Memo to:

Massachusetts Program Administrators
Massachusetts EEAC Consultants
National Grid, Rhode Island

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Date: September 21, 2021

RE: C&I Lighting Controls Savings Factors for PY2021 and PY2022

This memorandum presents the recommended commercial and industrial (C&I) lighting controls savings factors (LCSFs), which are expected to be applied retrospectively to PY2021 and prospectively to PY2022 in both Massachusetts and Rhode Island. While the work to assemble these recommendations was conducted under MA19C06-E-UPLGHT: Upstream Lighting Impact Evaluation (MA19C06-E-UPLGHT), the LCSFs should be applied to all controls measures across upstream, prescriptive, and custom program installations except where additional information is available to inform site-specific estimates. These savings factors are intended to be applied to the estimated lighting energy consumption in the absence of the control measure. This may be accomplished by applying the LCSF to the LED wattage. The recommended LCSFs included in this memo are based on a literature review conducted on behalf of the Connecticut Energy Efficiency Board (EEB) Evaluation Consultant Team as part of the Connecticut X1931-4 New Measure Advanced Lighting Controls Study.[1] In addition to the results from the literature review, Appendix B presents metering results from recent custom electric impact evaluations that corroborate the recommendations in this memo.

1 EXECUTIVE SUMMARY

With the introduction and advancement of networked lighting controls (NLC) and luminaire-level lighting controls (LLLC), it has been speculated that current savings factors for traditional lighting controls were likely underrepresenting savings from more advanced controls and for fixtures controlled by multiple technologies. To address this, the Massachusetts (MA19C06-E-UPLGHT) and Rhode Island PY2019 C&I Upstream Lighting Impact Evaluations included an objective to assess controls savings associated with LED fixtures with integrated controls sold through the Upstream Initiative.

Due to complications surrounding fieldwork during the COVID-19 pandemic, the DNV team had a small sample of upstream participant sites metered with fixtures with integrated controls (n=5). Because of this limited data, the DNV team leveraged results from a literature review completed by DNV as part of Connecticut X1931-4 New Measure Advanced Lighting Controls Study on behalf of the Connecticut Energy Efficiency Board (EEB) Evaluation Consultant Team. The EEAC Consultants and the PAs agreed that results from this literature review are applicable to savings from lighting controls across all programs, beyond just LED fixtures with integrated controls sold through the Upstream Initiative. Table 1-1 presents the recommended LCSF for retrospective application (2021) and prospective application (2022) as well as the previous LCSF from the PY2020 Technical Reference Manual[2] (TRM) for comparison.

Table 1-1. Summary of Literature Review Results

Controls Technology	Recommended LCSF	PY2020 LCSF
Networked Lighting Controls (NLC)	49%	
Luminaire-Level Lighting Controls (LLLC)	49%	
Integral Dual Sensors w/Adaptive, Network-Capable Controls	N/A	35%
Integral Dual Sensor	N/A	30%
Dual Occupancy and Daylight Sensors	38%	
Combination of High-End Trim and Daylight Dimming	35%	
Combination of High-End Trim and Occupancy Sensors	33%	
High-End Trim	27%	

[1] The results of the Connecticut EEB literature review were shared with the Massachusetts team by a member of the EEB Consultant Team (Ralph Prahl)

[2] https://www.masssavedata.com/Public/TechnicalReferenceLibrary

Daylight Dimming	28%	28%
Occupancy Sensors	24%	24%

In addition to the results from this literature review, we compiled data from the five upstream participant sites as well as the two most recent Massachusetts custom electric studies (P80[3] and P88[4]) to provide additional evidence to support the LCSF. The methodology and results from the metering efforts are included in Appendix B. The literature review results are generally supported by the custom electric metering analysis, which provides some additional credibility to the results. However, it is important to note that the literature review results, and the custom electric results, do not necessarily represent upstream participants, which may be, in some cases, less sophisticated than the sites and customers who are represented in the literature review and custom electric results.

Recommendation 1. The Massachusetts PAs should adopt the controls savings factors presented in Table 1-1 identified by the literature review for retrospective application (2021) and prospective application (2022). These literature review results are generally supported by the historical analysis of primary data from custom electric evaluations in Massachusetts. To calculate savings from the control technology, the savings factors should be applied to the estimated consumption of installed lighting equipment in the absence of the control measure. This may be accomplished by applying the LCSF to the LED wattage.

Consideration 1. The Massachusetts PAs, EEAC Consultants, and National Grid Rhode Island should continue to monitor results from the ongoing controls study in Connecticut, which may provide additional results in fall 2021. Insofar as the results from the Connecticut study provide additional credible evidence for alternative impact factors, the PAs and EEAC Consultants should consider adopting these factors.

