

**LIGHTING CONTROLS:  
WHERE ARE WE AND WHERE ARE WE GOING**



**Presentation to:  
Association of Energy Service Professionals International  
14<sup>th</sup> National Energy Services Conference and Exposition  
December 9, 2003**

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## **LIGHTING CONTROLS: WHERE ARE WE AND WHERE ARE WE GOING**

### **INTRODUCTION**

The Lighting Research Center (LRC) is part of Rensselaer Polytechnic Institute and is the world leader in university based lighting research. With funding from the U.S. Department of Energy, the LRC has conducted extensive research on the use and barriers of lighting controls. This paper limits its discussions to lighting controls, current and future, used in non-residential applications and for fluorescent lighting systems.

Successful market transfer and technology acceptance occur through a process that recognizes the roles of key market players and the market enabling mechanisms that are in play with each new technology. The LRC has developed a technology transfer model for lighting controls to help it understand where a lighting technology is currently in the process of market acceptance and who the key players are to move the technology to full customer use. For example, motion sensors have achieved technological acceptance and their energy savings provide users with positive economic outcomes if properly employed. However, the specification and installation of occupancy sensors still needs to be explained to achieve full market acceptance. The solution is education for specifiers and installers, or what the technology transfer model calls *doers*.

This paper discusses two commercialized lighting controls, motion sensors and photo sensors for dimming fluorescent lights in the presence of daylight. An emerging lighting control technology will also be discussed; Digital Addressable Lighting Interface (DALI) which is beginning to be commercialized. Lighting ballast and control manufacturers believe it's the next big breakthrough since the introduction of electronic ballasts. The question is, do customers see this as something they want or are willing to pay a premium price. The last technology discussed is one in the developmental stages. Load management, distributed resources or whatever the latest buzz word is will play a major role meeting the needs of peak electric demands in both regulated and deregulated electric markets. Therefore, a cost effective load shedding ballast is being developed.

### **MARKET RESEARCH**

Understanding what customers need and want is an important first step in developing new lighting control technologies. The Lighting Research Center, as part of its research contracts, has conducted a series of focus groups and surveys to understand the market and, thereby, direct technology development. Too many organizations rush to the technology development stage without due consideration of what the customer wants. This leads to product failures in the marketplace because the technology is too complicated, does not provide an economic return or its features are not wanted. The lighting industry sometimes suffers from the lack of giving the customer what he/she wants.

## ***Primary Market Research Findings***

There is consistency among all surveys conducted by the LRC on the basic needs of customers.

- Above all else, customers want a reasonable return on any investment they make regarding lighting or any other energy efficiency improvement.
- The technology must be easy to install, operate and maintain. Customers do not want to have to employ specially trained personnel to make the technology work properly.
- Customers want products to be fully developed and tested prior to entering the marketplace. They do not want the manufacturer to find it necessary to further modify the technology after it has been installed.
- Customers want substantiated proof of any technology or economic claim. Customers want to know/see that the technology has been successfully employed by others (the well known first to be second syndrome).

While these findings are pretty much intuitive and common sense, they seem to get lost when a technology is being developed. Yet, these findings can explain lighting technology acceptance or rejection within the marketplace.

For example, the electronic ballast became widely accepted because it satisfied all of the customer needs. It is very cost effective. The technology can be installed by most electrical contractors without any special skills. It operates without additional human intervention. While electronic ballasts had some technological problems after their market introduction, they were easily corrected. Today electronic ballasts make up the majority of ballast sales.

Conversely, photo sensors for dimming fluorescent lighting have not made inroads in the marketplace because of the high cost of the dimming ballast, the complexity in correctly commissioning the photo sensor, the horror stories that persist in their continued use and lack of substantiated proof of their benefits.

## ***Daylight Dividends Market Research***

Market research conducted for the LRC and its sponsoring organizations for a program in daylighting called “Daylight Dividends” revealed the following<sup>1</sup>: For the full report of the market research findings and much more information on daylighting, please review the Daylight Dividends website at [www.daylightdividends.org](http://www.daylightdividends.org).

- Building designers and owners/developers have a positive attitude toward building design which makes widespread use of natural light.
- The final decision about using daylighting and its associated lighting controls is a financial decision made by building owners/developers.
- Building designers and owners/developers indicated the major benefits of daylighting are the occupants of the building feeling better/more comfortable, reduced energy consumption, increased employee productivity, improved building appearance/aesthetics and increased marketability of the building to tenants or buyers.
- The greatest barrier to the expanded use of daylight is the capital costs involved; the second largest hurdle was problems with technologies including lighting controls.

- Building designers and owners/developers said they most often get their information about daylighting from industry publications. Other sources included seminars, web sites, sales people/vendors, case studies and trade shows.

