2.15 Summarize current state of the art for each component evaluated above. Elucidate the technical and market barriers for each with an overall synopsis of potential opportunities. Develop a peer review group consisting of industry leaders and authorities.

The LRC summarized the technologies, barriers and potential opportunities in a white paper, shown below. The LRC also sent a letter to Ron Lewis at DOE suggesting names of possible participants in the peer review group.

Preliminary discussion and recommendations for overcoming barriers to lighting controls in commercial/industrial applications using fluorescent systems in the United States

Introduction

The goals of this project are to identify barriers to the penetration of lighting controls into commercial/industrial (C/I) applications that employ fluorescent lamp technologies, and to recommend means for overcoming those barriers. Preliminary recommendations have been developed after discussions with various stakeholders and examinations of published research and patents. Subsequent efforts over the next two years will refine, improve and validate the preliminary recommendations presented here.

There are four categories of barriers that have been identified that include several barriers within each category: lamp–ballast compatibility, component compatibility, installation/commissioning assurance, and marketing. Penetration of lighting controls for fluorescent systems into C/I applications will not be simple or rapid. Indeed, to reach significant penetration into the market a cultural change will have to occur in the lighting industry. This cultural change can be characterized as developing effective communications among all stakeholders in electric energy efficiency and load management, particularly those charged with the responsibility of establishing rational social policies for power generation and transmission.

I. Lamp - ballast compatibility

Static, on-off fluorescent lighting systems are the most common technology used in C/I applications. This technology evolved over the middle of the 20th century to become the commodity lighting system because it was more energy efficient and required less maintenance than incandescent technologies. Compatibility among different lamp and ballast manufacturers was another attractive feature of fluorescent systems prior to the 1980s. Virtually any fluorescent lamp could be operated with virtually any magnetic ballast to achieve the same operating performance and life prior to this time.

As a consequence of the energy crisis of the 1970s, significant improvements in the efficacy of fluorescent systems were achieved in the last two decades of the 20th century. The physical properties of fluorescent lamps and ballasts were continually optimized during this era to improve not only efficacy, but also to give them smaller size, better maintenance (lumen depreciation and life), lower mercury content, and higher visual quality (better color rendering and reduced flicker). This evolving sophistication has led to higher and higher expectations of fluorescent system performance in terms of energy efficiency, maintenance, visual satisfaction and, of course, low cost. One down side of this sophistication, however, has been the proliferation of products that provide poor system reliability. Lamps operated on ballasts that do not have optimized starting and operating electrical properties for those lamps will fail prematurely, leading to dissatisfaction among specifiers, owners, and facility managers. This was a common situation in the 1980s and early 1990s as the electronic ballast manufacturers learned how to operate lamps produced by the “big three” global manufacturers: GE, Philips and OSRAM. Today, there are still stories of poor performance, but those days are essentially over for static, on-off fluorescent systems, largely because the global manufacturers have taken control of the specifications for ballasts that operate their lamps. This fairly modest but important step reflects the fact that modern fluorescent lamps and ballasts are two parts of the same system.

The confidence levels among specifiers, owners, and facility managers for dimming electronic ballasts are not nearly as high as they are for static, on-off fluorescent systems. Anecdotal reports from the field suggest that lamps are failing prematurely when operated on dimming electronic ballasts. Manufacturers have discussed new requirements for lamp seasoning among the, but consensus standards cannot be obtained because the operating characteristics of fluorescent dimming systems are not defined. Presently, a specifier or building facility manager must simply trust the company representative to obtain a reliable fluorescent dimming system. It is important to note that the global manufacturers of lamps and ballasts do not fully understand the basic physics involved in operating fluorescent lamps under dimmed conditions. Coupled with an emphasis on low mercury lamps, there is much more to be understood about fluorescent dimming systems than is currently known.

Poor reliability of fluorescent dimming systems, real or imagined, is a significant barrier to the penetration of dimming controls into C/I applications, and one that is not being presently addressed by any of the controls manufacturers. This is a problem for control manufacturers because the controls may properly communicate with the ballast, but the ballast may not reliably start and operate the lamp, leading to premature failure or inconsistent operation. An owner or facility manager really won’t understand *why* the system failed, but he/she will swear never do that again!

