



Advanced Demand Responsive Lighting

Host: Francis Rubinstein

**Demand Response Research Center
Technical Advisory Group Meeting
August 31, 2007
10:30 AM - Noon**

Meeting Agenda

- Introductions (10 minutes)
- Main Presentation (~ 1 hour)
- Questions, comments from panel (15 minutes)

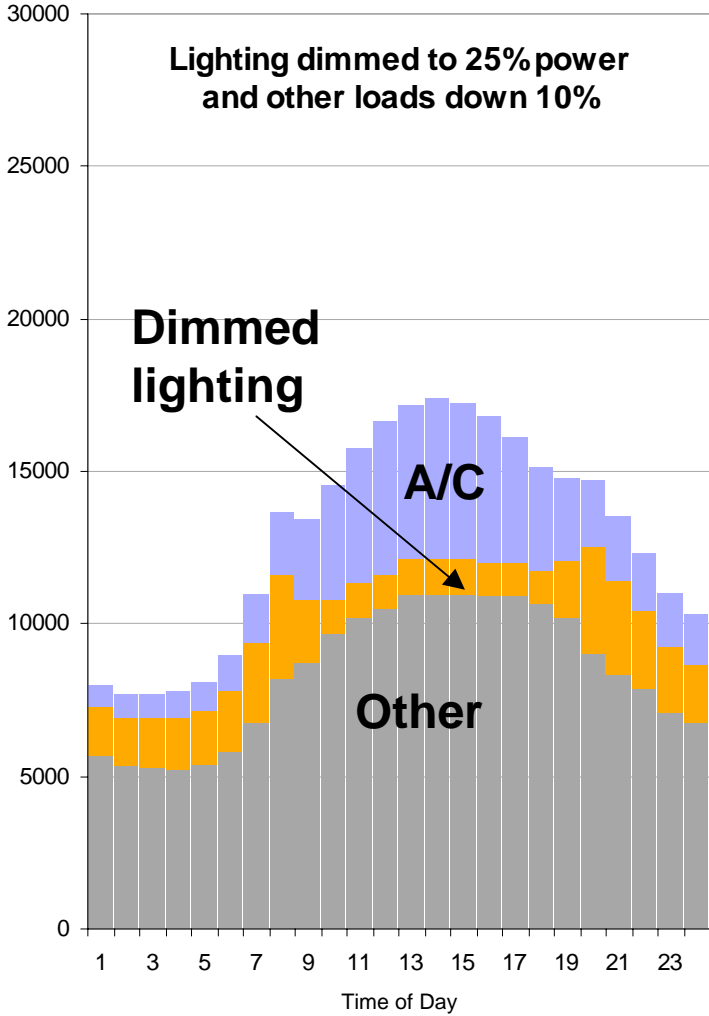
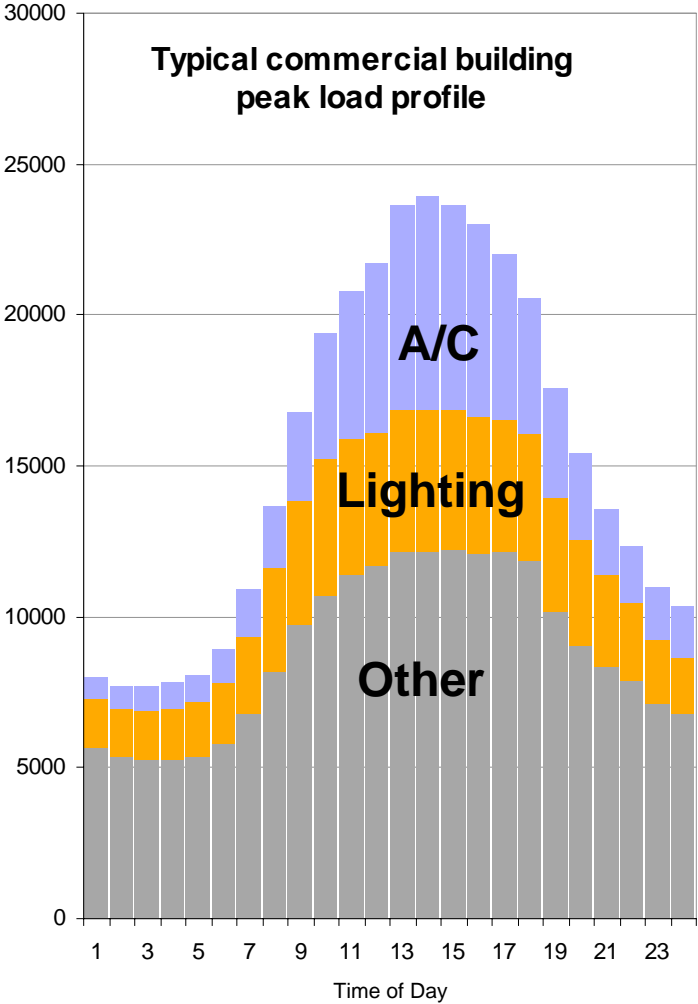
Project History

- Lighting Scoping Study (completed January 2007)
 - Identified potential for energy and demand savings using demand responsive lighting *systems*
 - Importance of dimming
 - New wireless controls technologies
- Advanced Demand Responsive Lighting (commenced March 2007)