2 LITERATURE REVIEW RESULTS

The following section provides a summary of the literature review conducted in Connecticut and the results that are applicable to Massachusetts and Rhode Island. Phase one of the Connecticut literature review included 19 sources that included quantified savings based on independent research.[5] The sources were reviewed and vetted, and two sources were identified as having the best available information based on primary data for the corresponding controls technologies. Additional sources are presented in Appendix A. The two primary sources are:

- DLC and Northwest Energy Efficiency Alliance (NEEA), "Energy Savings from Networked Lighting Control (NLC) Systems with and without LLLC," Energy Solutions, Sept 24 2020. (DLC and NEEA, 2020)
    - This source analyzed data from NLC systems, with and without LLLC, in 194 buildings across a variety of building types in North America, with an average of 13 weeks of data per building. The data included in the analysis was provided by manufacturers and by utilities/end users. This source was referenced in other reviewed sources and the Illinois TRM; an older version of the study (published in 2017) is referenced in the Mid-Atlantic and New York TRMs.
- Williams, A., B. Atkinson, K. Garesi, E. Page, and F. Rubinstein. 2012. "Lighting Controls in Commercial Buildings." The Journal of the Illuminating Engineering Society of North America 8 (3): 161-180. (Williams, et al., 2012)
    - This source was a meta-analysis of energy savings identified in the literature – 240 savings estimates from 88 papers and case studies. Only papers and case studies with primary data sources were included in the meta-analysis. Additional research was conducted through a literature review and by

[3] https://ma-eeac.org/wp-content/uploads/MA_CIEC_Stage5_Report_P80_Custom_Impact_Evaluation_PY2016_Final.pdf
[4] https://ma-eeac.org/wp-content/uploads/MA_CIEC_Stage5_Report_C07_Custom_Electric_Impact_Evaluation_PY2017_18_FINAL-2020-06-01.pdf
[5] CTX1931-4 ALC PSD Phase 1 Memo. July 22, 2021

consulting utilities, controls manufacturers, California Energy Commission, and NEMA. This source was referenced in other reviewed sources and the Massachusetts, Mid-Atlantic, PA, and WI TRMs.

Table 2-1 provides the resulting savings factors by control technology as well as the source from which the values were derived. While few of the reviewed sources provided LLLC-specific savings, three sources provided evidence supporting treating LLLC and NLC systems as a combined category.

- A NEEA study comparing savings for four LLLC systems to a single NLC system found no significant differences between the savings.[6]
- A PG&E study found the savings at a single LLLC facility were similar to the DLC and NEEA study.[7]
- The Illinois TRM groups NLC and LLC technologies into a single category.

Based on this evidence, we have selected a single factor that represents NLC and LLLC.

Table 2-1. Summary of Literature Review Results

Controls Technology	Savings Factor	Source
Networked Lighting Controls (NLC)	49%	DLC and NEEA, 2020
Luminaire-Level Lighting Controls (LLLC)	49%	DLC and NEEA, 2020
Dual Occupancy and Daylight Sensors	38%	Williams, et al., 2012
Combination of High-End Trim and Daylight Dimming	35%	Calculated based on High-End Trim and Daylight Dimming savings factors from Williams, et al., 2012
Combination of High-End Trim and Occupancy Sensors	33%	Calculated based on High-End Trim and Occupancy Sensor savings factors from Williams, et al., 2012
High-End Trim	27%	DLC and NEEA, 2020
Daylight Dimming	28%	Williams, et al., 2012
Occupancy Sensors	24%	Williams, et al., 2012

[6] NEEA, "Luminaire Level Lighting Controls Replacement vs Redesign Comparison Study." Sept 3 2020

[7] PG&E's Emerging Technologies Program, "Ace Hardware LED High Bay Lighting and Controls Project" Sept 27 2013.

APPENDIX A: DETAILED LITERATURE REVIEW RESULTS

Table A-2. Expanded Literature Review Values

Savings Factors	Technology						
Source	NLC	Occ Sensor	DLH	LLLC	High-End Trim	Occ & DLH	Bi-Level
DLC and Northwest Energy Efficiency Alliance (NEEA), "Energy Savings from Networked Lighting Control (NLC) Systems with and without LLLC", Energy Solutions, Sept 24 2020.	49% - All NLCs 63% - NLCs w/ LLLC 35% - NLCs w/o LLLC				27%		
DNV KEMA (2014) Retrofit Lighting Controls Measures Summary of Findings FINAL REPORT, October 2014.		24%	28%				
EmPOWER Maryland DRAFT Final Impact Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Commercial & Industrial Prescriptive & Small Business Programs, Navigant, March 31, 2014.		kWh 28%, kW 14%					
Galasiu, A.D.; Newsham, G.R.; Suvagau, C.; Sander, D.M.,"Energy Saving Lighting Control Systems for Open-plan Offices: A Field Study." National Research Council Canada. July 2007.	42 - 47%	35%	20%				
Jennings, Rubinstein, DiBartolomeo, & Blanc, "Comparison of Control Options in Private Offices in an Advanced Lighting Controls Testbed." LBNL. 2000.		23%	21%		23%	46%	23%
Lighting Research Center. "Literature Review of Energy Savings from Luminaire-Integrated Controls." Last revised November 19, 2015.	47%						

