TRM WORKPAPER

Networked and Luminaire Level Lighting Controls Measure Characterization

PREPARED FOR:

DesignLights Consortium
10 High Street, Suite 10
Medford, MA 02155

AUTHORS:

Dan Mellinger, Energy Futures Group
Zack Tyler, Energy Futures Group

ACKNOWLEDGEMENTS:
We gratefully acknowledge the contributions of the following individuals who shared their insights and expertise as peer reviewers.

Amy Dickerson, National Grid
Chris Wolgamott, Northwest Energy Efficiency Alliance
Sam Dent, VEIC

TABLE OF CONTENTS

ACRONYMS AND ABBREVIATIONS

Acronym/Abbreviation	Definition
C&I	Commercial and Industrial
CSF	Control Savings Factor
DLC	DesignLights Consortium
EFG	Energy Futures Group
EUL	Effective Useful Life
IECC	International Energy Conservation Code
NEEA	Northwest Energy Efficiency Alliance
NLC	Networked Lighting Controls
NLC-All	Networked Lighting Controls with an unknown presence of LLLC
NLC-NoLLLC	Networked Lighting Controls without LLLC
LLLC	Luminaire-Level Lighting Controls
QPL	Qualified Products List
RTF	Regional Technical Forum
TRM	Technical Reference Manual

WORKPAPER PURPOSE AND OVERVIEW

This workpaper was developed by Energy Futures Group (EFG) on behalf of the DesignLights Consortium (DLC)and it's utility and energy efficiency program members. The purpose of this workpaper is to provide a guide for calculating the energy and demand savings associated with networked lighting controls (NLC) and luminaire-level lighting controls (LLLC). NLC and LLLC present substantial savings opportunities, yet these measures are not included in all program offerings or Technical Reference Manuals (TRMs). This workpaper provides a template for a state, province or utility to easily incorporate these measures within an existing TRM or similar engineering resource.

For states, provinces or utilities that already incorporate these measures, this workpaper presents a recommended set of input value assumptions and sources that should be considered for future TRM updates. Program implementers, lighting controls manufacturers, and lighting market actors installing these products would all benefit from the standardization of NLC and LLLC data requirements. In addition, greater consistency amongst North American TRMs can improve and streamline implementation and program tracking across jurisdictions.

DLC Member utilities and energy efficiency programs (and their authorized implementation contractors and evaluators) are invited to utilize recommendations and values in this paper to populate their own workpapers to submit new NLC and LLLC savings measures to their state, province, or regional TRMs.

EFG conducted a detailed review of 36 known TRMs in use throughout North America. Our review revealed 21 states or provinces with TRMs that include NLC, LLLC, or both, as measures with energy and demand savings calculations. EFG reviewed each of these TRMs to identify the algorithms, input variables, and values assumed for NLC and LLLC savings calculations. Below we present the findings associated with this research, the range of values assumed for key variables in the current literature, and recommended values for adoption in any future TRM applications.

This workpaper is accompanied by the report, "A Review of Technical Reference Manuals in the U.S. and Canada: Networked and Luminaire-Level Lighting Control Measure Prevalence and Best Practices," prepared by Energy Futures Group for DesignLights Consortium. This report provides a comprehensive analysis of TRMs in North America, focusing on NLC and LLLC measures. Please contact the DLC with any questions or feedback on the workpaper or the report at info@designlights.org.

KEY VARIABLES FOR SAVINGS CALCULATIONS

This section provides a detailed summary of the key variables that are used for calculating savings for NLC and LLLC measures. Specifically, this section provides a definition of key variables, a summary of the values used by current TRMs for each variable, and the DLC recommended value and source.

CONTROL SAVINGS FACTOR

Control Savings Factor (CSF) is a variable used to estimate the percentage reduction in energy consumption that results from implementing lighting control measures. It accounts for lighting being turned off and/or dimmed by different control strategies, such as occupancy sensors, daylight harvesting, and high-end trim. CSF is used in TRMs to standardize the expected savings for various lighting control technologies, ensuring consistency across energy efficiency programs. CSF is sometimes referred to as control savings fraction, savings factor, or other similar terms.

SUMMARY OF CURRENT TRMS

NLC-All

Of the 21 states or provinces with TRMs that were identified as including algorithms for NLC or LLLC, 17 of them (81%) include CSFs for NLC generically or for NLC where the presence of LLLC is unknown (also referred to as '***NLC-All***'). The mean CSF among the 17 TRMs was 0.53 while the median was 0.49.