Objectives

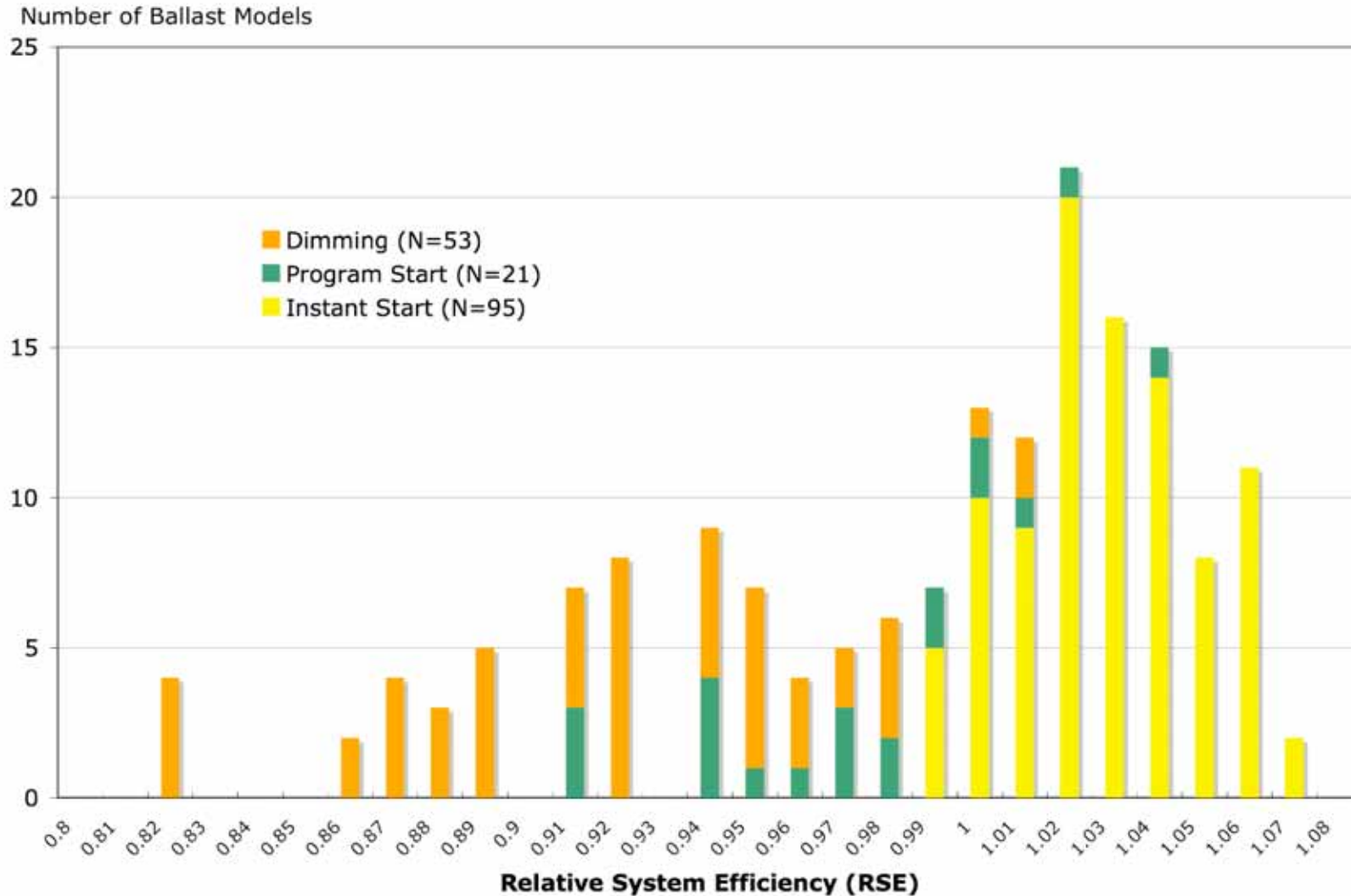
- Provide up-to-date information on the *reliability, predictability of dimmable lighting* as a demand resource under realistic operating load conditions
- Identify potential negative impacts of DR lighting on lighting quality

Potential of Demand Responsive Lighting Control



Dimming Ballasts Becoming More Energy-Efficient

Relative System Efficiencies Compared for Instant Start, Program Start and Dimming Ballasts



Project Tasks

- ***Testing and certification framework*** for lighting control systems
- ***Pilot tests*** of promising demand-responsive lighting systems in buildings
- ***Technology transfer*** component

Testing and Certification Framework

Requirements

- System-based
- Performance-based
 - Technical specifications
- Manufacturer-agnostic
- Technology neutral

- **Initial Focus:**
 - Demand responsive lighting
 - Other lighting control strategies later (daylighting, tuning, etc)

System-based

- Complete end-to-end solutions
- Software matters
- Monitoring and verification “in-the-box”
- Calibration and commissioning

Examples of Performance Metrics

- Lamp-Ballast Efficiency
 - Relative System Efficiency (RSE)
- System Response (Latency)
 - “Spinning Reserve” capability
- Reliability
 - Depth of shed
 - Uncertainty (variability) of shed

What's Needed for Ballast Efficiency

A **Figure of Merit** that can be used to select ballasts according to lamp/ballast system efficacy

What's Wrong with Existing Metrics?

- Ballast Efficacy Factor (BEF) is incorrectly normalized
 - Makes it difficult to compare BEFs between different ballasts
 - The units of BEF are awkward (1/watts)
- System Lumens Per Watt (LPW) conflates lamp-only variables (phosphor type) with ballast-only variables (ballast efficiency)
- The electrical efficiency of the lamp/ballast system cannot be easily disentangled from LPW

Ballast Efficacy Factor

BEF characterizes the lamp/ballast system efficacy of a test ballast operating a generic lamp type (T-8, T-12, T-5 etc)

Definition of BEF:

$$BEF \equiv \frac{\text{Ballast Factor} \times 100}{\text{Ballast Input Power}}$$

where :

$$\text{Ballast Factor} \equiv \frac{\text{Lamp Lumens on Test Ballast}}{\text{Rated Lamp Lumens}}$$

Relative System Efficacy

RSE is the BEF, but properly normalized to the *rated lamp efficacy*

Definition of RSE:

$$RSE \equiv \frac{\text{Ballast Factor}}{\frac{\text{Ballast Input Power}}{\text{Total Rated Lamp Power}}}$$

where :