## ***Load Management Market Research***

The LRC conducted a market research effort to understand customer needs regarding using lighting controls to reduce peak electric demand. This project was conducted as part of the development of a cost effective load shedding ballast for fluorescent lighting. The project is funded by the California Energy Commission. Results revealed<sup>2</sup>:

- To attract business customers to load management programs, the cost to participate must be in line with the customer benefits.
- Lighting is an excellent load to control because there is so much of it and there is little impact on building occupants or operations if controlled properly. Lighting also provides a predictable amount of load control.
- An ideal lighting control scheme must allow the lights to be dimmed from a single location and must be easy to use.
- Load-shedding ballasts must be cost effective and be easy to install.
- Other important, required characteristics of load-shedding ballasts are: minimal impact on lamp life with no impact on the manufacturer's warranty; a "good housekeeping" seal of approval beyond the normal UL listing (such as the ENERGY STAR<sup>®</sup> mark); the signal to dim cannot create interference with other customer equipment; and manufacturer to provide technical support of the ballast and signaling equipment after installation.
- Customers would allow utilities to control load-shedding ballasts directly if customers had override capabilities.
- Customers want demonstrated proof that the load-shedding technology works.
- Customers would first look to their utility for information regarding load-shedding ballasts and a related load management program and then to their trade associations.
- Electronic communications regarding information on load-shedding ballasts or load management programs is not desired by customers.

## **TECHNOLOGY TRANSFER MODEL<sup>3</sup>**

The technology transfer model was developed to help the LRC visualize where existing lighting technologies stood in their technical and market developments, what is needed to move the technology toward market acceptance and who could assist in moving the technology forward. The model reflects the LRC's understanding of information discovered during the market research phase such as customers want to see the technology working. This is included in the model by ensuring there is a step to demonstrate the properties and economics of the technology.

Successful technology transfer must recognize the technical foundation and market enabling mechanisms that are in play with each new technology and the organizations, companies and representatives (or players) that interact with these mechanisms. By knowing where a technology is in relationship to these mechanisms and who the drivers/players are to move the technology through the

remaining steps of the mechanisms, a collaborative plan can be developed. The plan will reflect the strengths of each organization/player in their area of expertise. The plan coordinator must tailor communication efforts that are of interest to each organization so they willingly participate in the plan.

Figure 1 below depicts the key players and activities they pursue under today’s current practices of technology transfer. The ultimate goal of technology transfer is to have the technology so widely used that the impact of the technology is written into laws, regulations, codes and/or standards.

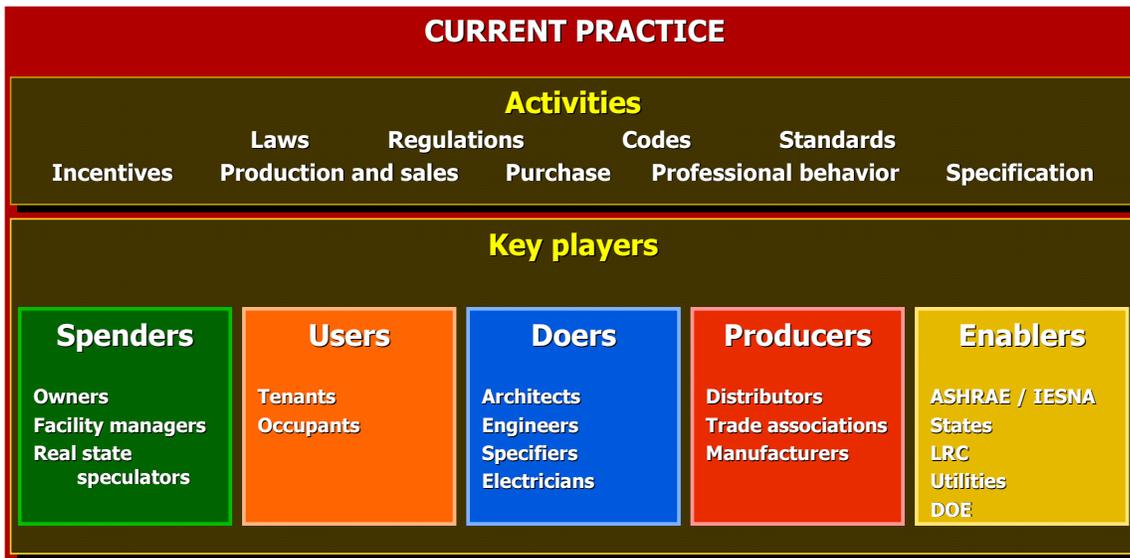
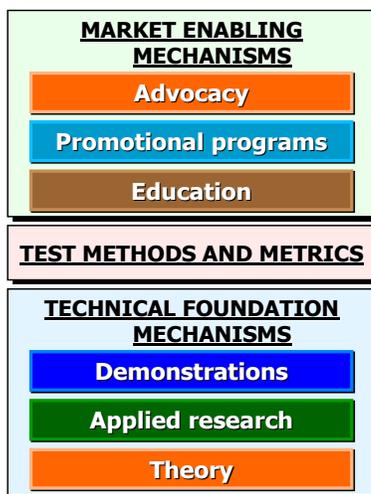


Figure 1

Key players include:

