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Memorandum

Clarifications to the 2020 Report: "Energy Savings from Networked Lighting Control (NLC) Systems With and Without LLLC"

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About the Northwest Energy Efficiency Alliance

The Northwest Energy Efficiency Alliance (NEEA) is an alliance of more than 140 utilities and energy efficiency organizations working on behalf of more than 13 million energy consumers. NEEA is dedicated to accelerating both electric and gas energy efficiency, leveraging its regional partnerships to advance the adoption of energy-efficient products, services and practices. Since 1997, NEEA and its partners have saved enough energy to power more than 700,000 homes each year.

About the DesignLights Consortium

The DesignLights Consortium® (DLC), an initiative of Efficiency Forward, Inc., is a non-profit organization whose mission is to achieve energy optimization by enabling controllability with a focus on quality for people and the environment. The DLC promotes high-quality, energy-efficient lighting products in collaboration with utilities and energy efficiency program members, manufacturers, lighting designers, and federal, state, and local entities. Through these partnerships, the DLC establishes product quality specifications, facilitates thought leadership, and provides information, education, tools and technical expertise.

Acknowledgments

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List of Acronyms and Abbreviations

Acronyms	Description
CSF	Control savings factor
DLC	DesignLights Consortium
EE program	Energy efficiency program
LLLC	Luminaire-level lighting controls
NEEA	Northwest Energy Efficiency Alliance
NLC	Networked lighting controls
TRM	Technical reference manual
2020 Savings Report	The report titled “Energy Savings from Networked Lighting Control (NLC) Systems With and Without LLLC”
2020 Redesign Report	The report titled ““Luminaire Level Lighting Controls Replacement vs Redesign Comparison Study”

Introduction

After the publication of the report “Energy Savings from Networked Lighting Control (NLC) Systems With and Without LLLC” in 2020 (referred to as “the 2020 Savings Report” hereafter), the documented control savings factors (CSFs) have been referenced by many technical reference manuals (TRMs) or equivalent and energy efficiency programs. In the meantime, NEEA and the DLC have observed challenges in interpreting or applying the information presented in the report, likely caused by ambiguous descriptions or key points not prominently highlighted. The two organizations subsequently surveyed the stakeholders to identify opportunities for clarifying the information documented in the original 2020 Savings Report, and this memo presents the clarification based on the survey findings.

NEEA and the DLC surveyed stakeholders involved in energy efficiency programs (EE programs), including program implementers, evaluators, TRM developers and advisors, and consultants for utility energy savings potential studies. The surveys were performed primarily via phone interviews with email follow-ups as necessary. The feedback provided by the stakeholders was analyzed and synthesized into digestible insights highlighted in this memo.

The purpose of this memo is not to present new information but *to provide clarity* on interpreting the presented information and further elaborate on key points in the 2020 Savings Report. The following topics are specifically called out in the following sections to clarify the research team’s original intent and interpretation of the presented information.

- Definition of luminaire-level lighting controls (LLLC)
- The effect of NLC system programming and optimization on control savings factors (CSFs)
- Confirming CSFs with a smaller sample data set
- Interpretation of CSFs broken down by control strategies
- Interpretation of CSFs broken down by building types
- Relation of the 2020 Savings Report to other related studies

As part of this follow-up to the 2020 Savings Report, NEEA and the DLC updated the executive summary of the original report to reflect the findings from the exercise. The updated executive summary is included in this memo. In addition, an errata sheet is appended at the end of the memo to correct clerical errors and show the correct message the original report intended to convey. The corrected information is used where the main body of the memo refers to the original report that is also in the errata.

Please see the original 2020 **Energy Savings from Networked Lighting Control (NLC) Systems With and Without LLLC** report for full details, background, and methodology.

Clarification of the Original 2020 Study

Definition of LLLC

To incentivize LLLC, it is crucial for energy efficiency (EE) programs to specify product eligibility. Different definitions of LLLC exist in the lighting industry. The 2020 Savings Report used the DLC's definition for the LLLC capability below, where LLLC is a system capability of an NLC system, to distinguish NLC with and without LLLC.

The** DLC's definition of **LLLC was used to differentiate NLCs with and without LLLC.

> *The capability to have a networked occupancy sensor and ambient light sensor installed for each luminaire or kit, and directly integrated or embedded into the form factor during the luminaire or kit manufacturing process. In addition to these required integrated components, LLLC systems must have control persistence capability as described in this document.*[1]

In other words, the CSFs for NLC with LLLC, as documented in the 2020 Savings Report, are most applicable to systems that meet the LLLC definition above. The individual addressability of an NLC is a key enabler of the high-end trim capability and the corresponding savings it can generate. The integral occupancy sensor and ambient light sensor provide control input, resulting in savings from occupancy sensing and daylight harvesting controls (collectively referred to as savings from "other control strategies" in the 2020 Savings Report). It will be up to the EE programs or the TRM developers to determine if it is appropriate to expand the application of the CSFs to similar systems that deviate from the DLC's LLLC definition.

Control Savings Factors

This section clarifies several critical aspects of interpreting the CSFs documented in the 2020 Savings Report.

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[1] The DesignLights Consortium. "Networked Lighting Control System Technical Requirements." Version NLC5. June 23, 2020. https://designlights.org/dlc_nlc5-technical-requirements_06232023/

System Programming and Optimization

The CSFs represent the savings potentials averaged across NLC systems with various degrees of system programming and should not be construed as the maximum achievable savings with optimized system programming.