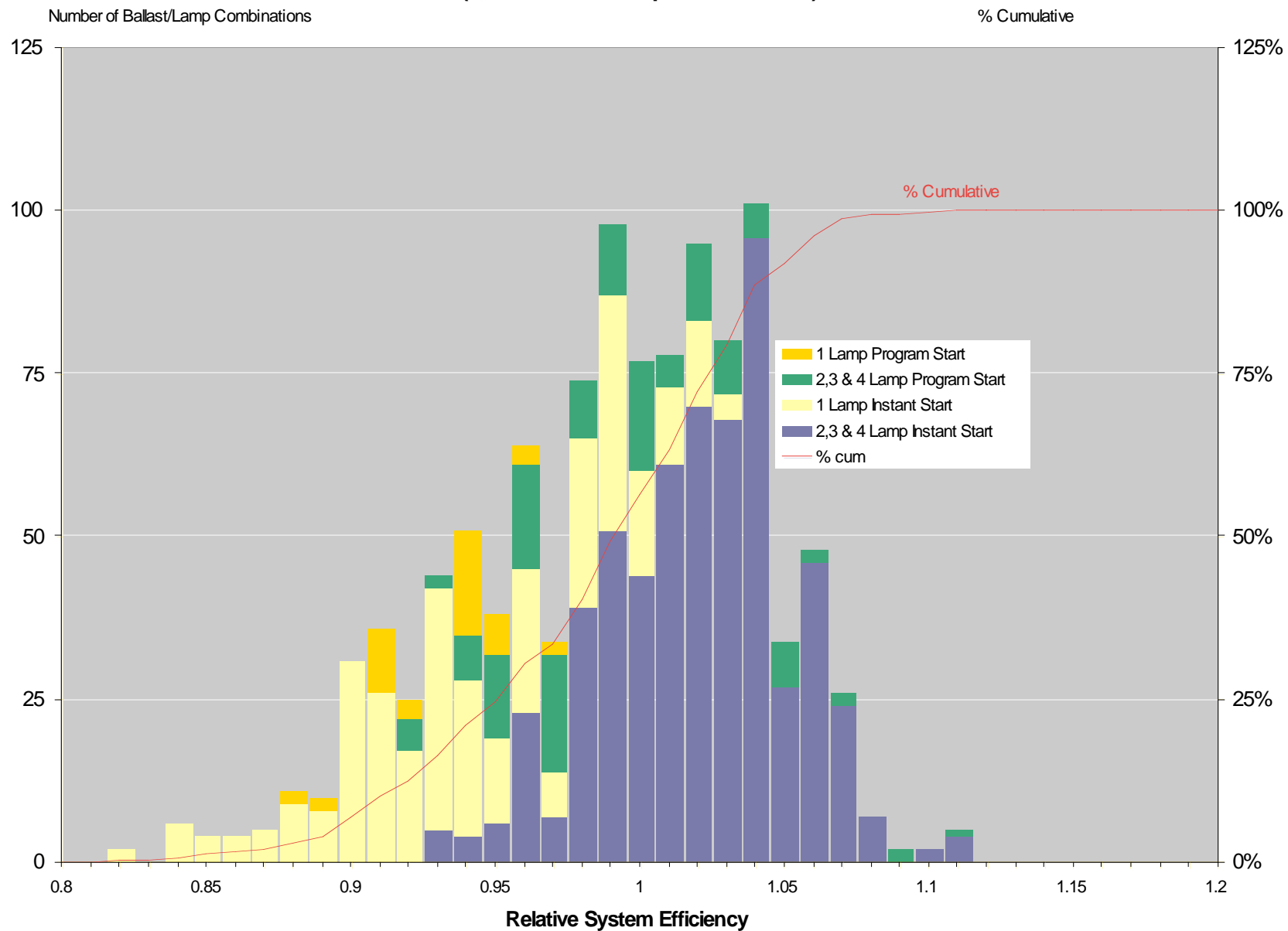
Total Rated Lamp Power \equiv # of Lamps per Ballast \times Rated Lamp Power

Why is Relative System Efficacy Superior?

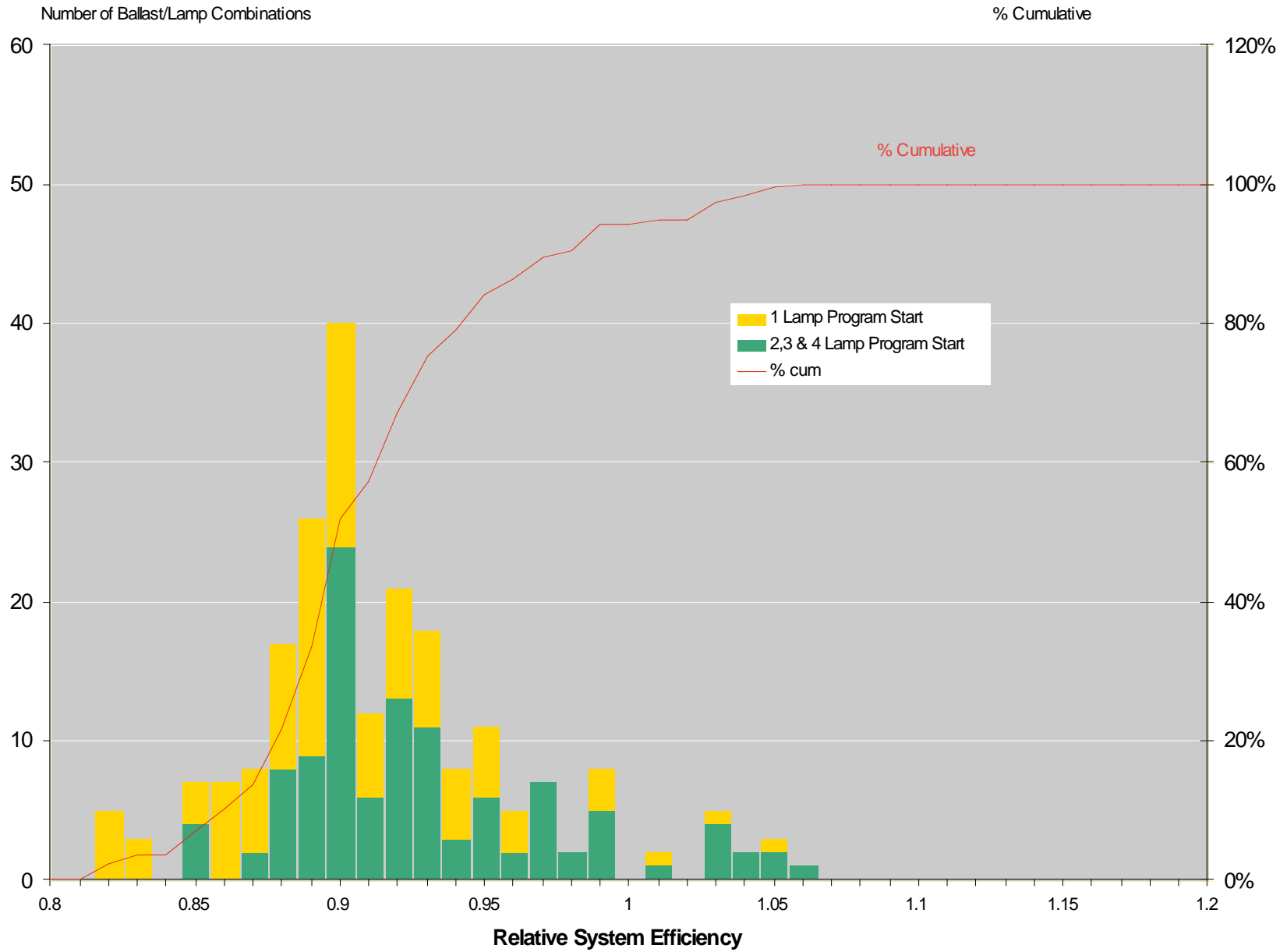
- RSEs from multiple ballast types can be easily compared on “level playing field”
- RSE easily calculated from data already supplied by lamp and ballast manufacturers

