Cost-effectiveness Analysis of Reducing Interior Lighting Allowances

DOE Proposal: C-8; ICC proposal: TBA
for 2018 IECC commercial code

Pacific Northwest National Laboratory
September 2015; *Revised December 2015 (Smaller Reduction in Office LPD)*
E. Richman, S. Loper, J. Zhang & R. Hart

PURPOSE

Find the cost-effectiveness of lighting power allowance reduction.

BASIS

The cost-effectiveness analysis is conducted according to the DOE cost-effectiveness methodology.[1] In the DOE method, the long term economic impacts for two cases are determined:

- Scenario 1 is for publicly-owned buildings and is based on a FEMP method. [2]
- Scenario 3 is for privately-owned buildings and is based on the 90.1-2016 scalar method.[3]

14 year measure life; Basis: 50,000 hour life LED fixtures are the major component of the improved LPD. Looking at the two prototypes analyzed, measure lives are as follows:

Prototype:	Stand Alone Retail	Small Office	Applied
Lighting equivalent full load hours	3613	3642	
Measure Life	13.8	13.7	14

A rounded measure life of 14 years is used across the board for the analysis.

Scenario 1 electric UPW factor[4] with 3% discount and EIA energy escalation for PV savings: 11.95

Blended Fossil UPW factor with 3% discount and EIA energy escalation for PV savings: 12.83

The Scenario 3 threshold for electric savings over a 14 year measure life is 10.2 years. In Scenario 3, measures are found cost-effective when the simple payback ≤ the scalar threshold.

ENERGY PRICES

Commercial Sector		2014	Annual Average		Most recent full year			
		2015 July	EIA Short Term Energy Outlook					
Fossil Price			Conversion to therms				quads heating per BEDB	
Natural Gas	8.87	$/ kCuFt	0.097124	$0.8615	$/therm	1.69		89.4%
Heating Oil	3.72	$/ gal	1.385	$2.6859	$/therm	0.20		10.6%
Blended Fossil Rate				**$1.0555**	**$/therm**	1.90		
Electricity Price				**$0.1075**	**$/kWh**			

Prices	$0.1075	$/kWh	$1.0555	$/therm	(2014 EIA average)	for Scenario 1 analysis
	$0.1013	$/kWh	$1.0000	$/therm	SSPC 90.1 for 2016	for Scenario 3 analysis

[1] Hart, R., and Liu, B. (2015). *Methodology for Evaluating Cost-effectiveness of Commercial Energy Code Changes.* Pacific Northwest National Laboratories for U.S. Department of Energy; Energy Efficiency & Renewable Energy. PNNL-23923 Rev1. https://www.energycodes.gov/development/commercial/methodology.

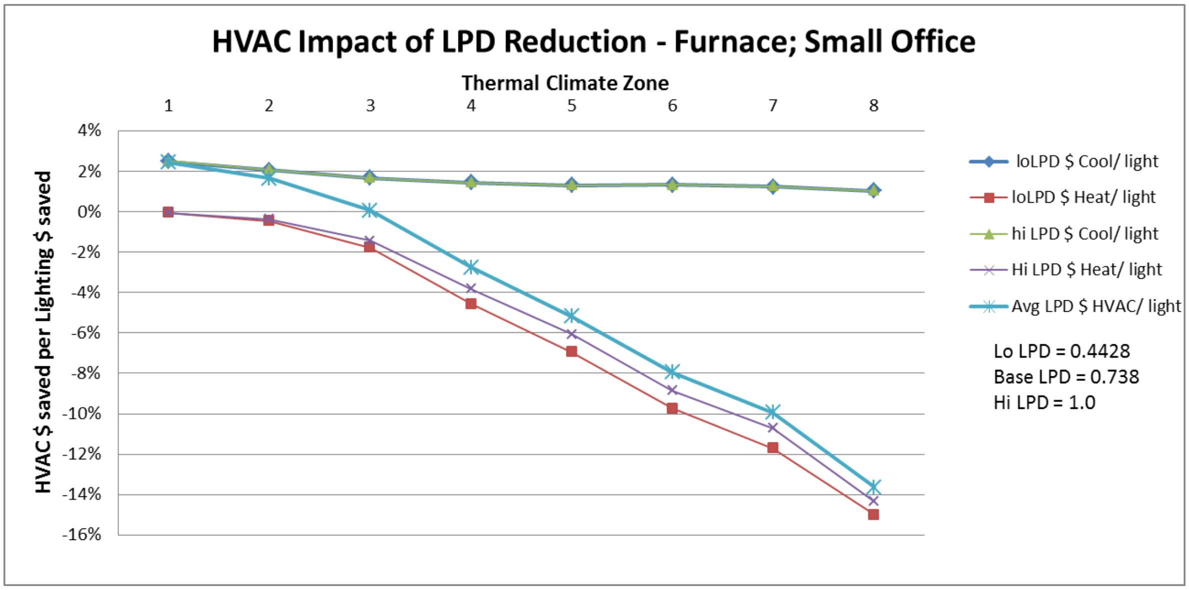
[2] Fuller, Sieglinde, and Stephen Petersen. "LIFE-CYCLE COSTING MANUAL for the Federal Energy Management Program." NIST, U.S. Deptartment of Commerce, 1995. http://fire.nist.gov/bfrlpubs/build96/PDF/b96121.pdf.

