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)

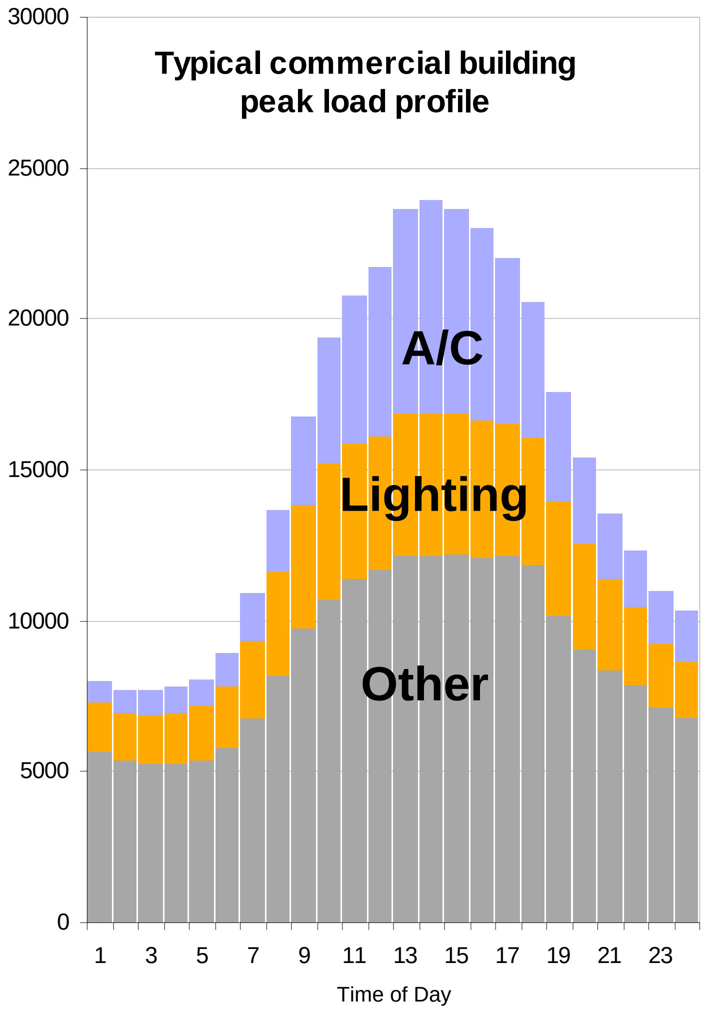
Project History

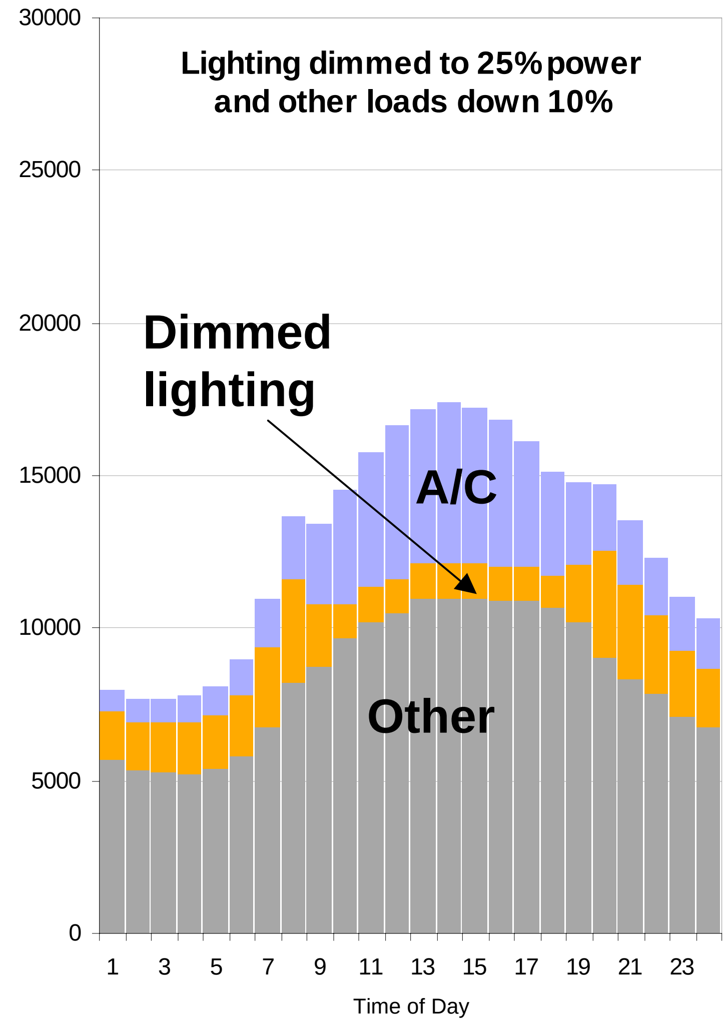
- Lighting Scoping Study (completed January 2007)
  - Identified potential for energy and demand savings using demand responsive lighting *systems*
  - Importance of dimming
  - New wireless controls technologies
- Advanced Demand Responsive Lighting (commenced March 2007)

