Sustainable Design & Energy Management using Addressable Lighting Controls

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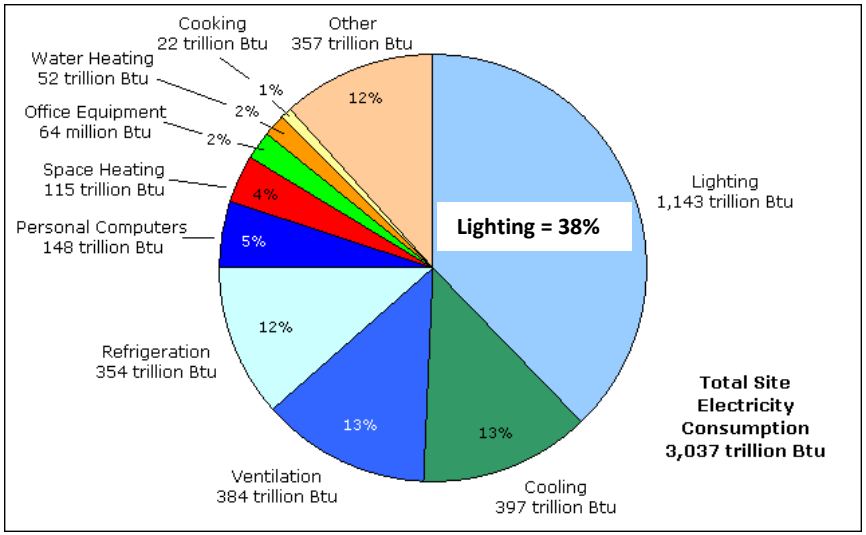
Sustainable Design & Energy Management

- Lighting Controls & Energy Management
- Sustainable Design and Addressable Lighting Controls
- Energy Management Strategies
- Industry Case Studies
- Conclusions

Lighting Controls & Energy Management

- On average, lighting accounts for one-third of energy use in office buildings, and thus often dominates the opportunity for energy savings among all electrical systems
  - Buildings consume more than one-third of the total primary energy used in the USA
  - About two-thirds of a building's primary energy use is attributed to electricity [1],[5],[6]



Source : U.S. Energy Information Administration

Addressable Lighting Controls

- What are “Addressable Lighting Controls”?
  - The ability to address and control each fixture or peripheral device (such as occupancy sensors, photo sensors and wall controllers) individually.
  - All devices (each with a unique address) are networked and centrally controlled through a central software interface.
    - This allows for addressable dimming or switching of light fixtures independent of electrical circuiting.

Addressable Lighting Controls……(cont'd)

- An example illustrating the Graphical User Interface (GUI) for an "Addressable Lighting Control System".

- Once installed commissioning and administration of the entire system can be performed via the front-end software.

Contribution to Sustainable Design

- Addressable Lighting Controls contribute to the following sustainable building design principles:

1. Optimize Site/Existing Structure Potential
   - Maximize daylight use
2. Optimize Energy Use
5. Enhance Indoor Environmental Quality (IEQ)
   - Provide reduced levels of diffused general illumination
6. Optimize Operational and Maintenance Practices
   - Energy reporting software can track lighting energy use down to the individual fixture level

Lighting & HVAC

- According to U.S. Department of Energy heat generated by standard lighting increases a building's cooling load and can account for up to 42% of the building's cooling load in a "typical" commercial building

  - 1 W/ft.^{2} of extra lighting power requires 15-20% of extra cooling air [2]

  - A good rule of thumb is every 3 W of lighting energy saved = 1 W HVAC energy saved

Conventional Lighting Controls

- Low voltage relay based controls
  - Most prevalent form of facility wide lighting control
  - Turn lights “ON/OFF” by lighting circuit/switch leg (zone) based on time schedule

- Occupancy Sensors
  - Automatically turn lights off if occupancy is not detected
  - Local controls only – no sharing of data with centralized control system or other building systems

Conventional Lighting Controls: Limitations

- No ability to address & control individual fixtures
  - Zoning restricted to lighting circuiting
- No workspace or task specific control
  - i.e. tuning light levels based on use
- Lack of centralized “intelligence” to allow deployment of combined energy management strategies
- Limited ability to integrate or share data with other building systems such as HVAC, Security and Fire

Addressable Lighting Controls - Advantages

- Addressable lighting controls are the most effective method to shed lighting load in commercial buildings
  - Addressable control capabilities – switching/dimming
  - Centrally managed facility wide control systems designed specifically for energy management
  - Bring control point down to individual fixture level via unique address
  - Controlled through front end software and integrated with BAS and other building systems
    - Remote re-zoning and changes in energy management strategies

Types of Addressable Lighting Controls

- Use of Addressable (Digital) ballasts (i.e., DALI)
  - Addresses embedded into digital ballast
  - Typically requires re-commissioning upon ballast replacement
  - Ballasts costs much higher than 0-10v (Analog) ballasts