- **Spenders** – These are building owners, facility managers, real estate speculators and developers. They make the ultimate buying decision but are influenced by the other types of key players and what they read and see in different types of communication outlets.
- **Users** – These are the ultimate users of the technologies such as building tenants and occupants. They must be satisfied with the technology’s performance and its ability to deliver its claims.
- **Doers** – These are the architects, consulting engineers, specifiers and installers of the technology. They have great influence over the *spenders*. When *doers* recommend or install a technology, they risk their reputation on whether the product will perform as advertised.
- **Producers** – These are the people who make and distribute the technology and their respective associations/organizations. They must have a reliable and marketable technology that will earn profits for the company. Besides the key role of manufacturing the technology, they act as marketers.
- **Enablers** – These are the organizations that write laws, regulations, codes and/or standards such as state and federal governments, American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE), National Electrical Manufacturers Association (NEMA) or Illuminating Engineering Society of North America (IESNA). Also included are organizations who influence

law, regulation, code and/or standard writers such as the Natural Resources Defense Council (NRDC) or American Council for an Energy Efficiency Environment (ACEEE). *Enablers* are also represented by organizations such as the Lighting Research Center who has relationships and partnerships with all of the key players within an industry and is able to bring these dissimilar types of players together in collaborative and mutually beneficial efforts to successfully perform technology transfer. Also included with this grouping are utilities and state/regional organizations such as Xcel Energy and the Northwest Energy Efficiency Alliance, which are charged with the responsibility for implementation of energy efficiency programs.



**Figure 2**

The transformation mechanisms shown in Figure 2 are methodical, step-by-step processes for developing, demonstrating, evaluating, commercializing and, finally, customer acceptance of a technology. The successful achievement of each step’s goals is a prerequisite to moving onto the next step. Failure to meet these goals, or an attempt to skip a step, reduces the chances of the technology being accepted by the *spender, user* or *doer*.

The mechanisms include:

- **Theory** – This mechanism identifies a possible technology to satisfy an unfulfilled customer or *user* need. The technology gets defined and researchers determine if the technology is achievable at some reasonable cost to the *user*. While research organizations like the LRC and other *producers* are the primary players for this mechanism, input and funding from the other key players is mandatory.
- **Applied Research** – This mechanism must prove the technical and economic concepts of the technology through technical and market research. Prototypes are developed as part of meeting this step’s goals. Again, close collaboration with all key players is necessary as the research or manufacturing organizations endeavor to meet the goals of this mechanism. As one of its goals,

the applied research mechanism identifies manufacturers willing to commercialize the technology and begin performing the necessary engineering for manufacturing.

- **Demonstrations** – Full scale demonstrations are necessary to “show the world” that the technology works and delivers the promised benefits. The demonstrations must answer any questions or concerns raised by *users* or *spenders* during the market research phase. The proof must be of the technology and its economics as applied to an actual, rather than laboratory, situation. Successful demonstrations with multiple locations or situations increase the acceptance of the technology. Funding and defining the measured metrics for this phase must come from other key players.
- **Test Methods and Metrics** – The method and metrics on which the evaluation is conducted of a technology, especially during the demonstration step, must be acceptable and agreed to by the research community as well as all the key players. Test results must withstand the rigors of review. While this mechanism may seem intuitive, it may be the most important step of all transformation mechanisms. It sets the stage as to how believable the claims made by the technology will be to the *spenders*, *users*, *doers*, *producers* and *enablers* and, ultimately, how successful the technology will be in the marketplace. Also, it provides a uniform means to measure results utilizing the same technology in different labs and facilities.
- **Education** – The education mechanism is meant to be broad in scope to include the necessity to educate all the key players about the benefits, abilities and limitations of the technology and why it should be adopted in the marketplace, i.e. what it will do to help society. This is the first step in bringing the technology to the market. Yet, many times organizations responsible for technology development do not view the educational function as part of their responsibilities. Funding for education should be included as part of any technology development or else the technology may never advance to the market.
- **Promotional Programs** – If the rigors of the test methods and metrics are met and if a successful education program is funded and executed, then, and only then, will the *producers*, *enablers*, utilities and state/regional agencies charged with the conduct of energy efficiency programs promote the use of the technology to the *spenders*, *doers* and other *users*. Promotional programs can take many forms such as utility incentive programs or endorsements. Manufacturers also play a role in promoting their products through advertisements and sales personnel.
- **Advocacy** – This is the final step in the technology transfer model but does not occur until after the technology has reached some level of acceptance within the marketplace. It only occurs when there is public consensus of the use and benefits of the technology. Advocates then request that the benefits of the technology are included in regulations, codes and/or standards.

Combining the market enabling mechanisms and the key players allows for the identity of players for each step of the process.

	Status	Key Players				
		Spenders	Users	Doers	Producers	Enablers
Advocacy				NAESCO, AESP	NEMA	ACEEE, NRDC
Promotional Programs					manufacturers	Utilities, NYSERDA, CEC, NEEA
Education		BOMA	BOMA	ASHRAE, NECA, IESNA, AIA, NAESCO	NEMA	DOE, LRC, Utilities, NYSERDA, CEC, NEEA
Test Methods & Metrics		BOMA		ASHRAE, AIA, etc.	NEMA	DOE, LRC, universities
Demonstrations					NEMA, manufacturers	DOE, LRC, utilities, NYSERDA, CEC, NEEA
Applied Research					manufacturers	DOE, LRC, universities
Theory					manufacturers	DOE, LRC, universities

Figure 3

The technology transfer model works best when combining current practices with transformation mechanisms. One must identify the key players for each of the mechanisms for each technology to be transferred to the marketplace. As a result, this will allow for the development of a transfer plan with targeted audiences and messages.

The model works by identifying where the technology is along the mechanism steps and who the key players are to move it to the next step.