NLC system programming refers to how the control system functionalities are determined when it is placed in service, including whether a particular control strategy is enabled and, if so, where the parameters associated with the control strategy are set. Some common parameters include the timeout period and sensor sensitivity for occupancy sensing controls, the setpoint for daylight harvesting controls, the high-end trim level, the low-end trim level, etc.

The system commissioning process confirms whether an NLC system is programmed according to the design documents, such as the control intent narrative (CIN) and sequence of operations (SOO). In smaller and more budget-constrained retrofit projects, which are the typical targets for prescriptive EE programs, there is typically very little design documentation.

The CSFs documented in the 2020 Savings Report are sometimes misconstrued as the savings potential from properly programmed or properly set up NLC systems. What we can confirm is that the systems included in the study were programmed as they were all functioning and generated various amounts of savings. As one can infer from Figure 16 of the 2020 Savings Report, reproduced in Figure 1 with slight modifications to show the average CSFs for NLC with and without LLLC separately, not all systems were *properly or optimally* programmed.

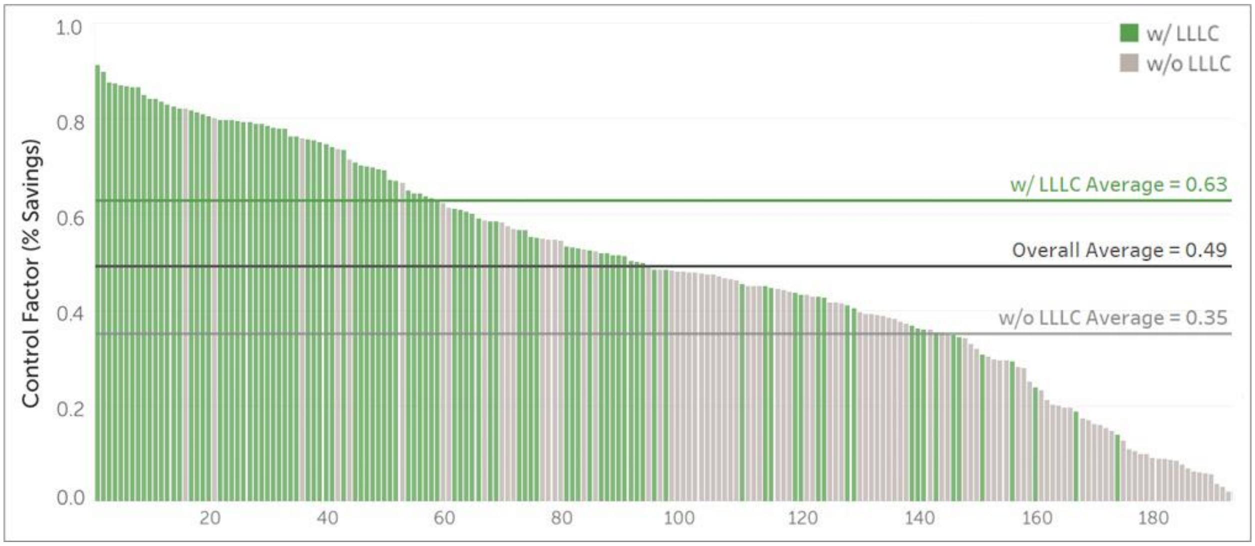

FIGURE 1. CONTROL FACTORS OF NLCS WITH AND WITHOUT LLLC ACROSS ALL 194 BUILDINGS ANALYZED.

The CSFs documented in the 2020 Savings Report should be interpreted as the *average savings* a program could see across a portfolio of projects and NLC systems; some systems will be more optimally programmed, while others will not. An EE program with mechanisms to specify or verify system programming should expect higher savings, and applying the CSFs in the 2020 Savings Report could inadvertently penalize energy savings the EE program may be eligible to claim.

CSFs Derived from Large Data Set

The CSFs in the 2020 Savings Report were derived from a relatively large sample size of NLC projects to be statistically meaningful, including energy data from 98 NLCs with LLLC and 96 NLCs without LLLC. Program evaluation typically relies on a random sample of a small subset of projects in determining program portfolio savings. As evident in Figure 1, if randomly picking a small number of the CSFs from the 194 data sets, the average of the sampled CSFs will likely deviate significantly from the average of the entire data set, because the variance of the entire data set is high. Therefore, while sampling is still a fine approach, one must consider the potential bias a small sample set could introduce.

Savings derived from a small sample set of NLC projects could drastically differ from the CSFs documented in the 2020 Savings Report.

Broken-down CSFs for Control Strategies

In addition to the average CSFs, Table 2 of the 2020 Savings Report, reproduced here as Table 1, broke down savings contributions from high-end trim and "other control strategies". In the study, we were able to break out savings from high-end trim with a high degree of confidence; however, it was not possible to further break down savings from other control strategies. Therefore, the broken-down CSFs were reported in two distinct categories: "high-end trim contribution" and "other control strategies."

The three primary sources of NLC control savings are high-end trim, occupancy sensing, and daylight harvesting, and while savings could result from other NLC functionalities, the magnitude of such savings will be dwarfed by those from the three primary control strategies. Therefore, it is reasonable to assume that the "other control strategies" CSFs represent the combined savings from occupancy sensing and daylight harvesting.