[3] Based on the approach and assumptions established by the ASHRAE Standard 90.1project committee for 90.1-2016.

[4] Rushing, Amy S., Joshua D. Kneifel, and Priya Lavappa. *Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis-2014: Annual Supplement to NIST Handbook 135*, 2015. http://dx.doi.org/10.6028/NIST.IR.85-3273-29.

Energy Savings Results

Measures that reduce lighting power and energy use inside the building cause an increase in heating energy use and a reduction of cooling energy use. Using results of a small office analysis of LPD impact, the increased heating that offsets lighting savings is greatest in Climate Zone 8, so analysis is completed for Climate Zone 8, as net savings will be greater in other climate zones. If an interior lighting measure is found cost-effective in Climate Zone 8, it will be cost-effective in all other climate zones. The relative impact of HVAC costs for lighting reductions by climate zone is shown in the graph below.



The office energy savings is developed using EnergyPlus analysis for lighting power density reduction in the small building prototype. DOE prototypes[5] for small offices and stand alone retail buildings are simulated in EnergyPlus. The changes in LPD simulated are:

Prototype:	Stand Alone Retail	Small Office
Baseline LPD, Watts/ft^2	1.41	0.82
Proposed LPD	1.08	0.79
LPD reduction	0.33	0.03
Percentage difference	23.5%	3.7%

For this analysis, office used the building method, and retail used the space-by-space method.

Office results (based on small office, building method):

Energy Savings per 1000 square feet

	Gas	Electric	Total	Prices
Unit Savings	-1.0 therm	100 kWh	244 kBtu	
$ Savings/year	-$1.04	$10.77	$9.73	Scenario 1
$ Savings/year	-$0.98	$10.20	$9.22	Scenario 3
PV Savings	-$13	$129	$115	Scenario 1, 14 years

[5] Details on building prototypes available at: https://www.energycodes.gov/commercial-prototype-building-models.

Stand-alone Retail results (space-by-space method):

Energy Savings per 1000 square feet

	Gas	Electric	Total	Prices
Unit Savings	-13.0 therm	1,301 kWh	3,138 kBtu	
$ Savings/year	-$13.75	$139.88	$126.13	Scenario 1
$ Savings/year	-$13.03	$131.82	$118.79	Scenario 3
PV Savings	**-$176**	**$1,672**	**$1,495**	Scenario 1, 14 years

COST

Costs were developed for the upgrade from current lighting technology to LED luminaires where appropriate. Based on the 14 year life, there were no replacements needed for the LED fixtures, while standard fixtures require lamp and ballast replacements. Luminaire layouts and quantities to meet the base and proposed lighting power density are based on ASHRAE SSPC 90.1 lighting subcommittee developed designs. This method is further described in the prior cost-effectiveness analysis of 90.1-2013.[6] Interior LED fixture costs are based on a recent Canadian study,[7] while standard fixture and lamp and ballast costs are gathered from internet sources. Labor is based on 2014 Means Electrical.[8] The costs for LED lighting are changing rapidly due to manufacturing innovation of this developing technology and are adjusted based on a broad study of LED lighting price trends.[Error! Bookmark not defined.] The cost of LED fixtures is adjusted from Q4 of 2015 to Q4 of 2017 based on the end of statistical cost projections in the study. The incremental initial cost and periodic replacement cost differences between the baseline and proposed lighting systems are shown in the table below:

