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Luminaire Level Lighting Controls Market Baseline

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Market Baseline

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Table of Contents

List of Figures and Tables

Figures:

Tables:

Executive Summary

Northwest Energy Efficiency Alliance (NEEA) is currently developing an initiative to accelerate the adoption of luminaire-level lighting controls (LLLC), an integrated lighting control approach that combines multiple control schemes to potentially provide 50 to 60 percent energy savings with low installed cost, ease of retrofit in existing buildings, and performance compatible with high efficiency technology such as LEDs. LLLC is defined by the following capabilities:

- Dimming
- Distributed control at each luminaire without the need of a central controller. The distributed system should make use of networking functionality to enable remote measurement and verification (M&V), remote diagnostics, and simplified maintenance.
- Local sensor inputs (and corresponding controls) for each luminaire including at a minimum an occupancy sensor, a light-level sensor, and energy metering.
- Standards-based integration to dimmable technologies (e.g. dimming ballasts, LED drivers, voltage regulation, etc.)

Before initiating such an efficiency program, developing a market baseline for the energy savings measure is crucial in order to measure the future impacts of the program. Thus, NEEA contracted Navigant to develop a market baseline for LLLCs in the Pacific Northwest (PNW). This market baseline includes:

- A current estimate of the installed base and sales of LLLCs
- A current estimate of the total installed base of lighting fixtures in buildings eligible for replacement/retrofit with LLLC
- A forecasted growth of the installed based and sales of LLLCs over a 20-year period

In order to develop the advanced lighting controls market baseline, Navigant used a combination of primary research and secondary research. First, Navigant estimated the installed base of applicable fixtures for LLLCs. Second, Navigant calculated the available market, or maximum market potential for LLLC penetration based on an analysis of various market segments (new construction, major renovation, luminaire retrofit, and voluntary retrofit). Third, using Bass diffusion curves, Navigant estimated the portion of the available market captured by LLLC in each year. Lastly, Navigant developed a stock turnover model to track the sales and installed stock of LLLC in the Northwest.

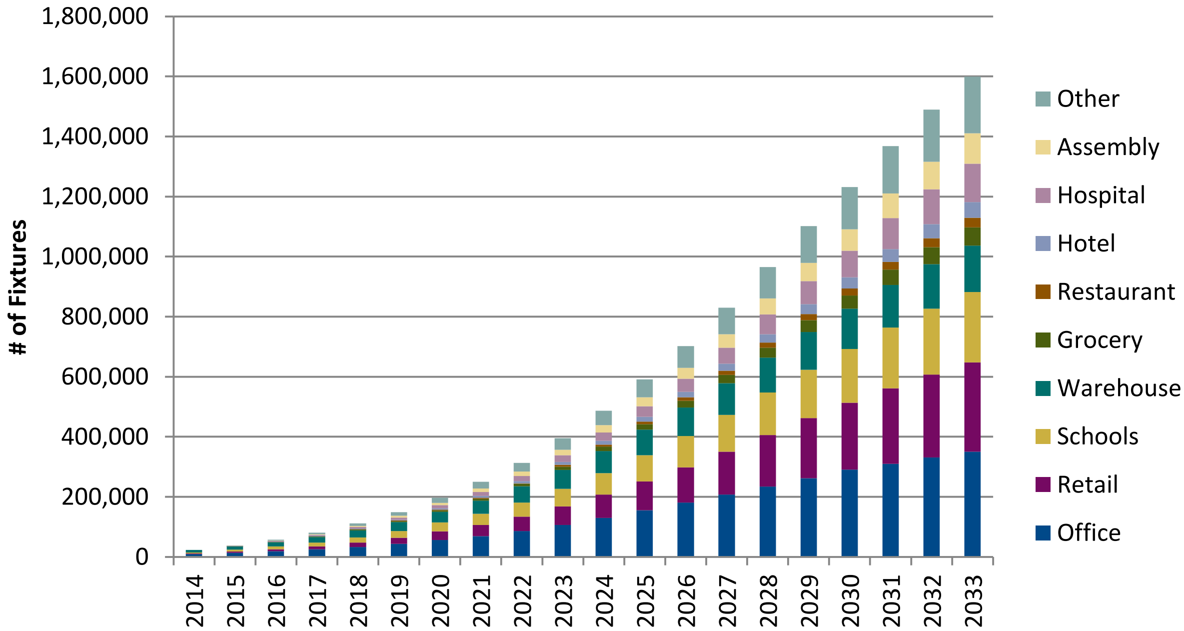
Table ES-1 presents the 2013 installed base of applicable fixtures and LLLCs in the PNW, developed through interviews, secondary market research, and analysis of the 2014 draft CBSA data.