The global manufacturers are beginning to understand reliable operation of lamps on dimming ballasts, but progress is slow because of low market demand for dimming ballasts. Thus, there is a “Catch 22”; poor demand retards development and retarded development leads to poor demand. Nevertheless, there is some reason for optimism because all three global manufacturers are now taking responsibility for both the lamp and the ballast. And whereas there may not be a complete understanding of the underlying physics in operating lamps under dimmed conditions, it seems likely that the major manufacturers will eventually produce dimming ballasts that work well, if not perfectly, with any commodity fluorescent lamp. If market demand for dimming increased substantially, it seems very likely that reliable fluorescent dimming systems would be produced more quickly. But, again, without that demand, there is little reason to expect commodity fluorescent dimming systems to work reliably in the near future.

II. Component compatibility

One barrier that is being effectively addressed by the control manufacturers is the issue of interoperability of control components. On a local level, interoperability means attaining communication to control the ballast. More globally, interoperability concerns communication between individual control devices and, at a higher level, with whole building automation systems (BAS). Lighting controls manufacturers are working successfully to develop products that conform to open communication and command protocols (rather than proprietary systems) for all of the control technologies peripheral to the ballast. Several protocols are being discussed and it seems likely that standards will continue to be developed and refined in the next two years that will facilitate utilization of control components in larger systems.

Most lighting control manufacturers offer one or more product types that conform to the popular communications protocols and can be integrated into BASs. LONworks and BACnet have the most support from the lighting controls manufacturers. Devices range from protocol translators to control devices fitted to support the protocol directly. Proprietary protocols from Johnson Controls, Honeywell and Modicon are also supported by the lighting controls manufacturers, but to a lesser extent. At the physical communication level of many of these protocols is the Ethernet protocol. The widespread use and success of Ethernet for computer local area networks (LANs) has undoubtedly aided in establishing Ethernet for building process controls and has helped to lower the cost of hardware components. Other, higher-level communication network protocols from the computer industry are being used and reconfigured for BASs. For example, Microsoft's OPC (Object Linking and Embedding for Process Control) protocol is based on Microsoft's earlier and successful OLE network protocol and it leverages the previously established and widely accepted Windows client/server technology. A review of product literature and advertisements in trade magazines reveals lighting control products offering Internet connectivity, web browser interfaces, and remote monitoring technologies. Therefore, it is evident that controls manufacturers are quick to incorporate the latest crossover technology from the computer industry into their product offerings.

There have also been some recent advances at the more local level of control between individual control devices and fluorescent lamp ballasts, although progress here seems slower than for the higher-level network controls. Direct digital control (DDC) was introduced to the controls industry about 25 years ago and has greatly improved the performance and functionality of building systems. Digital controls operate security, HVAC, fire alarm, and many other specialty systems in modern buildings, yet only in the last year or so has any direct digital control ballast been available on the US market. The lack of a robust and reliable control method with fluorescent lamp ballasts can partly explain why lighting systems are not routinely connected to building energy management systems, except at the electrical panel for simple, on/off control of large areas. Currently, however, there is much activity in the lighting industry regarding digital control interface protocols for fluorescent lamp ballasts. The ESI Superdim DDC protocol and ballast is presently the only system available in the US market that offers one-way communication with ballasts for both on/off and dimming control. The market share of ESI ballasts, however, is very small. DALI is a current protocol used in Europe that has recently been accepted as an ANSI standard. Although no products that incorporate DALI yet exist on the US market, the major fluorescent lamp and ballast manufacturers have shown support for incorporating the standard protocol in future products, and the leading ballast manufacturer in Europe, Tridonic, has plans to begin marketing a DALI-equipped ballast in the US.

DDCs for ballasts will offer many advantages over the existing hardware available for lighting control by providing reliable, consistent control and simplified installation. More importantly, a uniform implementation of a protocol based on a widely accepted standard can increase market penetration of control technologies by raising people's confidence in using products that bear a seal of conformity. A widely accepted dimming control protocol such as DALI could serve these purposes.

One significant problem, however, is that these controls manufacturers are not effectively discussing the issues of controls outside their own community. There is no discussion with the ballast manufacturers on reliable operation of fluorescent lamps and ballasts. There is little if any discussion with installers, and, as will be emphasized later, there is no discussion with utilities and government agencies charged with the responsibility of providing reliable electric power to the public. *Without these discussions, there will be little demand for control systems no matter how robust the controls protocols.* Effective interaction with all stakeholders, particularly with the utility industry and related government agencies, is essential to creating market demand and thus overcoming the major barrier to the penetration of fluorescent lighting controls into C/I applications.