- Use of 0-10v (Analog) ballast with Addressable Input/Output (I/O) device
  - Use of standard 0-10v ballasts & sensors connected to an addressable I/O device
  - No re-commissioning required upon ballast failure
  - Systems are not tied to a single ballast vendor

Simple upgrading & Stand alone control

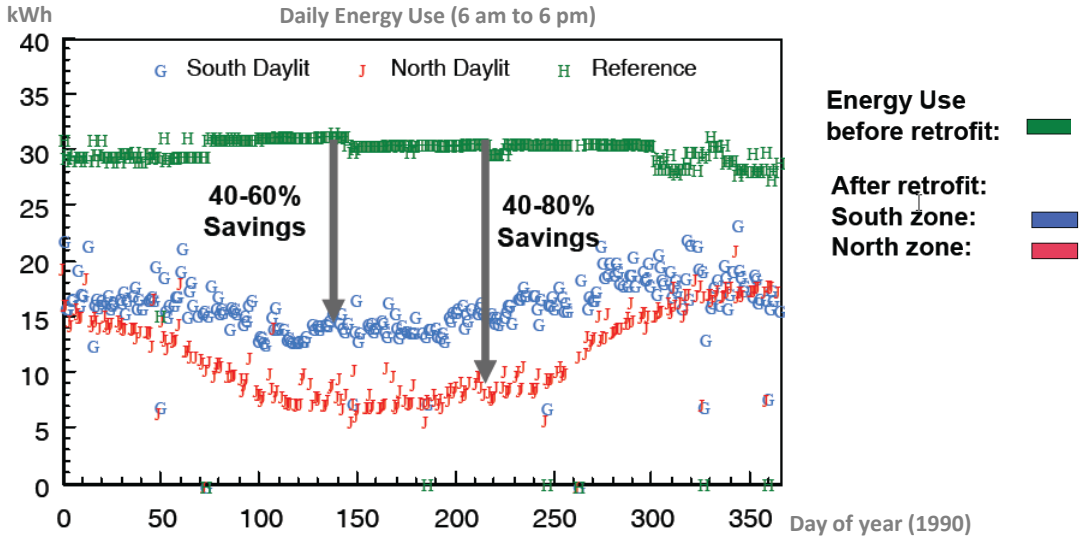
- Simple upgrading of a lighting system with more efficient technologies (e.g., T12 ➔ T8 upgrade) offers some potential for reduction in lighting energy consumption.

- Replacement or upgrading of existing fixtures with energy efficient lighting equipment alone won't produce optimum energy savings.

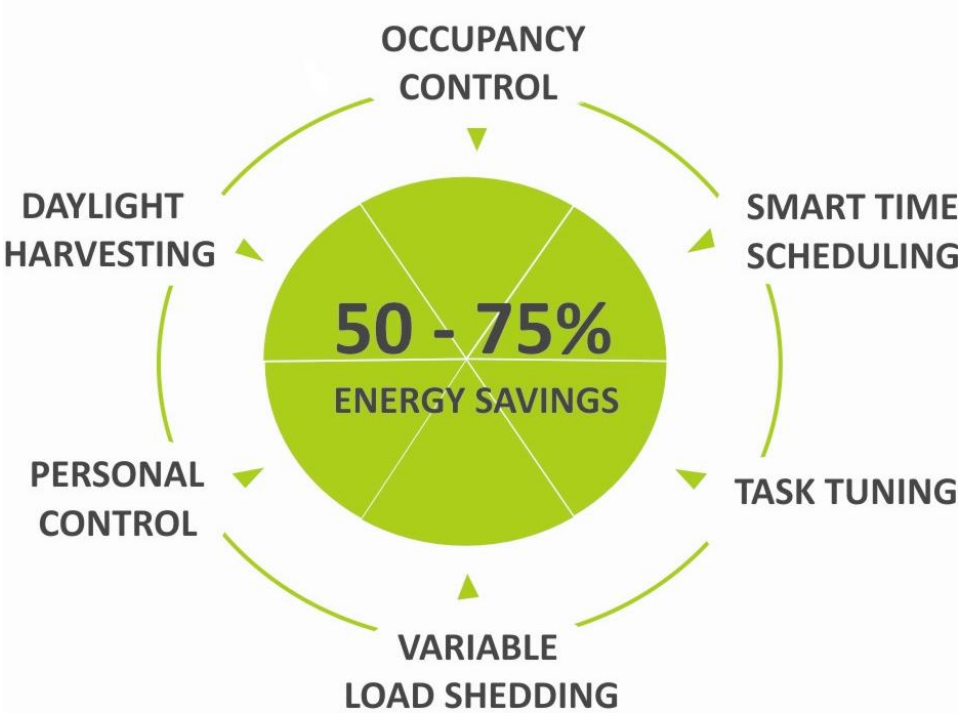
- Stand alone local lighting controls (such as occupancy sensors) are one dimensional switching strategies that are not networked and do not offer the multiple dimming strategies