RSE is ideal metric for distinguishing premium efficiency ballasts from standard

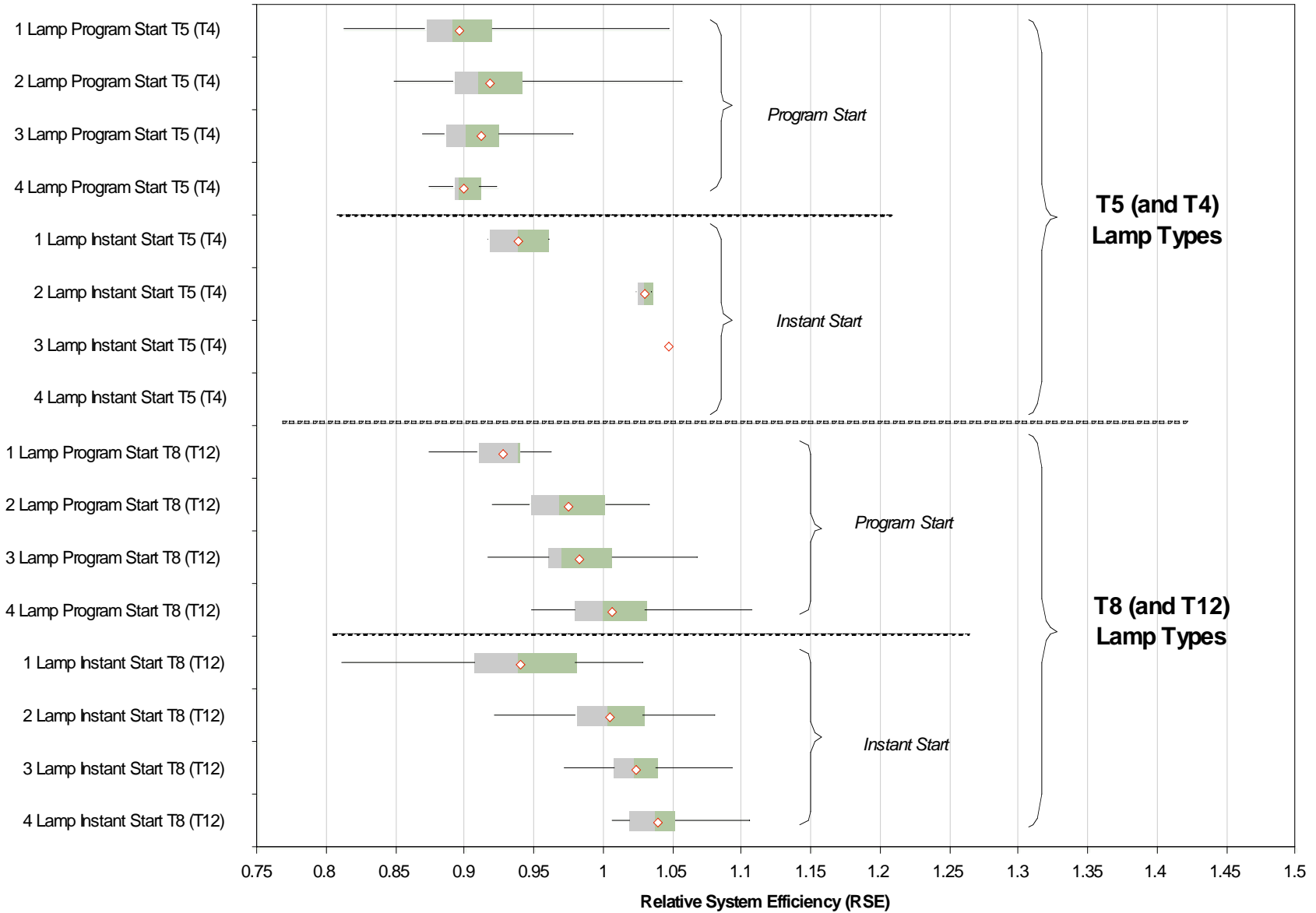
Relative System Efficiency (RSE) for T-8 Fluorescent Ballasts (1,092 Ballast/Lamp Combinations)



Relative System Efficiency (RSE) for T-5 Fluorescent Ballasts (218 Ballast/Lamp Combinations)



Relative System Efficiency (RSE) for 1298 Fluorescent Ballast/Lamp Combinations from a Single Ballast Manufacturer



Summarizing

- RSE is superior to BEF for distinguishing ballasts in terms of system efficacy
- It is easy to calculate RSE from BEF without any additional data

Lessons Learned from Lighting Controls Demonstrations

- **Evaluating the energy savings from lighting controls is harder than evaluating the savings from electronic ballasts**
 - Electronic ballasts save energy simply *because* they are installed
 - Lighting controls only save energy if they positively impact operational performance
- **Need independent, third party evaluation of controls savings**
 - Manufacturer information not reliable
- **Critical to measure energy usage both *before* and *after* installation of controls**
 - The baseline matters!
- **Demand response should be integrated with energy efficiency strategies**
- **Lighting controls should monitor and archive energy data as well as control lighting**

Reducing the Risk of Installing Lighting Controls

Utilities need a consistent, reliable methodology for evaluating the energy savings and demand shed potential for various combinations of lighting control strategies in different building applications, regardless of networking technology.

