Lighting Controls

Measure Number: I-C-5 j
Portfolio: 77
Status: Active
Effective Date: 1/1/2014
End Date: TBD
Program: Business Energy Services
End Use: Lighting

Referenced Documents

- Calculating Lighting and HVAC Interactions
- NEEP CI Lighting LS FINAL Report_ver 5_7-19-11
- Lighting Controls TRM Reference_2012
- Controls Baseline EVT Data 2009-2011
- WasteHeatAdjustment

Description

Controls for interior & exterior lighting, including occupancy sensors and daylight sensors.

Estimated Measure Impacts

N/A

Algorithms

Electric Demand Savings

ΔkW	$= kW_{connected} \times SVG \times OTF \times ISR \times WHF_d$

Symbol Table

Electric Energy Savings

ΔkWh	$= kW_{connected} \times HOURS \times SVG \times OTF \times ISR \times WHF_e$

Symbol Table

Heating Increased Usage

Oil heating is assumed typical for commercial buildings.

$\Delta MMBTU_{WH}$	$= (\Delta kWh / WHF_e) \times 0.003413 \times (1 - OA) \times AR \times HF \times DFH / HEff$

Symbol Table

Waste Heat Adjustment

Cooling savings are incorporated into the electric savings algorithm with the waste heat factor (WHF). See above.

Where:

ΔkW	=	gross customer connected load kW savings for the measure. This number represents the maximum summer kW savings – including the reduced cooling load from the more efficient lighting.

ΔkWh	=	gross customer annual kWh savings for the measure (includes the reduced cooling load from the more efficient lighting)
$\Delta MMBTU_{WH}$	=	Gross customer annual heating MMBTU fuel increased usage for the measure from the reduction in lighting heat.
AR	=	Typical aspect ratio factor. The ASHRAE heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones. It is assumed that 70% is the typical square footage of commercial buildings within 15 feet of exterior wall.
DFH	=	Percent of lighting in heated spaces. For prescriptive lighting, assumed to be 95%
HEff	=	Average heating system efficiency. For prescriptive lighting assumed to be 79% in existing buildings and 83 % in new Construction. See WasteHeatAdjustment.doc.
HF	=	ASHRAE heating factor of 0.39 for lighting waste heat for Burlington, Vermont[10]
HOURS	=	annual lighting hours of use per year; refer to table by building type
ISR	=	In service rate, or the percentage of units rebated that actually get used. For prescriptive measures, this is assumed to be 98%.[1]
$kW_{connected}$	=	kW lighting load connected to control. For multi-level and perimeter switching in the Comprehensive Track the savings is applied to all interior lighting kW load.
OA	=	Outside Air - the average percent of the supply air that is Outside Air, assumed to be 25%[11].
OTF	=	Operational Testing Factor. OTF = 1.0 for all occupancy sensors and for daylight dimming controls when the project undergoes Operational Testing or commissioning services, 0.80 for daylight dimming controls otherwise.
SVG	=	% of annual lighting energy saved by lighting control; determined on a site-specific basis or refer to table by control type
WHF_d	=	Waste heat factor for demand to account for cooling savings from efficient lighting. For prescriptive lighting in existing buildings, the default value is 1.082 (calculated as 1 + (0.47*0.67*.808) / 3.1))[2]. For prescriptive lighting in new buildings, the value is 1.084 (calculated as 1 + (0.47*0.67*.808) / 3.4))[3]. The cooling savings are only added to the summer peak savings. For refrigerated case lighting, the value is 1.29 (calculated as (1 + (1.0 / 3.5))). Based on the assumption that all lighting in refrigerated cases is mechanically cooled, with a typical 3.5[4] COP refrigeration system efficiency, and assuming 100% of lighting heat needs to be mechanically cooled at time of summer peak. For freezer case lighting, the value is 1.50 (calculated as (1 + (1.0 / 2.0))). Based on the assumption that all lighting in freezer cases is mechanically cooled, with a typical 2.0 COP[5] freezer system efficiency, and assuming 100% of lighting needs to be mechanically cooled at time of summer peak.
WHF_e	=	Waste heat factor for energy to account for cooling savings from efficient lighting. For prescriptive lighting in existing buildings, the default value is 1.033 (calculated as 1 + ((0.47*0.29*.75) / 3.1))[6]. For prescriptive lighting in new buildings, the value is 1.030 (calculated as 1 + ((0.47*0.29*.75) / 3.4))[7]. For refrigerated case lighting, the value is 1.29 (calculated as (1 + (1.0 / 3.5))). Based on the assumption that all lighting in refrigerated cases is mechanically cooled, with a typical 3.5[8] COP refrigeration system efficiency, and assuming 100% of lighting heat needs to be mechanically cooled at time of summer peak. For freezer case lighting, the value is 1.50 (calculated as (1 + (1.0 / 2.0))). Based on the assumption that all lighting in freezer cases is mechanically cooled, with a typical 2.0 COP[9] freezer system efficiency, and assuming 100% of lighting needs to be mechanically cooled at time of summer peak.

