DRAFT MEMO

CT X1931-4 ALC PSD Phase 2 Memo

Recommendations for ALC Measure Parameters

Prepared for: CT EA Team
Prepared by: Benjamin Crosby and Kerri-Ann Richard, DNV

Date: May 29, 2021

ABSTRACT

The objectives of this study are to update, where necessary, and enhance the technical basis of the savings factors and measure lives for new residential and commercial Advanced Lighting Controls (ALC) measures adopted in phase 1[1]. The results are to be incorporated into the 2023 Connecticut Program Savings Document (CT PSD). In Phase 1 of this study, these new measures were developed through a literature review, discussions with experts, and program administrator (PA) interviews. In this second phase of the study, in-depth interviews with market actors and industry experts, as well as a review of program custom project files, have been used to inform conclusions.

The three measures developed as part of phase 1 were:

1. Commercial Interior Lighting Controls (including networked lighting controls (NLC), luminaire-level lighting controls (LLLC), the combination of high-end trim with daylight dimming or occupancy sensors, dual occupancy and daylight controls, high-end trim, daylight dimming, and occupancy sensors),
2. Residential Connected LED Lighting, and
3. Residential Occupancy Sensors.

DNV interviewed four industry experts and four market actors, and reviewed 12 custom NLC project files from Eversource Energy and United Illuminating Co. In addition, the study team reviewed the methodology used in the DLC study[2], which is the basis for the advanced lighting controls' savings assumptions.

The study found a large variance in responses from interviews and a large variance in potential savings from reviewed custom project files. This variability in the custom project data and interview responses highlights the need for a more in-depth study of advanced lighting controls. The variance and nuances produced by the research also made clear the need to better understand the LLLC product and its installation when attributing energy savings.

The research team proposes maintaining all measure savings factors defined in Phase 1, apart from LLLCs. The team also proposes that LLLCs be divided into two categories: LLLC – Networked and commissioned, and LLLC – Non-networked or networked but not commissioned. LLLC – Networked and commissioned controls will maintain the 49% savings factor identified in Phase 1, and the LLLC – Non-networked or networked but not commissioned controls will adopt a 35% savings factor. This 35% savings factor is the average of the combination controls identified in Phase 1. The distinction between these two is important, as the networking and proper installation of LLLCs has consequences on their saving potential. This memorandum provides distinct savings factors for each.

[1] The measures are: 2.1.3 Interior Lighting Controls, 3.1.3 Interior Lighting Controls, 4.1.2 Connected LED Lighting, and 4.1.3 Occupancy Sensors.

[2] DLC and Northwest Energy Efficiency Alliance (NEEA), "Energy Savings from Networked Lighting Control (NLC) Systems with and without LLLC", Energy Solutions, Sept 24, 2020.

Table of contents

List of figures

List of tables

1 INTRODUCTION

As part of CT X1931-4 phase 2, the study team is seeking to update or verify the findings of the first phase and solidify new measure savings factors for lighting controls in Commercial and Industrial settings. The research team conducted in-depth interviews (IDI) and custom project file review to answer the following research topics as defined at the end of phase 1:

1. Confirm of update phase 1 findings through empirical data and interviews
2. Investigate savings factor differentiation between NLCs and LLLCs
3. Application of savings factors for combination controls beyond dual occupancy and daylight sensors
4. Explore appropriate coincidence factors and measure lifetimes per control technology through expert and market actor interviews

Special emphasis was placed on the NLCs, LLLCs, and Residential Connected LED Lighting, as these are the most novel of the control technologies and those that the study team deemed the most “advanced,” though the study team still confirmed the categorization of the broader group of controls measures when interviewing experts and market actors.

2 SUMMARY RESULTS

The outcome of this study confirmed those findings in phase 1 for all measures, with the exception of LLLCs. As the study team progressed with expert and market actor interviews, the nuances of LLLCs—how they are sold, installed, commissioned, and networked—became more obvious, and the need to separate these measures by those that are networked and commissioned versus those that are not became clear. Commissioning includes field calibration, field programming, and controls education. Phase 1 reported a 49% savings factor for all LLLC measures. Phase 2 responses led the researchers to keep that factor for LLLC systems that are networked and commissioned and add a new category for LLLC systems that are not networked, or are networked but not commissioned, with a 35% savings factor. Table 2-1 summarizes the 2022 PSD and final recommended savings factors.

Table 2-1. Lighting control measure factors

Sector & Application	Measure	2022 PSD Savings Factor	Recommended Savings Factor
Commercial Interior Lighting Controls	Networked Lighting Controls (NLC)	49%	49%
	Luminaire-Level Lighting Controls (LLLC) – Networked & Commissioned	49%	49%
	LLLC – Non-networked, or networked but not commissioned		35%[3]
	Dual Occupancy and Daylight Sensors	38%	38%
	Combination High-End Trim and Daylight Dimming	35%	35%
	Combination High-End Trim and Occupancy Sensors	33%	33%
	High-End Trim	27%	27%
	Daylight Dimming	28%	28%
	Occupancy Sensors	24%	24%
Residential Connected LED Lighting	Connected LED Lighting	29%	29%
Residential Occupancy Sensors	Occupancy Sensors	17%	17%

The research found no reason to distinguish measure life as a function of control technology. Instead, life is linked to the life of the controlled fixture, presumed to be LEDs, which is in turn a function of event type. This finding is unchanged from Phase 1. The 2022 PSD references lamp life in lighting control measures. Table 2-2 summarizes the results.

[3] 35% is the rounded average of Dual Occupancy and Daylight Sensors, Combination High-End Trim and Daylight Dimming, and Combination High-End Trim and Occupancy Sensors. Per discussion with the EA team on 4/25/22, this was agreed to be a reasonable assumption for a fixture with multiple controls that is not networked or verified/commissioned.