III. Installation/commissioning assurance

The ability to install and commission controls ranges from very good to nonexistent. The reliable installation of on-off controls into C/I applications is simple and can be accomplished easily by trained technicians. Time controls, occupancy sensors, and manual switching are reliable and easy to install. There is not, however, significant market demand for on-off lighting controls beyond simple switches in C/I applications. This barrier will be discussed in the next section.

Dimming systems, however, are both expensive to acquire and difficult to install. Commissioning photosensors is prohibitively time-consuming and, consequently, photosensors are almost never installed. Recent development by the Lighting Research Center of a simplified-commissioning photosensor to take advantage of daylight may, however, overcome this barrier.

Even if this photosensor technology becomes commercially available, there are still nagging small barriers to installing and commissioning lighting controls, particularly dimming systems. These barriers include wiring uncertainty, identification and zoning issues for groups of ballasts, the need for manual overrides, and the training of installation personnel.

As mentioned previously, DDC ballasts are essentially non-existent in the United States. Therefore, the only options today for dimming control are either a 0-10V analog control interface or a line voltage phase-chop signal interface, neither of which conform to any open standards. 0-10V control is by far the most common for dimming ballasts. At first glance, the 0-10V control appears to follow the newly introduced standard for 0-10V control in the entertainment industry (ANSI E1.3-2000). Closer inspection reveals, however, that the 0-10V control used with fluorescent lamp ballasts in C/I applications differs significantly from the entertainment industry standard. In fact, the ANSI E1.3 standard draws attention to this point.

Even if dimming fluorescent lamp ballasts did conform to this particular standard, problems would remain. One problem is that the standard does not detail the functional relationship between the control signal level and the light output level of the ballast. Therefore, a consistent dimming level across different ballast types is not assured. For example, a 5V signal from one ballast manufacturer may result in a 30% dim level, while that same 5V signal may result in a 50% dim level for another manufacturer's ballast. Controls must be field-calibrated to work consistently in many cases, and mixing ballasts from different manufacturers under the same controller will likely result in different light levels.

Perhaps a bigger problem with the 0-10V-control scheme as implemented in ballasts today is the lack of application guidelines that result in poor field performance. These problems arise from the fact that 0-10V signals are susceptible to electrical interference, yet little or no information is given to installers concerning proper cabling practices. Examples of wiring installation practices that lead to performance problems include lamp flickering, lamp brightness striations, and lamp extinguishing at low dim levels. These problems are the result of running the control wires in close proximity to power lines and/or lamp leads, excessive control wire lengths, and reversing polarity of one or more control wires when operated on parallel circuits. The wide skepticism among lighting specifiers about fluorescent dimming systems could be reduced by educating installers about the special wiring requirements for dimming ballasts, providing clear and readily available literature on system installation, and improving product design to eliminate these field problems.

In addition to hardware and wiring problems, there are logistical problems when installing and commissioning large installations with dimming ballasts. For conventional analog input ballasts, the task of zoning must be done when the ballasts are installed. In other words, the zoning is “hard-wired” for the life of the lighting system. This makes the zoning difficult to change should the space be renovated or used for a different purpose. For the newer DDC ballasts appearing on the market, zoning is done after installation as part of the commissioning process. This makes re-zoning much easier as the space functions change, but zoning is still a laborious task because each ballast location must be manually identified to the controller. While different communication protocols offer different methods of assigning addresses, all methods involve time-consuming human interactions that increase cost as well as the potential for problems.

Finally, attention must be paid to insure that all systems are equipped with manual overrides for unpredictable events. Occupants want to have control over their lighting during unusual work schedules or events. However, engineers and facility managers seem hestitant to provide manual overrides, because it is assumed that people will use them too often and energy savings will be lost. In general, and as discussed below, automatic controls should be used to turn lights off when no one occupies the space. Manual controls should be used to turn lights on when the space is occupied. These principles consistently meet the demands for occupant satisfaction and energy savings. Automatic dimming during occupancy is still an area of uncertainty, because no principles have been established for occupant acceptance of the amount of dimming and the rate of dimming. This uncertainty further undermines the confidence of engineers and facility managers in dimming systems, but could be addressed with a program of human factors research.