Objectives

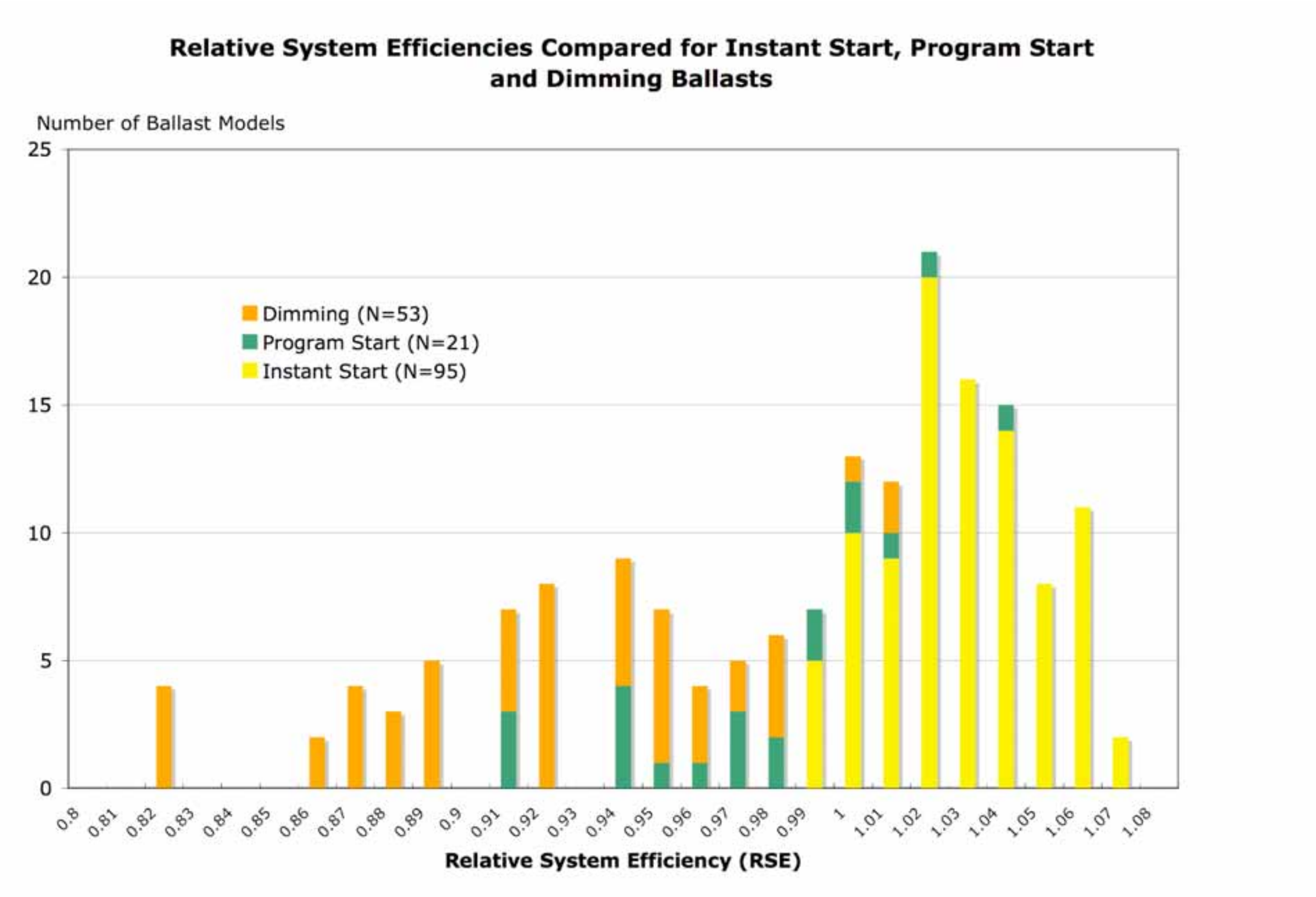
- Provide up-to-date information on the *reliability*, *predictability* of *dimmable lighting* as a demand resource under realistic operating load conditions
- Identify potential negative impacts of DR lighting on lighting quality

Potential of Demand Responsive Lighting Control





Dimming Ballasts Becoming More Energy-Efficient



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:

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

$$where:$$

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

Relative System Efficacy

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

Definition of RSE:

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

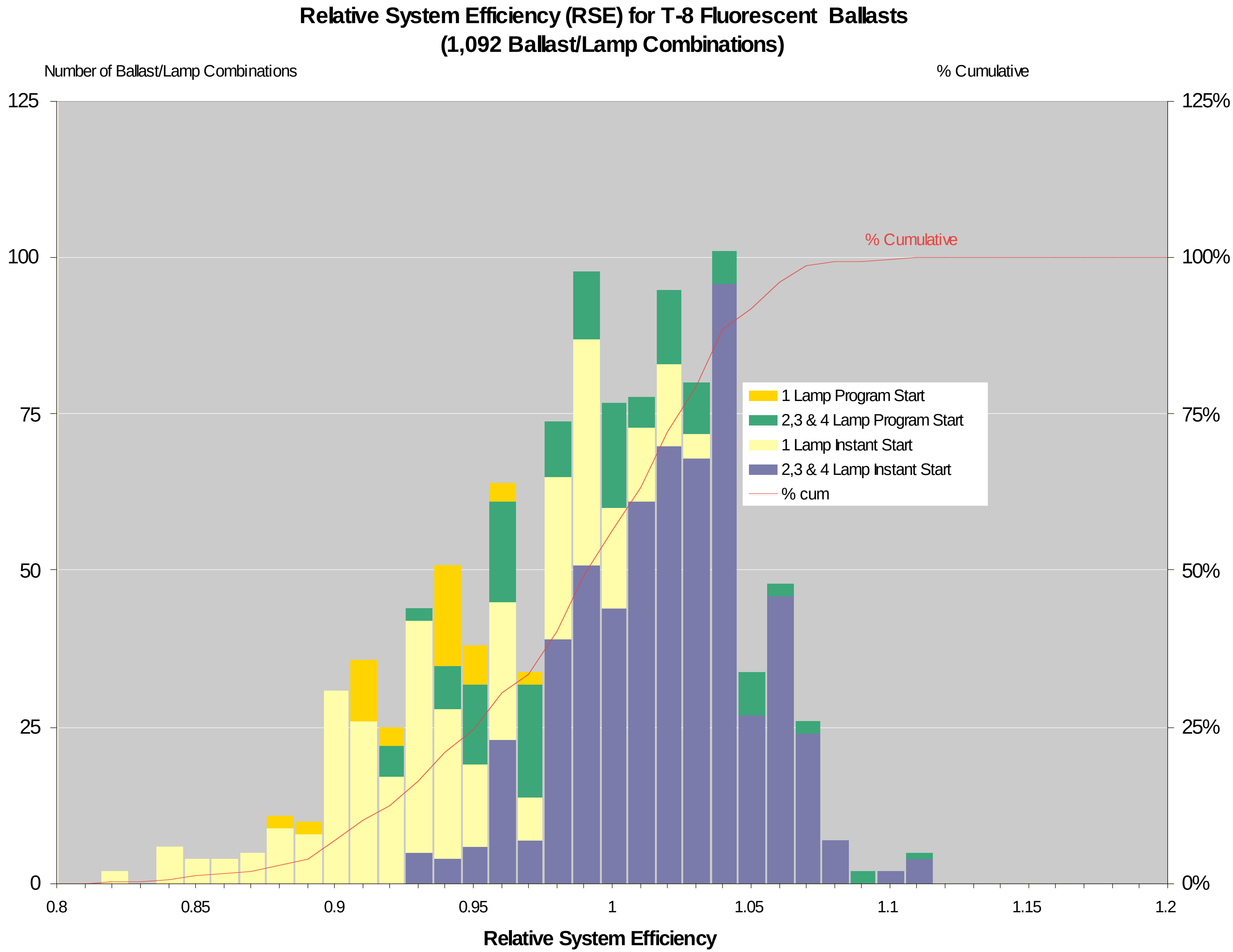
$$where:$$

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

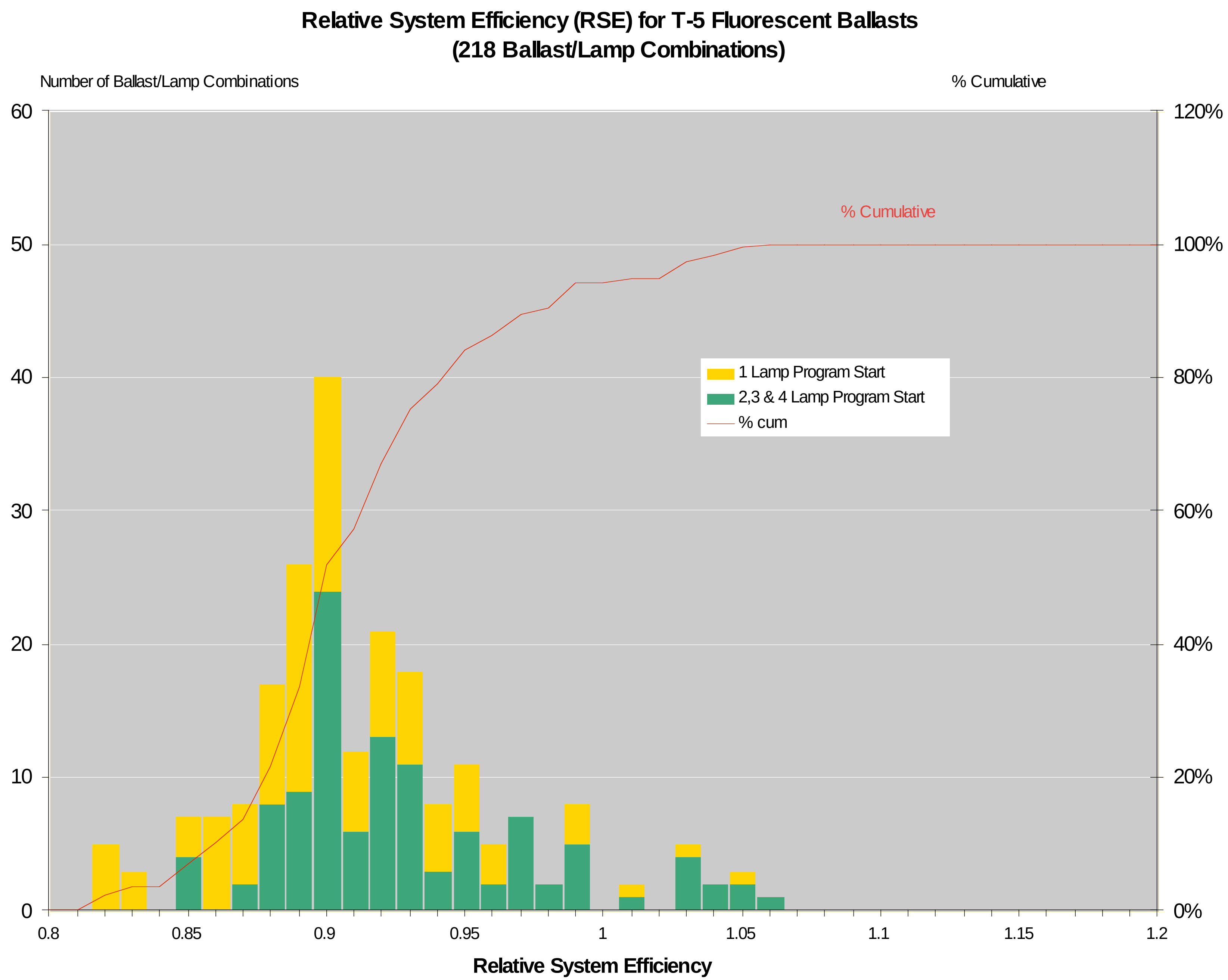
Why is Relative System Efficacy Superior?