Table 1. Summary of NLC-All CSF Values

	NLC-All CSF Values	States or Provinces Covered
n	*17*	ON (Canada), CO, CT, DE, DC, IL, IN, IA, MD, MA, MI, MN, NJ, NY, PA, TX, WI
Min	0.47	
Max	0.64	
Mean	0.53	
Median	0.49	

Of the 17 TRMs that include NLC where the presence of LLLC is unknown:

- 10 exclusively define a CSF for NLC with an unknown LLLC presence.
- 4 define CSFs for LLLC, NLC without LLLC, and NLC with an unknown LLLC presence.

- 3 define CSFs for NLC with an unknown LLLC presence and for LLLC as a stand-alone measure. In each of these instances the CSF is the same for NLC with an unknown LLLC presence and for LLLC.

Two TRMs, covering a total of three states, include CSFs for different building types. In these instances, the 'Office' building type is used in the results presented in Table 1.

NLC-NoLLLC

Based on our review, there are currently eight states or provinces where the TRMs provide a CSF for NLC and specify that the CSF is for NLC without the inclusion of LLLC (also referred to as '***NLC-NoLLLC***'). Table 2 provides a summary of the CSF values from the eight TRMs that include a NLC-NoLLLC measure. As shown, there is a tight range of CSFs – the mean CSF is 0.38 and the median is 0.40. Four states – Idaho, Montana, Oregon, and Washington – all use the Northwest Power and Conservation Council's Regional Technical Forum (RTF) as the foundation for their savings calculations.

Table 2. Summary of NLC-NoLLLC CSF Values

	NLC-NoLLLC CSF Values	States or Provinces Covered
n	*8*	ID, IL, IN, IA, MN, MT, OR, WA
Min	0.35	
Max	0.40	
Mean	0.38	
Median	0.40	

Two TRMs, covering a total of five states, include CSFs for different building types. In these instances, the 'Office' building type is used in the results presented in Table 2.

LLLC

Our research identified 10 states or provinces where the current TRMs include LLLC as a measure with distinct savings assumptions. Table 3 presents a summary of the range of values currently used for LLLC CSF. As shown, the range of CSF values used for LLLC ranges from 0.49 to 0.77, with an average of 0.62 and a median of 0.63.

Table 3. Summary of LLLC CSF Values

	LLLC CSF Values	States or Provinces Covered
n	*10*	CT, IA, ID, IL, IN, MN, MT, NJ, OR, WA
Min	0.49	
Max	0.77	
Mean	0.62	
Median	0.63	

Two states – Connecticut and New Jersey – are using a CSF of 0.49 for both NLC and LLLC. The technologies are split into distinct lighting control types within these TRMs, but both NLC and LLLC use the same value. Again, it is worth pointing out that four states – Idaho, Montana, Oregon, and Washington – all use the Northwest Power and Conservation Council's RTF as the foundation for their savings calculations. The RTF recently updated the CSF for LLLC from 0.60 to 0.65.

Two TRMs, covering a total of five states, include CSFs for different building types. In these instances, the 'Office' building type is used in the results presented in Table 3.

Recommendations

We recommend that TRM administrators adopt two measures to cover NLC:

- NLC without LLLC (NLC-NoLLLC)
- LLLC

As detailed in Table 1, many TRMs currently offer a deemed CSF for NLC where the presence of LLLC is unknown. This is useful to the extent that a program is tracking the presence of NLC, but not LLLC. However, this value offers a CSF that is quite a bit higher than the CSF associated with NLC-NoLLLC (see Table 2). This results in the potential to overstate savings in a scenario where 1) NLC-NoLLLC are installed and 2) the only CSF available covers NLC where the presence of LLLC is unknown. Of course, this also results in the potential to understate savings in the case where 1) LLLC are installed and 2) the only CSF available covers NLC where the presence of LLLC is unknown.

For these reasons, we advocate that program administrators ensure they are tracking the presence of both NLC and LLLC as part of their program implementation. This will allow for more detailed granularity when applying CSFs and other factors, such as measure life, while reducing evaluation risks. Table 4 presents our recommended CFS values for NLC-NoLLLC and LLLC. These values are consistent with the findings from the 2020 NEEA and DLC report titled "*Energy Savings from Networked Lighting Control Systems With and Without Luminaire Level Lighting Controls*". This report, which recently had a clarifications memo published, is the primary source of NLC and LLLC CSF assumptions in the TRMs that we reviewed. Our research did not uncover a more recent set of primary research results on these values, and therefore we suggest that TRM administrators adopt these values for NLC and LLLC moving forward.

Table 4. Recommended CSF Values

Control Type	CSF
NLC-NoLLLC	0.35
LLLC	0.63

OPERATING HOURS

Operating hours refer to the number of hours per year that a lighting system is in use, before accounting for any reductions due to controls. TRMs define default operating hour values for different building types and sometimes even space types. These default values are critical for deemed savings estimates in incentive programs and are often based on measured data from state or regional studies. Typically, the default operating hours are applied across all lighting measures within a single TRM. Many energy efficiency programs use the default operating hours only if the actual hours are not reported or known.