Using Addressable Lighting Controls

- Advanced lighting controls in conjunction with various energy management strategies can typically yield a combined lighting energy savings of 40% – 80% in office buildings [15],[21]
  - According to Stephen Selkowitz, Chairman, Building Technologies Department at Lawrence Berkeley National Laboratory all lighting should be "dimmable and addressable"

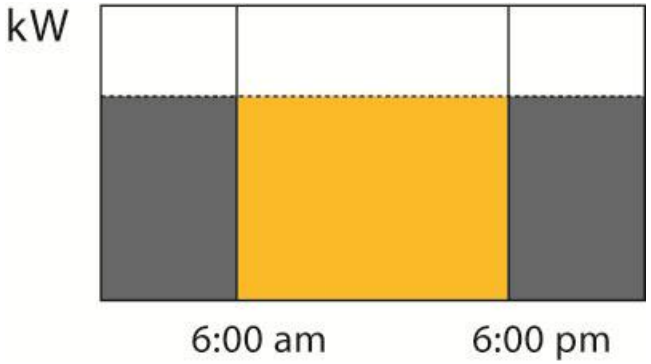


Energy Management Strategies



Smart Time Scheduling

- With time scheduling, lights in a facility can be turned “ON”, “OFF”, or “DIMMED” according to day, night, holiday and other schedules.



- Lights can be scheduled to be turned on/off by zones as small as an office, workstation or even a light fixture
- When used as a standalone strategy can save 15% - 25% of lighting energy [13],[14],[15],[23]

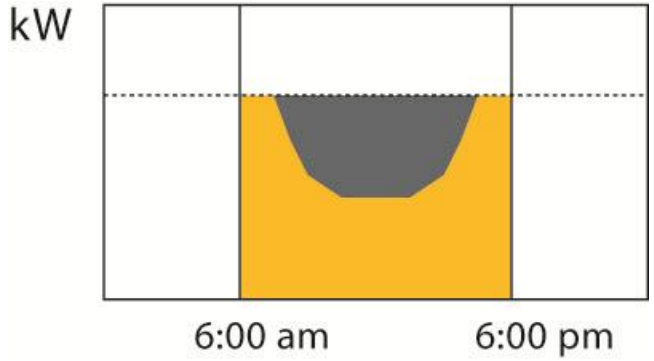
Addressable vs. Conventional Comparison

- Unlike conventional lighting controls, addressable dimming lighting controls offer the ability to program time schedules down to the individual fixture level (independent of electrical circuiting) resulting in significant savings.

- Lighting schedules can be made to automatically extend in the event that after hours occupancy is detected via the “virtual occupancy sensor” feature.
  - Virtual occupancy sensor = Lights stay on in response to PC keyboard/mouse movements

Daylight Harvesting

- With daylight harvesting, lights are dimmed or switched in response to sensed ambient light levels.



- As daylight levels fall off, dimming levels of individual fixtures are adjusted so that total illumination is evenly maintained throughout the space at the required level.
- When used as a standalone strategy can save 20% - 50% of lighting energy[5],[8],[13],[15],[18]

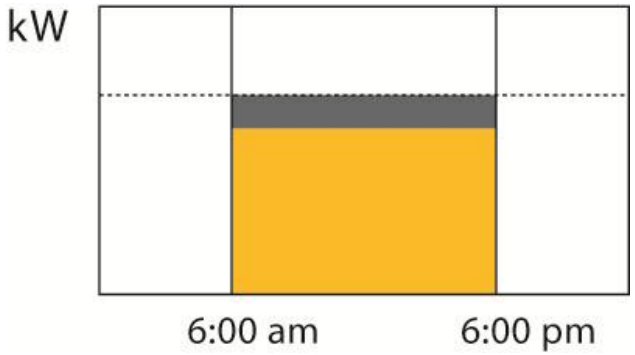
Addressable vs. Conventional Comparison

- Conventional daylight harvesting systems require one photo sensor to control a group of ballasts typically on one circuit or switch leg.
  - Due to this limitation, conventional controls operate a large group of fixtures all in the same manner thereby limiting the full potential of daylight harvesting.

- In the case of addressable dimming lighting controls, photo sensor to fixture associations are software based.
  - In fact, just one photo sensor can be used for daylight harvesting an entire facade of a floor.
  - The amount of dimming for each individual fixture can be adjusted based on its proximity to a natural light source and is controlled digitally through software, thus significantly enhancing the energy saving potential.

Task Tuning

- "Tuning" or setting default light levels to suit the particular task or use of a workspace
  - Light levels are "tuned" fixture by fixture throughout a facility (through dimming), thereby eliminating over-lighting.