Table ES-1: 2013 Northwest Installed Applicable Fixtures and LLLCs

Building Type		**Installed Applicable Fixtures**	**# of Fixtures with LLLCs**
Office	Large Off	2,153,433	26,591
Office	Medium Off	970,210	11,980
Office	Small Off	1,138,416	14,057
Retail	Big Box	1,184,634	0
Retail	Small Box	2,187,999	0
Retail	High End	547,000	0
Retail	Anchor	1,056,102	0
K-12	K-12	2,551,012	8,282
University	University	1,274,724	4,138
Warehouse	Warehouse	1,426,561	37,553
Grocery	Supermarket	844,843	0
Grocery Other	Minimart	360,239	0
Restaurant	Restaurant	491,693	0
Hotel	Lodging	1,032,405	0
Hospital	Hospital	594,320	0
Hospital Other	Other Health	1,315,295	0
Assembly	Assembly	1,588,020	0
Other	Other	4,293,225	0
Total		**25,010,129**	**102,602**

Based on the baseline forecast developed, Navigant expects that annual LLLC sales, shown in Figure ES-1, will increase rapidly in the first 10 to 15 years, and then reach an inflection point as the market becomes more saturated with networked controls technologies. Navigant forecasts that the sales will grow at an average compound annual growth rate (CAGR) of 37% for the first 10-year period and at a CAGR of 15% for the next 10-year period, with 20-year average of 25%. The largest markets for LLLCs reside in the office buildings and warehouses.

Figure ES-1: Annual LLLC Sales by Building Type



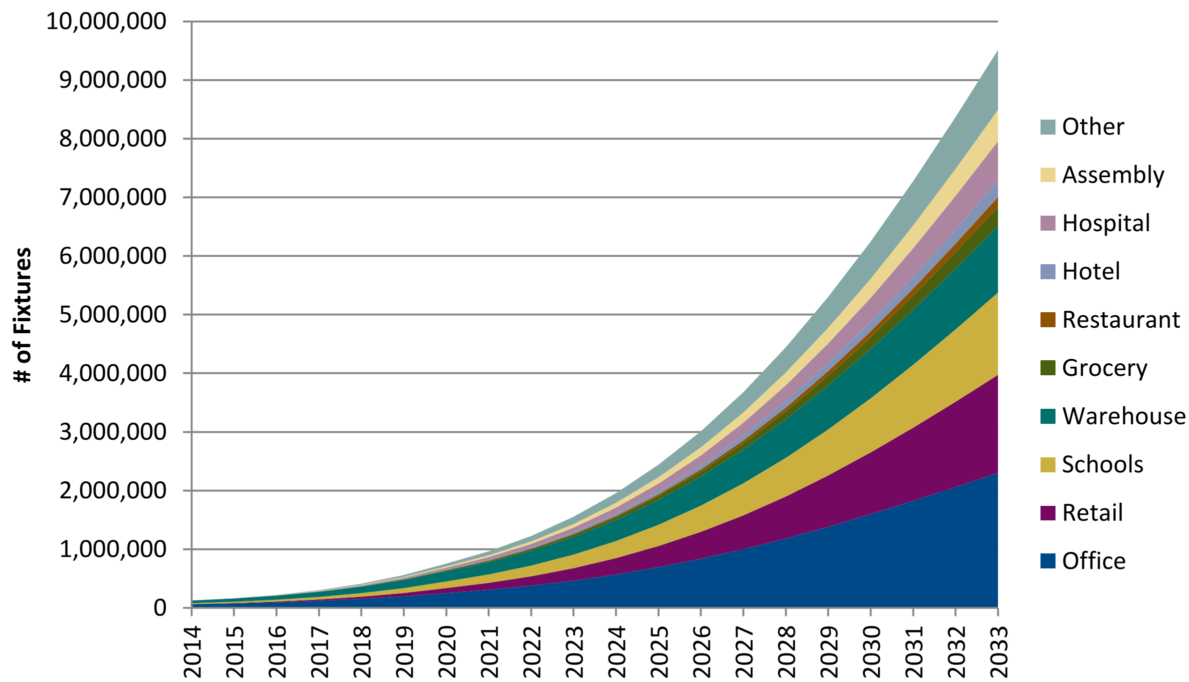
The majority of the sales will come through the market segments associated with a purchase of a new luminaire (new construction, major renovation, and luminaire retrofit). Major renovations account for between 63% and 69% of the sales. The second largest share of the sales will come from the new construction market with between 15% and 20% of sales. Sales of LLLCs associated with retrofitting only the lighting controls, termed voluntary retrofit, constitutes the smallest portion of sales as it represents the market segment with the lowest return on investment. Table ES-2 provides the annual LLLC sales projections by market share.