Summary of Current TRMs

All of the TRMs included in our review specify unique operating hours based on the building type in which the lighting controls are installed. In most instances, the operating hours for different building types are used for all deemed savings calculations associated with lighting measures in the commercial and industrial (C&I) sector. The number of building types and the operating hours associated with them varies considerably from jurisdiction to jurisdiction. Figure 1 presents the range of operating hours for 'Office' building types in TRMs that include NLC and/or LLLC; this is a good example of the wide variation associated with operating hours across TRMs.

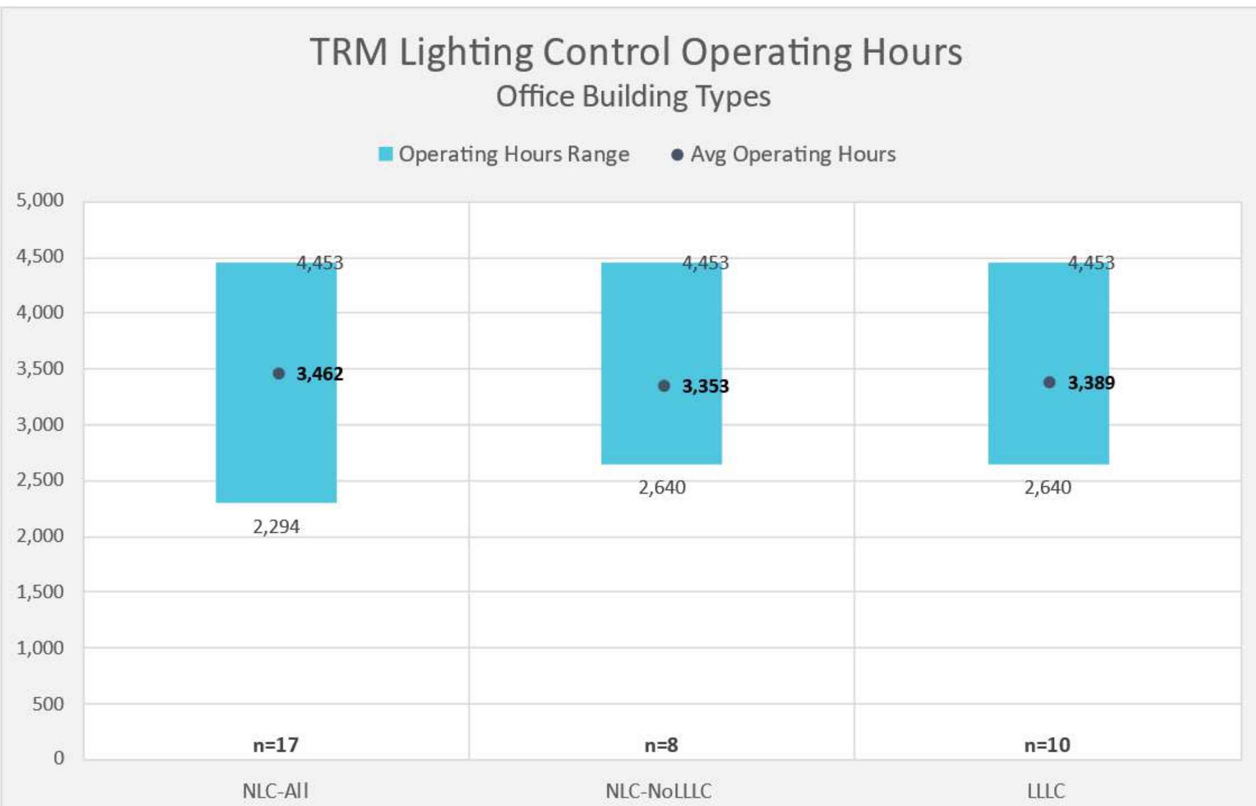

Figure 1. TRM Operating Hours for NLC and LLLC

Two TRMs (Illinois, and by extension Indiana which references the Illinois measure) use operating hours from the [2020 NEEA/DLC study](#) that looked at savings from NLC with and without LLLC. That study found that the inferred operating hours calculated for buildings with NLC systems were higher than what most TRMs assumed for the majority of building types. The report notes that this could be due to buildings with longer operating hours being naturally inclined to implement NLC systems. The study appropriately points out that this suggests the current operating hours used by many TRMs could underestimate the impact of NLC and LLLC systems. Table 5 presents the values currently used in the Illinois TRM for NLC and LLLC, which originate from the 2020 NEEA/DLC study on savings for NLC with and without LLLC.