- When used as a standalone strategy can save 10% - 25% of lighting energy[7],[14],[15]

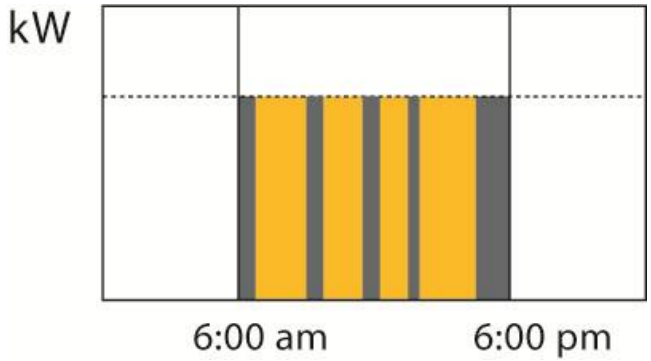
Addressable vs. Conventional Comparison

- With conventional lighting controls, fine tuning of lighting based on workspace or task is not possible.
  - Conventional controls are generally applied at the circuit level causing large groups of fixtures to be controlled together.

- With addressable lighting controls,
  - Each fixture in a facility can be task tuned on an individually addressable basis from the software
  - There's no guessing – exact light levels are easily set for all areas of a facility
    - retune work areas as usage changes
  - Lighting design can sometimes be simplified even if aggressive power density levels are desired

Occupancy Control

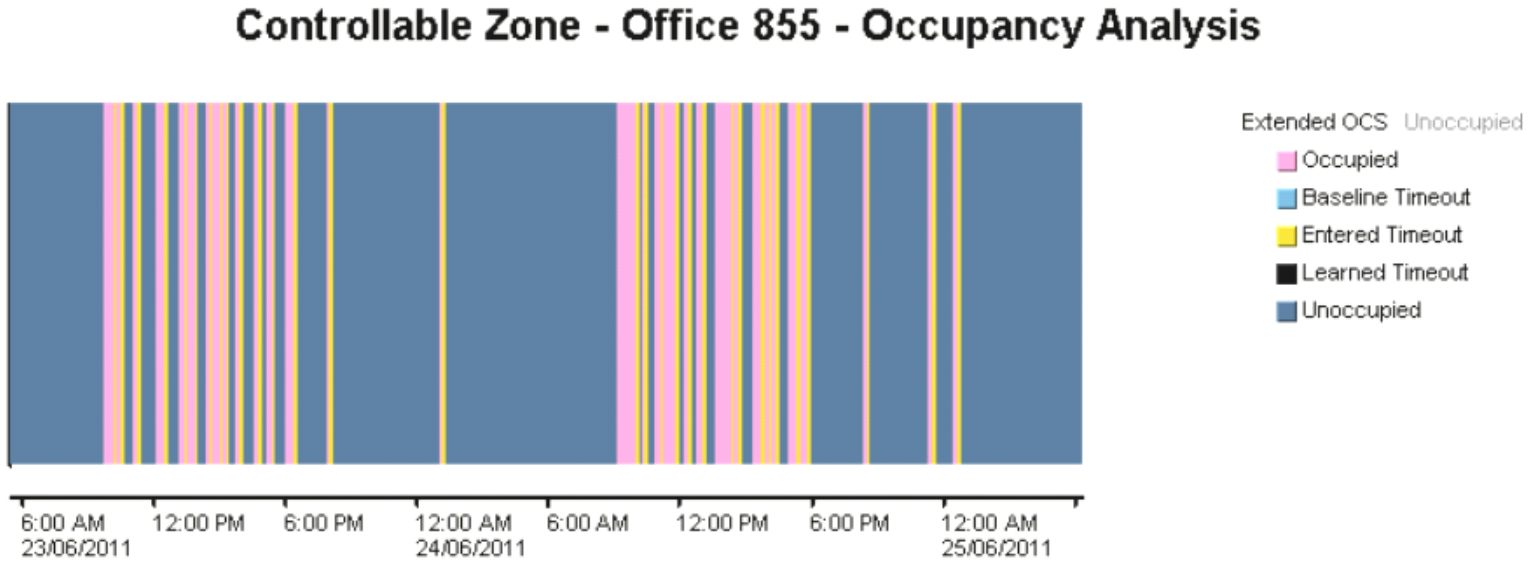
- Occupancy sensors switch the lights “OFF” when the space is not occupied and switch the lights “ON” when the space is occupied.



- When used as a standalone strategy can save 20% - 45% of lighting energy[11],[14],[15],[18]

Some Advantages..

Change sensor time-outs based on actual data



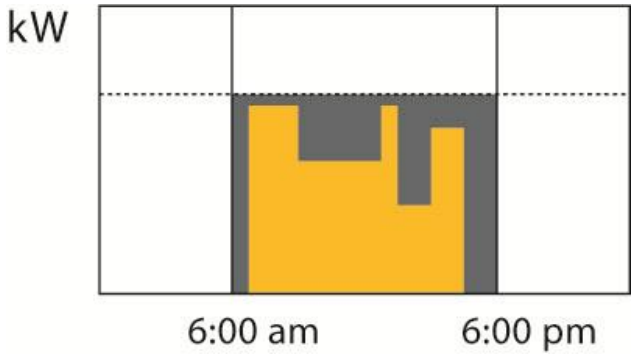
Addressable vs. Conventional Comparison

- Conventional occupancy controls a group of ballasts typically on one circuit or switch leg.