- If the technology is in relatively wide use, approach the *enablers* for the advocacy of the benefits of the technology to promote regulations, codes and standards.
- If the technology is ready for widespread use, use promotional programs to convince the *doers* and *spenders* of the benefits of the technology.
- If the technology has been developed and demonstrated to be of value but is not in use, convince utilities and others to promote the technology.
- If the technology has been developed but is not proven on a wide scale, seek funding for demonstration and evaluation projects and to educate *spenders*, *users*, *doers* and *enablers* of the unbiased results.
- If the technology is in the applied research stage, seek funding to prove/disprove the technology and its economics. Also seek someone from the *producer* segment to manufacture the product.
- In all cases, ensure communications across all key player types of the technologies possibilities, evaluations, etc.

**MOTION SENSORS**

Motion sensors turn lighting fixtures either on or off based on existence of someone being present in a space controlled by the occupancy sensor. The sensor detects motion either through changes in the infra-red radiation pattern or actively through detection of reflected ultrasonic microwave signals. The lack of detection causes the sensor to signal a controller to turn off the lights. Occupancy sensors are commonplace today in new construction (estimates of up to 60% of commercial construction projects now utilize them) but much of the existing floor space has not been retrofitted with these devices.

***The Technology Transfer Model for Occupancy Sensors<sup>3</sup>***

**Figure 4**

	Status	Key Players				
		Spenders	Users	Doers	Producers	Enablers
<b>Advocacy</b>	Ongoing			NAESCO, AESP	NEMA	ACEEE NRDC
<b>Promotional Programs</b>	Ongoing				manufacturers	Utilities, NYSERDA, CEC, NEEA
<b>Education</b>	Ongoing	BOMA	BOMA	ASHRAE, NECA, IESNA, AIA NAESCO	NEMA	DOE, LRC Utilities, NYSERDA, CEC, NEEA
<b>Test Methods &amp; Metrics</b>	Complete					
<b>Demonstrations</b>	Complete					
<b>Applied Research</b>	Complete					
<b>Theory</b>	Complete					

The model tells us occupancy sensors are a proven technology that require additional education of building owners/occupants on the benefits of this technology and specifiers and electrical contractors (*doers*) on selection, location and installation of the sensors. This education is best provided by the manufacturers (*producers*) and utilities and others charged with operating energy efficiency programs (*enablers*).

***Energy Savings***

Debate over the potential energy savings achievable through the use of occupancy sensors has created doubt in the minds of building owners/occupants (*spenders/users*) as to the benefits of the technology. Therefore, based on market research (customers want proof), most customers are not retrofitting existing buildings.

The LRC consulted its extensive resource collection to compile a group of 26 case studies and claims by manufacturers regarding the effectiveness of occupancy sensor technologies. We organized the data in different ways in the various studies, often by specific room type (restrooms, hallways, coffee break

rooms, conference rooms). We reviewed the literature and organized studies into broader occupancy categories based upon private (“owned”) vs. shared and scheduled vs. sporadic use:

- Private (“Owned”) Spaces (such as single-person offices or spaces in which the user takes “ownership”)
- Shared Spaces, Scheduled use (such as classrooms)
- Shared Spaces, Sporadically used (such as public spaces, open-plan offices, corridors, bathrooms, storage rooms)
- Private (“Owned”), scheduled occupancy was not a legitimate category.

For private offices, all data were averaged leading to an average savings of 31.7%. This average represents a wide range of hours of use, so we also examined the percentage of energy savings in those studies that were based upon documented “core hours” between 7.5 to 10 hours per day. This analysis yielded a lower average energy savings of 26%, as expected because the former analysis was dominated by studies using longer hours of use as a base line. This latter percentage (26%) is perhaps a better estimate of potential energy savings from occupancy sensors because, for buildings showing wasted energy use outside the core hours, other technologies such as time clocks are usually more cost effective than occupancy sensors. The LRC recommends 25% as an easy to remember best estimate of energy savings for private offices with sporadic use.

For shared spaces that are used sporadically, the average savings was 40.8%. Again, there was a wide range of hours of use, but it seems inappropriate to base energy savings on “core hours” (7.5 to 10 hours per day) because hallways, stairs, etc. can be used at any time day or night. Therefore, we recommend 40% energy savings as the best estimate for shared, sporadically occupied spaces. Note, however, that some spaces should be illuminated without occupancy if lighting is used to signal potential occupants that a business is open or if the lights being on provide occupants with a sense of security or safety.

For shared, scheduled spaces, in particular classrooms, it is often difficult to ascertain the hours of use. Classrooms are used not only for teaching during the day, but also for community activities during the night. Often more than one teacher uses the space but does not “own” the classroom. Since these spaces are sporadically used and do not have a clear “owner,” occupancy sensors are a good choice for reducing wasted lighting energy. The average energy savings was 31.7%. We recommend 30% energy savings as an easy to remember best of estimate for shared, scheduled, spaces. Note, however, that one study of teacher “owned” classrooms reviewed for this task showed that more energy waste due to the time delays on the occupancy sensors. Consequently, the specifier must have a clear understanding of classroom use before applying occupancy sensors to reduce wasted energy.