Table 5. Annual Operating Hours for NLC and LLLC, by Building Type, in Illinois TRM v13.0

General Building Type	Annual Hours of Use
Education	4,231
Manufacturing	5,365
Office	4,453
Retail	6,936
Warehouse	5,116
All Other	Use local operating hour assumptions associated with different building types for other C&I lighting measures

Recommendations

We recommend that TRM administrators use the values presented in Table 5 for each of the five building types with operating hours from the NEEA/DLC study.[1] The NEEA/DLC study included projects from all over the United States and Canada, ultimately covering 110 different buildings. As previously noted, the study found that buildings with NLC and LLLC systems are likely to have higher operating hours than the default values specified in most TRMs. The values in Table 5 represent these higher operating hours and will result in higher savings associated with NLC and LLLC systems.

For all building types outside of those listed in Table 5, we recommend that TRM administrators use the values that are currently defined in their existing TRM for other C&I lighting measures.

We recommend that TRM administrators consider documenting the difference between buildings with and without NLC and LLLC systems when updating operating hour assumptions. Any primary research that accounts for these differences should supersede the values recommended in Table 5.

CONTROLLED WATTS

The amount of load (watts) controlled by a lighting system is a key variable used in the calculation of lighting control energy savings. This information can be provided as a reported value for the actual load of the controlled lighting, such as on custom projects and in some prescriptive programs. Alternatively, controlled watts can be a deemed value, such as in some prescriptive and nearly all midstream programs.

[1] The inferred operating hours for "Assembly", "Healthcare", and "Restaurant" were excluded due to the reported small sample sizes in the NEEA/DLC study.

Summary of Current TRMs

Of the 21 states or provinces that have an NLC and/or LLLC measure in their TRM, 16 (76%) rely on a reported value for controlled watts. This information must be provided by a customer or contractor on an incentive application. The other five use deemed values for controlled watts to represent the typical or average amount of controlled lighting load. A deemed value is often necessary for midstream programs since installation conditions are not typically reported at the time of sale.

Deemed controlled watts can be applied on a per-square foot basis (often for NLC) or per-luminaire basis (often for LLLC). If the value is per-square foot, then the project size in square feet must also be defined or reported. Table 6 presents the deemed values used for controlled watts in each of the five TRMs where a deemed approach is incorporated for controlled watts. Four of the five TRMs – Illinois, Indiana, Iowa, and Michigan – are all based on the same assumptions. Ontario incorporates controlled watts by building type, and the value shown in Table 6 is an average across all building types.

Table 6. Deemed Values for Controlled Watts

State/Province	Control Type	Controlled Watts Input	Controlled Watts	Controlled Watts Unit
IL, IN, IA, MI	NLC-All	Deemed	0.61	per ft^2
IL, IN, IA	NLC-NoLLLC	Deemed	0.61	per ft^2
IL, IN, IA	LLLC < 10,000 lumens	Deemed	31	per Luminaire
IL, IN, IA	LLLC >= 10,000 lumens	Deemed	118	per Luminaire
ON (Canada)	NLC-All	Deemed	0.82	per ft^2

Recommendations

We recommend that the total wattage controlled by NLC and/or LLLC be collected from the customer and documented as part of the program implementation process whenever possible. These wattages should be used to calculate the savings associated with these systems. This will result in the most accurate savings possible for each NLC/LLLC application. Typically, reported values will be feasible on prescriptive and custom programs, but may not be practical to collect on midstream programs. Accordingly, we recommend that midstream LLLC programs rely on the reported wattage on the DLC qualified products list (QPL) for the luminaire(s) associated with the LLLC.

For luminaires with selectable wattage ranges, we recommend that the same wattage assumptions be used for both the luminaire and the luminaire controls. It is important to maintain consistency across the savings calculations used for both luminaires and controls, both of which should represent the installed conditions for luminaires with selectable wattages.

MEASURE LIFE

Measure life, also known as Effective Useful Life (EUL), represents the expected lifespan of energy savings before a measure fails, is disabled, or requires significant maintenance. Measure life is typically shorter than a product's functional life since there are factors that may cause energy savings to cease before the product fails. For lighting controls, an example limiting factor would be a sensor that is overridden due to occupant dissatisfaction.

Summary of Current TRMs

Our team reviewed the measure life associated with NLC and/or LLLC in each of the 21 states/provinces with TRMs covering these measures. Figure 2 presents the range of findings associated with the TRMs included in our analysis. As shown, the average measure life was 11.5 years for NLC-All, 14.1 years for NLC-NoLLLC, and 13.1 years for LLLC.