Table 2-2. Measure life

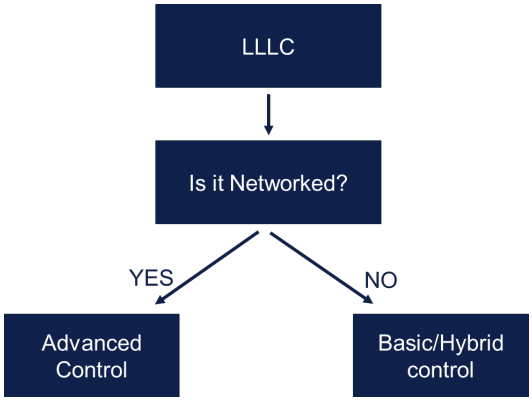
Event Type	2022 PSD Measure Life (Years)	Phase 1 Recommended Measure Life (Years)	Phase 2 Recommended Measure Life (Years)
Lost Opportunity	C&I interior lighting: 10 Residential connected LED lighting: 15 Residential occupancy sensors: 10	12.2	12.2
Early Replacement	C&I interior lighting: 10	7.0	7.0

3 RECOMMENDATIONS

Based on the findings from market actor and industry expert interviews, review of utility custom NLC project files, and discussions with the EA team, the team identified the following recommendations and areas for further investigation.

1. LLLCs have been shown to differ in savings potential depending on the installation and verification of networking. Because of this, this study recommends that LLLCs have two associated savings factors: the first for a commissioned, networked LLLC, getting the 49% prescribed in phase 1 and the second for an LLLC not networked, or networked but not commissioned, getting a 35% savings factor, which is the median value of hybrid controls. This study recommends that program implementers work with evaluators and the EA team in CT to define the exact parameters required for an LLLC to be considered networked and commissioned. For example, an IDI respondent indicated that in certain geographies, implementers and installers used a defined checklist during the installation to verify that a lighting control measure was being installed to the criteria necessary to meet a deemed savings value.

    a. If a program cannot ensure that a network is commissioned, the non-commissioned value should be used. Ensuring commissioning in midstream programs is quite difficult but may be possible, such as through a combination of contractor training and program requirements.



2. Due to the small number of CT custom project data files and relative infancy of the advanced technologies, the study team recommends a future study to review installation practices for LLLCs, verification of LLLCs and NLCs, and metering for ALCs to accurately quantify the savings factors and coincidence factors.

    a. There is little Connecticut-specific about these savings factors. The EE community generally would benefit from further field research. Performing a regionally supported study is a technically viable option. In particular, Massachusetts plans to perform a C&I lighting controls impact study in 2022. Collaborating with that effort is one option to leverage resources.

4 FINDINGS TO SUPPORT RECOMMENDATIONS

The study team fielded two survey guides as part of phase 2. Both target populations had high familiarity with lighting controls, their savings, the market, and the mechanics of these controls. The first was written for market actors, with a goal of getting their estimates of control measure savings, the lifetime of the product, insight into seasonal control practices, additional understanding of how they see LLLC and NLCs in the market, and the prevalence of commissioning and retro-commissioning. The survey guide for industry experts was similar, but focused more on savings, measure lives, customer and installer understanding of ALCs, and market conditions. Both can be found in APPENDIX A.

Multiple respondents stated that commissioning of networked LLLC control systems was necessary to ensure that the systems are programmed properly and operators are educated on them to achieve the savings they estimated in the ranges above. Commissioning can be defined as the "'systematic process of ensuring that all building systems perform interactively according to the documented design intent and the owner's operational needs.' This can include factory start-up, sensor calibration and owner notification of the operation and intent of the control systems."[4] Typical commissioning will tune the initial angular placement, sensitivity and time delay of sensors, auto-shut off ("sweep") schedule, and dimming limits and troubleshoot false switching.

In the interviews, for example, when asked about barriers to customers adopting fixtures with integrated controls (essentially what LLLCs become without networking), a respondent noted a project where they saw a corporate headquarters install 1,500 fixtures with occupancy sensors, but they were not installed correctly. The lights *"…went out with CEO in restroom and he uninstalled all sensors and tried to return them."* Additionally, when we asked market actors about the typical default setting for LLLCs, we received responses indicating a wide range of possibilities:

"Yes, factory default settings vary by manufacturer; occupancy sensors [delay] can be set around 5-15 minutes. High end trim typically must be set manually."

"[Controls] typically aren't shipped pre-programmed at the factory unless ordering individual knows what programming is, but typically test in the field before programming it."

The lighting industry generally uses the term "commissioning" to describe the process rather than who does it[5] and the study team interpreted the respondent comments as being in that spirit as well.

Additionally with LLLCs, when simply reviewing the PSD listing, one could draw the conclusion that regardless of how a customer purchases an LLLC, they will have the opportunity to derive high savings like NLCs. Some of the respondents started to shed light on this distinction and that much of the success of LLLCs is due to their networking, less the fixture itself. For example, when asked "Can you please define the differences between these [LLLCs and NLCs] as you understand it?", one respondent said:

"*There are three levels, first one is luminaire that has external devices associated with it, then luminaire with embedded sensors in it, then networked system with luminaires with embedded sensors and external devices that ties it all together*."

Another provided more context, saying:

"LLLC means the fixture itself can be controlled but doesn't necessarily mean the controls play well with others – compared to kids playing on a playground doing different things. NLC says 'hey I can get these two

[4] National Electrical Contractors Association's *Guide to Commissioning Lighting Controls*, p.1. http://apps.necanet.org/files/ACF363E.pdf.

[5] Ibid. "Commissioning should involve all members of the design and construction team and is typically led by the commissioning agent, who may be an electrical contractor, commissioning specialist, manufacturer technician or some other professional."

kids to play on a seesaw together and have them work seamlessly', that is beginning of it. LLLC to him doesn't mean a good thing, because everyone is not doing the same thing, or we can't tell everyone to do the same thing."