- With addressable lighting controls,
  - Lights are automatically turned “ON”, “OFF” or “DIMMED” based on occupancy detection (independent of electrical circuiting)
  - Soft association of sensors to fixtures via software
  - Allows for overlapping and support zones
  - Can share real time occupancy data with other building systems via BACnet® or Tridium interface
  - Ability to change sensor to manual “ON”/auto “OFF” mode (vacancy sensors) to provide another layer of energy saving

Personal Control

- Personal lighting controls allows “ON/OFF” switching or dimming using virtual slide dimmers located on the occupant’s computer or IP phone.



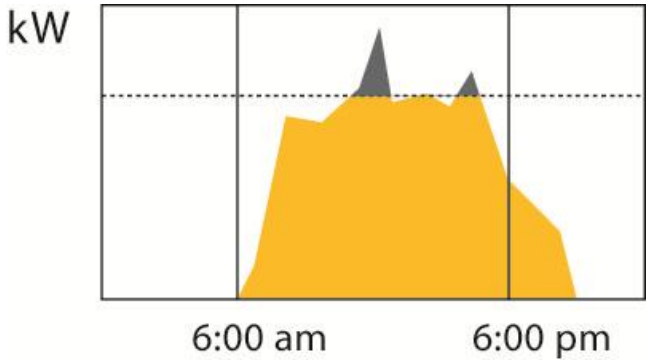
- When used as a standalone strategy can save 7% - 23% of lighting energy[5],[10],[11]

Addressable vs. Conventional Comparison

- Each light fixture can be dimmed or turned off individually (independent of electrical circuiting) allowing users ultimate flexibility in setting preferred light levels
  - PC is used as secondary form of occupancy sensor
  - Significant contributor to energy savings as most users dim lights below default light levels
- Studies of personal lighting control suggest that it offers office occupants a route to a more comfortable physical work environment resulting in increased productivity while also delivering energy savings[10]
- Energy saving with a comfortable physical work environment is possible only with lighting that is individually addressable and dimmable as is the case with advanced lighting controls.

Variable Load Control

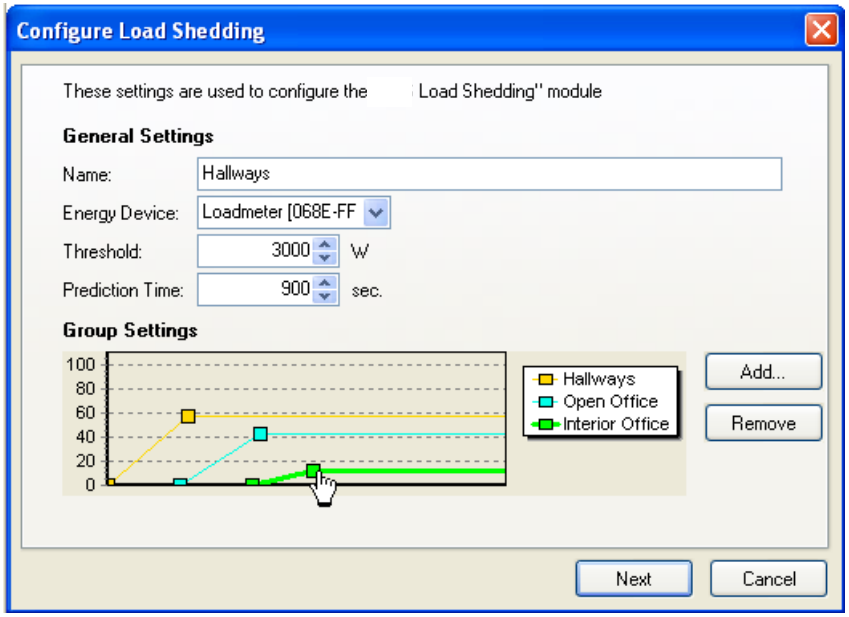
- System automatically executes load shedding in response to energy price spikes or to reduce peak demand
  - System can respond to information from a demand meter, a utility demand response signal, or a signal from building or energy management systems



- When used as a standalone strategy can save 15% - 25% of lighting energy[12],[15],[16],[17],[18],[20]

Addressable vs. Conventional Comparison

- With addressable lighting controls,
  - Lights can be dimmed based on a prioritized hierarchy of zones
    - System will not allow diming beyond a threshold value thus ensuring the comfort and safety of the occupants
  - Configurable fade rate allows for gradual dimming of lights in a manner generally imperceptible by occupants