IV. Marketing

First cost remains a barrier for lighting controls. Often the person or department that pays for the installation of lighting equipment does not receive the benefit from the reduced electrical bills. Also, in existing buildings, managers do not want the “hassle factor” of implementing a change. First cost and hassle factor have been overcome for other energy-efficient lighting technologies with demand-side management (DSM) incentive programs, market transformation program procurement, shared-savings marketing by energy service companies (ESCOs), and new code requirements. Combinations of these approaches increase market demand for energy-efficient lighting products, leading to lower product cost and market transformation. Products such as T8 lamps, electronic ballasts, and LED exit signs are examples of successful lighting market transformations. Lighting controls, however, have yet to benefit substantially from these market forces because of the difficulty in predicting the energy savings resulting from control use.

DSM program developers and evaluators, code developers, and ESCOs do not have adequate information to predict expected savings by control measures. They need to know, for example, when and for how long the control switches off or dims the lights. There are case study examples, but robust, statistically significant control use factors need to be developed that will afford the program developers confidence that a specific control installation will deliver a specific energy savings. With this confidence, controls will more likely find their way into lighting incentive programs, code provisions, and ESCO strategies.

The lighting industry is a fragmented collection of component manufacturers. No sector of the lighting community, private, public, or non-profit, is the recognized champion for lighting. Each agency works very hard to communicate the value of its own product or service. However, that communication is most often to other lighting component agents. Consequently, the lighting industry members do not and cannot communicate the value of lighting to specific markets such as auto manufacturers, health care professionals, sports and recreation, community development, etc. Remarkably, the industry remains largely uneducated about the perceived value of lighting to these sectors, focusing on market share in traditional markets rather than growing new markets. This is a significant cultural barrier to the penetration of fluorescent lighting controls into the C/I market.

In particular, lighting controls manufacturers fail to communicate the value of lighting of their products. The lighting controls manufacturers are insulated not only from the public, but also from other sectors of the lighting industry (e.g., lamp and ballast manufacturers) and from specifiers. Lutron is one notable exception. They have established themselves not as a component or even system manufacturer, but, rather, they have successfully reached the specification community by providing assurances that their lighting controls will work and will deliver value to their customers. The majority of the lighting controls manufacturers remain focused on components, which drives down price. With little profit, there is little innovation or marketing. Consequently, there has been little penetration of lighting controls into the C/I market.

The overwhelming sentiment among the installers of controls technologies, other than those produced by Lutron, is that they can make controls work, but there is no market demand. They believe that some agency needs to repeatedly and effectively communicate the value of lighting controls to building owners and facility managers. This sentiment is essentially correct, but misses perhaps the largest opportunity for fluorescent lighting controls, both static and dimming.

To understand this potential, one must first ask the basic question: “What is the value of lighting controls?” Lutron has identified a need for lighting controls in multi-use spaces, particularly conference rooms, and fulfilled it in the marketplace. There is indeed a real need for controls in these spaces. Often the conference room is a space designed to create a positive impression with customers and clients and perhaps, dynamic lighting during a meeting, meal or formal presentation. Most often AV needs in a conference or meeting room require multiple lighting levels. Lutron has focused on this market and has established a reputation for reliable solutions, albeit at a cost well in excess of the components involved.

There seems to be little or no need, however, for multiple lighting scenarios in the largest C/I spaces, private and open-plan work areas. Tasks performed by office workers do not demand sophisticated lighting controls, with one clear exception: control of sunlight and, to a lesser extent, daylight. A recent study of private offices showed that workers rarely used dimmers on a regular basis, although the majority of workers did prefer to set electric light levels in daylight spaces below those found in interior offices (approx. 500 lx). Thus, even though building occupants may perceive individual lighting control to be of some value, that perception is not a major driver for widespread implementation of control technologies.

The main driver for lighting controls is most often assumed to be energy savings. However, there is always the concern that controls may compromise the productivity of the workers in controlled spaces. Common wisdom for saving energy, therefore, requires turning lights off when the space is unoccupied. Certainly, on-off strategies such as time clocks, occupancy sensors, and even manual switching are effective and commonly employed strategies for saving energy. Indeed, there is no technical barrier to implementing these tried-and-true techniques except establishing awareness on the part of owners considering a lighting retrofit or renovation. Again, the installers of lighting controls identified this failure to communicate the value of (static) lighting controls to the important sectors of the building industry as the major barrier to their penetration into the C/I market.