These two perspectives illustrate that there are varying types of LLLCs and although they are capable and have advanced control functionalities, proper networking and setup is what makes them work well and maximize savings. This suggests correct setup does not necessarily mean all LLLCs will yield the same savings, but the range of savings would overall be higher depending on the building type, use type, and other factors than they would without proper setup. This would suggest that the high savings comes not only from the advanced measure, but also the setup and networking.

In addition to the apparent differences within LLLCs, many ranges of savings opportunity were reported by the experts and market actors, as seen in Table 4-1. This variability and spread from higher to lower percent savings tracked closely to how savings factors were reported in the DLC study used by phase 1. Figure 4-2 shows the distribution reported in the DLC study.

Table 4-1. Interview respondent savings factor estimates

Respondent Number	Respondent Type	NLC Estimated Savings %	LLLC Estimated Savings %
1	Industry Expert	25% 40%	25% - 40%
2		49%	63%
3		49% - 70%	49% - 70%
4		No Response	No Response
5	Market Actor	30% - 40%	30% - 40%
6		50% - 60%	50%
7		70%	40% - 50%
8		70% - 80%	70%

Figure 4-1. IDI estimates saving factors for NLCs (commissioning not defined in interview for NLCs)

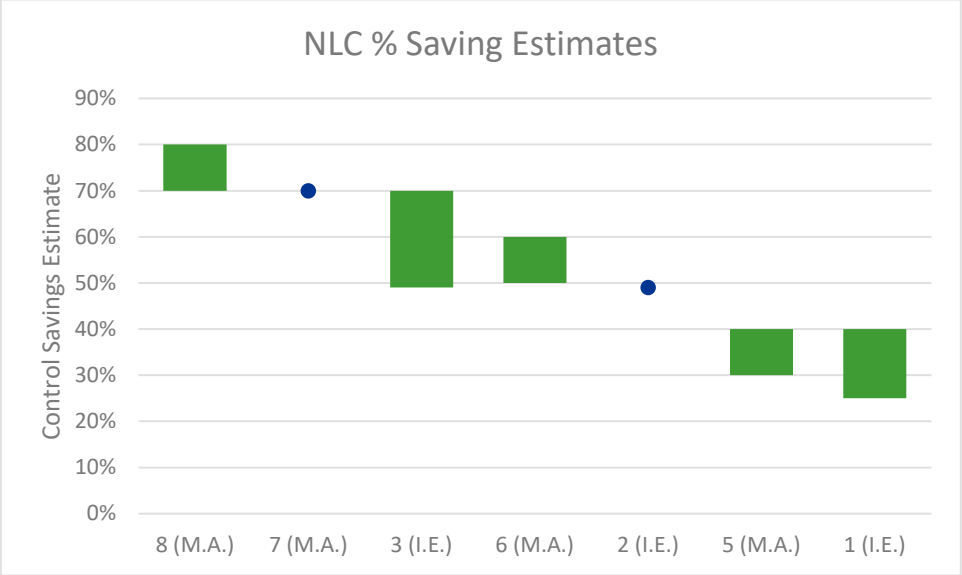
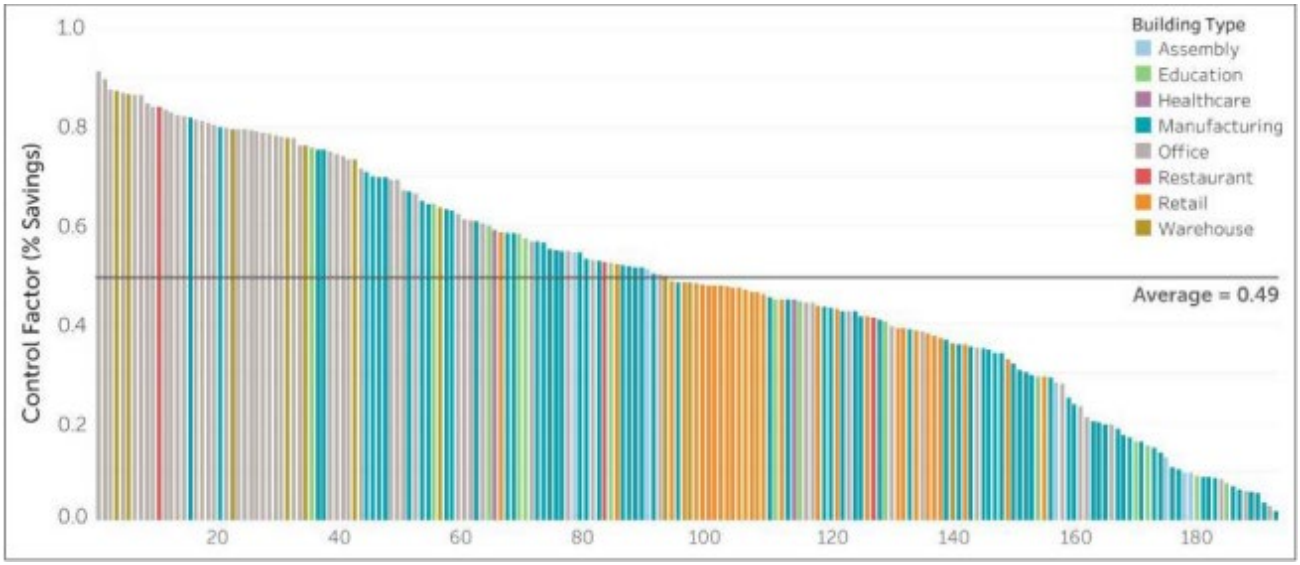


Figure 4-2. DLC project savings data for NLCs[6]



Furthermore, respondents felt that standalone controls and combination controls, as recommended from phase 1, had savings factors that seemed appropriate. Multiple respondents acknowledged the DLC study cited in phase 1 as the most definitive source available. Details on its method are addressed later in this document.