With such a database, utilities will be able to appropriately incentivize the installation of energy savings controls in all building types.

Rationale for Pilot Tests

- Energy and demand savings from lighting controls systems must be evaluated under realistic building conditions
- Consistent evaluation of alternative solutions relative to well-defined baseline
- Evaluate changes in luminous environment under different lighting scenarios

Pilot Test Methodology

- Evaluate demand and energy savings under different lighting scenarios
 - Permuting the general and task lighting
- Define fair, consistent baseline against which to compare DR alternatives
- Evaluate changes in luminous environment under different lighting scenarios using High Dynamic Range photometry

Lighting Quality Evaluation

- Lighting quality metrics to be considered include:
- Near-hemispherical, accurate luminance maps of illuminated workstations from key viewpoints, presented as iso-luminance and false color renderings
- Statistical luminance analysis considering luminance ratios, distribution and uniformity of all visible surfaces, including computer monitors
- Detailed glare analysis of all sources including daylight from windows
- Horizontal illuminance distributions at the working plane and vertical illuminance at key viewing directions
- Spectral content, color temperature, S/P ratios

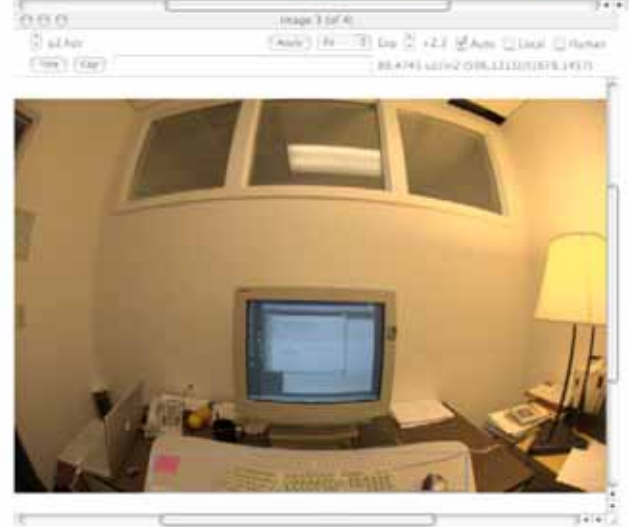
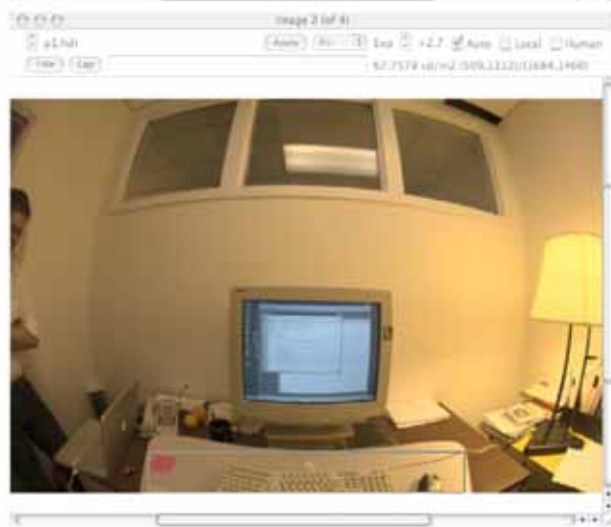
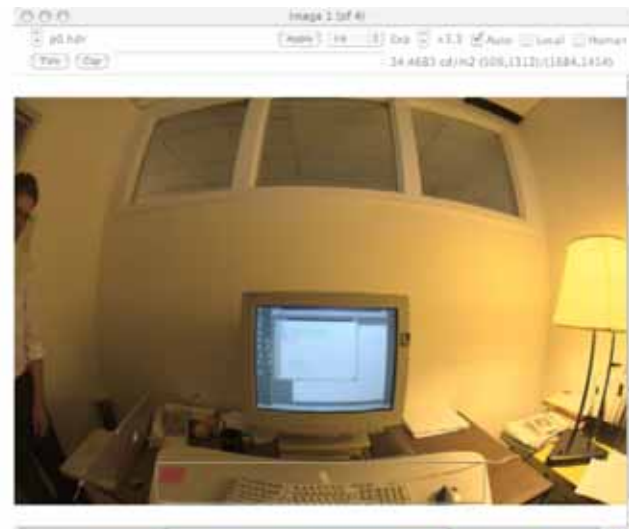
Status of Pilot Tests

- Two workstation-specific lighting control systems at Philip Burton Federal Building
 - Agiliti by Lightolier
 - Edapt by Ledalite
 - Low ambient basecase
- Building 90 flex space
 - LMCS by Lumenergi
 - ZigBee wireless ballasts by RF Arrays (?)