To ensure against disappointment in this communication of the value of lighting controls, however, there are some important principles to be considered for simple on-off strategies that have emerged from research into lighting controls. First, the goal of static controls is to turn lights off when no one is in the space. This strategy cannot annoy the occupant or compromise the worker's productivity in the space because the space is unoccupied. Because no technology is completely foolproof, however, it is essential that there be a local, manual override to any automatic strategy to turn the light "off." For example, if a worker is working late one evening and the automatic time clock initiates an "off" command, the worker must be able to manually override the automatic command in the work space and in areas needed for exiting the work space. Again, these simple principles and the technologies for achieving energy savings are well established; there are no technical or human barriers to turning the lights off in unoccupied spaces to achieve energy savings. There is simply "a failure to communicate" that *static, on-off lighting control technologies that turn lights off in unoccupied spaces are reliable and cost effective.*

It is much more difficult; however, to garner energy savings in occupied spaces. People do not like lights to go on or off unpredictably. Although some pilot data are available, little is known about the acceptance of automatic dimming in occupied spaces. There are limits to the amount of dimming and the rate of dimming that occupants will accept, but again, no guiding principles have been established. A program of human factors research could provide valuable information.

Daylight dimming is the most obvious strategy for dimming in occupied spaces. Ideally, the natural light offsets electric light to save energy and the dimming goes largely unnoticed by the occupant. However, daylight dimming represents several significant barriers to energy savings. Most notably, it is difficult or impossible to commission commercially available photocells. Recent research and development at the Lighting Research Center offers some promise for a simplified-commissioning technology. Nevertheless, the energy saved by photocells is limited largely to windowed spaces, and these spaces represent only about 20% of the commercial building stock. The amount of energy saved by dimming electric lighting in daylit spaces is also small. One study suggests that the incremental energy savings from dimming over simple switching in daylit spaces may be only 10%. Further, the level of dimming is not usually proportional to the amount of power reduction in the lighting system. Rapid-start fluorescent lighting systems are usually employed with dimming systems because filament heat must be provided to the lamp during operation. Thus, the ballast continues to use some fixed amount of power at every level of dimming. Finally, the price of electricity is a barrier to energy savings. Electric energy is inexpensive relative to the incremental cost of dimming ballasts. Presently, dimming ballasts cost 100% more than static ballasts. All of these economic factors lead to a very long return on investment (ROI) for daylight dimming, usually more than a decade. Other strategies such as lumen depreciation and manual dimming for energy savings are also cost-prohibitive, again, not just in terms of first costs but also in terms of commissioning costs. Finally, the effects of dimming on lamp life are not, as yet, well understood by the lamp-ballast manufacturers. Anecdotal reports of premature lamp failures and other problems such as flicker and brightness striations permeate the industry and create a perception of high risk for fluorescent dimming systems.

These issues paint a very bleak picture for fluorescent dimming systems. There is little perceived value of dimming by the occupants, and there is no cost incentive for widespread investment. The simple conclusion is that the barriers are too high to be overcome to have a significant effect on energy efficiency. However, there is an important angle that has not been addressed by the lighting industry, reflecting again their insular behavior. Some states and regions in the United States are struggling to meet the growing demand for electric power at traditionally low prices. Utilities must build power capacity for peak demand, not for average demand. In California for example, peak demand coupled with inadequate supply and price caps for exceedingly high energy costs have led to sporadic blackouts and high wholesale energy costs. Dimming fluorescent systems used in conjunction with utility communication systems offer a potentially valuable means of keeping businesses operating during periods of peak demand while maintaining relatively low energy prices and, most significantly, while avoiding construction of new power plants and transmission corridors.

Central to understanding the potential value of dimming systems is an examination of the real costs of electric energy. The cost of electric energy usage for lighting can be measured in several ways, and each measurement differentially affects the value, or potential value, of lighting controls. To understand the value of lighting controls, it is necessary to delineate the costs and the benefits for all of the stakeholders when maximizing the use of electric energy with lighting controls.