Savings Factors	Technology						
Source	**NLC**	**Occ Sensor**	**DLH**	**LLLC**	**High-End Trim**	**Occ & DLH**	**Bi-Level**
National Renewable Energy Laboratory (NREL), "Chapter 3: Commercial and Industrial Lighting Controls Evaluation Protocol; The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures". Sept 2017.		30%	10-30%			35-40%	
Navigant Consulting. Department of Energy Solid-State Lighting Program. Energy Savings Forecast of Solid-State Lighting in General Illumination Applications. December 2019.	53-72%	15-42%	4-15%				
Northwest Energy Efficiency Alliance (NEEA), "Luminaire Level Lighting Controls Replacement vs Redesign Comparison Study." Sept 3 2020.	NLC + LLLC 67%			60%			
PA Consulting Group. Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0. March 22, 2010.		41%	40%				Varies based % time off by space type, and 50% bi-level factor
Pacific Northwest National Laboratory for US DOE "Evaluation of Advanced Lighting Control Systems in a Working Office Environment." Nov 2018.	43%	24%	28%		21%	38%	
PG&E's Emerging Technologies Program, "Ace Hardware LED High Bay Lighting and Controls Project" Sept 27 2013.		24%	8%	29%	15%	26%	

Savings Factors	Technology						
Source	**NLC**	**Occ Sensor**	**DLH**	**LLLC**	**High-End Trim**	**Occ & DLH**	**Bi-Level**
Seventhwave, "Adjusting Lighting Levels in Commercial Buildings." 2015.					22%		
WHAT'S NEW IN THE 2019 CODE? NONRESIDENTIAL LIGHTING, Title 24, part 6, Table 140.6-A: Lighting Power Adjustment Factors (PAF)		20-40%	10-30%			35%	
WI TRM							40%
Williams, A., B. Atkinson, K. Garesi, E. Page, and F. Rubinstein. 2012. "Lighting Controls in Commercial Buildings." The Journal of the Illuminating Engineering Society of North America 8 (3): 161-180.		24%	28%		36%	38%	
AVERAGE	**47%**	**28%**	**25%**	**42%**	**23%**	**37%**	**32%**

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APPENDIX B: RECENT METERING RESULTS

This appendix presents the results from recent metering results including the Massachusetts (MA19C06-E-UPLGHT) and Rhode Island PY2019 C&I Upstream Lighting Impact Evaluations as well as the two most recent custom electric studies (P80[8] and P88[9]) conducted in Massachusetts. These results are included in addition to the literature review to provide verification of the literature review results and to help the PAs and EEAC Consultants as they think ahead to the 2022 to 2024 program period.

B.1 Upstream Lighting Impact Methodology

As part of the upstream impact evaluations, meters were installed at a sample of four sites with integrated controls in Massachusetts and one site with integrated controls in Rhode Island. Unfortunately, delays associated with the COVID-19 pandemic resulted in the metering being pushed back past the PY2020 Annual Report deadline. Due to changes in customer behavior and operating schedules as a result of the pandemic, the PAs and EEAC Consultants decided to leave meters in the field for a longer period, in hopes of observing lighting usage under closer to normal operating levels. While things have not yet returned to normal in Massachusetts and Rhode Island, DNV retrieved meters in early May.

As part of these efforts, the DNV team reviewed site-level tracking documentation, verified and metered LED fixtures with integrated controls received though the Upstream Initiative, and completed pre/post comparative analysis for each of the five sites. Where occupancy sensors were installed, a Dent CT-clamp logger was installed to capture the on/off operation schedule of the metered program lighting. For fixture(s) with dimming and occupancy sensors, a Dent Elite power logger was installed in the electrical panel to capture the power variations throughout the metering period. The data collected during the metering period was extrapolated to 8,760 hourly data. Holidays and building-specific operating schedule adjustments were collected on-site and incorporated in the analysis. The loggers were installed for an average of 21.6 weeks or 5.0 months.