The "other control strategies" ***CSFs represent the combined savings from occupancy sensing and daylight harvesting.***

The CSFs for high-end trim and "other control strategies" are presented in a way that allows the magnitude of savings to be compared and applied independent of each other. When both high-end trim and "other control strategies" are in effect, high-end trim reduces the lighting load first, and "other control strategies" then save energy from the remaining, trimmed lighting load. If the savings from "other control strategies" are presented as a fraction of the entire lighting load, this number will be dependent on the high-end trim savings and would not be representative of the true savings potential for "other control strategies". Therefore, the CSFs for "other control strategies" in the 2020 Savings Report are calculated and presented by removing the effect of high-end trim. This provides a way to assign savings and incentivize control strategies separately if so desired by a program or a TRM.

The CSFs broken down by high- *end trim and "other control strategies"* ***are meant to represent savings potential from two sources of savings independent of each other.***

Take "NLC with LLLC" for example (the first row in Table 1), the average CSF for high-end trim and "other control strategies" are 0.37 and 0.41, respectively. This should be interpreted as 37% (0.37 CSF) of the lighting load has already been trimmed, and "other control strategies" can further save 41% (0.41 CSF) of energy from the remaining 63% (1 – 0.37 = 0.63, or 63%) of the lighting load. As a result, the portion of energy saved by "other control strategies," compared to the original untrimmed lighting load, would be 26% (63% x 41% = 26%), or 0.26 CSF (see the fifth column in Table 2 below). It is this 0.26 "other control strategies" CSF and the 0.37 high-end trim CSF that will add up to the 0.63 overall average CSF. However, the 0.26 CSF does not pertinently represent the savings potential for "other control strategies" because it is contingent on high-end trim claiming the first 0.37 CSF. If high-end trim is disabled, the "other control strategy" should be able to save 41% of the full untrimmed lighting energy, i.e., 0.41 CSF. Therefore, the "other control strategy" CSFs are presented in Table 1 in a manner that is independent of high-end trim CSFs.

Example

To further illustrate this concept, assume this NLC system has a 10,000 watts (10 kW) lighting load, as depicted in Figure 2, and operates on average 1,000 hours per year. Without any control, the system would have consumed 10,000 kWh of energy annually.

$$\mathbf{10\ kW \times 1,000\ hours = 10,000\ kWh}$$

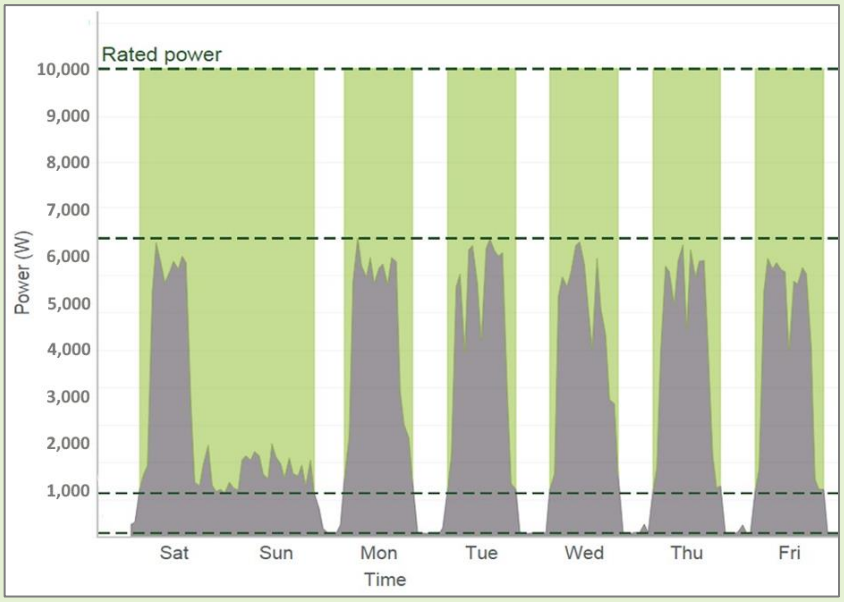

FIGURE 2. EXAMPLE: AN NLC SYSTEM CONTROLS A 10,000-WATT LIGHTING LOAD.

With high-end trim enabled to trim the lighting load by 37%, reducing the lighting load by 3,700 watts (3.7 kW), it translates to 3,700 kWh savings.

$$\mathbf{3.7\ kW \times 1,000\ hours = 3,700\ kWh}$$

In other words, the CSF of high-end trim is 0.37.

$$\mathbf{3,700\ kWh/10,000\ kWh = 0.37}$$

Suppose the "other control strategies" contributed to an additional 2,600 kWh of savings annually. Combining both savings, the overall CSF will be 0.63.

$$\mathbf{(3,700\ kWh + 2,600\ kWh)/10,000\ kWh = 0.63}$$

When the 2,600 kWh savings from "other control strategies" are presented as a fraction of the lighting energy use at the rated lighting load, the CSF would be 0.26.

$$\mathbf{2,600\ kWh/10,000\ kWh = 0.26}$$

This "other control strategies" CSF, however, is contingent on the high-end trim savings, and this is why the two CSFs, the 0.37 high-end trim CSF and the 0.26 "other control strategy" CSF, add up to the overall CSF of 0.63.

An "other control strategies" CSF that is representative of the true savings potential should be evaluated based on the **effective** lighting load, which, in this case, would be 6,300 watts--think of this as an equivalent system with a rated lighting load of 6,300 watts--, and the annual energy use of this equivalent system would be 6,300 kWh.

$$\mathbf{6.3\ kW \times 1,000\ hours = 6,300\ kWh}$$

The 2,600 kWh savings from "other control strategies" CSF calculated against the 6,300 kWh effective baseline would be 0.41.

$$\mathbf{2,600\ kWh/6,300\ kWh = 0.41}$$

Now, for instance, if high-end trim is not enabled in this NLC system, the "other control strategies" would save a 0.41 fraction (41%) of the total lighting energy use, which is 4,100 kWh.

$$\mathbf{10,000\ kWh \times 0.41 = 4,100\ kWh}$$

TABLE 1. SUMMARY OF ESTIMATED CONTROL FACTORS BY LLLC AND CONTROL STRATEGIES.