While these saving estimates are averages based on extensive research, the potential savings for a specific application will vary based on the occupancy and behavioral patterns of a particular space.

**Percent Savings from Occupancy Sensors  
(Mean Values)**

	<b>Private ("Owned")</b>	<b>Shared</b>
<b>Sporadically Use:</b>	25	40
<b>Scheduled Use:</b>		30

**Table 1 - Recommended values for the three types of spaces.<sup>4</sup>**

***Tips for Manufacturers and Installers***

Here are a few tips for manufactures and installers that could help reduce the installation and commissioning time and hassle:

Manufacturers should:

- Supply circuit schematics or documentation explaining inputs and outputs to the sensors and power packs.
- Use the same wire color scheme across manufacturers. This will facilitate the installation of sensors and power packs or any other components that are not from the same manufacturer.
- Supply documentation on how to override the system after the power packs are installed. In general, power packs are installed before the sensor and installers do not have enough information about how to override the system after the sensor is installed.
- Develop a diagnostic interface that can be plugged in each power pack and sensor to speed up commissioning and diagnosing problems.
- Include zero-delay setting to the sensor to allow faster commissioning.
- Set up a 24-hour hotline customer service to allow nightshift installers to have customer support at night.

Installers should:

- Never disable manual controls when installing motion sensors; existent light switches should be supplemented, not replaced, by the motion sensor.
- Provide a sufficient number of sensors, placed appropriately, in open plan offices. Saving money by reducing the number of motion sensors used in open-plan areas may result in poor performance and thus, dissatisfaction and rejection.
- Place occupancy sensors close to areas where small movements are made (e.g., near desks, over bathroom stalls) to improve sensitivity to these motions.
- Put two sensors in hallways, one at each end, pointing toward the center of the controlled area to provide good coverage and avoid false triggering.

For more information on occupancy sensors, please go to the LRC website:  
[www.lrc.rpi.edu/programs/NLPIP/publications.asp](http://www.lrc.rpi.edu/programs/NLPIP/publications.asp) and look under Specifier Reports.

**PHOTO SENSORS**

Photo sensors discussed here are for dimming fluorescent lighting in non-residential applications when sufficient daylight is present. This is not about architectural dimming for aesthetic purposes or multi-medai spaces. The purpose of dimming is to improve the energy efficiency of the building.

***The Technology Transfer Model for Photo Sensors<sup>3</sup>***

	Status	Key Players				
		Spenders	Users	Doers	Producers	Enablers
<b>Advocacy</b>	Not started				NEMA	ACEEE, NRDC
<b>Promotional Programs</b>	Not started				Manufacturers	Utilities, NYSERDA, CEC, NEEA
<b>Education</b>	Ongoing	BOMA	BOMA	ASHRAE, NECA, IESNA, AIA, NAESCO	NEMA	DOE, LRC, Utilities, NYSERDA, CEC, NEEA
<b>Test Methods &amp; Metrics</b>	Ongoing				NEMA	LRC
<b>Demonstrations</b>	Ongoing	BOMA	BOMA		Manufacturers	LRC, DOE, Utilities, NYSERDA, CEC, NEEA
<b>Applied Research</b>	Complete					
<b>Theory</b>	Complete					

**Figure 5**

Current commercialized photo sensor technology does not meet customer needs. They are not easy to install or maintain and customer payback, based on energy savings, exceeds customer acceptable levels. Therefore, photo sensors have not been widely accepted. Even where they have been installed problems persist with building occupant satisfaction because of the difficulty of maintaining sufficient lighting levels. The technology transfer model tells us insufficient demonstrations and testing occurred.

***Current Photo Sensor Technology***

All commercialized photo sensors use analog technology to establish the dimming algorithm necessary to maintain a constant lighting level on the work surface. Analog technologies require manual intervention to commission the photo sensor. This is a tedious process that, at best, is trial and error. Complicating matters is that the same signal level from the photo sensor to ballasts produces different levels of dimming for different manufacturers’ products. i.e. This technology does not meet identified customer needs, not easy to install, use or maintain.

Dimming ballasts are approximately three times as expensive as an instant start ballast which is the current market standard. The instant start ballast has captured over 85% of the electronic ballast market and costs approximately \$10 while the full dimming ballast is about \$45. Can energy savings pay for the added cost of the ballast over a reasonable time? The answer is it depends on what the customer is paying for electricity. Table 2 below expresses the energy and cost savings for the use of a dimming system that responds to the presence of daylight.<sup>5</sup> Explanations and assumptions include:

- The analysis is conducted on a per light fixture basis.
- The light fixture used is a three lamp, T-8, electronic ballast, parabolic fixture. This type of fixture is currently the most commonly used in new construction or remodeling.
- Lights are on 10 hours per day and 260 days per year.
- Based on initial findings in the photo sensor project, the annual energy savings is 30% of the light fixture energy use with no daylighting controls. This amounts to 78 kWh per year.
- Credit is included in the energy cost savings for a reduction in peak electric demand due to the light fixture being dimmed. Since most buildings' peak demand occurs on sunny days due to solar heat gain, assuming the fixture would be in a dimmed mode is reasonable.
- Actual electric rates from utilities located in the sampled regions are used to calculate savings.
- The differential cost of a full dimming ballast versus an instant start electronic ballast is \$35. An additional \$5 per fixture in incremental investment is included to compensate for the control portion, i.e. photo sensor. This makes the total incremental investment \$40 which must be offset by the energy savings.