[6] DLC and Northwest Energy Efficiency Alliance (NEEA), "Energy Savings from Networked Lighting Control (NLC) Systems with and without LLLC", Energy Solutions, Sept 24 2020.

Most respondents were less familiar with residential lighting controls and often noted lower adoption as a reason. One expert did estimate the Residential Connected LED Lighting as having a savings potential of 25-40% and one Market Actor noted 40%, but two responses was not deemed enough evidence to change the estimate reported in phase 1.

An objective of phase 2 was to use interviews to look into the coincidence factors associated with these controls. Table 4-2 and Table 4-3 show responses recorded for both C&I and residential seasonal practices. The lack of consensus further showed the study team that the values currently used should not be altered.

Table 4-2. Sample coincidence factor question responses – commercial & industrial

Question	Answers
From your experience, do C&I facilities typically have unique control settings for a typical summer and a typical winter?	*"Would say no, the same year round, other than times of coming on depending on daylight hours"*
	"*Yes, definitely pick up additional energy savings based on longer daylight hours, also pick up summer – people on vacations etc, offices are darker, longer schedules built into the system design, have a calendar programmed in as part of the system"*
	"Yes, depends on level of light entering space, if have skylights or large windows or have sawtooth story windows in the roof, however time scheduling when we have a networked system allows us to adjust A) to astronomical time clock differences between DST and Standard time and also allows us to schedule different events – ex cleaning crews, also allows us to dim on demand when company requires it, so advantages to having NLC hooked into utility Demand response systems"

Table 4-3. Sample coincidence factor question responses – residential

Question	Answers
From your experience, do residences typically have unique control settings for a typical summer and a typical winter?	"*No, same thing, just lights coming on"*
	"*Depends on if someone is home, if someone works from home a lot get greater savings year-round, someone who doesn't work at home is harder to determine/pinpoint"*
	"No, it doesn't seem that disciplined"

Measure lives were addressed, but by asking interviewees about the lifetimes of the controls in relation to the fixtures they are controlling. The responses suggest that the controls could last longer, but are often replaced as a package

with the fixture. Sample answers can be seen in Table 4-4 and Table 4-5. With such a small sample of responses and a lack of clear consensus to alter, we do not have a basis for changing the recommendation made in Phase 1.

Table 4-4. Sample measure life question to industry expert

Question to Industry Expert	Answers
In your experience, do hybrid controls or ALCs last as long, less, or the same as the bulb that they are controlling?	*"Has no idea, would be lying if gave any kind of answer to that."*
	"In his experience life of fixture is life of lighting system, won't typically reuse equipment and what will see is all lighting in a system that was existing, if there was a lag will just install new equipment."
	"Probably not as long, think is more of a firmware and software, not that chips burn out but more something isn't bright in the settings and it gets worked around."

Table 4-5. Sample measure life question to market actor

Question to Market Actor	Answers
If the customer has NLC or LLLC, how would you characterize the life of the control in relation to the lights it is controlling?	*"The better the quality of the control, the longer it will last and be able to adapt."*
	"Controls will often outlive the lights they control. LED boards get over 10 years of useful life while drivers get 5-7, so the driver will likely fail first."
What do you anticipate customers would do with NLCs and LLCs if lighting fixtures/bulbs needed to be replaced on schedule? On burnout?	*"Typically, customers replace NLCs or LLCs upon burnout or on schedule. Most fixtures are plug-and-play so can easily get a replacement part but this varies – sometimes you need to replace the whole system".*

Table 4-6. NLC custom project SFs

Project	Savings Factor
1	76%
2	67%
3	49%
4	32%
5	30%
6	38%
7	30%
8	20%
9	20%
10	14%
11	13%
12	10%

The study team reviewed custom project files for NLCs from both PAs from 2019 to 2021. There were five applicable projects from UI and seven from Eversource. Table 4-6 shows the spread of savings due to the NLC systems in each. The projects produced a spread of savings factors from 10% up to 76%, with the majority falling below the 49% recorded in the PSD and recommended in phase 1. This highlights an area for more research but is not conclusive enough to alter study findings. This also reinforces the question of commissioning in advanced lighting controls, how prevalent it is, and the need for it. It is worth noting that the average savings factors found in the custom project files were 51% for United Illuminating and 21% for Eversource. The individual project records did not provide sufficient information to explain the difference and the counts are too small to consider these differences in the PSD.

Finally, the study team reviewed the methodology used in the DLC study that the phase 1 results rely on for NLCs. Some key takeaways are as follows:

Methods:

1. Sampling was based on convenience with about 70 organizations contacted in 2020 and 2017. Twenty-four of them responded and provided metered data on 194 buildings that informed the study.
2. Targeted sources included end-use customers (only in 2020) and organizations that sponsored research (2020 and 2017)–manufacturers, research organizations, and utilities.
3. The data was characterized by building type, location, control product, zone/fixture type, interval data, and limited space type.
4. The study used an inferred baseline, as no pre-installation data was used in informing the baseline.

Potential Biases:

1. The study assumes 100% power for on-times in the baseline.
2. The study assumes 0 savings for off-times in the baseline
3. Manufacturing was over-represented in the data. The control savings for those facilities was a below average 40%.
4. Industry self-selection of projects

The combination of interviewee estimated ranges covering the DLC results, their unsolicited reference of the DLC report, and the study team's closer review its methods reinforce its viability as the best available reference. They do highlight that more research into advanced lighting controls is needed.