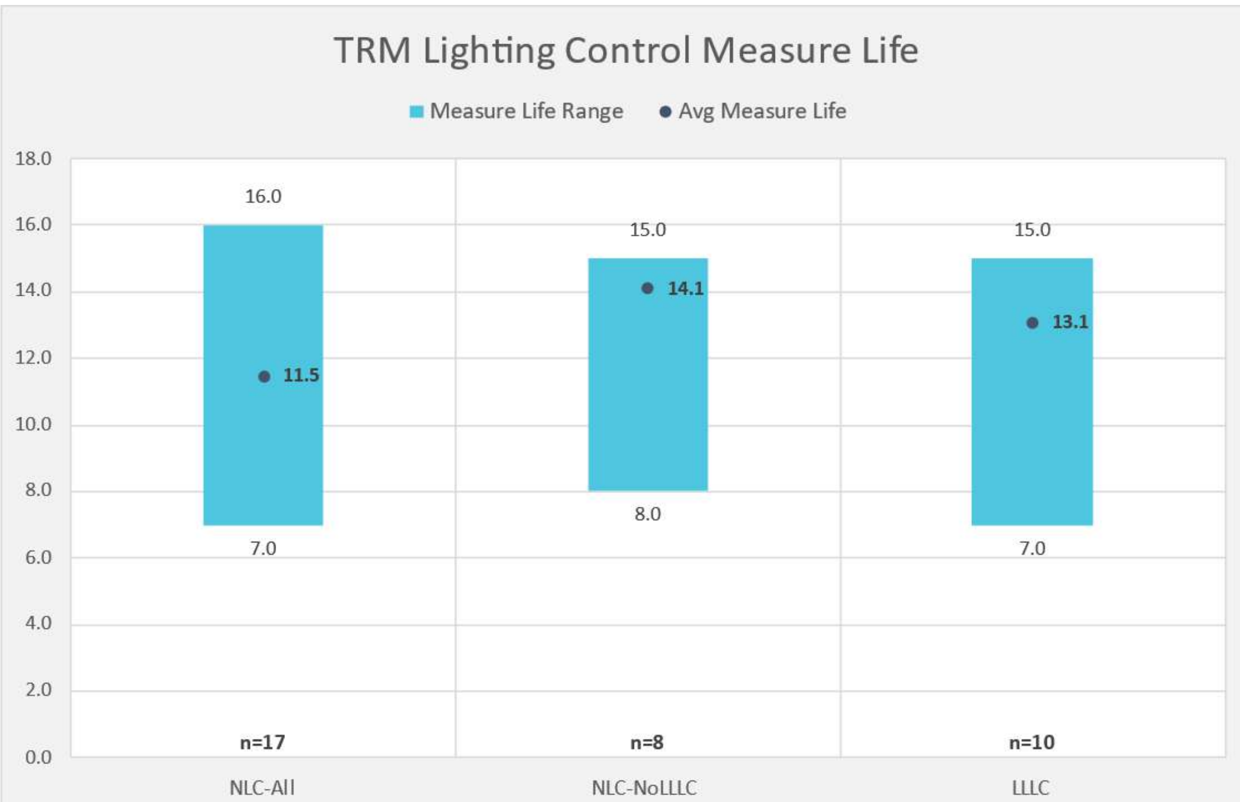

Figure 2. Measure Life

The Minnesota TRM prescribes a different measure life for NLC and LLLC – this was the only state in our review that includes both NLC and LLLC measures and offers different measure life values for the two technologies. The TRM notes that LLLC are integrated into luminaires and, as a result, the measure life for LLLC should be equivalent to that of the luminaire. Minnesota uses a measure life assumption of 11 years for LEDs, and this same value is applied to LLLC. The measure life for NLC-NoLLLC is 8 years and is consistent with the measure life of other non-LLLC lighting control technologies.

Recommendations

We recommend that TRM administrators take the following approach when determining measure lives for NLC-NoLLLC and for LLLC measures.

- For NLC-NoLLLC, use the measure life associated with other C&I lighting control measures.
- For LLLC, use the measure life associated with C&I LED luminaires.

Most TRMs that include both NLC-NoLLLC and LLLC measures use the same measure life for both. However, the logic associated with the Minnesota TRM is sound and reflects the reality that LLLC are an integrated component of LED luminaires, and the measures lives should be identical.

INCREMENTAL MEASURE COST

Incremental measure cost represents the difference between the cost of purchasing and installing a minimum efficiency or baseline piece of equipment and the cost of installing a high efficiency piece of equipment. For LLLC, the baseline is typically an LED luminaire without LLLC functionality, and the upgrade case is an LED luminaire with LLLC functionality. For NLC, the baseline is a lighting project without an NLC system[2], and the upgrade case is a lighting project with an NLC system. The baseline for a new construction project would be the minimum controls required by code.