**Table 2**

<u>Location</u>	<u>Annual Savings Per Fixture</u>	<u>Simple Payback</u>
New York City	\$16.32	2.45 years
Ohio	\$7.05	5.67 years
Chicago	\$10.36	3.86 years
Georgia	\$7.20	5.56 years
Connecticut	\$7.58	5.28 years
New Jersey	\$9.68	4.13 years
San Francisco	\$8.17	4.90 years
Washington State	\$5.36	7.20 years

Most commercial type end use customers have an investment criteria which will allow for capital improvements that produce a simple payback of three years or less. This criteria changes based on the general business climate. During economic downturns, businesses will shorten paybacks wanting to recover their investments in shorter periods of time. Conversely, during economic upturns, the payback period may be extended.

Therefore, the use of daylighting (and its accompanying photo sensor) for most of the United States must be justified on more than the economics associated with energy savings. Environmental, health and productivity benefits must be proven, quantified and added to those of energy.

For more information on dimming ballast and controls please go to the Lighting Research Center website at [www.lrc.rpi.edu/programs/NLPIP/technologies.asp](http://www.lrc.rpi.edu/programs/NLPIP/technologies.asp).

## *New Photo Sensor Technologies*

Photo sensors must enter the digital age. The LRC has developed a photo sensor that is as cost effective as current technologies but is self commissioning to meet customer needs for ease of installation and operation through funding provided by Connecticut Light and Power Company..

The LRC photosensor consists of two separate devices: a wall-switch controller and a remote, wireless sensor. Figure 6 shows a photograph of the two devices. The wall-switch controller, installed in an electrical gang-box, replaces the traditional light switch located near the entrance of a room. This controller could be placed elsewhere in larger open offices. The wall-switch controller receives power and is connected to the dimming ballasts in the room via the power line wires and dimming control wires brought to the electrical gang-box. The wall-switch controller can then control the dimming of the fluorescent lighting as well as switch the power supplied to the dimming ballasts for on/off control. The wall-switch controller also incorporates a manual on/off switch, a user preference/override input button, and three LED status indicators.

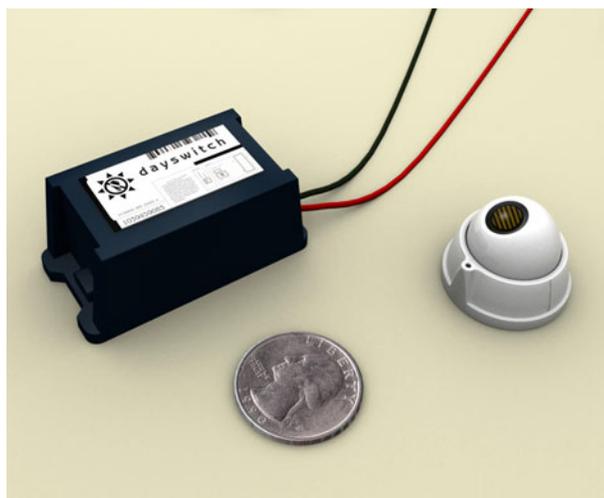
The remote sensor is a wireless, self-powered device that senses and transmits light level information to the wall-switch controller via an infrared optical transmitter. The wall-switch controller receives the transmitted signals, processes the information according to the programmed control algorithm, and dims and/or switches the fluorescent lighting. The remote sensor also transmits a simple commissioning instruction when a button on the device is pressed, initiating the commissioning process.

Commissioning is accomplished by first placing the remote sensor on the work surface and pressing the commissioning button. The sensor takes light readings with the artificial lights off (daylight only) and then with the lights on fully. This allows for the calculation of the differences between the two sources. The remote sensor is then placed at its permanent location and the commissioning button is depressed again. The sensor again cycles through the same readings. All this information is transmitted to the wall unit which contains a memory chip and processor. The readings allow the processor to develop an algorithm that will maintain light levels on the work surface. Commissioning also requires the processor to learn the dimming values of the ballast. This is necessary because different manufacturers' dimming ballasts have different dimming response curves. The wall-switch controller must know what control voltage corresponds to a certain amount of light output from the lamps. The entire commissioning process takes less than three minutes and produces results in dimming the fluorescent lighting to maintain either constant work surface illumination or increasing work surface illumination as daylight enters depending on occupant preference.<sup>6</sup>



**Figure 6**

Even this technology must be linked to a costly dimming ballast. While the new technology overcomes customer concerns with installation and operation, it does not meet the customers' economic criteria. Currently, the only means of overcoming the economic issues is to not use a full dimming ballast. If an approach is taken to save a little less energy by only turning off the lights in the presence of sufficient daylight, then one can employ an instant start ballast with a photo sensor that turns off the light fixture. Initial research by the LRC indicates the difference in energy savings is approximately 10 percentage points. The reduction in costs to achieve savings is substantial. Initial economic analyses indicate this approach can meet customer economic needs. The LRC is developing a "dayswitch" (Figure 7) that utilizes the technology developed for the digital, self commissioning photo sensor so the "dayswitch" will be easy to install and operate as well as meeting customer economic needs.