APPENDIX A. MARKET ACTOR INTERVIEW GUIDES

4.1 Expert interview guide

CT Program Savings Document (PSD) Measure Update & Lighting future potential – Advanced Lighting Controls Market Actor Guide DRAFT

4.1.1 Study Objective

X1931: CT Program Savings Document (PSD) Measure Update – The primary objective of the X1931 study is to update entries for recently added residential and commercial Advanced Lighting Controls (ALC) measures incorporated into the CT Program Savings Document (PSD). Updates are supported by primary and secondary research in an effort to gain better understanding of advanced lighting control technology and market potential.

C2014: C&I Lighting Saturation and Remaining Potential – The primary objective of the C2014 study is to characterize the status of the C&I lighting market, forecast the remaining potential for lighting programs, and updated PSD parameters impacted by a rapidly changing market. As part of Phase 2, DNV is examining additional savings opportunities associated with the lighting market including the addition of advanced controls capabilities, retro commissioning, and TLED to LED Luminaire replacements.

Interview Objective and Approach

Due to both the of subject matter, the expert interviews scoped under both X1931 and C2014 will be conducted in unison. The objectives of these interviews are designed to support both efforts. The overarching goal of these interviews is to gather insights on the ALC industry, confirm or update relevant savings factors for new ALC measures, and understand market trends from leading experts in the lighting and ALC market. Table 4-7 aligns the study-specific research objectives with the study and questions. Table 4-8 provides a summary of the data collection approach.

Table 4-7. Study-specific research objectives and identifying survey questions

Research Objectives	Study	Question Number
Accuracy and appropriateness of current controls categories	X1931-4 and C2014	1-3
Common controls and customer familiarity with controls. Also targeting customer and expert familiarity with NLC/LLLC and differences.	X1931-4 and C2014	4-9
Appropriateness and calculation of savings factors. Differentiation between LLLC and NLC	X1931-4	10-13
Measure life	X1931-4	14-15
TLEDs: Satisfaction and replacement behavior	C2014	16-17
Future potential of TLEDs and LED Fixtures	C2014	18

Fixtures with integrated controls: barriers, replacement behavior, commissioning/RCx	C2014	19-21
ALCs: barriers, replacement behavior, commissioning/RCx	C2014	22-25

Table 4-8. Overview of data collection approach

Data Collection	Description
Population Description	Industry experts on advanced lighting controls
Sample Size	4 - 6
Instrument Type	Phone Interview
Survey/Interview Length	Approximately 45 minutes
Description of Contact Sought	Advanced lighting controls experts

4.1.2 Instrument: Interview Script

Interviewee		**Interviewer**	
Interviewee Company		**Interview Date**	
Interviewee Phone #		**Interviewee email**	

Introduction

Thank you for taking the time to talk with me today. As a reminder, we are currently working on a study in Connecticut looking at ALCs, and relevant savings factors and measure lives associated with those ALCs. The potential savings associated with various controls technologies and controls strategies can vary based on control type, proper installation, user knowledge, building type, and many others. We are hoping your insight can aid us in confirming or updating our understandings. We will reference the control strategies that I previously provided to you. While answering the following questions, please feel free to additionally offer any perspectives you may have on the market or controls technologies.

Would you be open to us recording this interview session? We would like to do so, because some of the questions designed to for an open-ended response which may require some additional review to capture all of your feedback. Also, we would like to include paraphrased versions of some of your responses in the report appendix. They will be anonymized, and your name/contact information will not be included anywhere.

Table 4-9. Measures and controls

Measure	Control Category	Control Type	Description	Current Savings Factor *(Relative to Manual On-Off Control)*
Commercial and Industrial Interior Lighting Controls	Basic Lighting Controls	Occupancy Sensors	Reduces lighting operation hours by switching off lighting in unoccupied spaces.	24%
		Daylight Dimming	Reduces lighting output to a set level or reduces lighting operating hours in response to natural daylighting using continuous, stepped, or on/off dimming capabilities.	28%
		High-End Trim	Reduces lighting output of individual lights or groups of lights to a set level continuously.	27%
	Hybrid Lighting Controls	Combination high-End Trim and Occupancy Sensors	Combines the capabilities of high-end trim and occupancy sensors	33%

		Combination High-End Trim and Daylight Dimming	Combines the capabilities of high-end trim, reducing the lighting output to a set level continuously, and daylight sensors, allowing lighting fixtures to reduce output to respond to daylight.	35%
		Dual Occupancy and Daylight Sensors	Combines the capabilities of occupancy and daylight sensors, allowing lighting fixtures to respond to occupancy and daylight.	38%
	Advanced Lighting Controls	Luminaire Level Lighting Controls (LLLC)	Integrates high-end trim, occupancy and daylight sensors into the LED fixture	49%
		Networked Lighting Controls (NLC)	An intelligent network of individually addressable luminaires and control devices for remote access by the user. NLC have fixture networking capabilities, individual addressability, occupancy sensing, daylight harvesting, high-end trim, flexible zoning, continuous dimming, scheduling, and cybersecurity.	49%

Residential Connected LED Lighting	Basic Lighting Controls	Connected LED Lighting	Connected LED lighting that allows for remote user control through Wi-Fi and/or a smart device. Allows for remote on/off, adjustment of brightness, and schedule setting.	29%
Residential Occupancy Sensors	Advanced Lighting Controls	Occupancy Sensors	Reduces lighting operation hours by switching off lighting in unoccupied spaces.	17%

[Share table without savings factors in advance of interview]

Questions

We would like to start by talking about your understanding of the different controls technologies and strategies.

1. Lighting controls present opportunity to bring additional savings though the strategies can be complicated. We have compiled a number of controls categories to try and capture the options available in the market. Do these categories allow us to capture all the differences in control capabilities?
   [Probing questions, if necessary]
   a. Are we missing any key lighting controls strategies you are seeing in the table that are not highlighted?
   b. Are there other important segmentations to capture?
   c. Are there too many categories?