Table A-2 provides an example of how the baseline hours of use are derived from the logger data of a fixture or group of fixtures with occupancy sensor controls. The baseline value is calculated using the percent on from the logger data for the hour of interest and the hour before and/or after. If the logger data for the hour of interest is greater than 0% and is 0% for the hour before, the baseline percent on at that hour equals the percent on from the logger data (see hour two). If the logger data for the hour of interest and the hours before and after are all greater than 0%, the baseline value is set to 100%, which assumes that the fixture(s) would have operated 100% of the time during this hour when manually controlled (see hour three). If the logger data for the hour of interest is greater than 0% and but is 0% for the hour after, the baseline percent on at that hour equals the percent on from the logger data (see hour four).

Table A-3. Derivation of Occupancy Sensor Control Baseline

Hour	Logger Data Percent On	Baseline Percent On
1	0%	0%
2	64%	64%
3	52%	100%
4	52%	52%
5	0%	0%
6	0%	0%
7	48%	48%
8	56%	100%

For fixtures with dimming controls where power was metered, the baseline assumption is 100% load for each hour where the metered load is greater than 0%.

[8] https://ma-eeac.org/wp-content/uploads/MA_CIEC_Stage5_Report_P80_Custom_Impact_Evaluation_PY2016_Final.pdf
[9] https://ma-eeac.org/wp-content/uploads/MA_CIEC_Stage5_Report_C07_Custom_Electric_Impact_Evaluation_PY2017_18_FINAL-2020-06-01.pdf

B.2 Upstream Lighting Metering Results

As shown in Table A-3, the five sites metered in Massachusetts and Rhode Island employed either occupancy sensor controls (three sites) or dimming and occupancy sensor controls (two sites). The average percent reduction for these sites was approximately 32%.

During the meter retrieval visit, each site contact was asked if the operation of the program fixtures during the metering was different than it was before the COVID-19 pandemic and if they adjusted the control strategy as a result of the pandemic. As shown in Table A-3, the fixtures at two of the five metered sites operated with adjusted schedules/occupancy due to the pandemic. It is important to note that the building types of the two sites that operated under the same schedule were a pharmacy and a parking garage. None of the site contacts reported any changes in the control strategy for the program fixtures due to the pandemic.

Table A-4. Massachusetts and Rhode Island Metered Site Results

Site #	Building/ Space Type	State	Operation compared to pre-pandemic	Operation description change due to pandemic	Controls adjusted due to pandemic	Occupancy	Dimming and Occupancy	Controls % Reduction
Site 1	Pharmacy	MA	Same	N/A	No	Yes		34%
Site 2	Parking Garage	MA	Same	N/A	No	Yes		30%
Site 3	Museum	MA	Different	Occupancy decrease	No		Yes	30%
Site 4	Offices/ Hallways	MA	Different	Occupancy decrease	No		Yes	10%
Site 5	University Hallways	RI	Different	Occupancy decrease	No	Yes		58%
	Massachusetts Only Average							**26%**
	Overall Average							**32%**

B.3 Custom electric metering results

Given the relatively low sample size (five sites) and complications associated with operations due to the pandemic, DNV sought to include additional data on control savings to help the PAs and EEAC Consultants as they think ahead to the 2022 to 2024 program period. DNV analyzed Custom Electric sites that included controls to help provide context on the level controls savings possible – our analysis focused on the two most recent custom lighting studies (P80 and P88). These evaluations were performed before the pandemic, in 2017/2018 and 2019/2020, respectively. Table A-4 shows the average percent reduction by control strategy and configuration based on the data mined through this effort.

Table A-5. Custom Electric Controls Reduction Estimates by Control Strategy and Configuration

Control Strategy/Configuration		Site Count	% Reduction			
			Mean	Median	Maximum	Minimum
Single Control Strategy	Dimming/Trimming[10]	7	35%	36%	64%	23%
	Occupancy	9	29%	27%	55%	3%
	Dimming/Trimming OR Occupancy	**16**	**32%**	**31%**	**64%**	**3%**
Multiple Control Strategy	Dimming/Trimming and Daylight Harvesting	5	44%	42%	53%	28%
	Dimming/Trimming and Occupancy	13	36%	30%	58%	9%
	Occupancy and Daylight Harvesting	1	29%			
	Occupancy and Trimming	2	48%	48%	68%	28%
	Occupancy and Photocell	1	81%			
	Any Multiple strategy	**22**	**48%**	**36%**	**81%**	**9%**
All Dimming/Trimming (Single & Multiple)		**27**	**38%**	**38%**	**68%**	**9%**
All Occupancy (Single & Multiple)		**26**	**36%**	**30%**	**81%**	**3%**
All Controls (Single & Multiple)		**38**	**37%**	**33%**	**81%**	**3%**

[10] Note: We did not encounter any sites that implemented only a trimming strategy. Each site that included initial trimming also implemented another control strategy.