- 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

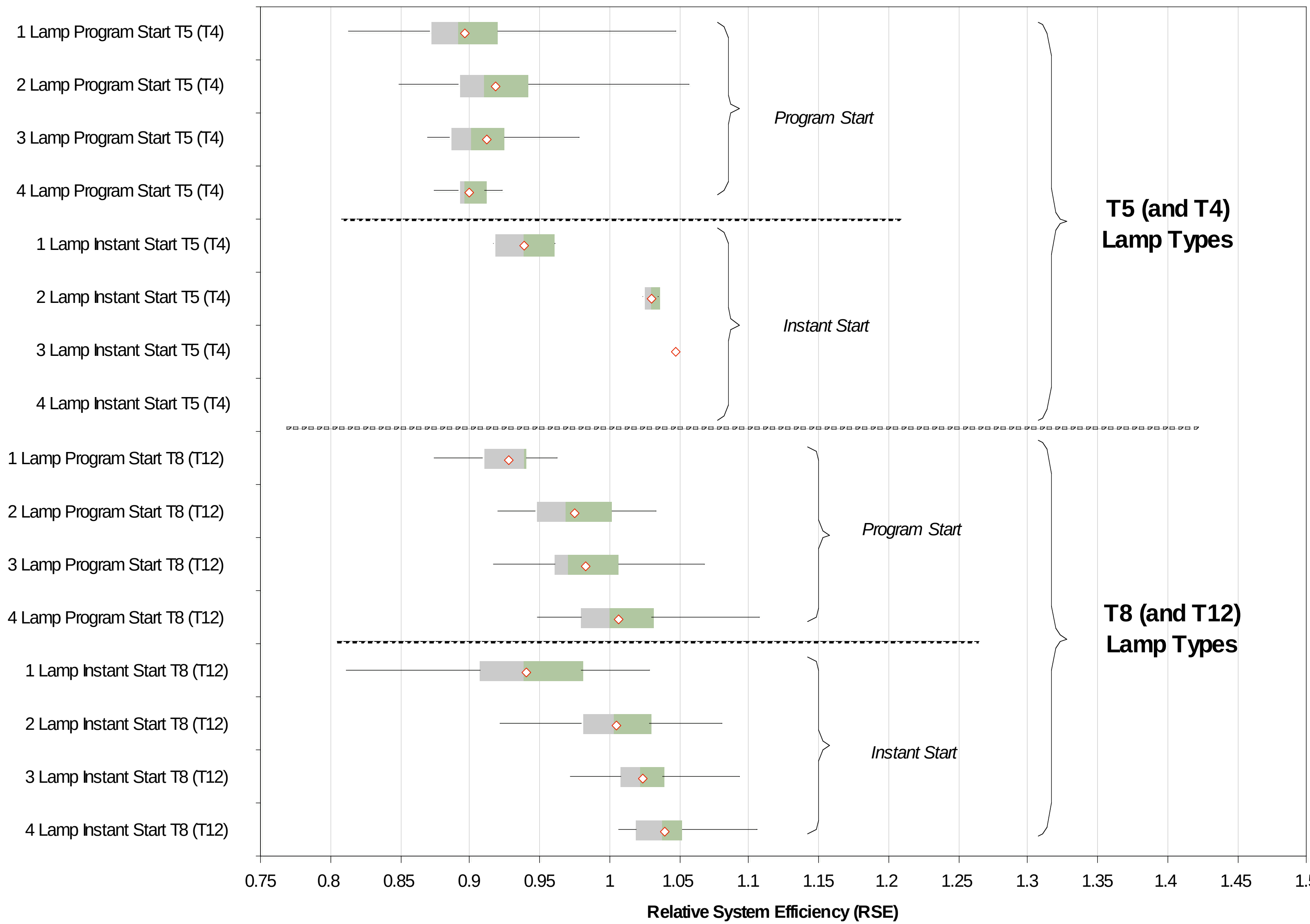
RSE is ideal metric for distinguishing premium efficiency ballasts from standard



Relative System Efficiency (RSE) for T-8 Fluorescent Ballasts
(1,092 Ballast/Lamp Combinations)
Number of Ballast/Lamp Combinations
% Cumulative
125
100
75
50
25
0
125%
100%
75%
50%
25%
0%
% Cumulative
1 Lamp Program Start
2,3 & 4 Lamp Program Start
1 Lamp Instant Start
2,3 & 4 Lamp Instant Start
% cum
0.8
0.85
0.9
0.95
1
1.05
1.1
1.15
1.2
Relative System Efficiency


Relative System Efficiency (RSE) for T-5 Fluorescent Ballasts
(218 Ballast/Lamp Combinations)
Number of Ballast/Lamp Combinations
% Cumulative
60
50
40
30
20
10
0
120%
100%
80%
60%
40%
20%
0%
% Cumulative
1 Lamp Program Start
2,3 & 4 Lamp Program Start
% cum
0.8
0.85
0.9
0.95
1
1.05
1.1
1.15
1.2
Relative System Efficiency

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-document, production system for HDR capture and analysis