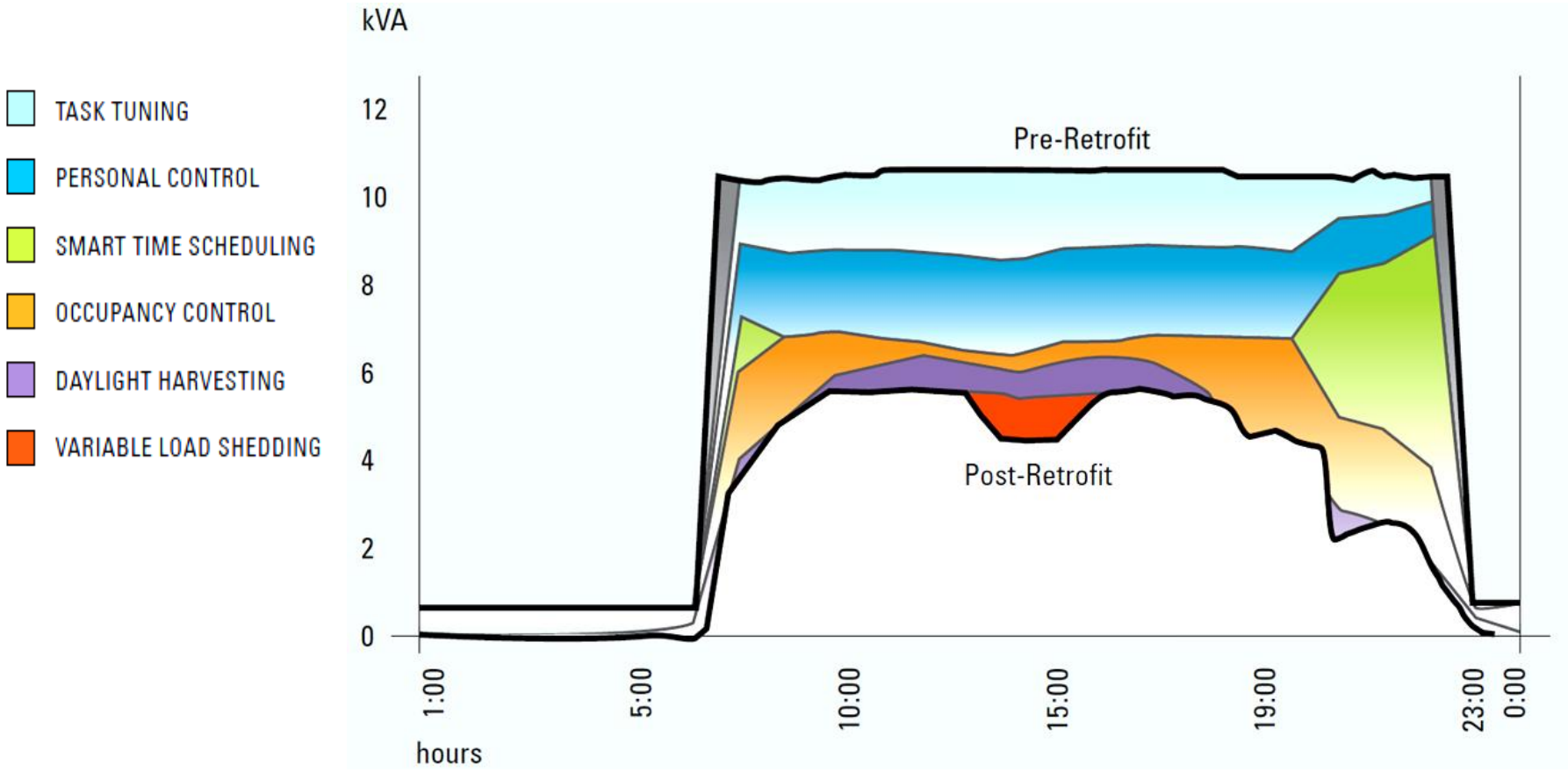
- Conventional lighting controls offer limited abilities when it comes to integration or sharing occupancy or load shedding data with building automation systems (BAS)
  - They, therefore, lack the ability to provide or react to load shedding/demand response signals effectively.