The most obvious measure is the cost of the electricity used to operate the lighting system. The cost of electricity is measured in $/kWh. Depending upon the retail power supplier and the type of C/I customer, this rate will typically vary between $0.06/kWh and $0.12/kWh. Both the amount of power needed to operate the lighting and the time the lights are operated will affect the annual cost of operating the lighting. Static, on-off lighting controls can reduce both the time of operation and the number of systems operating. Dimming (step or continuous) controls can reduce the power required to operate the lighting system.

Another common measure is based upon the building peak energy use during a billing period. These peak demand charges are presently used to support the cost of installing and maintaining power infrastructure to the C/I customer. Before deregulation of the utility industry, peak demand charges also included the cost of generating and supplying power during peak periods of operation, but this is no longer the case. Static, on-off lighting controls can reduce peak demand by turning off unnecessary lighting. Dimming controls can reduce power demand without turning the lights completely off.

Both of these measurements are in place in most C/I applications and are reasonably well understood by all stakeholders when performing economic analyses. Depending on the cost of energy and peak demand, reflected in the utility billing structure, the C/I customer will or will not select lighting controls for installation. It is fair to say, however, that these measures have not been major drivers to the penetration of lighting controls into C/I applications. Less than 2% of C/I applications have more than simple manual switching for lighting control.

Although the cost of electric energy and peak demand are important, these are not the only measures that can affect the value of lighting controls. The cost of purchasing power can vary throughout the day and throughout the year. The cost of power is strictly a matter of supply and demand. As demand increases and base load is exhausted, the cost of adding additional electric power increases, sometimes exponentially. It has been estimated by the New York State Public Service Commission that during the hottest day of the year 2000, the last 100MW of power demanded in NYC cost ratepayers $100M. This is $1/W! If that peak demand for power could be reduced or if the real cost of using power during the peak was passed on to the customers that use it, the yearly average energy-use rate paid to electric utilities by C/I customers could be significantly reduced. Unfortunately, this is not the case, because there is no strong incentive to customers to eliminate wasteful energy use during peak periods of system demand. Moreover, as wasted lighting energy increases, the need for additional power generation increases to meet the ever-growing peak demand. To pay for this added capacity, the average electricity rates increase, creating increased operating costs for all C/I customers and a net economic downturn. Lighting controls offer a significant potential benefit to ratepayers, and to the economy, if two things occur. First, the peak system demand must be reduced reliably and predictably. Second, customers demanding power during peak periods should actually pay for the added costs of supplying that power, either in the bidding process or for construction of new power-plants.

It is not necessarily obvious, however, how guaranteed peak load reductions could be obtained in C/I applications. Certainly no employer would want to turn off computers, copiers, or even lights in most spaces. Few would want to increase ambient temperatures in air-conditioned spaces during hot summer days when peak demand is greatest. However, it is possible to dim the lighting in these spaces without significantly compromising the productivity of employees. In fact, no other technology that depends upon electricity is so readily amenable to load reductions. Not only will people accept some dimming, the technology for dimming is largely in place. Moreover, utility real-time pricing communication systems have been developed and are already being used in some applications. Neither the dimming nor the communication systems have been optimized and integrated.

Table 1 provides several dimming fluorescent lighting control scenarios using current pricing structures for electric energy and power demand, together with the value of avoiding expensive power and costs of adding new generating capacity. For example, consider a New York City office with luminaires containing two 32-watt lamps that are dimmed by 30% during peak demand. The price of energy is \$0.10/kWh and demand charges are \$18.00/kW/month. Demand charge savings would be \$4.08 per year and energy savings are \$1.62 per year for that dimmed luminaire, plus the value of the system demand reduction is \$1.81. If the lamps are operated 50 hours a week and are dimmed 33% of this time, the ten-year present value of a load-shedding ballast would be \$55.34. The cost of a dimming electronic ballast is currently between \$50.00 and \$60.00, while a static electronic ballast is about \$20.00. Thus, the incremental cost of a dimming electronic ballast is between \$30.00 and \$40.00. In this example the payback for dimming electronic ballasts is at least five years. It is important to note, however, that the estimated incremental cost to manufacturers for producing a load-shedding electronic ballast that would dim to just 30% is currently between \$0 and \$10. This would significantly shorten payback periods to between six months and two years.