Sample HDR

Workstation Specific Luminaires I

Agiliti by Lightolier

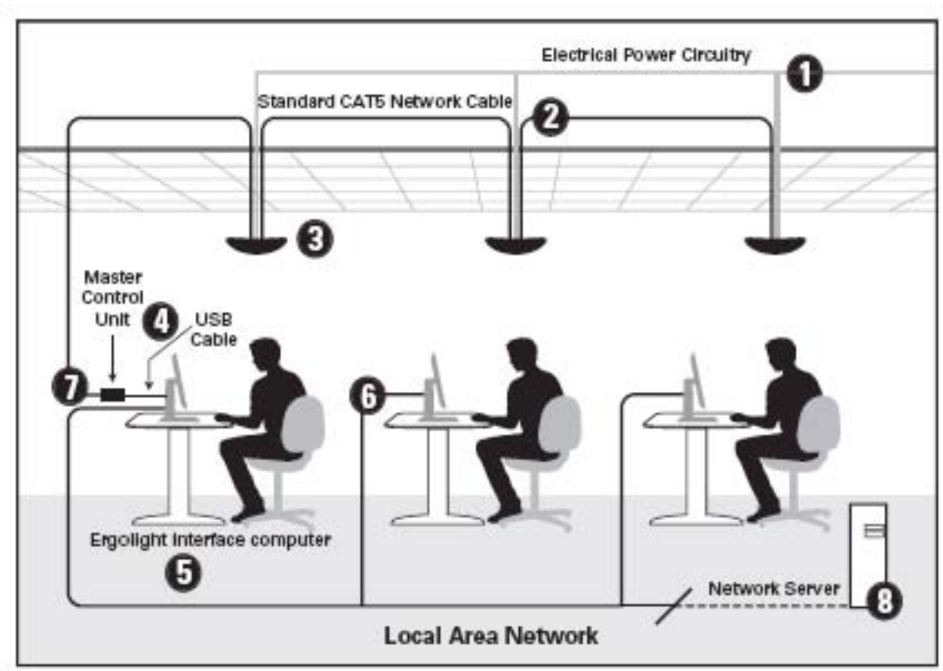
Two T-5 HO lamps top-over bottom

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

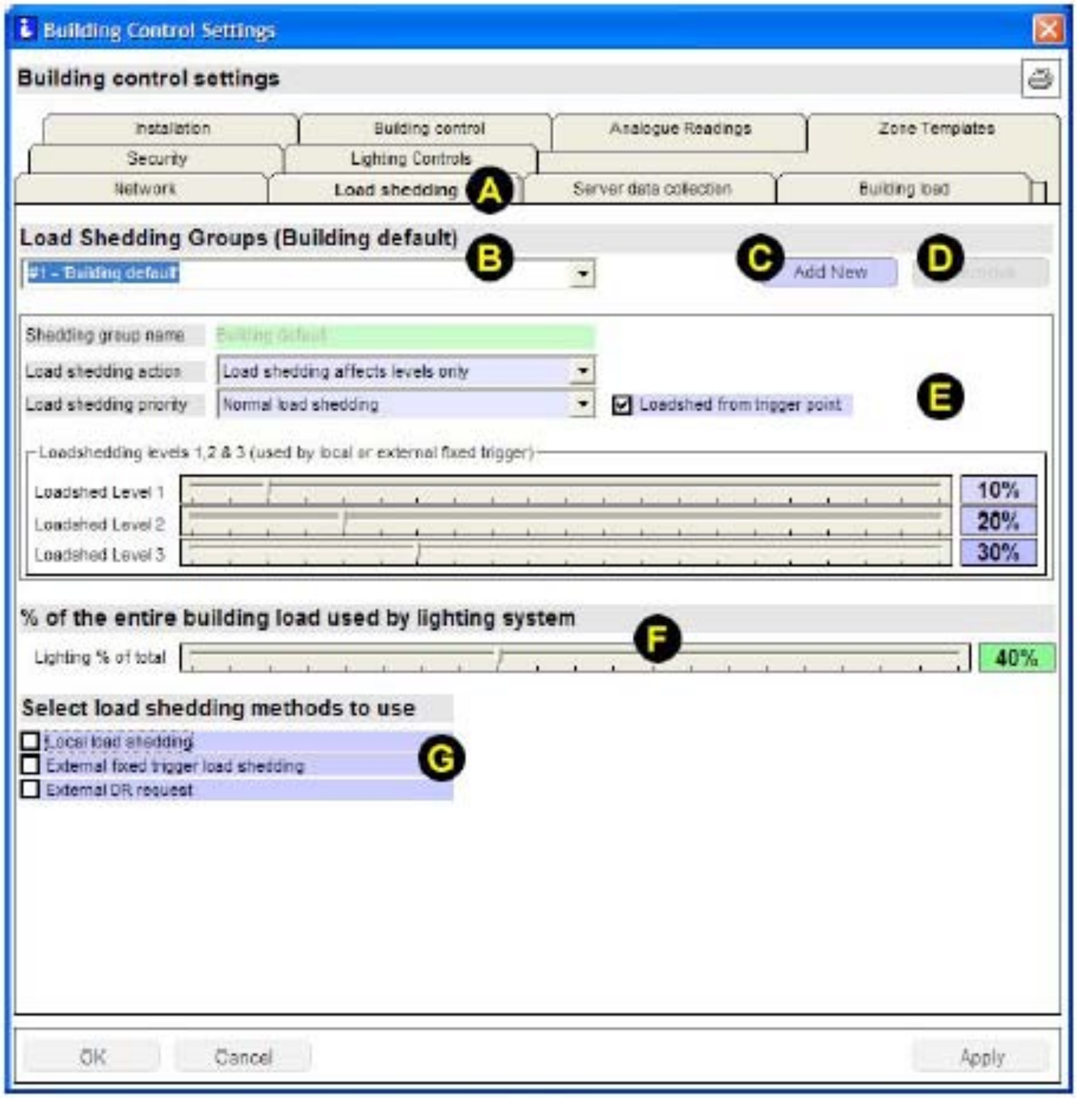
RS-485 network

User control of two outer lamps