2. Prior to this call, how familiar were you to these lighting control categories? (Basic, hybrid, advanced) Not at all familiar, slightly familiar, moderately familiar, very familiar, extremely familiar.

   a. [If they are familiar with advanced controls] Prior to this call and the explanation of our categories, how would you define the difference between LLLC and NLC.
   b. Advanced controls means different things to different people, how do you define advanced controls?

3. In your experience, how familiar are the typical C&I customers with these control categories? Residential?

   a. What control do you think customers most commonly think of if they report advanced lighting controls? Residential? C&I?

4. In your experience, what are the most common control technologies that are currently selected for commercial locations? Residential locations?

    a. [If answer to 4 is non-advanced controls] At what point do you see advanced controls becoming common practice, if ever? Residential v C&I?
    b. Do you have any insight into replacement practices?

5. Are there customers that are better suited for advanced controls capabilities?

    a. Is it due to size of facility? Hours of use? Building type? LLLC vs. NLC?

6. In your experience, how familiar are customers with the capabilities and differences of LLLCs and NLCs?

7. How familiar do you think installers are of the capabilities of LLLCs and NLCs?
    a. Do you have anything to add on this?

8. Can you provide insight into how you've seen LLLC and NLC systems typically set up and operated?

    a. Are NLCs and LLLCs installed correctly? Are functionalities being fully utilized? Are there installation issues due to existing lighting?

    b. Typical design conditions and control parameters? E.g., Is there a comprehensive building design to controls? Are they room-by-room? Fixture-by-fixture? Full building?

9. Are you seeing any trends in the sale/implementation of fixtures with integrated controls? By this we mean fixtures that have the capabilities of the hybrid controls such as occupancy paired with trim, etc. [Make clear not an advanced control]

    a. Are these more, less, or roughly equivalent in frequency to LLLC and NLCs?

We are now going to ask you a number of questions about the saving potential of ALC and their measure lifetimes.

10. From your experience, for the control strategies listed above, can you estimate the energy savings per fixture that they provide a facility compared to having more traditional manual switching or scheduling with a timer function prior to installation? For example, for high-end trim, what is the average percent reduction (%) of the fixture wattage? For occupancy sensors, what is the percent (%) reduction in operating hours due to the controls? Etc. [Enter in Table 4-10]

    a. [Probing Question] How do you determine these savings? Existing literature? Experience, primary data?

11. If added to a lighting system with typical occupancy and daylight dimming sensors, can you estimate the additional savings that NLCs and LLLCs would provide? [Enter in Table 4-10]

Table 4-10. Q10 and Q11 answer table

Measure	Control Type	Q10	Q11
Commercial and Industrial Interior Lighting Controls	Occupancy Sensors		-
	Daylight Dimming		-
	High-End Trim		-
	High-End Trim and Occupancy Sensors		-
	High-End Trim and Daylight Dimming		-

	Dual Occupancy and Daylight Sensors	-
	NLC	
	LLLC	
Res Connected LED Lighting	Connected LED Lighting	
Res Occupancy Sensors	Occupancy Sensors	-

12. [Read the existing PSD savings factors associated with the controls options: "These are the currently used savings factors associate with lighting controls in CT]
    [If respondent reports control savings >5% different from PSD, ask about those that differ:]
    Knowing your estimation differs from the existing estimation for CT, can you expand on your reasoning and why you may think they differ?

13. [If NLC and LLLC differ]
    Can you please discuss why you estimate LLLCs to typically save more/less than NLCs?

14. Do you think the savings from ALCs maintains, increases, or degrades over time?

    a. [If degrades] How fast? Can you provide a % per year?
    b. [If degrades] Is this the same, worse, or better than degradation from basic controls?

15. In your experience, do hybrid controls or ALCs last as long, less, or the same as the bulb that they are controlling?

We would like to spend the remainder of the conversation discussing potential opportunities for utility-sponsored energy efficiency programs to continue to transform the C&I lighting market.

16. TLEDs, tubular LEDs, are measures that have allowed customers to upgrade linear florescent systems cost effectively. From your experience, how satisfied are customers with the performance of TLEDs? (Extremely satisfied, Very Satisfied, Moderately Satisfied, Slightly Satisfied, not at all satisfied)

17. As TLED systems start to age and eventually burn out or fail, what do you think most customers will plan to replace them with? [Options include: A one-for-one replacement TLED, a complete replacement of the existing fixture with a new LED fixture, a non-LED tube or fixture, or other.]
18. Moving forward, do you think TLEDs or LED fixtures will have a more dominant market share in the C&I sector? Can you please explain?

19. Now I have a couple questions about fixtures with integrated controls.

    What are the primary barriers to adopting fixtures with integrated controls and those containing hybrid controls?

    a. [if they do not cite cost] Do you think that cost is a significant barrier?

    b. [Follow up] What types of program interventions are needed to increase the adoption of fixtures with integrated control and hybrid controls.

20. For customers that decide to retrofit their existing lighting systems and include the addition of controls, what are the primary motivations that influence their decision?

21. Based on your experience, are LED fixtures with integrated controls [hybrid, not ALC] generally set up to specifications and receive the necessary commissioning to confirm efficiency?

    a. Do you think retro-commissioning LED fixtures with integrated controls has the opportunity to generate additional savings?

22. We are going to shift a bit and focus specifically on advanced lighting controls. ALC technologies seem to be continually changing. Do you see any trends in the technology or capabilities of advanced controls? Please Explain.

23. What types of preexisting conditions are necessary for ALCs to be appealing to C&I customers?

    a. [Follow up] Does it ever make sense to retrofit existing LED lighting systems to include advanced lighting controls?

24. From your experience, are ALC systems generally set up to specifications? Do they received the necessary commissioning to confirm they are maximizing efficiency?

