



# Ultra-Smart Luminaires, Windows & Skylights

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## New, Market Driven Technologies



... we need a simplified, inexpensive daylight harvesting control system that turns off half of the lights in areas with plenty of daylight, such as next to windows and under skylights ...

## Not enough daylight: 100% lighting



## "Enough" daylight: 50% lighting



## Even more daylight: 0% lighting



# **Bi-Level Switching**



# **Bi-Level Switching**



## Commercialization

### LS-102 Daylighting Controller by Watt Stopper/Legrand

- On/Off Switching based on available daylight
- Automatic, continuous calibration
- Adjustable set points
- Adjustable time delay

From the Lab...



... To the Marketplace



## New, Market Driven Technologies



... we need a simplified, inexpensive daylight harvesting control system that turns off half of the lights in areas with plenty of daylight, such as next to windows and under skylights ...



... we need a daylight harvesting system that reliably dims electric lights based on available daylight indoors ...

## **Traditional Daylight Sensing Strategies**



### Advantages

Measures light in the space

### Disadvantages

- Requires re-calibration for long-term changes (geometry and reflectance of interior surfaces)
- Cannot differentiate between:
  - Daylight changes (fluctuations in daylight levels)
  - Short-term space changes (moving occupants/objects)

### Advantages

• Not affected by changes in the space

### Disadvantages

- Requires commissioning
- Not an accurate indicator of daylight levels in the space

## **Dual-Loop Daylight Sensing**



## **Field Testing**

West Sacramento Wal-Mart Store





## Effect of Space Changes on Sensor Signal



12/25/08: EL = 4.75



12/26/08: EL = 4.77



12/29/08: EL = 4.94



01/01/09: EL = 5.77



01/04/09: EL = 6.34



01/05/09: EL = 6.97 (+47%)!



## Commercialization

### Dual Loop Commercial Prototype Watt Stopper/Legrand



### From the Lab...



### ... To the Marketplace



## Smart Skylights for Performance Optimization

 Bring enough daylight to minimize electric lighting requirements ...

... AND then ...

- Manage daylight penetration to minimize glare & HVAC loads
- Automation
  - Automated calibration
  - Automated operation
- Dual loop integrated control
  - Dimming of electric lighting
  - Modulation of skylight transmittance



## **Skylight Performance Optimization**



- Electric lights are dimmed until off, based on available daylight
- After electric lights are off, skylight transmittance is modulated to keep daylight at the level that electric lights turned off

## Smart Windows & Skylights

### • Multi-sensor-based automated controls

- Occupancy, light, air temperature, etc., indoors & outdoors
- Multiple performance aspects
  - Luminous, thermal, ventilation, view, safety, etc.





## **Dual Loop for Window Applications**



## Closed Loop Sensors in Each Luminaire



- You can fool one sensor at a time
- Fooling multiple sensors at the same time in the same way requires special choreography...

## Costs From One to Multiple Brains

	Installation	Commissioning	Operation
Building	\$\$\$\$	\$\$\$\$	\$\$\$\$
Floor	\$\$\$\$	\$\$\$\$	\$\$\$
Space	\$\$\$	\$\$\$	\$\$
Area	\$\$	\$\$\$	\$\$
Luminaire	\$	\$	\$

## **Ultra-Smart Luminaire**

- Integral sensors, logic controllers & actuators
- Customization at the factory
  - Sensors sense luminaire area
  - Actuators affect luminaire area
- Automated operation
  - Automatic calibration of sensors
- Network communications
  - Luminaires Broadcast signals
    - To anyone interested
  - Luminaires Receive signals
    - From anyone of interest
      - Other luminaires, windows, HVAC, occupants, ...
      - Utility Demand Response (DR) signals & real time pricing, ...
      - Weather data on irradiance, illuminance, cloud coverage, sun position, ...



## CLTC Daylight Harvesting Laboratory





## CLTC Daylight Harvesting Laboratory



### **Fenestration Elevation**

**Section** 

## CLTC Daylight Harvesting Laboratory







## **Integrated Control Strategy**

- During Occupancy Focus on Comfort
  - Adjust fenestration for daylight penetration
  - Adjust electric lighting for daylight contribution
  - Adjust HVAC for thermal comfort & indoor air quality
- During Vacancy Focus on Energy Efficiency
  - Adjust fenestration for cooling/heating loads
  - Turn electric lighting off or dim down
  - Adjust HVAC for thermal comfort & indoor air quality





# Thank You!

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