Building control of center lamp

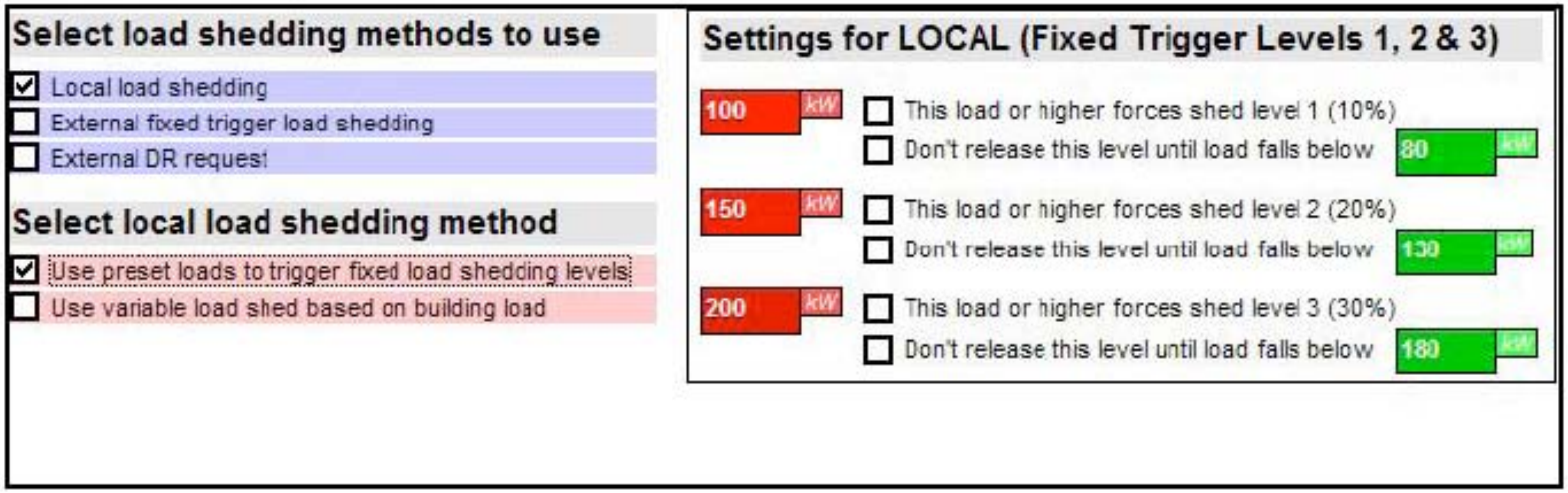
Control Panel for Demand Response

Load shedding – Building settings

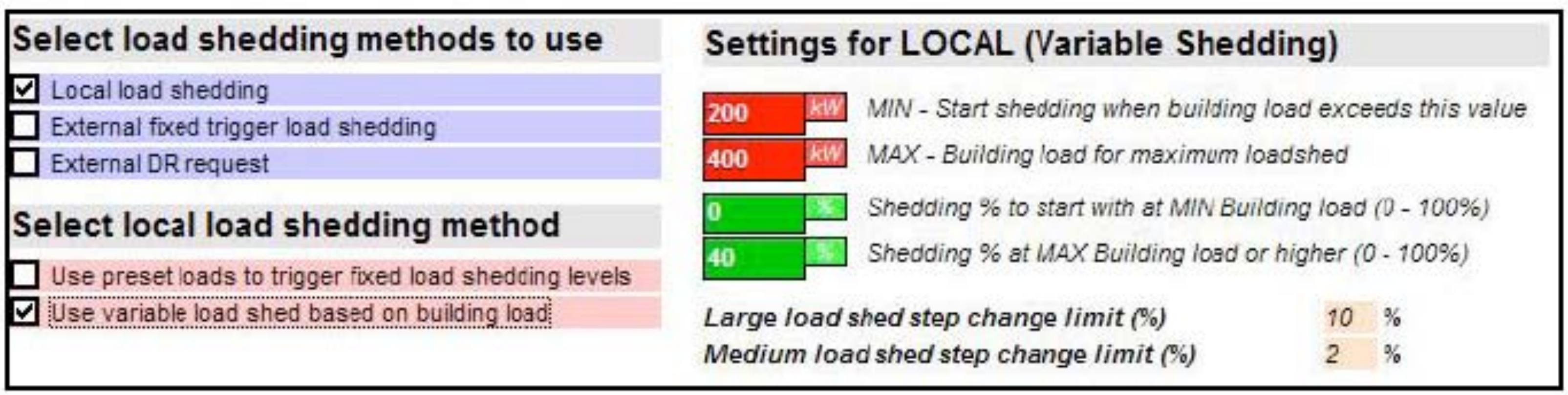


Control Panel for Fine-tuning the DR Strategy

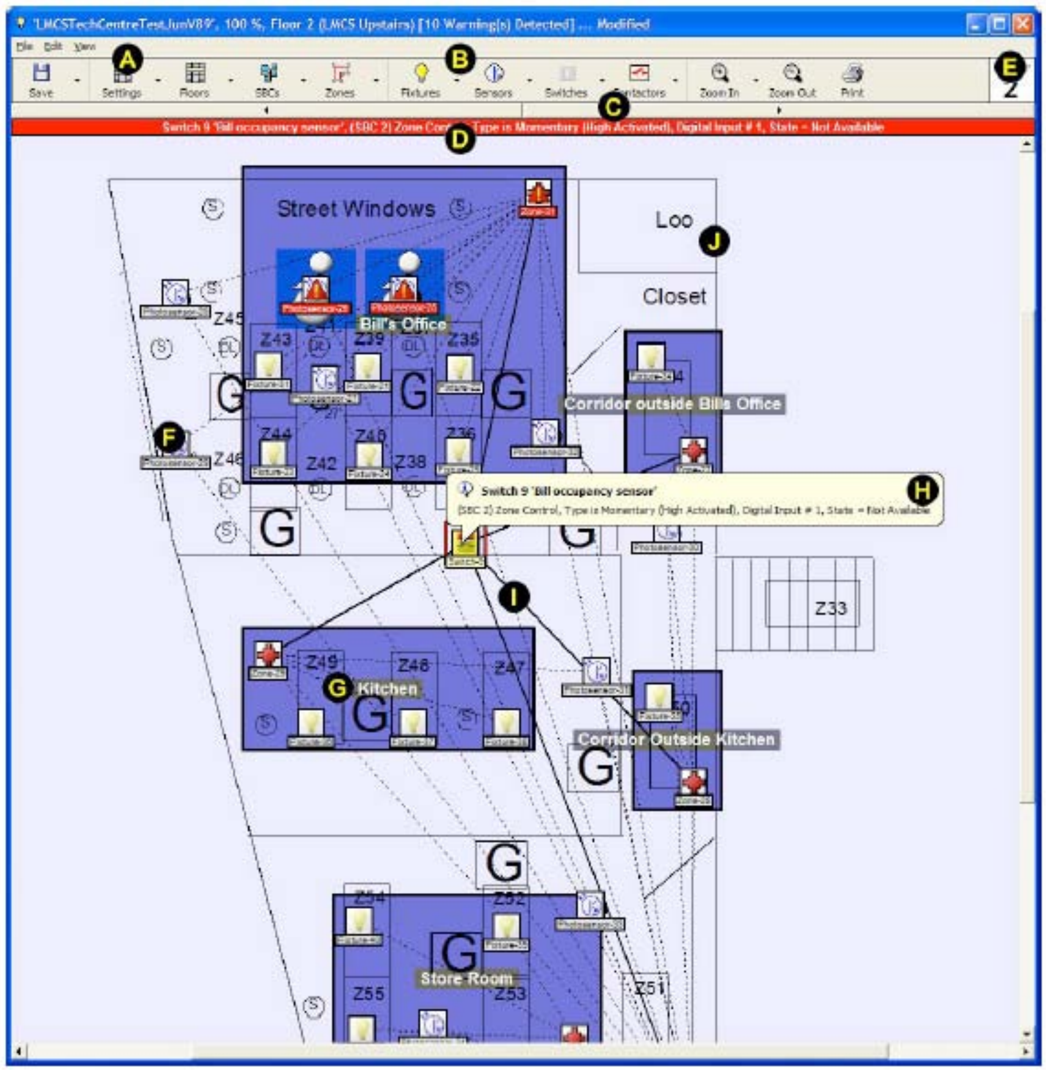
Local load shedding (Fixed trigger options)