25. In your experience, have you seen a need for retro-commissioning from customers for lighting systems?

    a. Do you think retro-commissioning ALC has the opportunity to generate additional savings?

Closing

Thank you very much for your time today.

If applicable: I look forward to receiving the resources we spoke about. Would you like me to send a follow up email so that you have my contact? Clarify communication channel, thank, end call.

4.2 Market actor interview guide

CT Program Savings Document (PSD) Measure Update & Lighting future potential – Advanced Lighting Controls Market Actor Guide DRAFT

4.2.1 Study Objective

Update entries for recently added residential and commercial Advanced Lighting Controls (ALC) measures incorporated into the CT program Savings Document (PSD). Updates are supported by primary and secondary research to gain better understanding of advanced lighting control technology and how its savings are calculated.

4.2.2 Interview Objective

As part of CT X1931-4 Advanced Lighting Controls Commercial and Residential – New PSD Measure study, we will be interviewing market actors familiar with ALCs. The primary objective of these interviews is to hear an insiders' view on the ALC industry and understand market trends. This is essential to the research team as we aim to gain insight into existing savings factors, measure lives, and coincidence factors.

Research Questions	Question number
Intro and background	1-8

LLLC versus NLC. Are they different enough?	9-13
Savings factor and coincidence factor questions	14-19
Measure Lives	20-25

4.2.3 Instrument and Data Collection Information

The research team has set a data collection approach which comprises of interviewing industry market actors to understand typical system setups and characteristics. During these interviews, the research team will collect data based on responses to the questions given in section 3 and use it to fine tune the analysis of the facility data. The market actor interviews will take place over the phone after PA interviews are complete. The research team has identified the following experts to interview.

Table 4-11. Overview of data collection approach

Data Collection	Description
Population Description	Lighting market actors, particularly designers/specifiers and suppliers
Population Size/Sample Frame	4 - 6
Type of Sampling	None
Target Sample – Survey Completion	All
Instrument Type	Phone Interview
Survey/Interview Length	Approximately 45 minutes
Description of Contact Sought	Market Actors in Lighting and Lighting controls with specific knowledge to the sales, design, and functionality of systems.

4.2.4 Instrument: Interview Script

Interviewee		**Interviewer**	
Interviewee Company		**Interview Date**	
Interviewee Phone #		**Interviewee email**	

Introduction

Thank you for taking the time to talk with me today. As a reminder, we are currently working on a study in Connecticut looking at ALCs, and relevant savings factors and measure lives associated with those ALCs. The potential savings associated with various controls technologies and controls strategies can vary based on control type, proper installation, user knowledge, building type, and many others. We are hoping your insight can aid us in confirming or updating our understandings. We will reference the control strategies that I previously provided to you. While answering the following questions, please feel free to additionally offer any perspectives you may have on the market or controls technologies.

Would you be open to us recording this interview session? We would like to do so, because some of the questions designed to for an open-ended response which may require some additional review to capture all of your feedback. Also, we would like to include paraphrased versions of some of your responses in the report appendix. They will be anonymized, and your name/contact information will not be included anywhere.

Table 4-12. Measures and controls

Measure	Control Category	Control Type	Description	Current Savings Factor *(Relative to Manual On-Off Control)*
Commercial and Industrial Interior Lighting Controls	Basic Lighting Controls	Occupancy Sensors	Reduces lighting operation hours by switching off lighting in unoccupied spaces.	24%
		Daylight Dimming	Reduces lighting output to a set level or reduces lighting operating hours in response to natural daylighting using continuous, stepped, or on/off dimming capabilities.	28%
		High-End Trim	Reduces lighting output of individual lights or groups of lights to a set level continuously.	27%
	Hybrid Lighting Controls	Combination high-End Trim and Occupancy Sensors	Combines the capabilities of high-end trim and occupancy sensors	33%

		Combination High-End Trim and Daylight Dimming	Combines the capabilities of high-end trim, reducing the lighting output to a set level continuously, and daylight sensors, allowing lighting fixtures to reduce output to respond to daylight.	35%
		Dual Occupancy and Daylight Sensors	Combines the capabilities of occupancy and daylight sensors, allowing lighting fixtures to respond to occupancy and daylight.	38%
	Advanced Lighting Controls	Luminaire Level Lighting Controls (LLLC)	Integrates high-end trim, occupancy and daylight sensors into the LED fixture	49%
		Networked Lighting Controls (NLC)	An intelligent network of individually addressable luminaires and control devices for remote access by the user. NLC have fixture networking capabilities, individual addressability, occupancy sensing, daylight harvesting, high-end trim, flexible zoning, continuous dimming, scheduling, and cybersecurity.	49%

Residential Connected LED Lighting	Basic Lighting Controls	Connected LED Lighting	Connected LED lighting that allows for remote user control through Wi-Fi and/or a smart device. Allows for remote on/off, adjustment of brightness, and schedule setting.	29%
Residential Occupancy Sensors	Advanced Lighting Controls	Occupancy Sensors	Reduces lighting operation hours by switching off lighting in unoccupied spaces.	17%

[Share table without savings factors in advance of interview]

First, we have a few background questions.

1. What is your job title?
2. How many years have you been involved with lighting controls systems?
    a. How many years has your company been involved with lighting control systems?
3. I want to understand what lighting controls products and services your company offers. I am going to name a few. For each one, please tell me if you company offers that service.

Lighting Control System Services	Have you specified or installed in the last year? (Select all that apply)
a. Which lighting control services do you provide?	Design Installation Repair
b. Which sectors do you serve?	Residential, including multifamily Commercial
c. Which applications do you work on?	New, including major renovations Retrofits
d. Which Advanced control technologies do you specify/sell/install?	LLLC NLCs Combination Controls Other?

