-end commercial applications.

The structure of the lighting manufacturing industry in the United States may contribute to this problem. There are now only three major lamp manufacturers, who compete intensely with each other to define their market share. All three operate on an international basis. There are a few dozen ballast manufacturers, some very large and established, and some very small and new. There are over 500 fixture manufacturers, who tend to be smaller businesses with a tightly defined market niche and geographic territory, and limited resources.

When a new product is announced by one of the lamp manufacturers, first the ballast manufacturers must respond by adapting their ballast technology to meet the operating requirements of the lamp. Screw-based CFL assemblers may try to market a new integral lamp/ballast combination. The dedicated CFL fixture manufacturers must respond by redesigning their fixtures to accommodate the new lamp configuration and light output pattern. Since ballasts are typically sold as part of a dedicated CFL fixture, the fixture manufactures must also procure a supply of ballasts that will function correctly with the new lamp.

Lamp manufactures often try to secure market share by making their lamp products as distinct as possible from the other manufacturers. They refer to them by very different terminology. The lamps may have different operating characteristics or base configurations. Ballasts which are created to operate a new lamp are sometimes found later to be incompatible with another manufacturer's lamp which was believed to be equivalent. Given the constant rate of change and innovation, such incompatibilities sometimes are not discovered until a consumer goes to replace the original lamps.

Recommendation: Support Industry Standardization. Industry standards that insure lamp-ballast compatibility and interchangeability of lamps will greatly assist the public and help achieve full market potential for compact fluorescent lamps. The CEC could take a leadership role in helping to identify key areas that could benefit from standardization, and in bringing diverse members of the industry together who can discuss the problems and suggest solutions. California can also strongly recommend that the federal government assist in promoting the development of standards within the lighting industry.

Other Recommendations

The final report of the project included additional recommendations for supporting lighting education and needs for research in lighting energy use that there is not room to discuss here. These recommendations were considered to be necessary measures to support the success of the policy initiatives discussed above. A full discussion of education and research priorities is found in the final Recommendations Report of the project. (Heschong Mahone Group, 1997, Vol IV) .

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