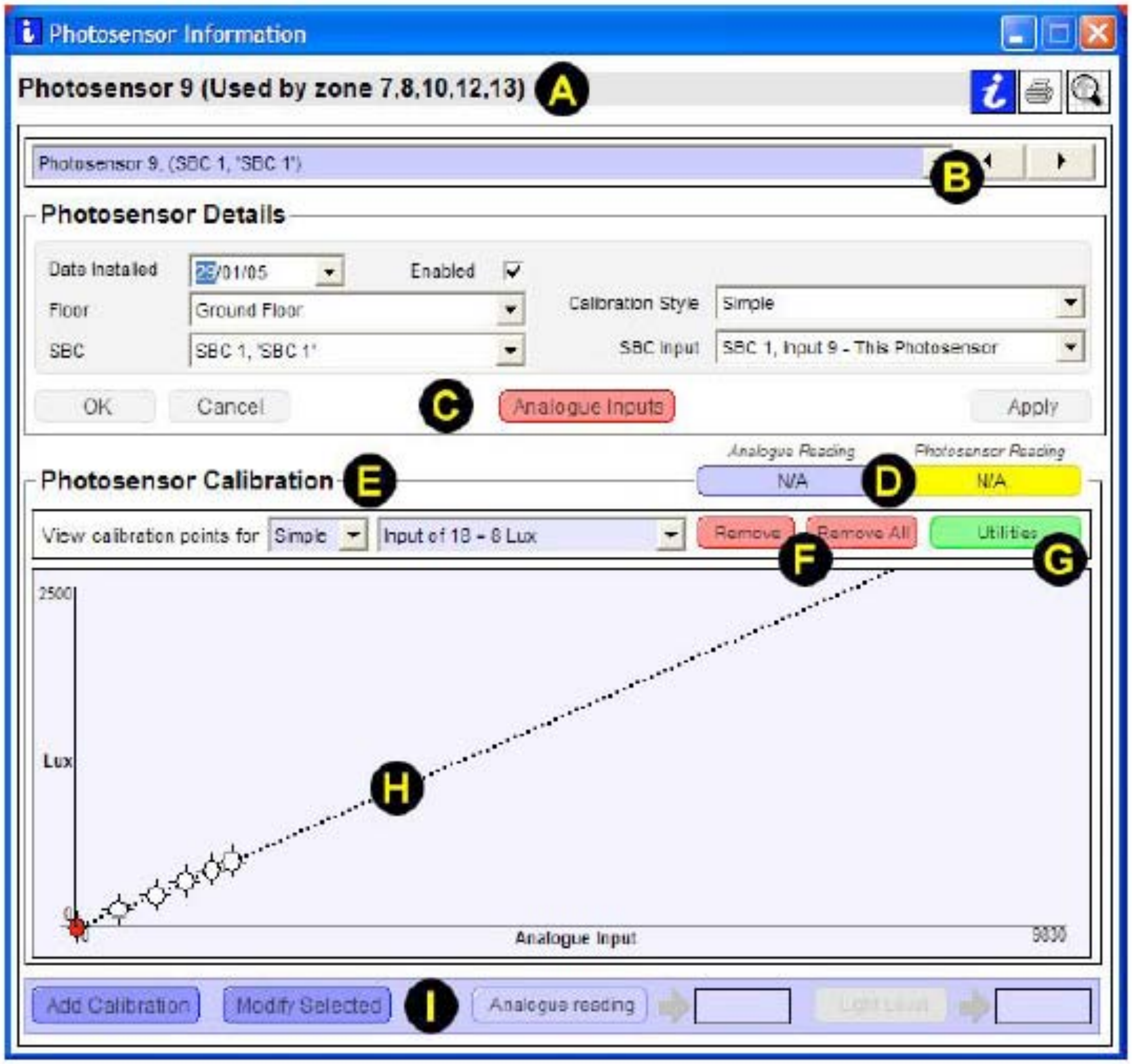
Local load shedding (Variable shedding options)