High Dynamic Range Photometry

- Canon 5D with fisheye lens
- Automated image capture
- Analysis of data in Adobe Photoshop CS 3
 - Well-documented, production system for HDR capture and analysis

Sample HDR



Workstation Specific Luminaires I



Agiliti by Lightolier

Two T-5 HO lamps
top-over bottom

DALI-based

User control of
lower lamp

Building control of
upper lamp

Workstation Specific Luminaires II

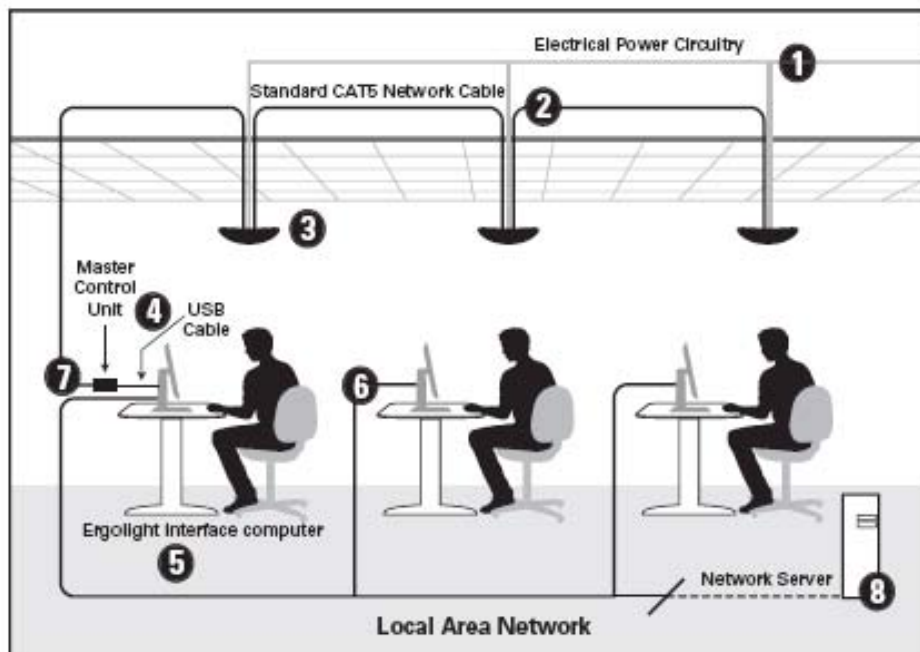
Edapt by Ledalite

Three T-8 lamps per luminaire

RS-485 network

User control of two outer lamps

Building control of center lamp



Control Panel for Demand Response

Load shedding – Building settings

Building Control Settings

Building control settings

Installation | Building control | Analogue Readings | Zone Templates
Security | Lighting Controls | Server data collection | Building load
Network | **Load shedding** (A)

Load Shedding Groups (Building default)

#1 - Building default (B) [Add New (C)] [Delete (D)]

Shedding group name: Building default

Load shedding action: Load shedding affects levels only

Load shedding priority: Normal load shedding Loadshed from trigger point (E)

Loadshedding levels 1, 2 & 3 (used by local or external fixed trigger)

| | |
|------------------|-----|
| Loadshed Level 1 | 10% |
| Loadshed Level 2 | 20% |
| Loadshed Level 3 | 30% |

% of the entire building load used by lighting system

Lighting % of total: 40% (F)

Select load shedding methods to use

- Local load shedding
- External fixed trigger load shedding (G)
- External DR request

OK Cancel Apply

Control Panel for Fine-tuning the DR Strategy

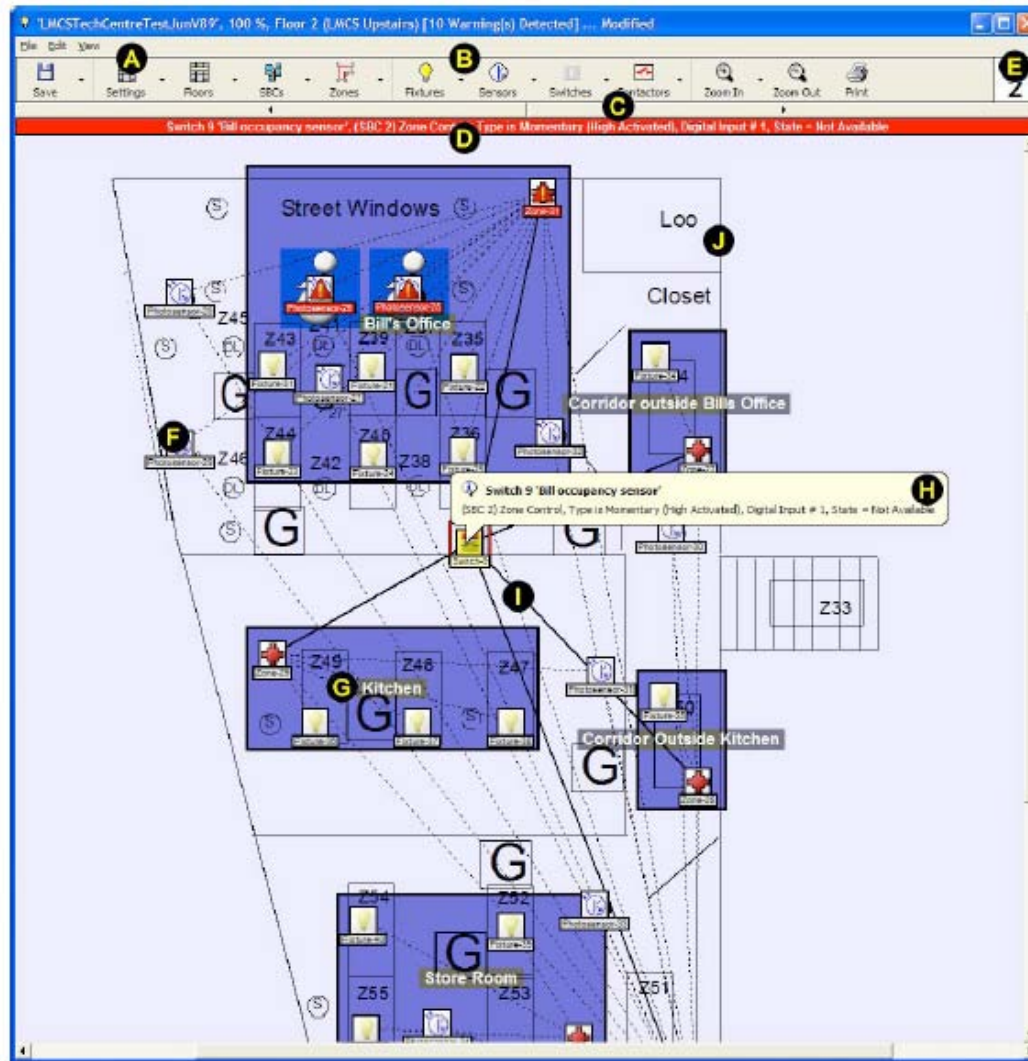
Local load shedding (Fixed trigger options)