Industry Case Studies

Energy Management Strategies	Lighting energy savings due to Addressable Lighting Controls				Average Savings by Strategy *
	Multi-Tenant office building (300,000 ft.^{2})	Headquarters of a major entertainment company (400,000 ft.^{2})	Hospital Administration Building (175,000 ft.^{2})	Major sports complex (1.3 million ft.^{2})	
Smart Time scheduling	13.91%	8.91%	22.2%	24.01%	15 - 25%
Daylight Harvesting	0.60%	3.96%	8.15%	3.4%	20 - 50%
Task Tuning	9.0%	10.95%	13.24%	5.32%	10 - 25%
Occupancy Control	31.3%	24.94%	25.38%	37.21%	20 - 43%
Personal Control	6.12%	10.64%	1.8%	2.1%	7 - 23%
Variable Load Control	0.03%	4.65%	3.2%	5.1%	15 - 25%
Cumulative savings due to Addressable Lighting Controls	60.96%	64.05%	73.97%	77.14%	

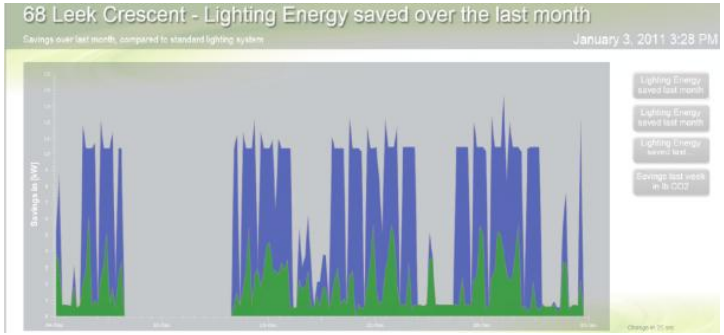
*Values are quoted from independent studies referenced in the last page

Hospital Administration Building

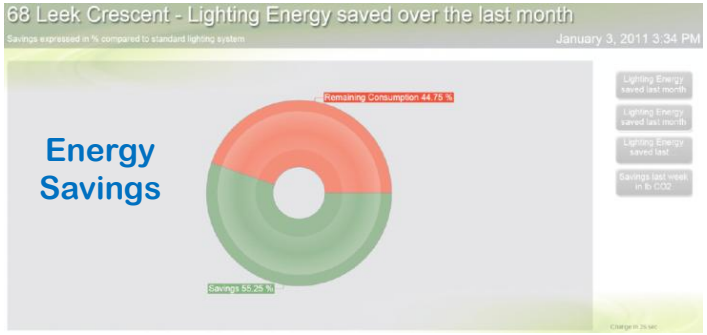


Additional Advantages

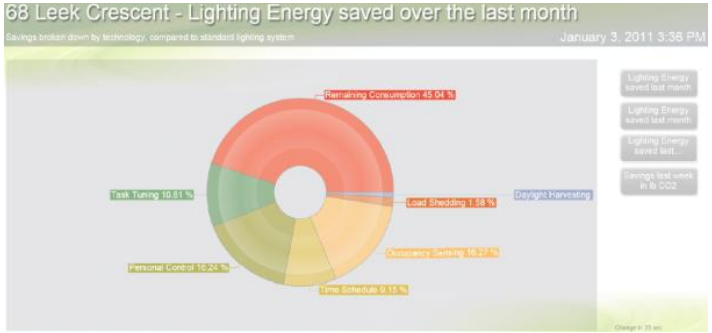
Energy Demand History
(by space, by hour, day,
week, month, year)

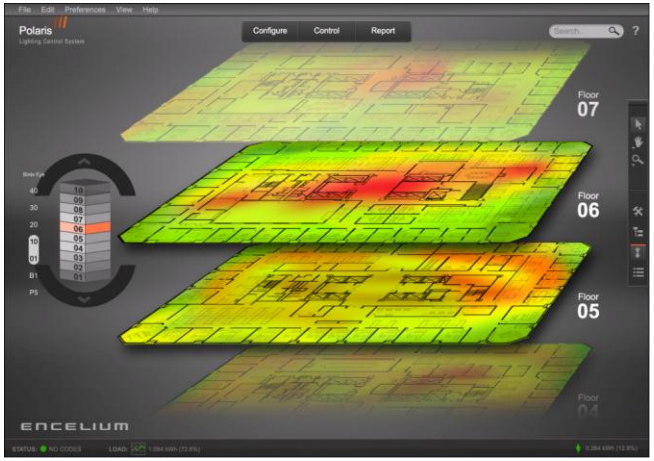


Energy Savings



Energy Savings by Strategy





Conclusions – Conventional Lighting Control

- With conventional lighting control technologies, it is impossible to implement multiple energy management strategies
  - Consequently, the aggregate energy saving potential with conventional lighting control is generally limited to one energy management strategy at a time
  - Changes in zoning and/or energy management strategies have to be performed on the individual devices

Conclusions – Addressable Lighting Controls

- Addressable dimming lighting controls, on the other hand,
  - Allow simultaneous use of all six energy management strategies by using networked addressable controls
  - Meet the specification for “Intelligent Buildings”
  - Allow the entire control system managed through graphical user interface (GUI) based front-end software
    - In other words, remote re-zoning and changes in energy management strategies can be performed with just a mouse click instead of manipulation at the device level
    - Participation in the “Energy Demand Management” program
  - Provide superior energy savings (50% - 75%) as compared to conventional lighting controls
  - Contribute towards LEED points (12 - 18 points) in multiple categories
  - Provide advanced load shedding capabilities by aggregating multiple building loads to execute demand response
  - Improve workplace ergonomics by providing the right amount of light where and when required.