Baseline Efficiencies

This TRM applies only to Prescriptive Projects, or those projects less than 10,000 Square Feet and less than 250 rebate-eligible items, by agreement with DPS. Analysis of Occupancy Sensors and Daylight Dimming on custom projects will be calculated on a custom basis using the actual site conditions.

High Efficiency

Controlled lighting such as occupancy sensors and daylight dimming.

Operating Hours

The lighting operating hours are collected from the prescriptive application form. If not available, then assume hours per year from the table titled Lighting Operating Hours by Building Type.

Load Shapes

12d Commercial Indoor Lighting - Blended
15c Commercial A/C

Number	Name	Status	Assigned To	Portfolio	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW	Effective Date	Expiration Date
12	Commercial Indoor Lighting - Blended	Active			48.8 %	19.5 %	22.2 %	9.5 %	46.9 %	67.9 %	1/1/2012	
15	Commercial A/C	Active			18.0 %	10.0 %	46.0 %	26.0 %	0.0 %	34.2 %	1/1/2012	

Net Savings Factors

Measures

LECOCCUP	Occupancy sensors
LECDAYLT	Daylighting
LECOCCEX	Exterior Occupancy Sensors
LECOCCRE	Refrigerator Case Controls
LECOCCFR	Freezer Case Controls

Tracks

6012CNIR	C&i Retro
6013CUST	Cust Equip Rpl
6013PRES	Pres Equip Rpl
6014A250	Act250 NC
6014NANC	Non Act250 NC

Track Name	Track Nr.	Measure Code	Free Rider	Spillover
C&i Retro	6012CNIR	LECOCCUP	0.89	1.00
C&i Retro	6012CNIR	LECDAYLT	0.89	1.00
C&i Retro	6012CNIR	LECOCCEX	0.89	1.00

C&i Retro	6012CNIR	LECOCCRE	0.89	1.00
C&i Retro	6012CNIR	LECOCCFR	0.89	1.00
Cust Equip Rpl	6013CUST	LECOCCUP	0.97	1.00
Cust Equip Rpl	6013CUST	LECDAYLT	0.97	1.00
Cust Equip Rpl	6013CUST	LECOCCEX	0.97	1.00
Cust Equip Rpl	6013CUST	LECOCCRE	0.97	1.00
Cust Equip Rpl	6013CUST	LECOCCFR	0.97	1.00
Pres Equip Rpl	6013PRES	LECOCCUP	0.98	1.00
Pres Equip Rpl	6013PRES	LECDAYLT	0.98	1.00
Pres Equip Rpl	6013PRES	LECOCCEX	0.98	1.00
Pres Equip Rpl	6013PRES	LECOCCRE	0.98	1.00
Pres Equip Rpl	6013PRES	LECOCCFR	0.98	1.00

Persistence

The persistence factor is assumed to be one.

Lifetimes

Controls – 10 years. Analysis period is the same as the lifetime.

Measure Cost

Lighting Controls - Incremental Cost Assumptions

Lighting Control Type	Location	Incremental Cost
Wall Occupancy Sensor	Interior	$55 per control
Fixture-Mounted Occupancy Sensor	Interior	$67 per control
Remote-Mounted Occupancy Sensor	Interior	$125 per control
Fixture-mounted Daylight Sensor	Interior	$50 per ballast controlled
Remote-Mounted Daylight Sensor	Interior	$65 per ballast controlled
Refrigerator Case Controls	Interior	$60 per control
Freezer Case Controls	Interior	$60 per control
Exterior Occupancy Sensor[23]	Exterior	$82 per control

O&M Cost Adjustments

N/A

Fossil Fuel Description

N/A

Reference Tables

Lightings Controls - Default Percent Savings (SVG)