| | |
|--------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|
| Select load shedding methods to use | Settings for LOCAL (Fixed Trigger Levels 1, 2 & 3) |
| <input checked="" type="checkbox"/> Local load shedding | 100 kW <input type="checkbox"/> This load or higher forces shed level 1 (10%) |
| <input type="checkbox"/> External fixed trigger load shedding | <input type="checkbox"/> Don't release this level until load falls below 80 kW |
| <input type="checkbox"/> External DR request | 150 kW <input type="checkbox"/> This load or higher forces shed level 2 (20%) |
| Select local load shedding method | <input type="checkbox"/> Don't release this level until load falls below 130 kW |
| <input checked="" type="checkbox"/> Use preset loads to trigger fixed load shedding levels | 200 kW <input type="checkbox"/> This load or higher forces shed level 3 (30%) |
| <input type="checkbox"/> Use variable load shed based on building load | <input type="checkbox"/> Don't release this level until load falls below 180 kW |

Local load shedding (Variable shedding options)

| | |
|-----------------------------------------------------------------------------------|--------------------------------------------------------------------------|
| Select load shedding methods to use | Settings for LOCAL (Variable Shedding) |
| <input checked="" type="checkbox"/> Local load shedding | 200 kW MIN - Start shedding when building load exceeds this value |
| <input type="checkbox"/> External fixed trigger load shedding | 400 kW MAX - Building load for maximum loadshed |
| <input type="checkbox"/> External DR request | 0 % Shedding % to start with at MIN Building load (0 - 100%) |
| Select local load shedding method | 40 % Shedding % at MAX Building load or higher (0 - 100%) |
| <input type="checkbox"/> Use preset loads to trigger fixed load shedding levels | Large load shed step change limit (%) 10 % |
| <input checked="" type="checkbox"/> Use variable load shed based on building load | Medium load shed step change limit (%) 2 % |

Graphic User Interface



Commissioning Panel for Daylight Controls

The screenshot displays the 'Photosensor Information' window for 'Photosensor 9 (Used by zone 7,8,10,12,13)'. The interface is divided into several sections:

- Photosensor Details:** Includes fields for 'Date Installed' (22/01/05), 'Enabled' (checked), 'Floor' (Ground Floor), 'SBC' (SBC 1, 'SBC 1'), 'Calibration Style' (Simple), and 'SBC Input' (SBC 1, Input 9 - This Photosensor). Buttons for 'OK', 'Cancel', 'Analogue Inputs', and 'Apply' are present.
- Photosensor Calibration:** Shows 'Analogue Reading' and 'Photosensor Reading' both as 'N/A'. It includes a 'View calibration points for' dropdown set to 'Simple' and 'Input of 10 - 8 Lux', along with 'Remove', 'Remove All', and 'Utilities' buttons.
- Graph:** A plot of 'Lux' vs 'Analogue Input' showing a series of calibration points and a dotted trend line. The y-axis ranges from 0 to 2500 Lux, and the x-axis ranges from 0 to 9999.
- Bottom Panel:** Contains 'Add Calibration', 'Modify Selected', 'Analogue reading' (with a numeric input field), and 'Light Level' (with a numeric input field) buttons.

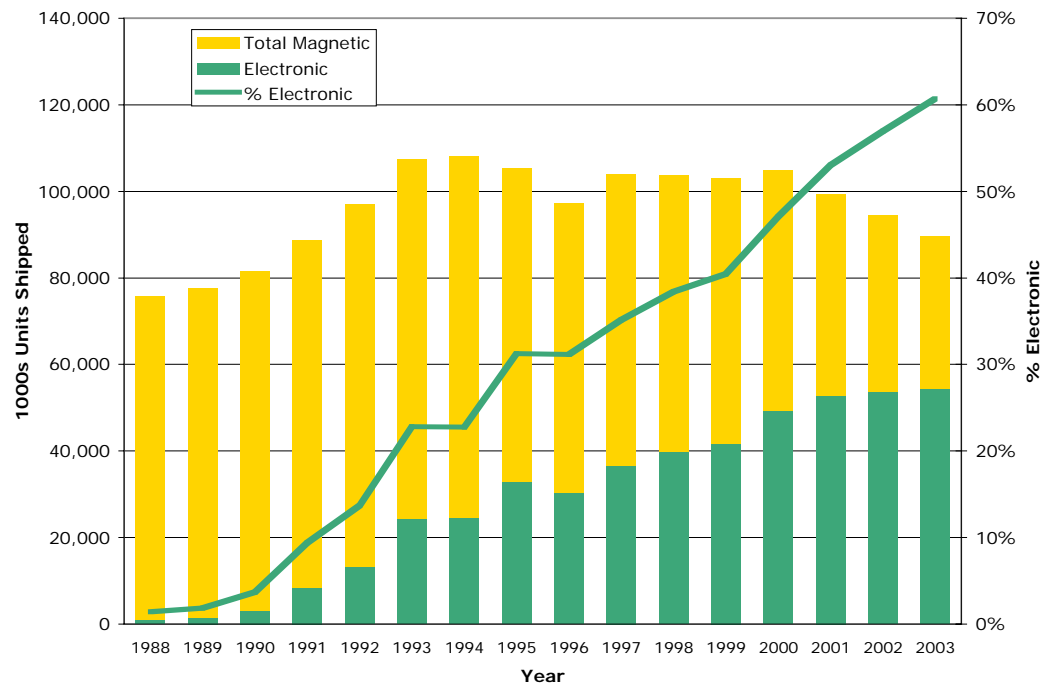
Yellow callout letters A through I are overlaid on the interface to highlight specific elements: A (Title bar), B (Navigation arrows), C (Buttons), D (Readings), E (Section header), F (Remove buttons), G (Utilities button), H (Graph point), and I (Bottom panel buttons).