Summary of Current TRMs

Of the 21 states and provinces with NLC and/or LLLC measures in their TRM, only 8 include assumptions for the incremental cost associated with NLC and LLLC. Table 7 presents the costs associated with these eight states and provinces. The incremental costs are reported in different units across different technologies and jurisdictions. Figure 3 presents the incremental costs from Table 7 only the per luminaire costs for LLLC have been converted to a per square foot estimate.[3] As shown, the incremental costs associated with these technologies have generally declined over time and that is reflected in the more recent TRM resources.

[2] The baseline scenario may include existing controls.

[3] This figure excludes Colorado which reports incremental costs in terms of dollars per watt. The LLLC incremental cost was converted from per luminaire to per square feet using an assumption of 100 square feet per LLLC luminaire. ‘NLC-All’ and ‘NLC-NoLLLC’ were merged in the figure as the incremental costs are the same for these two measures in each of the jurisdictions that cover both.

Table 7. Incremental Measure Costs for NLC and LLLC Measures

State/Province	Control Type	Cost	Unit
CO	NLC-All	$0.72	per watt
DE	NLC-All	$2.06	per ft^2
IL, IN, IA	LLLC	$56.00	per luminaire
IL, IN, IA	NLC-All	$0.40-$0.86[4]	per ft^2
IL, IN, IA	NLC-NoLLLC	$0.40-$0.86Error! Bookmark not defined.	per ft^2
MI	NLC-All	$1.68	per ft^2
ON (Canada)	NLC-All	$2.28	per ft^2
WI	NLC-All	$0.57	per ft^2

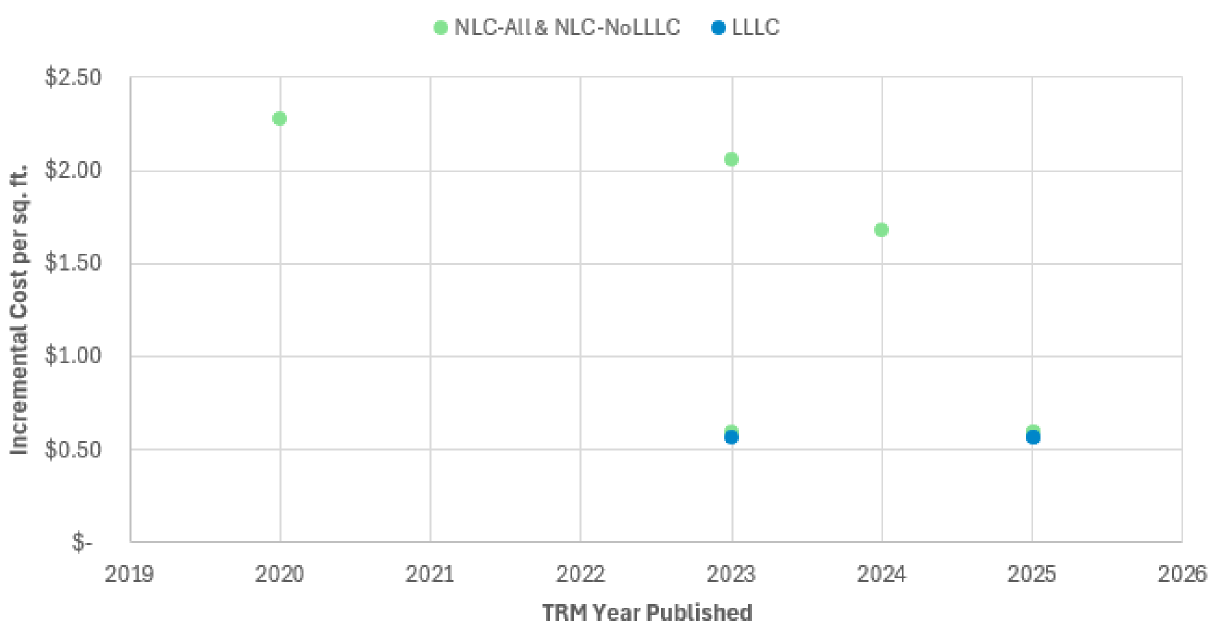

Figure 3. Incremental Cost per Square Foot

Recommendations

We recommend that TRM administrators use the values in Table 8 for incremental measure costs. The incremental cost for LLLC comes from a 2022 NEEA incremental cost study and represents the average incremental cost of three different LLLC technologies. The 2022 study is an update to a 2020 NEEA incremental cost study that is referenced by half of the states/provinces listed in Table 7. The incremental cost we recommend for NLC-NoLLLC measures is $0.53 per square foot. This is based on the

[4] The incremental cost varies depending on building size as follows: $0.86 per ft^2 for buildings < 10,000 ft^2; $0.59 per ft^2 for buildings between 10,000-100,000 ft^2; and $0.40 per ft^2 for buildings > 100,000 ft^2.

same data from the 2022 NEEA study and assumes an LLLC luminaire typically covers 100 square feet.[5] We recommend using the incremental cost associated with LLLC as a proxy for NLC; this is due to the fact that the most recent incremental cost research associated with NLC-NoLLLC systems is a [2019 study from California](). The 2022 NEEA study shows that the incremental costs for LLLC have come down in recent years, and as a result we believe the more recent LLLC data is more accurate than the 2019 study data on NLC-NoLLLC systems.