LLLC Presence	Total Buildings	Control Factor (% Savings)			
		Average	25th–75th Percentile	High-End Trim Contributions	Other Control Strategies*
NLCs w/ LLLC	98	0.63	0.50 - 0.79	0.37	0.41
NLCs w/o LLLC	96	0.35	0.17 - 0.48	0.17	0.22
All NLCs	194	0.49	0.35 - 0.69	0.27	0.32

Note: The numbers provided in this table are meant to provide a high-level overview of average savings trends. Additional study is needed to control for potentially confounding variables, and thus at this time does not imply that LLLC is universally superior and applicable to all building types.

*In this report, the control factors for control strategies other than high-end trim, unless otherwise noted, are in comparison to an inferred baseline with savings from high-end trim removed. Therefore, the control factors for high-end trim and other control strategies will not add up to the overall control factor. See Page 33 for a more detailed discussion.

Table 10 in the 2020 Savings Report intended to provide the CSFs of high-end trim and “other control strategies” that add up to the overall average CSF so the readers could see the two ways of presenting “other control strategies” CSFs side-by-side. Unfortunately, incorrect numbers were pasted into the original table. The corrected Table 10 is included in the errata, and the same table is also reproduced in Table 2 below. The CSFs in the fifth column of the table with the header “Other Control Strategies Savings as a Fraction of the Full Rated Load when High-end Trim is Enabled” represent savings from “other control strategies” with respect to the entire lighting load. Values in this column and the high-end trim CSFs will add up to the overall average CSFs. The CSFs in the last column with the header “Other Control Strategies Savings Regardless of Whether High-end Trim is Enabled”, on the other hand, represent savings from “other control strategies” with respect to the already trimmed lighting load.

TABLE 2. SUMMARY OF ESTIMATED CONTROL FACTORS BY LLLC AND CONTROL STRATEGIES.

LLLC Presence	Total Buildings	Control Factor (% Savings)			
		Average	High-End Trim Contributions	Other Control Strategies Savings as a Fraction of the Full Rated Load when High-end Trim is Enabled[1]	Other Control Strategies Savings Regardless of Whether High-end Trim is Enabled[2]
NLCs w/ LLLC	98	0.63	0.37	0.26	0.41
NLCs w/o LLLC	96	0.35	0.17	0.18	0.22
All NLCs	194	0.49	0.27	0.22	0.32

1. *Control factors were calculated with respect to the inferred baseline.*
2. *Control factors were calculated with respect to a baseline where influence and savings from high-end trim were removed.*

Note: The numbers provided in this table are meant to provide a high-level overview of average savings trends. Additional study is needed to control for potentially confounding variables, and thus at this time does not imply that LLLC is universally superior and applicable to all building types.

Broken-down CSFs for Building Types

The CSFs for each building type represent the savings potential of the entire building served by an NLC, including the primary functional areas and all supporting spaces.

Table 5 in the 2020 Savings Report, reproduced here as Table 3, provides CSFs that are broken down into different building types. These building types were identified by the owners of the data sets who contributed to the study as the primary function of the buildings where the NLCs were installed. In other words, the NLC systems would have served the entire facility, including the main functional areas and the supporting spaces. Consequently, the CSFs derived from each data set represent the savings potential of a facility as a whole and not just the main functional areas. For example, the CSF of the "manufacturing" building type should be interpreted as the overall savings potential of all the manufacturing floors, supply storage rooms, equipment maintenance areas, administrative offices, break rooms, hallways and other relevant spaces within the facility combined. Unlike the traditional building energy modeling--where a building model is made up of various functional spaces with each assigned a different set of factors, such as lighting power, occupancy schedule, etc.--the

CSFs in Table 3 are not meant to be used as the CSFs of a specific functional space within a building and be further synthesized for a building-level CSF.

TABLE 3. SUMMARY OF ESTIMATED CONTROL FACTORS BY BUILDING TYPES.

Building Type	Total Buildings	Unique Manufacturers	Control Factor (% Savings)			
			Average	25th–75th Percentile	High-End Trim Contributions	Other Control Strategies
Assembly	6	2	0.28	0.11 - 0.45	0.07	0.23
Education	14	5	0.41	0.19 - 0.58	0.19	0.32
Healthcare	2	1	0.52	0.48 - 0.56	0.33	0.24
Manufacturing	73	4	0.40	0.20 - 0.55	0.16	0.29
Office	57	8	0.64	0.53 - 0.81	0.46	0.36
Restaurant	3	2	0.59	0.47 - 0.68	0.27	0.30
Retail	29	1	0.44	0.39 - 0.48	0.22	0.27
Warehouse	10	2	0.68	0.53 - 0.79	0.38	0.48
Overall	194	12	0.49	0.35 - 0.69	0.27	0.32

* A control factor is a number between 0 and 1, representing the fraction of the energy saved through controls. 0 represents no savings, and 1 means all energy is saved. Control factor is equivalent to percent savings (% savings) when presented in percentage. For example, a control factor of 0.49 is equivalent to 49 percent savings (49% savings).

** The range for the middle 50% is displayed instead of the full range between the minimum and the maximum to provide a more representative range of savings one can generalize and expect.