Graphic User Interface



Commissioning Panel for Daylight Controls

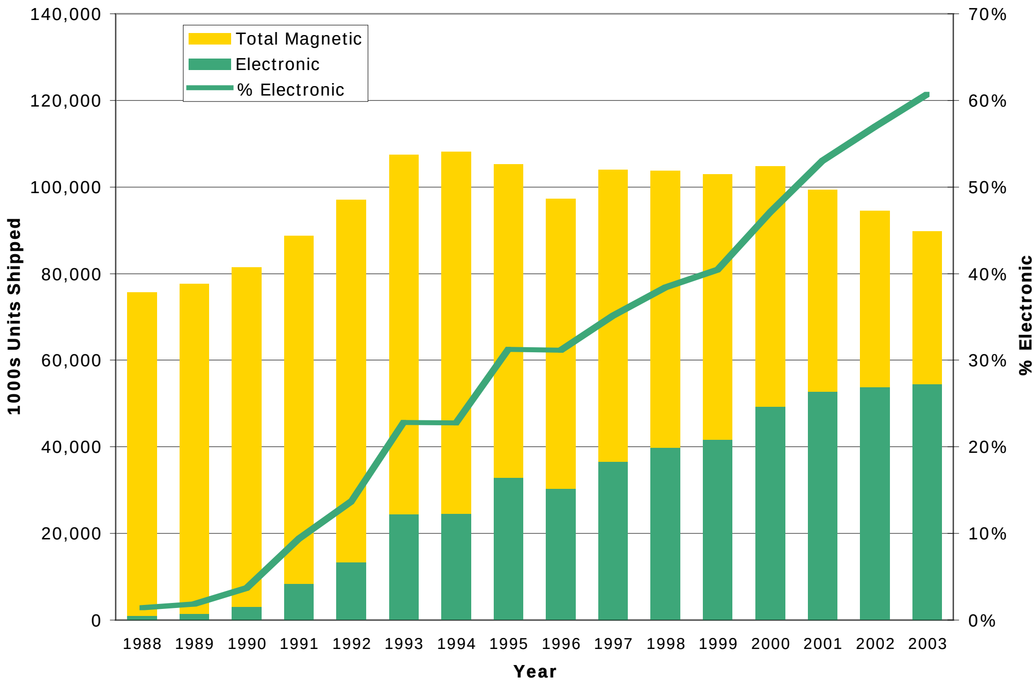


Technology Transfer

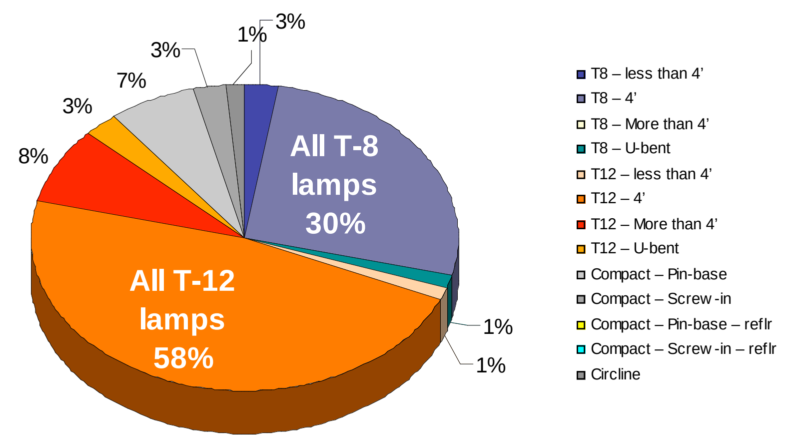
- Informed, public-interest TAG guiding research
  - No manufacturers
- Developing the market transformation vehicle
- Setting RSE efficiency targets
- Evaluating potential negative impacts

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 Recommended Professional Installers and Contact Information	EBMUD Qualifying WaterSmart Irrigation Controller Model Name 1	WaterSmart Irrigation Controller Cost 2	Number of Stations 3	Helpful Scheduling Engine 4	Web Interface for Programming Required 5	Communicates with Off-site Weather Station 6 (How controller obtains weather information)	Subscription Fee Required 7 (How controller obtains weather information)	On-site Sensor Required 8 (How controller obtains weather information)	Outdoor / Indoor Model 9	Option to Retrofit Existing Automatic Timer 10	Hand-held Remote Option at Additional Cost 11	Flow Sensor Option Available
	**Aqua Conserve** www.aquawss.com 877-922-7787	ET-Residential Pro Pack	$264 – $394	6 to 14					•	I			
		ET-Commercial	$477 – $3,744	8 to 32					•	O / I	•	•	
		ET-Ultima	$1,173 – $5,330	14 to 56					•	O / I		•	•
	**ET Water Systems** www.etwater.com/ebmud 800-438-3400	Smart Controller 100	$476 – $590	9 to 12	•	•	•	•		O / I	•	•	
		Smart Controller 200	$773 – $1,965	12 to 48	•	•	•	•		O / I	•	•	•
	**Hunter** www.hunterindustries.com 800-733-2823	ET System requires Hunter controller	$429 – $858	3 to 48	•				•	O / I	•	•	•
	**HydroPoint-WeatherTRAK** www.weathertrak.com/ebmud 800-362-8774 ext 121	WeatherTRAK ET Plus	$350 – $600	6 to 24	•		•	•		O / I	•		
		WeatherTRAK ET Pro	$985 – $2,575	12 to 48	•	Optional	•	•		O / I	•	•	•
	**Irritrol** www.irritrol.com 800-634-8873	Smart Dial	$309 – $889	6 to 24	•		•	•		O / I	•		
	**Rain Master** www.rainmaster.com 800-777-1477	Eagle-i	$1,500 – $2,600	6 to 36	•	•	•	•		O / I	•	•	•
	**Toro** www.toro.com 800-664-4740	Intelli-Sense	$209 – $553	6 to 24	•		•	•		O / I	•		
	**Weathermatic** www.smartline.com 888-444-3726	Smartline 800 with W10 Weather Station	$210 – $245	4 to 8	•				•	I		•	
		Smartline 1600 with W10 Weather Station	$252 – $584	4 to 24	•				•	O / I		•	

Footnotes

1) For product test r…
Click on SWAT / P…

2) The cost of mode…

3) A station operates…
area of your lands…
18, 24 or more sta…
least as many sta…

4) Instead of tradition…
enters factors incl…
sun/shade condi…
determines irrigat…

5) Customer program…
landscape descrip…

6) Local weather info…
puter server and se…
the Web

7) A nominal annual…
weather informati…

8) Controllers using…
requirements to b…

9) Outdoor models c…
Indoor models ca…
or outdoor model…

10) Contact WaterSm…
in your existing a…
to a WaterSmart i…
more affordable a…

11) Hand-held device…
to test for leaks or…
the landscape. No…
WaterSmart irriga…

Disclaimer