Table 1 shows that there is a value to ratepayers for *not* using electric energy for lighting. Presently, however, there are several barriers to capturing that value. First, the cost of dimming is prohibitive for several reasons. The first cost for all load-shedding control technologies is high, especially for fluorescent dimming systems. Architectural dimming ballasts cost 100% more (or higher) than static, on-off ballasts. Installation and commissioning costs are also quite high, as is the perceived increased risk for poor performance due to lamp-ballast compatibility. Second, presently there is no infrastructure (hardware and software) that guarantees load shedding from lighting controls when it is needed. In the late 1980s, guaranteed energy savings were ensured through utility rebate programs that removed less efficient (T12/magnetic ballast) lighting systems for more efficient (T8/electronic ballast) lighting systems. Without guaranteed savings from lighting controls, there is little chance for significant market penetration of lighting controls systems. New communication technologies need to be developed and coordinated with dimming fluorescent lighting systems. Third, the people who would pay for technologies that garner energy savings and load reduction are often not the ones who would benefit from those investments. High demand during peak hours is averaged over all ratepayers, rather than assigned to those who actually create the high demand. New methods of billing, such as real-time pricing, need to be implemented before there is a significant cost incentive for load reduction and energy savings. Fourth, utility rate structures only pay for load offset from current generation and transmission, not for the potential for new power plant and transmission corridor planning and construction. The US Department of Energy's Annual Energy Outlook forecasts the need for at least 1300 new power plants nationwide by 2020, about half of which could be avoided by increased energy efficiency. Yet there is no way to capture the value of lighting controls when offsetting construction of new power generation and transmission systems.

Clearly then, a combination of technical and policy barriers must be overcome before the value of lighting controls can be captured.

Table1: Dimming fluorescent lighting control scenarios for electric energy and power demand

											10 year present value	*10 year present value*	*10 year present value*	*10 year present value*
measure	Power	occupancy	dim on demand	measure penetration	***measure savings***	energy rate	demand charge	demand savings	energy savings	turn off when needed	energy savings PV	demand savings PV	turn off when needed	total 10 year PV/6%int
2 lamp/ 20% dimming	**63**	**50**	**20**	**33**	**12.6**	**0.10**	**18.00**	**2.72**	**1.08**	**1.21**	**7.96**	**20.03**	**8.90**	**36.89**
2 lamp/ 20% dimming	**63**	**50**	**20**	**33**	**12.6**	**0.10**	**13.00**	**1.97**	**1.08**	**1.21**	**7.96**	**14.47**	**8.90**	**31.33**
3 lamp/ 20% dimming	**93**	**50**	**20**	**33**	**18.6**	**0.10**	**18.00**	**4.02**	**1.60**	**1.79**	**11.75**	**29.57**	**13.14**	**54.46**
3 lamp/ 20% dimming	**93**	**50**	**20**	**33**	**18.6**	**0.10**	**13.00**	**2.90**	**1.60**	**1.79**	**11.75**	**21.36**	**13.14**	**46.24**
2 lamp/ 30% dimming	**63**	**50**	**30**	**33**	**18.9**	**0.10**	**18.00**	**4.08**	**1.62**	**1.81**	**11.94**	**30.05**	**13.35**	**55.34**
3 lamp/ 50% dimming	**93**	**50**	**50**	**33**	**46.5**	**0.10**	**18.00**	**10.04**	**3.99**	**4.46**	**29.36**	**73.92**	**32.86**	**136.14**
2 lamp/ 20% dimming	**63**	**50**	**20**	**33**	**12.6**	**0.08**	**18.00**	**2.72**	**0.86**	**1.21**	**6.37**	**20.03**	**8.90**	**35.30**
2 lamp/ 20% dimming	**63**	**50**	**20**	**33**	**12.6**	**0.08**	**13.00**	**1.97**	**0.86**	**1.21**	**6.37**	**14.47**	**8.90**	**29.73**
3 lamp/ 20% dimming	**93**	**50**	**20**	**33**	**18.6**	**0.08**	**18.00**	**4.02**	**1.28**	**1.79**	**9.40**	**29.57**	**13.14**	**52.11**
3 lamp/ 20% dimming	**93**	**50**	**20**	**33**	**18.6**	**0.08**	**13.00**	**2.90**	**1.28**	**1.79**	**9.40**	**21.36**	**13.14**	**43.89**
2 lamp/ 30% dimming	**63**	**50**	**30**	**33**	**18.9**	**0.08**	**18.00**	**4.08**	**1.30**	**1.81**	**9.55**	**30.05**	**13.35**	**52.95**
3 lamp/ 50% dimming	**93**	**50**	**50**	**33**	**46.5**	**0.08**	**18.00**	**10.04**	**3.19**	**4.46**	**23.49**	**73.92**	**32.86**	**130.27**
2 lamp/ 20% dimming	**63**	**50**	**20**	**33**	**12.6**	**0.12**	**18.00**	**2.72**	**1.30**	**1.21**	**9.55**	**20.03**	**8.90**	**38.48**
2 lamp/ 20% dimming	**63**	**50**	**20**	**33**	**12.6**	**0.12**	**13.00**	**1.97**	**1.30**	**1.21**	**9.55**	**14.47**	**8.90**	**32.92**
3 lamp/ 20% dimming	**93**	**50**	**20**	**33**	**18.6**	**0.12**	**18.00**	**4.02**	**1.92**	**1.79**	**14.09**	**29.57**	**13.14**	**56.81**
3 lamp/ 20% dimming	**93**	**50**	**20**	**33**	**18.6**	**0.12**	**13.00**	**2.90**	**1.92**	**1.79**	**14.09**	**21.36**	**13.14**	**48.59**
2 lamp/ 30% dimming	**63**	**50**	**30**	**33**	**18.9**	**0.12**	**18.00**	**4.08**	**1.95**	**1.81**	**14.32**	**30.05**	**13.35**	**57.72**
3 lamp/ 50% dimming	**93**	**50**	**50**	**33**	**46.5**	**0.12**	**18.00**	**10.04**	**4.79**	**4.46**	**35.24**	**73.92**	**32.86**	**142.02**