Relation to Related Studies

Replacement with LLLC vs. Redesign with NLC

The information in the 2020 Savings Report is sometimes confused with the results from another study also published in 2020 by NEEA. The report from this other study is titled "Luminaire Level Lighting Controls Replacement vs Redesign Comparison Study[2]", referred to as "the 2020 Redesign Report" hereafter. The 2020 Redesign Report compared the control savings between

The CSFs were not derived from systems with optimized redesign. NLCs without LLLC could achieve much higher savings when spaces are redesigned to optimize the luminaire layout, sensor placement, and system programming.

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[2] Mahić, A., et al. "Luminaire Level Lighting Controls Replacement vs Redesign Comparison Study." Northwest Energy Efficiency Alliance, Report #E20-315. September 3, 2020. https://neea.org/resources/lllc-replacement-vs-redesign-comparison-study

several one-to-one LLLC replacement scenarios in an existing space to a lighting redesign scenario using an NLC system without LLLC capability. In the one-to-one LLLC replacement scenarios, LLLC luminaires were dropped in places where the baseline fluorescent fixtures were. In the lighting redesign scenario, a professional lighting designer was consulted to optimize the luminaire layout, sensor placements, and NLC system programming. The 2020 Redesign Study concluded that the control savings from scenarios of one-to-one LLLC replacement and the scenario of an NLC system with redesigned lighting resulted in comparable control savings.

The conclusion from the 2020 Redesign Study seemingly contradicts the results of the 2020 Savings Study, which documented 0.63 and 0.35 average CSFs for LLLC and NLC without LLLC, respectively.

The savings from the NLC system with redesigned lighting in the 2020 Redesign Study, in many ways, represent the maximum achievable savings for NLC without LLLC as the system was optimally laid out and set up. On the other hand, the savings documented in the 2020 Savings Report for NLC without LLLC represent the average from systems spanning a significantly broader spectrum of design efforts in lighting layout and system setup, as can be observed in Figure 1.

Periodically Review and Update Savings when Possible

Calling for continued studies does not imply a lack of confidence in the reported CSFs as they are supported by real data.

Finding #2 in the 2020 Savings Report concluded that NLC systems with LLLC showed overall higher savings but suggested additional study to confirm the finding. This assertion was not meant to discredit the CSFs documented in the report but to encourage similar future endeavors to update control savings potential when possible. The CSFs reported in the 2020 Savings Report are supported by a meaningfully large and diverse set of measured energy data.

Recognizing that technology will advance over time, and different, ideally larger, data sets could further mitigate any bias that might exist in the data sets used in the study, it was prudent to recommend future studies to update the current findings when opportunities present. We have revised the statement related to this finding in the updated executive summary to better reflect the intent.

Executive Summary (2024 Update to 2020 Report)

While connected lighting currently comprises less than 1% of all luminaires in the United States[1], the Department of Energy (DOE) has estimated that it can provide up to one quad of energy savings by 2035[2]. By 2035, just under a third of installed luminaires in commercial buildings are expected to have network connectivity (DOE 2019).

Luminaire Level Lighting Control (LLLC) is a capability that is available in a subset of Networked Lighting Control (NLC) systems. Per the DesignLights Consortium's definition, LLLC is the capability to have a networked occupancy sensor and ambient light sensor installed for each luminaire or kit, and directly integrated or embedded into the form factor during the luminaire or kit manufacturing process. At a high level, NLCs with and without LLLC are differentiated in this study based on LLLC including sensors and control logic at each individual luminaire, whereas sensors in NLC systems without LLLC control groups of fixtures (zones).

The 2020 Energy Savings from Networked Lighting Control (NLC) Systems With and Without LLLC project was an expansion upon of the 2017 NLC data collection and analysis project, referred to hereafter as the 2017 NLC Savings Study, which culminated in the 2017 DesignLights Consortium report, *Energy Savings from Networked Lighting Control (NLC) Systems* (DLC 2017). The 2020 study builds upon the 2017 NLC Savings Study by utilizing all of the 2017 data and expanding the project sample size, increasing the representation of NLC systems with LLLC, providing a separate analysis for savings achieved by systems with LLLC, and increasing building-type diversity.

The 2020 research project collected, aggregated, and analyzed building-, zone- and fixture-level energy monitoring interval data from NLC systems, including those with and without LLLC, in 194 buildings across a variety of building types in North America, with an average of 13 weeks of monitoring data per building. Overall, the study found average energy

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[1] In their Forecast Report, the DOE defines connected lighting as "an LED-based lighting system with integrated sensors and controllers that are networked (either wired or wireless), enabling lighting products within the system to communicate and exchange data with other devices." (DOE, 2019)

[2] A quad is a unit of energy typically used (including by the DOE) when discussing global or national energy supply and demand. It is defined as 1 quadrillion (10^{15}) BTU, or 1.055×10^{18} joules.

savings from all NLC systems to be 49%, although values are highly site-specific (see Figure 1 and below) and encompass savings from NLCs spanning the full spectrum of how well each system was programmed for optimizing energy savings.