Table 8. Recommended Incremental Cost Values

Control Type	Cost	Unit
NLC-NoLLLC	$0.53	per ft^2
LLLC	$53.00	per luminaire

DRAFT TRM MEASURE CHARACTERIZATION

The sections below are intended to offer TRM administrators an easily accessible template for adopting and/or updating NLC and LLLC measure characterizations into their TRMs. Our intent is that the sections below can easily be incorporated into TRMs across the country with minimal need for customization.

TECHNOLOGY SUMMARY

For the purposes of this workpaper we are using the following definitions for NLC and LLLC.

Networked Lighting Controls (NLC) refer to advanced lighting control systems that combine sensors, network interfaces, and controllers to effect lighting changes in luminaires, retrofit kits, or lamps. These systems integrate multiple control strategies such as occupancy sensing, daylight harvesting, high-end trim, and scheduling to provide enhanced energy savings, automation, and performance tracking.

Luminaire-Level Lighting Controls (LLLC) are a subset of NLCs that use embedded sensors and controls within individual luminaires, enabling more granular control, easier installation, and increased flexibility.

BASE CASE DESCRIPTION

Retrofit

The baseline for any retrofit scenario is assumed to be the existing lighting system and can include manual or no controls or an existing control strategy that is being improved. Note, where an existing inefficient luminaire is replaced with an efficient luminaire control, use the luminaire measure to calculate savings from the wattage reduction first, then assume the efficient luminaire without control as the baseline for the control measure.

[5] The assumption of 100 square feet represents the midpoint of values reported by the Lighting Controls Association: https://lightingcontrolsassociation.org/2022/06/15/introduction-to-luminaire-level-lighting-controls/.

New Construction

In a new construction or lost opportunity scenario, the baseline should be based on the energy code that is in place for new construction in any given jurisdiction. For example, beginning with the 2012 International Energy Conservation Code (IECC), occupancy sensors are required in certain space types such as classrooms and private offices. The types of spaces included in this requirement have been expanded with recent iterations of the energy code and now include various office types, which are common space types for NLC and LLLC applications. Program administrators should use any local code requirements for lighting controls as the baseline condition in new construction applications.

UPGRADE CASE DESCRIPTION

The upgrade case is defined as any lighting that is controlled with either NLC or LLLC control strategies. These measures should be consistent with the definitions documented above. We recommend that eligible products be restricted to those listed in the DLC Qualified Products List (QPL) for Networked Lighting Controls.

Measure Life[1]

For NLC-NoLLLC measures, use the measure life associated with other C&I lighting control measures such as occupancy sensors. For LLLC, use the measure life associated with C&I LED luminaires.

Incremental Measure Cost[2]

If possible, the actual incremental cost of the measures shall be used. When not available, the following default values can be applied:

Table 9. Recommended Incremental Cost Values

Control Type	Cost	Unit
NLC-NoLLLC	\$0.53	per ft^2
LLLC	\$53.00	per luminaire

Energy and Demand Savings

Energy Savings

$$\Delta kWh = kW_{Controlled} \times Hours \times (CSF_{EE} - CSF_{Base}) \times IF_e$$

Where:

- $kW_{Controlled}$ is the number of kilowatts (kW) controlled by the NLC or LLLC system.

- Source and values: This information should be collected from the customer and documented as part of the program implementation process. The values will be variable as they should be customized for each project. We recommend that midstream LLLC programs rely on the reported wattage on the DLC QPL for the luminaire(s) associated with the LLLC.

- $Hours$ are the annual operating hours associated with the control system.
  - Source and values: Table 10 and current TRM assumptions for annual operating hours associated with other C&I lighting measures.

Table 10. Annual Operating Hours for NLC-NoLLLC and LLLC Measures[3]

General Building Type	Annual Hours of Use
Education	4,231
Manufacturing	5,365
Office	4,453
Retail	6,936
Warehouse	5,116
All Other	Use TRM specific operating hour assumptions associated with different building types for other C&I lighting measures

- CSF_{EE} is the Control Savings Factor (CSF) for the NLC-NoLLLC or LLLC measure.
  - Source and values: See Table 11

Table 11. CSF Values for NLC-NoLLLC and LLLC[4]

Control Type	CSF
NLC-NoLLLC	0.35
LLLC	0.63

- CSF_{Base} is the Control Savings Factor (CSF) for the lighting controls that existed before the new lighting controls were installed.