Assumptions: controls reduce demand at times of peak demand of both the building and the system.
Assumption: $8/kW/mo given to shed load when needed to offset new plant construction and current power at expensive rates.

V. Preliminary Recommendations

The following recommendations are ordered in terms of the relative effort needed to overcome identified barriers to the penetration of lighting controls into C/I markets. The first two recommendations are focused on existing, on-off lighting controls that have been demonstrated to be cost effective and reliable. These two recommendations can be implemented immediately. The remaining recommendations represent significant investment of resources to support widespread penetration of fluorescent dimming systems. As noted in this document, there are many significant barriers to the use of dimming fluorescent systems in C/I applications. These barriers will not be overcome using traditional economic models, and should not be attempted without a much stronger financial incentive. A new economic model that incorporates the cost to society for building new power generation infrastructure does offer a realistic financial foundation for overcoming the barriers to fluorescent dimming systems.

1. Support data collection that provides fixed numbers for expected energy savings and load reductions for various static on-off lighting control technologies in various applications.

2. Support programs that overcome the inertia to first costs to static on-off lighting controls, working with building owners, professional societies, code developers, ESCOs, and conservation program developers.

3. Support functional and substantive means of communication among lamp-ballast manufacturers, controls manufacturers, controls installers, building automation system manufacturers, utilities, and government agencies charged with maintaining public benefit. The economics of load management needs to be widely understood by all stakeholders in lighting controls. The first task would be to identify key decision-makers in these different sectors, and then to provide incentives for those disparate groups to cooperatively work together. These incentives could be in the form of demonstration projects specifically designed to cooperatively link the key sectors. Incentives could also include support for cooperative technology development. In particular, two development projects are immediately envisioned:

   3a. Develop an inexpensive, highly efficacious dimming ballast that responds to load-shed signals from the utility.

   3b. Support development of open communications systems that link utility need for shedding load to building fluorescent dimming systems. This implies a standard ballast-utility interface for load shedding.

4. Support a human factors research program that establishes the principles for dimming levels and dimming rates in occupied spaces.

5. Develop a long-term labeling and testing program that provides assurances to all stakeholders that (a) the dimming ballast reliably operates the lamp under all conditions, (b) all control system components work reliably together, (c) installation and commissioning of dimming systems are reliable, (d) articulates the value of lighting controls for energy and cost savings that reflect their social value by ensuring an inexpensive and reliable supply of electrical power.