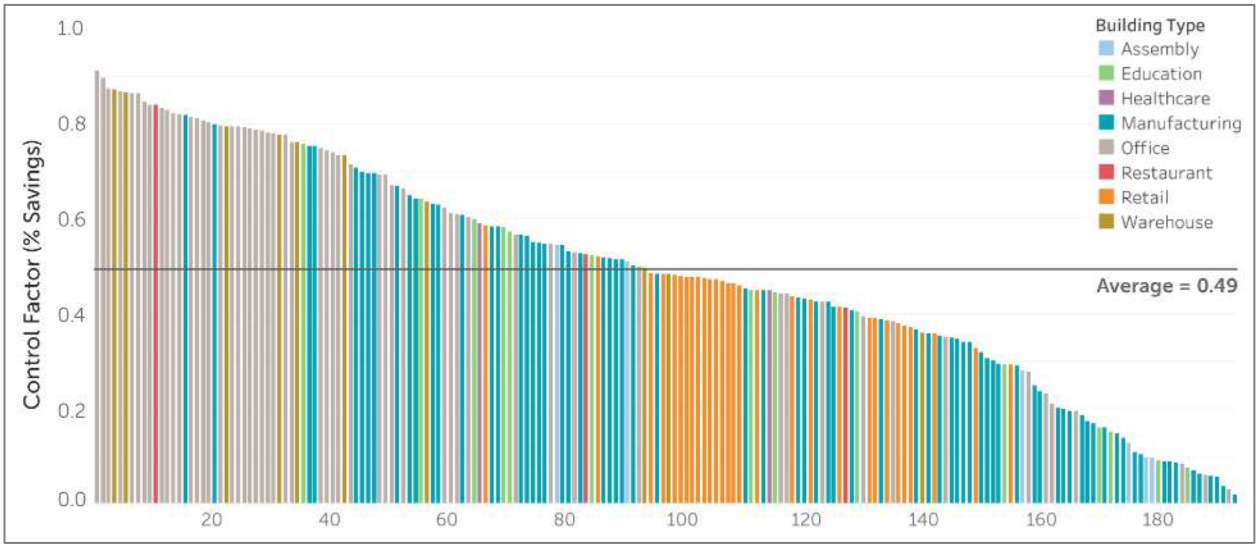

FIGURE 1. DISTRIBUTION OF NLC SAVINGS ACROSS ALL BUILDINGS ANALYZED (N=194).

TABLE 1. SUMMARY OF ESTIMATED CONTROL FACTORS BY BUILDING TYPES.

Building Type	Total Buildings	Unique Manufacturers	Control Factor* (% Savings)			
			Average	25th–75th Percentile**	High-End Trim Contribution	Other Control Strategies***
Assembly	6	2	0.28	0.11 - 0.45	0.07	0.23
Education	14	5	0.41	0.19 - 0.58	0.19	0.32
Healthcare	2	1	0.52	0.48 - 0.56	0.33	0.24
Manufacturing	73	4	0.40	0.20 - 0.55	0.16	0.29
Office	57	8	0.64	0.53 - 0.81	0.46	0.36
Restaurant	3	2	0.59	0.47 - 0.68	0.27	0.30
Retail	29	1	0.44	0.39 - 0.48	0.22	0.27
Warehouse	10	2	0.68	0.53 - 0.79	0.38	0.48
Overall	194	12	0.49	0.35 - 0.69	0.27	0.32

* A control factor is a number between 0 and 1, representing the fraction of the energy saved through controls. 0 represents no savings, and 1 means all energy is saved. Control factor is equivalent to percent savings (% savings) when presented in percentage. For example, a control factor of 0.49 is equivalent to 49 percent savings (49% savings).

** The range for the middle 50% is displayed instead of the full range between the minimum and the maximum to provide a more representative range of savings one can generalize and expect.

*** In this report, the control factors for control strategies other than high-end trim, unless otherwise noted, are in comparison to an inferred baseline with savings from high-end trim removed. Therefore, the control factors for high-end trim and other control strategies will not add up to the overall control factor. See Page 33 for a more detailed discussion.

This project reflects an important step towards advanced measurement and verification (M&V), or “M&V 2.0”, moving from generalized engineering calculations to leveraging building-specific, standardized energy data collected by building systems (in this case NLC lighting control systems) to predict, measure, and verify energy savings. This report provides key findings to inform energy savings estimates used by the building design and construction, lighting controls, and utility and energy efficiency program industries; as well as recommendations for improving methods for collecting and analyzing NLC monitoring data.

Key Findings and Recommendations

Finding #1: The portfolio-level average energy savings across all buildings in this study was 49%.

Similar to the trends observed from the 2017 NLC Savings Study, there does not seem to be a clear correlation between energy savings and building type. Site-specific variation is a much larger driver of energy savings than general factors such as building type. The variation in savings results among buildings within the same building type is likely due to the following factors:

- Site-specific NLC system commissioning and the combination of control strategies that are actually implemented.
- High variation in the programming of the parameters and settings for the strategies that are used.
- Variation in site characteristics, occupancy patterns, and user behavior.
  All the average savings values derived from the data and documented in the report should be interpreted as the average savings potential one can expect from NLCs across a portfolio of projects. Recognizing that not all the system programming would be well planned and carefully thought-through to optimize energy performance, the savings values do not represent the maximum achievable energy savings potential for NLCs.

A better understanding of the causal factors that influence energy savings is an important consideration for future study. This will require a significantly larger dataset and collection of additional site information, which is feasible if energy efficiency programs for NLCs begin collecting this data in a standardized fashion.

Recommendation #1: Based on this dataset, utility and energy efficiency programs are able to use 49% as the best estimate of average portfolio-level energy savings for NLC incentive programs

The portfolio-level average energy savings across all 194 buildings in the 2020 study was 49%. This estimate is similar to the 2017 NLC Savings Study. Because the buildings included in this study were not identified through a random sample, it is not possible to make statistical inferences about a broader building stock. For the same reason, it is also not possible to definitively determine if the 2% gain in the savings estimate is due to increased familiarity with the technology and improved programming and commissioning. However, 49% represents the average savings from NLC systems across twelve manufacturers, eight building types, and 194 buildings and is, therefore, the best available estimate of average NLC performance. A reasonable interpretation of the results is that “Across a portfolio of buildings, NLC is likely to save roughly half of the lighting energy.”