Incremental Cost for Lighting Power Allowance Reduction

LPA reduction	**Stand-alone Retail**	**Small Office**
First Cost:	$47,657	$2,526
Replacement (Year)		
1	$0	$3
2	$0	$3
3	$0	-$667
4	-$63,676	-$1,062
5	$0	$3
6	-$89	-$755
7	$0	$3
8	-$63,676	-$1,062
9	$0	-$667
10	-$11,695	-$1,260
11	$0	$3
12	-$63,765	-$1,820
13	$0	$3
14*	$38,915	$1,572

*Values in the last year represent residual value from replacements not fully exhausted.

6 Hart, R., R. Athalye, M. Halverson, S. Loper, M. Rosenberg, Y. Xie, and E. Richman. "Cost-Effectiveness of ANSI/ASHRAE/IES Standard 90.1-2013." Pacific Northwest National Laboratory (PNNL), Richland, WA (US), January 2015. https://www.energycodes.gov/sites/default/files/documents/Cost-effectiveness_of_ASHRAE_Standard_90-1-2013-Report.pdf.

7 Larry White, Nicole McCabe, and Len Horvath. "Providing Product Characteristics and Capability Data on Currently Available LED Interior Lighting Products." Quantum Lighting, Inc. for Canadian Codes Centre (CCC) National Research Council, August 2015.

8 Means, R. S. *2014 Electrical Cost Data*. R.S. Means Company, 2014. http://www.rsmeans.com/.

The difference in annual costs between the base and proposed case is discounted to present value so it can be combined with the incremental installation first costs for a total present value.

Present Value Incremental Cost for Lighting Power Allowance Reduction

LPA Reduction	Stand-alone Retail	Small Office
First Cost	$47,657	$2,526
PV Replacement (3.0%)	-$134,538	-$4,693
PV Costs, Scenario 1	**-$86,881**	**-$2,167**
Floor Area	24,690	5,500
Scenario 1 PV Costs $/1000 square feet	-$3,519	-$394
PV Replacement (6.8%)	-$106,155	-$3,711
PV Costs, Scenario 3	**-$58,498**	**-$1,185**
Scenario 3 PV Costs $/1000 square feet	-$2,369	-$216

COST-EFFECTIVENESS

The cost-effectiveness is evaluated using Scenario 1 for the public sector and Scenario 3 for the private sector.[9] An analysis of results for both offices and retail are included. When the present value of costs is negative, it indicates that the discounted value of replacement costs was lower for the proposed case.

Scenario 1 Analysis (Publicly-Owned)

LPA Reduction		Stand-alone Retail	Small Office
Present Value of Savings	$/1000 square feet	$1,495	$115
Present Value of Cost	$/1000 square feet	-$3,519	-$394
Savings to Investment Ratio (SIR)		Infinite	Infinite
SIR threshold:	≥1.0	Pass	Pass

Scenario 3 Analysis (Privately-Owned)

LPA Reduction		Stand-alone Retail	Small Office
Annual Savings	$/1000 square feet/year	$118.79	$9.72
Present Value of Cost	$/1000 square feet	-$2,369	-$216
Savings to Investment Ratio (SIR)		Immediate	Immediate
90.1 Scalar threshold:	≤10.2	Pass	Pass

CONCLUSION

The lighting power allowance reduction proposal is cost-effective both for public and private buildings and for both offices and retail buildings. The cost-effectiveness test would pass, even with significant increased cost, so the measure is very likely to be cost-effective in all building types.

[9] Hart, Reid, and Bing Liu. "Methodology for Evaluating Cost-Effectiveness of Commercial Energy Code Changes." Pacific Northwest National Laboratories for U.S. Department of Energy; Energy Efficiency & Renewable Energy., August 2015. https://www.energycodes.gov/development/commercial/methodology.