**Figure 7**

## **DIGITAL ADDRESSABLE LIGHTING INTERFACE (DALI)**

DALI, which is a standard developed in Europe, is coming to America. “The DALI standard includes addressable control of individual and groups of ballasts, as well as easier installation and maintenance due to the ability to mix and match DALI components seamlessly from multiple manufacturers into complete systems”, states Odile Ronat of International Rectifier which manufactures components for DALI ballasts.<sup>7</sup> Manufacturers agree to build these ballasts and lighting controls so a single communication protocol will work with all components.

DALI components use a twisted pair of communication wiring between components and a controller. The controller has the ability to control up to 64 lighting ballasts or control points. The controllers can be integrated into larger groups through the building’s automation system. Each ballast or control is given a digital address. A software program can then group different addresses into different lighting groupings without rewiring devices when a building change takes place. Since the ballasts and controls use digital technology, there are fewer components required. The communications that occurs is two-way which allows the ballast to indicate its status back to a central location.

Advantages of the DALI system over current lighting control systems are:

- Reduced installation costs due to simpler wiring requirements.
- Capability of monitoring lamp and ballast status from a central location. This may reduce maintenance costs.
- Increased flexibility in programming different lighting fixtures into groupings without having to rewire the fixtures.
- The ability to use any DALI manufacturers’ components with another manufacturer’s DALI equipment.

DALI has advantages where lighting system controls beyond simple on/off control are desired. However, the jury is still out as to customer acceptance of this new technology. Does DALI meet the needs and wants of business customers? Is it cost effective? Discussions above regarding photo sensors and dimming ballasts indicate less than desirable returns on customer investments based on simply energy savings. Is it easy to install and maintain? DALI requires extensive software programming to gain the greatest advantages from the technology. This is normally not a skill set found in the average building facility personnel. Is DALI a proven technology? It certainly has worked well in Europe.

## **LIGHTING AND LOAD MANAGEMENT**

Electrical load management creates winning situations for many constituencies including the end use customer, energy supplier, the environment and the distribution utility. The end use customer benefits are monetary in nature to reflect his/her willingness to reduce electrical loads when requested by a utility, energy supplier or regional transmission organization. The energy supplier mitigates their risks for the purchase of high priced electricity during periods of shortages by having the customer reduce the amount of electricity used. The environment benefits because reductions of peak electrical loads means less efficient, higher polluting generators will not run. The distribution utility may be able to postpone the need for expanded transmission or distribution capacity which is getting exceedingly harder to

acquire as consumers say “not in my back yard”. The Federal Energy Regulatory Commission (FERC) has recognized the value load management must play in providing for future electrical needs by including it as an integral part of its proposed Standard Market Design for the wholesale electric market. Hopefully, regulatory agencies responsible for retail electrical markets will also adopt the FERC’s suggestions regarding load management.

Can lighting meet the needs of the customer as well as the other players in the load management equation? Lighting and lighting controls certainly possess many positive attributes required for it to be successful in the load management marketplace. The majority of businesses have lighting loads so the number of customers eligible to participate is substantial. Reductions in lighting loads, unlike other manageable loads, are very predictable and repeatable, two highly desirable qualities for load management programs. With the development of additional advanced lighting controls, lighting loads become easy to control from either a remote location or at the point of use. Dimming, rather than turning off lights, has the added advantage of avoiding or minimizing any productivity losses.

What is missing in either the market or lighting technologies to allow for the successful use of lighting and its controls in the load management marketplace? A simple, low cost fluorescent dimming ballast and the communication links capable of communicating with a central controller are not commercially available. Whatever technology is developed must be easy to install and maintain and simple to operate. It also must be cost effective. The simple system should be easily integrated into accepting expanded

features such as remote system monitoring and two way communications if the customer so desires. The lighting industry is somewhat hesitant to invest in this technology development because it is uncertain of the economics associated with electric load management. Any technology development research efforts must also include demonstrations of the economic impact on the end use customer when the technology is employed. Both the customer and lighting manufacturers want proof through demonstration projects that the technology works, that it is acceptable to the customer (meets the customer needs listed above) so a market pull can be created and that the technology is economically justifiable to the customer and the manufacturer. i.e. the customer receives a reasonable return on his/her investment and the manufacturer can sell sufficient numbers of the technology to earn a profit. The final step, which should be considered in any research funding, is the successful market transfer of the technology and the underlying customer economic analysis. This will require funding for education of the lighting industry, end use customers, building design community, energy suppliers and energy service companies to create both market pull and push. This last step is extremely important and requires adequate funding if lighting is to be accepted as a load management technology.

	Status	Key Players				
		Spenders	Users	Doers	Producers	Enablers
<b>Advocacy</b>	Not started				NEMA	ACEEE, NRDC
<b>Promotional Programs</b>	Not started				Manufacturers	Utilities, NYSERDA, CEC, NEEA
<b>Education</b>	Not started	BOMA	BOMA	ASHRAE, NECA, IESNA, AIA, NAESCO	NEMA	DOE, LRC, Utilities, NYSERDA, CEC, NEEA
<b>Test Methods &amp; Metrics</b>	Ongoing				NEMA	LRC
<b>Demonstrations</b>	Ongoing	BOMA	BOMA		Manufacturer	LRC, DOE, Utilities, NYSERDA, CEC, NEEA
<b>Applied Research</b>	Ongoing					LRC, DOE, Utilities, CEC, NYSERDA
<b>Theory</b>	Complete					

**Figure 8<sup>3</sup>**

Current LRC efforts, which have been funded by U.S. Department of Energy, Connecticut Light and Power Company, California Energy Commission and New York State Energy Research and Development Authority, have lead to the development of a cost effective load shed ballast and communication system and is seeking manufacturers to commercialize these technologies. A full scale demonstration of the technologies will occur in 2004 with assistance from Consolidated Edison of New York and will prove the technical and economic merits.