- Source and values: This value should be set to zero (0) in instances where there were no lighting controls in the baseline scenario or when the prior existence of lighting controls is unknown. If non-networked lighting controls were already in place, the CSF values associated with those controls should be used.[6] For example, in Illinois, the CSF_{Base} value would be set to 0.24 when an interior occupancy sensor was already in place, or 0.28 when an interior daylight sensor was already in place. A larger CSF_{Base} value will result in smaller savings associated with the upgrade technology.

- IF_e is the Interactive Energy Factor associated with NLC-NoLLLC and LLLC measures. This represents the secondary energy impacts associated with decreased waste heat (and subsequently reduced cooling loads) from efficient lighting strategies.
  - Source and values: This value should be based on the IF_e values identified for all other C&I lighting measures. This value should be greater than 1 for any building with cooling. If the TRM does not include values for lighting-HVAC interactive effects, this value should be set to 1.

Heating Penalty for Electrically Heated Buildings

$$\Delta kWh_{HeatPenalty} = kW_{Controlled} \times Hours \times (CSF_{EE} - CSF_{Base}) \times IF_{HeatPenalty}$$

Where:

- $IF_{HeatPenalty}$ is a factor that accounts for the increased electric heating impacts associated with lighting controls. Because these controls reduce waste heat from lighting, the building's heating system must compensate accordingly. This factor is only applicable to electrically heated buildings—the heating penalty for other buildings is described below. If the TRM does not include values for lighting-HVAC interactive effects, this value should be set to 0.

Total Electric Energy Savings

$$\Delta kWh_{Total} = \Delta kWh - \Delta kWh_{HeatPenalty}$$

Heating Penalty for Buildings Not Heated with Electricity

$$\Delta Therms = kW_{Controlled} \times Hours \times (CSF_{EE} - CSF_{Base}) \times IF_{Therms}$$

---

[6] The CSF values for multiple control types are not additive. Most TRMs include CSF values for 'dual' lighting controls, such as occupancy sensors and daylighting controls. In these instances the CSF for the 'dual' lighting control measure should be used; the individual CSF values from the two separate control strategies should not be added together to develop the baseline CSF.

Where:

- IF_{Therms} is a factor that accounts for the increased fossil fuel heating impacts associated with lighting controls. This factor, measured in therms, includes any fossil fuel heating sources (e.g., natural gas, fuel oil, coal, etc.). Because these controls reduce waste heat from lighting, they do result in an increased heating load. This is only applicable to non-electrically heated buildings. If the TRM does not include values for lighting-HVAC interactive effects, this value should be set to 0.

Peak Demand Savings

$$kW_{Summer} = kW_{Controlled} \times (CSF_{EE} - CSF_{Base}) \times CF_S \times IF_{d\_s}$$

$$kW_{Winter} = kW_{Controlled} \times (CSF_{EE} - CSF_{Base}) \times CF_W \times IF_{d\_w}$$

Where:

- CF_S is the summer peak coincidence factor by building type used for C&I lighting measures.
  - Source and values: This value should be based on the CF_S values identified for other C&I lighting measures. This is often broken out by building type.
- CF_W is the winter peak coincidence factor by building type used for C&I lighting measures.
  - Source and values: This value should be based on the CF_W values identified for other C&I lighting measures. This is often broken out by building type.
- IF_{d_s} is the Summer Interactive Demand Factor that represents the impact on the cooling system associated with decreased waste heat from efficient lighting.
  - Source and values: This value should be based on the IF_{d_s} values identified for all other C&I lighting measures. If the TRM does not include values for this input, then the value should be set to 1.
- IF_{d_w} is the Winter Interactive Demand Factor that represents the impact on the heating system associated with decreased waste heat from efficient lighting.
  - Source and values: This value should be based on the IF_{d_w} values identified for all other C&I lighting measures. If the TRM does not include values for this input, then the value should be set to 1.

SOURCES

[1] DesignLights Consortium (2025). Review of Technical Reference Manuals in the U.S. and Canada. Networked and Luminaire-Level Lighting Control Measure Prevalence and Best Practices.
[2] Ibid.
[3] Northwest Energy Efficiency Alliance, DesignLights Consortium (2020). Energy Savings from Network Lighting Control (NLC) Systems with and without LLLC. https://designlights.org/resources/reports/report-energy-savings-from-networked-lighting-control-nlc-systems-with-and-without-lllc/
[4] Ibid.