References

1. "Scenarios for a Clean Energy Future" report commissioned by the U.S. Department of Energy
2. HVAC Systems Design Handbook by Roger W. Haines
3. "Considering Lighting System Performance and HVAC interactions in Lighting Retrofit Analysis": E. Franconi & F. Rubinstein, Lawrence Berkeley National Laboratory
4. "Integrated Lighting Approach Saves Energy in Post Office Facilities", Jeffrey C. Mitchell, Michael J. Siminovitch, Eric R. Page, Kevin W. Gauna, and Douglas A. Avery, Lawrence Berkeley National Laboratory.
5. "Energy Saving Lighting Control Systems for Open plan Offices: A Field Study", Anca D. GALAŞIU1, Guy R. NEWSHAM[1], Cristian ŞUVĂGĂU[2], Daniel M. SANDER[3]
   [1] National Research Council Canada, Institute for Research in Construction, Indoor Environment Program; [2] BC Hydro, Technology Solutions Power Smart; [3]National Research Council Canada (retired)
6. "Wireless Networked Lighting Systems for Optimizing Energy Savings and User Satisfaction", Yao-Jung Wen, Alice M. Agogino, IEEE Publications.
7. "Comparison of Control Options in Private Offices in an Advanced Lighting Controls Testbed", Judith D. Jennings[1], Francis M. Rubinstein[1], Dennis DiBartolomeo[1], Steven L. Blanc[2]
   [1]Building Technologies Department, Environmental Energy Technologies Division, Lawrence Berkeley National Laboratory; [2]Pacific Gas & Electric Company, Customer Energy Management Dept., Research & Development Group.
8. "Specifier Reports", Photosensors, National Lighting Product Information Program, Rensselaer Polytechnic Institute.
9. "An analysis of the energy and cost savings potential of occupancy sensors for commercial lighting systems", Bill VonNeida[1], Dorene Maniccia[2], Allan Tweed[2]
   [1]Lighting Research Center, Rensselaer Polytechnic Institute;
   [2]U.S. Environmental Protection Agency, ENERGY STAR Buildings Program.
10. "Effect of dimming control on office worker satisfaction and performance", Guy Newsham, Jennifer Veitch, Chantal Arsenault, Cara Duval, Institute for Research in Construction, National Research Council Canada
11. "Energy savings due to occupancy sensors and personal controls: A pilot field study", Anca D. Galasiu and Guy R. Newsham, Institute for Research in Construction, National Research Council Canada
12. "Energy savings for Load shedding ballasts for fluorescent lighting systems", Yukio Akashi, Jason Neches, Andy Bierman, Lighting Research Center, Rensselaer Polytechnic Institute.
13. "How to Select Lighting Controls for Offices and Public Buildings", U.S. Dept. of Energy, Energy Efficiency & Renewable Energy, Federal Energy Management Program, December 2000.
14. "Tips for Daylighting with Windows", Lawrence Berkeley National Laboratory.
15. Deep dive into Deeper Savings", CEE Winter 2020 Meeting, presentation by Thor Scordelis, Dave Alexander, Pacific Gas and Electric Company Lighting Team.
16. "Demand-responsive Lighting – A Field Study", Guy Newsham and Benjamin Birt, National Research Council Canada, Institute for Research in Construction (NRC-IRC)
17. "Research Matters", Guy Newsham, National Research Council Canada, Institute for Research in Construction (NRC-IRC), published in LD+A, Illiminating Engineering Society journal.
18. "Advanced Lighting Guidelines", 2003; New Buildings Institute, White Salmon, WA 98672.
19. "Lighting Quality and Office Work: A Field Simulation Study", Peter R. Boyce[1], Jennifer A. Veitch[2], Guy R. Newsham[2], Michael Myer[1], Claudia Hunter[1], Prepared for US Dept. of Energy by Pacific Northwest National Laboratory.
    [1]Lighting Research Center, Rensselaer Polytechnic Institute; [2]Institute for Research in Construction, National Research Council Canada.
20. "Demand Responsive Lighting: A Scoping Study", Francis Rubinstein, Sila Kiliccote, Lawrence Berkeley National Laboratory.
21. "Energy Efficiency Perspectives: Intelligent Networks and The Challenge of Zero Energy Buildings" by Stephen Selkowitz, Head of the Department, Building Technologies, Lawrence Berkeley National Laboratory.
22. U. S. Department of Energy, Building Energy Codes, Online training program
23. "Integrated Lighting Approach Saves Energy in Post Office Facilities", Jeffrey C. Mitchell, Michael J. Siminovitch, Eric R. Page, Kevin W. Gauna, and Douglas A. Avery, Lawrence Berkeley National Laboratory.
24. National Institute of Building Sciences
25. CISCO's Connected Real Estate group