Figure 9



Since the load shed ballast is built on the low cost instant start ballast platform, its incremental cost is approximately \$8.00 per ballast compared to a full dimming ballast incremental cost of approximately \$35. Added ballast circuitry allows the ballast to receive a signal from a central controller and reduce current to the lamps by approximately 33%. Dimming occurs over approximately 3 second period so building occupants do not see an abrupt change. LRC research indicates that people will accept up to a 30% decrease in illumination levels for short periods of time and up to 50% decrease if informed of the social/environmental benefits of load shedding.

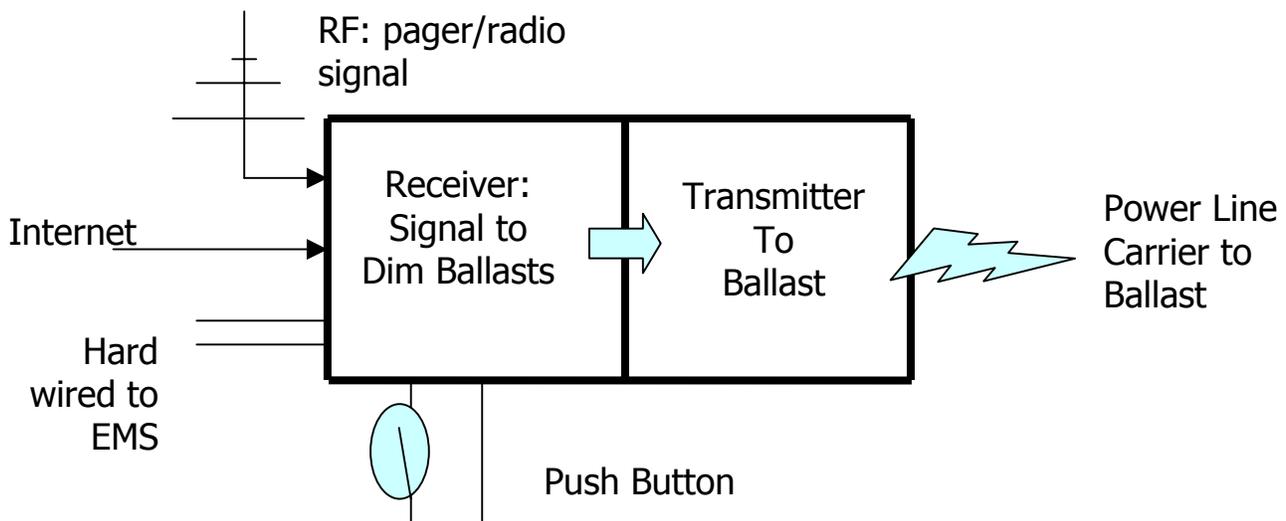


Figure 10

The load shed controller communicates to a series of ballasts via power line carrier. Since the ballast only requires a simple on/off signal, minimal bandwidth will suffice. This is an ideal situation for power line carrier communications. This solution has the added advantage of not requiring additional wiring. The controller, while physically located within the facility, can be controlled locally by the customer or remotely via a communication link by a utility or transmission system operator.

This load management system provides a reasonable payback to many electric customers today. The following table provides examples of simple paybacks at different locations across the country.

**Table 2: Economic Benefits of the Load Shed Ballast<sup>8</sup>**

	Benefit	Simple Payback
New York City	\$6/yr.	1.5 yrs.
Ohio	\$4/yr.	2.25 yrs.
Chicago	\$3.50/yr.	2.6 yrs.
Georgia	\$2.80/yr.	3.2 yrs.
Connecticut	\$3/yr.	3.0 yrs.
New Jersey	\$2.80/yr.	3.2 yrs.
California	\$3.50/yr.	2.6 yrs.

### **CONCLUSIONS/RECOMMENDATIONS**

- Motion sensors meet customer needs, are technically feasible and cost effective. They are ready for prime time implementation as long as education on selection and installation is done.
- Current photo sensor technologies are not conducive to meeting customer needs for ease of use and cost effectiveness. New digital technologies need to be employed.
- The cost of full dimming ballasts must be lower to meet customer payback criteria or the benefits received from the use of daylighting must increase. More exploration is needed into the productivity, health and school children education improvements that may occur with daylighting.
- The successful introduction of the DALI system is dependant on it defining and meeting customer needs at a reasonable price. Market research is needed to better position this product.
- Utilization of lighting as a load management tool must be explored in a manner to satisfy customer cost effectiveness and ease of installation and operation needs. Demonstration of the full load shed ballast system in a commercial building setting must be accomplished to prove the technology and economics to customers.

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