Lighting Control Type	Location	% Savings (SVG)
Wall Occupancy Sensor	Interior	30%
Fixture-Mounted Occupancy Sensor	Interior	30%
Remote-Mounted Occupancy Sensor	Interior	30%
Fixture-Mounted Daylight Sensor	Interior	30%
Remote-Mounted Daylight Sensor	Interior	30%
Refrigerator Case Controls[12]	Interior	40%
Freezer Case Controls	Interior	40%
Exterior Occupancy Sensors[13]	Exterior	41%

Lighting Controls - Default Controlled Wattage

Lighting Control Type	Location	Default Controlled Wattage[14]	Wattage Unit
Wall Occupancy Sensor	Interior	294	per control
Fixture-Mounted Occupancy Sensor	Interior	173	per fixture
Remote-Mounted Occupancy Sensor	Interior	456	per control
Fixture-Mounted Daylight Sensor	Interior	73	per ballast
Remote-Mounted Daylight Sensor	Interior	350	per control
Refrigerator Case Controls	Interior	184	per control
Freezer Case Controls	Interior	184	per control
Exterior Occupancy Sensors	Exterior	85	per fixture

Lighting Operating Hours by Building Type

Building Type	Annual Hours

Grocery/Convenience Store	6,019
Hospital	4,007
K-12 Schools	2,456
Lodging/Hospitality	4,808
Manufacturing	4,781
Office	3,642
Public Assembly	3,035
Public Safety	3,116
Religious	2,648
Restaurant	4,089
Retail	4,103
Service	3,521
University/College	3,416
Warehouse	4,009
Exterior	3,338

From C&I Lighting Load Shape Project FINAL Report, July 19, 2011, prepared by KEMA for NEEP. See document NEEP CI Lighting LS FINAL Report_ver 5_7-19-11.pdf. Exterior Lighting hours based on estimated mix of photocell-controlled lighting (12 hpd) and switch-controlled lighting.

Footnotes

[1] 2005 TAG agreement.

[2] Based on the following assumptions: 3.1 COP typical cooling system efficiency for existing buildings; average 47% of spaces have mechanical cooling; 33% average outside air; and 80.8% coincidence of cooling with the summer peak period. See WasteHeatAdjustment.doc for additional discussion.

[3] Based on the same assumptions used for existing buildings, except 3.4 COP typical cooling system efficiency for new buildings. See WasteHeatAdjustment.doc for additional discussion.

[4] Assumes 3.5 COP for medium temp cases based on the average of standard reciprocating and discus compressor efficiencies with Saturated Suction Temperatures of 20°F and a condensing temperature of 90°F.

[5] Assumes 2.0 COP for low temp cases based on the average of standard reciprocating and discus compressor efficiencies with Saturated Suction Temperatures of -20°F and a condensing temperature of 90°F.

[6] Based on the following assumptions: 3.1 COP typical cooling system efficiency; average 47% of spaces have mechanical cooling; 25% average outside air; and 29% of annual lighting energy contributes to cooling load. See "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993 and WasteHeatAdjustment.doc for additional discussion.

[7] Based on the same assumptions used for existing buildings, except 3.4 COP typical cooling system efficiency for new buildings. See WasteHeatAdjustment.doc for additional discussion.

[8] Assumes 3.5 COP for medium temp cases based on the average of standard reciprocating and discus compressor efficiencies with Saturated Suction Temperatures of 20°F and a condensing temperature of 90°F.

[9] Assumes 2.0 COP for low temp cases based on the average of standard reciprocating and discus compressor efficiencies with Saturated Suction Temperatures of -20°F and a condensing temperature of 90°F.

[10] From "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993.

[11] 2009 ASHRAE Handbook Fundamentals (p. 16.2): "Conventional all-air air-handling systems for commercial and institutional buildings have approximately 10 to 40% outside air."

[12] Refrigerator and Freezer savings are based on case studies of controls installed in Wal-Mart and Krogers refrigerator/freezer LED case lighting controls (http://www.wattstopper.com/getdoc/2240/Casestudy_WalMart0707.pdf, http://www.actonenergy.com/portals/0/forms/kroger_case_study_final.pdf). See Lighting Controls TRM Reference_2012.xlsx for more information.

[13] Application Assessment of Bi-Level LED Parking Lot Lighting (http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/gateway_raleys.pdf)

[14] Controlled wattage for interior wall, remote, and fixture-mounted occupancy sensors based on 2009-2011 EVT experienceDaylight dimming watts per ballast based on 3-lamp HPT8 fixtures. Exterior controls based on EVT experience (installed LED equipment with a minimum of 45 watts). Refrigerator case lighting wattage based on Pacific Gas & Electric and EVT experience. See Controls Baseline EVT Data 2009-2011.xls for more information.