4. Of the lighting control services your company offers, which services account for the largest share of your annual revenue?

5. [IF THEY INSTALL NEW/REPLACMENENT LIGHTING CONTROL SYSTEMS] In a typical year, roughly how many total lighting systems does your company install in Connecticut for non-residential customers? Residential customers? [NOTE: IF NEEDED, REMIND INTERVIEWEE THAT A "TYPICAL YEAR" WOULD NOT BE THE PANDEMIC-INFLUENCED 2020]

6. Last year, about what percentage of them involved advanced lighting controls such as LLLC or NLC?

7. When you are trying to sell a customer on new/upgraded lighting control systems for a new LED lighting system, what types of benefits do you typically promote?

    a. How are the lighting controls creating these benefits?

    b. How do you promote these?

8. Besides what you promote in your sales pitches, what other benefits of new/upgraded lighting control systems are you aware of?

    a. How are the lighting controls creating these benefits?

I would like to focus on the difference between Networked Lighting Controls and Luminaire Level Lighting Controls.

9. Can you please define the differences between these as you understand it?

10. Are you seeing any differences with customers in how they choose one versus the other?

11. Would you characterize, to the best of your ability, the amount one is being adopted versus the other?

12. Would you consider either to be current standard practice for new construction projects?

13. From your experience, have you seen a notable difference in energy savings between NLCs and LLLCs?

    a. Does one versus the other favor certain types of buildings or facilities?

I am now going to ask you a few questions about your understanding of controls operation

14. From your experience, for the control strategies listed above, can you estimate the energy savings per fixture that they provide a facility compared to having more traditional manual switching or scheduling with a timer function prior to installation? For example, for high-end trim, what is the average percent reduction (%) of the fixture wattage? For occupancy sensors, what is the percent (%) reduction in operating hours due to the controls? Etc. [Enter in Table 4-13]

    a. [Probing Question] How do you determine these savings? Existing literature? Experience, primary data?

15. If added to a lighting system with typical occupancy and daylight dimming sensors, can you estimate the additional savings that NLCs and LLLCs would provide? [Enter in Table 4-13]

16. From your experience, do C&I facilities typically have unique control settings for a typical summer and a typical winter? Please elaborate.
    a. How about Residential?

17. Does this control unit/system have the potential to be manually adjusted by occupant? [Read each control strategy and allow for response. Fill in response in Table 4-13]
    a. Typically, who programs it?
    b. Typically, who can override?

18. From your experience, do the controls tend to have typical default settings for specific time periods? Does this vary by control?

19. Compared to basic occupancy sensors, please estimate any potential increase in savings with this product in a percentage. [Read hybrid and Advanced control strategies and allow for response. Fill in response in Table 4-13]

Table 4-13. Q14, Q15, Q17, and Q19 answer table

Measure	Control Type	Q14	Q15	Q17	Q19
Commercial and Industrial Interior Lighting Controls	Occupancy Sensors		-		-
	Daylight Dimming		-		-
	High-End Trim		-		-
	High-End Trim and Occupancy Sensors		-		
	High-End Trim and Daylight Dimming		-		
	Dual Occupancy and Daylight Sensors		-		
	NLC				
	LLLC				
Res Connected LED Lighting	Connected LED Lighting				
Res Occupancy Sensors	Occupancy Sensors		-		-

Next I would like to discuss the measure lives for these controls.

20. In your experience, do the following controls last as long, less, or more than the bulb that they are controlling? [Enter response in Table 4-14 and distinguish between C&I and resi]

21. Do you think the savings from ALCs maintains, increases, or degrades over time? [Enter responses in Table 4-14]
    a. [If degrades] How fast? Can you provide a % per year?
    b. [If degrades] Is this the same, worse, or better than degradation from basic controls?

22. In your experience, when customers replace lighting equipment early, do they replace the lighting and the controls together (if there are existing controls)? [Enter response in Table 4-14 and distinguish between C&I and resi and ask about hybrid and advanced controls only]
    a. How about if they are replacing lighting when the bulb or fixture fails? [Enter response in Table 4-14 and distinguish between C&I and resi. Hybrid and advanced only.]

Table 4-14. Q20 through Q22 answer table

Measure	Control Type	Q20	Q21	Q21a	Q21b	Q22	Q22a
Commercial and Industrial Interior Lighting Controls	Occupancy Sensors		-	-	-	-	-
	Daylight Dimming		-	-	-	-	-
	High-End Trim		-	-	-	-	-
	High-End Trim and Occupancy Sensors		-	-	-		
	High-End Trim and Daylight Dimming		-	-	-		
	High-End Trim and Occupancy Sensors		-	-	-		
	NLC						
	LLLC						
Res Connected LED Lighting	Connected LED Lighting						
Res Occupancy Sensors	Occupancy Sensors		-	-	-	-	-

23. Of the advanced lighting controls you know of being sold, can you characterize the mix of standalone versus integrated into fixtures?

24. In the circumstances where advanced lighting controls are stand-alone from the fixture, do you think customers would replace them when replacing lighting early? When replacing on failure?

25. If the customer has NLC or LLLC, how would you characterize the life of the control in relation to the lights it is controlling?
    a. What do you anticipate customers would do with NLCs and LLCs if lighting fixtures/bulbs needed to be replaced on schedule? On burnout?

Closing

Thank you very much for your time today. It was a pleasure speaking with you. Have a wonderful day.

End Call

About DNV

DNV is a global quality assurance and risk management company. Driven by our purpose of safeguarding life, property and the environment, we enable our customers to advance the safety and sustainability of their business. We provide classification, technical assurance, software and independent expert advisory services to the maritime, oil & gas, power and renewables industries. We also provide certification, supply chain and data management services to customers across a wide range of industries. Operating in more than 100 countries, our experts are dedicated to helping customers make the world safer, smarter and greener.