The 49% figure in this recommendation and all other related control savings factors documented in this report focus on the portfolio-level energy savings potential. These portfolio-level savings factors do not represent the energy savings that would result from a single NLC installation, nor should they be construed as the maximum achievable NLC savings. An NLC system with carefully programmed control parameters and settings that are optimized for energy performance could see much higher savings than the portfolio average, especially in a building with variable occupancy patterns.

Finding #2: The NLC systems with LLLC showed overall higher savings, although further studies are encouraged to confirm this finding and periodically update the control savings factors.

Within this study’s dataset, NLC systems with LLLC showed overall higher savings than systems without LLLC (see

Table 2 below). While this finding suggests that more granular control may lead to higher savings, it should not be inferred at this time that LLLC is universally superior in all applications, building types, and design criteria. It is, however, an auspicious indication that LLLC may have a superior energy savings potential over NLC without LLLC in one-for-one luminaire changeout scenarios where advanced controls are added. A continual study including more diverse NLC systems with LLLC controlling for potentially confounding variables is still encouraged to solidify this finding at the portfolio level and update the CSFs as appropriate. Other complementary future studies may want to investigate the potential "checkerboard[3]" effect and the potential issues related to user perception and satisfaction.

TABLE 2. SUMMARY OF ESTIMATED CONTROL FACTORS BY LLLC AND CONTROL STRATEGIES.

LLLC Presence	Total Buildings	Control Factor (% Savings)			
		Average	25th–75th Percentile	High-End Trim Contributions	Other Control Strategies*
NLCs w/ LLLC	98	0.63	0.50 - 0.79	0.37	0.41
NLCs w/o LLLC	96	0.35	0.17 - 0.48	0.17	0.22
All NLCs	194	0.49	0.35 - 0.69	0.27	0.32

Note: The numbers provided in this table is meant to provide a high-level overview of average savings trends. Additional study is needed to control for potentially confounding variables, and thus at this time does not imply that LLLC is universally superior and applicable to all building types.

*In this report, the control factors for control strategies other than high-end trim, unless otherwise noted, are in comparison to an inferred baseline with savings from high-end trim removed. Therefore, the control factors for high-end trim and other control strategies will not add up to the overall control factor. See Page 33 for a more detailed discussion.

Recommendation #2: Based on this finding, it may be worthwhile to explore energy efficiency programs around LLLC for greater average energy savings

Further study is still encouraged to create more robust savings estimates for NLCs with LLLC at the portfolio level and for each building type. However, it may be worthwhile to pilot programs targeting the building types where LLLC seems to exhibit significantly higher savings, such as offices, warehouses, and some manufacturing facilities (see Table 7). Other aspects around LLLC can also be investigated through the pilot programs, including suitable applications (e.g., luminaire layouts, space configurations, etc.) and occupant perception, as noted in Finding #2.

Additional Findings and Recommendations

The control factor results described above in the executive summary, and in more detail in the Results and Discussion section in the 2020 report, are the primary outcome of the 2020 report. This section provides additional findings to inform the continued growth of the NLC

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[3] The "checkerboard" effect refers to the scenario where a connected space is unevenly lit, and the ceiling is showing dark spots as some luminaires are turned off or dimmed significantly. This occurs when each fixture turns off or dim itself in the absence of an occupant in its field of view while other locations within the same space is still occupied and the luminaires above the occupied areas are at a much higher light output level.

industry and utility and energy efficiency programs, as well as recommendations for improving how NLC monitoring data is collected and analyzed. For more in-depth discussions, see the Project Findings and Recommendations section of the report.

Finding #3: Ownership of, management of, and access to NLC energy data vary from NLC manufacturer to manufacturer.

During the data collection process, it became evident that NLC manufacturers had varying abilities to provide viable data to the study, stemming from varying levels of knowledge on the whereabouts and details of their NLC installations and the ability to provide energy data due to different sales models. Some manufacturers centrally manage energy data in the cloud and have contractual agreements with customers to access the data. Other manufacturers enable energy monitoring by default or as an option and store energy data locally within the system. Most of these manufacturers rely on sales representative agencies, distributors, and contractors for sales, installation, and commissioning; and, therefore, have little or no direct access to or knowledge about the installations.

This translated to a high level of effort in outreach and collecting NLC energy data for this study. More importantly, from the energy efficiency program perspective, it may not always be practical to expect the involvement and support from the manufacturers in submitting NLC energy data as part of the energy efficiency program. Recommendation #3 in the next section specifically advocates for energy efficiency programs for NLCs to be the primary drivers for collecting NLC energy data as part of their energy efficiency programs.

Recommendation #3: Energy efficiency programs for NLCs should drive the sharing and use of anonymized NLC energy data for all participating projects.

While the 49% portfolio savings for NLCs may be used as deemed savings in the near term, the most accurate savings claims will always be the savings measured at each installation. With energy reporting becoming widespread in NLCs, evaluating savings at each installation should be the ultimate direction energy efficiency programs move towards. As pointed out in Finding #3, administrators of energy efficiency programs for NLCs are the only market actor that have direct engagement with NLC program participants in all cases. Energy efficiency programs for NLCs should strongly consider including clauses in their customer participation agreements that authorize the sharing of anonymized data with the administrators of energy efficiency programs for NLCs.