Technology Transfer

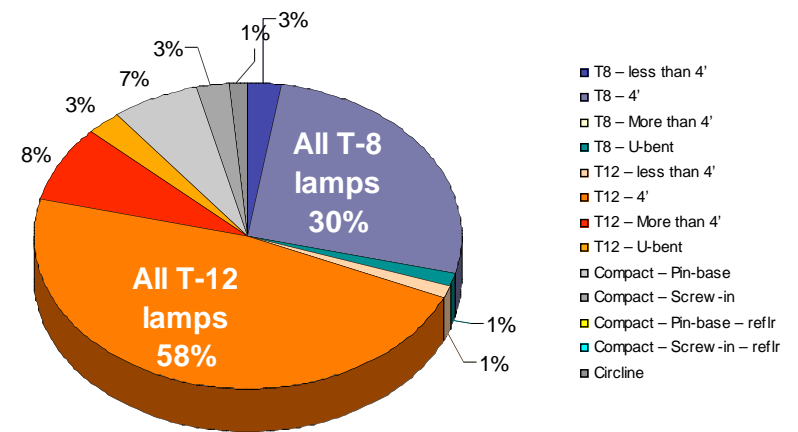
- Informed, public-interest TAG guiding research
 - No manufacturers
- Developing the market transformation vehicle
- Setting RSE efficiency targets
- Evaluating potential negative impacts

Impact of Electronic Ballasts and T-8 Fluorescent Lamps on Lighting Consumption

Annual Shipment of Ballasts in US (1988 – 2003)



Fluorescent Lighting in Commercial Buildings (2001)



After 20 years, 50% of US lighting still uses inefficient magnetic ballasts

Source: Navigant Consulting, Inc., U.S. Lighting Market Characterization, Volume I: National Lighting Inventory and, Energy Consumption Estimate, Final Report for US DOE, 2002

US Bureau of the Census

Market transformation vehicle

EBMUD WaterSmart Irrigation Controller Program Qualifying Products

Note: For better assistance, identify yourself as an EBMUD customer when you contact suppliers

| Manufacturer Recommendations Professional, Irrigation and Contact Information | EBMUD Qualifying WaterSmart Irrigation Controller Model Name ¹ | WaterSmart Irrigation Controller Cost ² | Number of Stations ³ | Water Scheduling Engine ⁴ | How controller obtains weather information | | | | | | | |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------|-------------------------------------------------------|---------------------------------|--------------------------------------|--------------------------------------------------------|------------------------------------------------------------|-------------------------------------------|-----------------------------------------|-------------------------------------|--------------------------------------------------|---------------------------------------------------------------|---------------------------------|
| | | | | | Web Interface for Programming Required ⁵ | Communicates with Cellular Weather Station ⁶ | Subscription Fee Required ⁷ | On-Site Sensor Required ⁸ | Outdoor / Indoor Model ⁹ | Option to Upgrade Existing Apparatus, Line 10 | Third-Party Remote System at Additional Cost ¹¹ | Flow Sensor Option Available |
|  Aqua Conserve www.aquacons.com 877-872-7787 | ET- Residential Pro Pack | \$264 - \$894 | 6 to 14 | | | | | | | | | |
| | ET- Commercial | \$427 - \$3,794 | 8 to 32 | | | | | | | | | |
| | ET- Ultima | \$1,472 - \$5,520 | 8 to 96 | | | | | | | | | |
|  ET Water Systems www.etwater.com 820-438-3400 | Smart Controller 100 | \$470 - \$590 | 9 to 12 | * | * | * | * | | 0/1 | * | * | |
| | Smart Controller 200 | \$773 - \$1,963 | 12 to 40 | * | * | * | * | | 0/1 | * | * | * |
|  Hunter www.hunterirrigation.com 820-735-3523 | ET System requires Hunter controller | \$420 - \$858 | 3 to 48 | * | | | * | | 0/1 | * | * | * |
|  HydroPoint-WeatherTRAK www.weathertrak.com 820-362-8774 ext. 121 | WeatherTRAK ET Plus | \$350 - \$600 | 6 to 24 | * | * | * | | | 0/1 | * | | |
| | WeatherTRAK ET Pro | \$965 - \$2,575 | 12 to 48 | * | Optional | * | * | | 0/1 | * | * | * |
|  Irritrol www.irritrol.com 820-634-8573 | Smart Dial | \$369 - \$889 | 6 to 24 | * | | * | | | 0/1 | * | | |
|  Rain Master www.rainmaster.com 820-777-1477 | Edge 1 | \$1,520 - \$2,400 | 6 to 36 | * | * | * | * | | 0/1 | * | * | * |
|  Toro www.toro.com 820-694-4740 | IntelliSense | \$229 - \$553 | 6 to 24 | * | | * | | | 0/1 | * | | |
|  Weathermatic www.weathermatic.com 888-444-3726 | Smartline 100 with W10 Weather Station | \$210 - \$245 | 4 to 8 | * | | | | | | | * | |
| | Smartline 1400 with W10 Weather Station | \$252 - \$594 | 4 to 24 | * | | | | | * | 0/1 | * | |

Footnote:

- For product details, click on SWAT / P
- The cost of model
- A station operates area of your lands 18, 24 or more stations (at least as many stations)
- Instead of traditional enters factors into sun/shade condition determines irrigate
- Customer program landscape design
- Local weather (in-pipe sensor and/or the Web)
- A nominal annual weather information
- Controllers using requirements to a
- Outdoor models or indoor models or outdoor model
- Contact WeatherTrak in your existing as to a WaterSmart if more affordable is
- Field field device to test for leaks on the landscape. No WaterSmart trips

Disclaimer

EBMUD does not warrant any of the accuracy of the information or the reliability of the data provided by the weather station and liability resulting from any use of the data, and does not warrant any of the accuracy of the information or the reliability of the data provided by the weather station and liability resulting from any use of the data.