In addition to collecting NLC energy data submitted by the program participants, this recommendation also advocates for the energy efficiency program administrator's active use of the collected data. A standardized data submission format and process (detailed in Recommendation #5) should be specified by the energy efficiency program and included as part of the customer participation agreement. This recommendation is consistent with and reinforces the recommendation in the DLC report, *Interoperability for Networked Lighting Controls* (DLC 2020), that the program administrator should be the primary driver and promoter for the use case of energy data reporting for incentive savings verification.

Finding #4: The process for exporting static attributes of the energy data, such as the post-NLC rated power, is more error-prone than for time-series data and can skew the estimated savings.

For energy data directly reported by NLCs, the time series data is a direct export from the NLCs. The static attributes, on the other hand, were typically provided in a separate document during the data collection period, which is much more susceptible to human data entry and transcribing errors. Some NLCs may be able to export static attributes, but they are still only as accurate as the information manually entered into the NLC by the commissioning providers at the time of system startup, programming, or commissioning.

Recommendation #4: As part of the NLC energy data, essential static attributes of an NLC installation should be required and verified carefully to ensure accuracy and quality of the analyses.

Whether or not NLC energy data is collected as part of a utility or energy efficiency program or for future savings characterizations like this study, the static attributes, such as the post-NLC rated power, gross building area of the NLC installation, etc., need to be carefully verified by the data collector for accuracy. This is critical in ensuring the accuracy and quality of estimated savings, as discussed in Findings #4. From the energy efficiency program perspective, the best time to accurately collect these essential static attributes is at the completion of the NLC installation. A new standard, ANSI C137.9 "Networked Lighting Systems Configuration" is expected to become available in early 2025 to guide standardized reports of static attributes.

Finding #5: Most manufacturers do not have an existing mechanism to easily export the data required for energy efficiency program evaluation.

The size of a dataset grows rapidly as the spatial and temporal granularities and the overall duration of measurement increase[4]. The highly granular and long duration datasets used in this study presented challenges, both in terms of the data providers transferring the data, and in the time required for the project team to process, normalize, and load the datasets into the NLC database.

The challenges encountered in this study suggest that it would not be a scalable model for utility and energy efficiency programs to require the most granular energy data for NLCs. The program data requirements will need to strike a balance between accuracy and scalability, as suggested in Recommendation #5 in the next section.

Recommendation #5: Energy efficiency programs for NLCs should standardize the NLC energy data reporting format and requirements to facilitate program participation and streamline the process. Based on these reporting guidelines, manufacturers should consider developing administrator-specific reporting functionality to support energy efficiency program data intake process.

As Finding #5 points out, the large size of some NLC data files will make data intake, processing, and analysis very challenging and unscalable for efficiency programs. It is critical for energy efficiency programs for NLCs to specify and standardize the spatial and temporal granularity and duration requirements based on the metrics and methodology that will be used to assess or verify the NLC energy performance.

A standardized data reporting format and requirements will also provide manufacturers with clear guidance and motivation to develop NLC energy reporting functionalities that support the efficiency program needs.

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[4] Spatial granularity refers to the spatial level at which the data is provided (i.e., building-level, zone-level, and fixture-level). Temporal granularity refers to the reporting interval (i.e., hourly, 15-minute intervals, event-based, etc.). These terms are explained in more detail in the Data Normalization and Aggregation section.

The DLC is supporting progress on Recommendations #4 and #5 through the NEMA ANSI C137 committee. This progress will enable the DLC and program administrators to encourage products with standardized data reports for Recommendation #3.

Finding #6: In this study, buildings with NLC systems had significantly longer operating hours than typical prescribed estimates of building operating hours.

The average occupied hours for buildings in this study's dataset are substantially longer than the average lighting system operating hours assumed by many efficiency programs throughout the US in their Technical Reference Manuals (TRMs). This is consistent with previous findings from the 2017 NLC Savings Study. Figure 20 in the Findings and Recommendations section compares hours found in this study and operating hours for fixtures across several TRMs, including California, Illinois, Mid-Atlantic, New York, and the Northwest regions. The large discrepancy between observed hours and the operating hours found in TRMs may result in lower overall savings for projects using deemed operating hours. This study, and any future updates to this study, could serve as additional data points for the TRMs to calibrate the deemed operating hours.

Errata

TABLE 10. SUMMARY OF ESTIMATED CONTROL FACTORS BY LLLC AND CONTROL STRATEGIES.

LLLC Presence	Total Buildings	Control Factor (% Savings)			
		Average	High-End Trim Contributions	Other Control Strategies Savings as a Fraction of the Full Rated Load when High-end Trim is Enabled[1]	Other Control Strategies Savings Regardless of Whether High-end Trim is Enabled[2]
NLCs w/ LLLC	98	0.63	0.37	0.26	0.41
NLCs w/o LLLC	96	0.35	0.17	0.18	0.22
All NLCs	194	0.49	0.27	0.22	0.32

1. *Control factors were calculated with respect to the inferred baseline.*
2. *Control factors were calculated with respect to a baseline where influence and savings from high-end trim were removed.*

Note: The numbers provided in this table are meant to provide a high-level overview of average savings trends. Additional study is needed to control for potentially confounding variables, and thus at this time does not imply that LLLC is universally superior and applicable to all building types.

Please see the original 2020 **Energy Savings from Networked Lighting Control (NLC) Systems With and Without LLLC** report for full details, background, and methodology.