Table ES-2: Percent of Annual LLLC Sales by Market Segment

	2018	2023	2028	2033
New Construction	20%	17%	15%	15%
Major Renovation	69%	67%	64%	63%
Luminaire Retrofits	1%	7%	13%	16%
Voluntary Retrofits	10%	9%	8%	6%

Navigant forecasted installed base LLLCs by adding new sales of fixtures with LLLCs to the previous year’s installed stock, while accounting for building renovations and demolitions. Figure ES-2 shows the LLLC installed base over 20-year by building type.

Figure ES-2: LLLC Installed Base by Building Type



While CBSA data and existing information on the current installed base of luminaires and lighting controls was critical to the formation of Navigant's baseline model, information from interviews and other supplemental market research helped paint a broader picture of the numerous trends that will affect the adoption of LLLC in the future

The broad expectation by manufacturers and customers alike is that smarter lighting control systems will proliferate widely in the coming years. There is less agreement, however, on whether those smarter controls will follow the path of LLLC or that of another control strategy. Not surprisingly, manufacturers who focus on LLLC solutions are optimistic that this type of control will continue to gain a larger and larger share of the market, while manufacturers who focus on other types of lighting control strategies expect LLLC adoption to be more limited. Navigant expects many different types of strategies to be present in the commercial market for the foreseeable future. From the interviews, Navigant developed a list of potential market drivers and barriers that will affect the adoption of LLLC in the future:

Market Drivers	**Market Barriers**
Building codes	Long payback periods
Demand response	Complexity
Energy savings	Resistance from lighting designers
Non-energy benefits	
Ease of design and installation	

There are a number of important caveats and limitations associated with the results of these forecast and modeling efforts. For this study, behavior of the market, limitations in data available and high levels of forecasted market penetration are key uncertainties. Current 2014 CBSA data is limited and not fully updated. In several cases Navigant made estimates to fill the gap at the building type level data. While the best available data was utilized, it may not reflect the actual market characteristics of the Northwest region. Data on the non-energy benefits impact is limited. While Navigant qualitatively accounts for the non-energy benefits, further study is required to quantify the non-energy benefits.

Navigant concluded that new construction and major renovation markets represent high potential in the early years, while luminaire retrofit market instigated by LEDs represents higher potential in the later years with increasing LED penetration. Retrofits that involve only adding lighting controls to existing lighting systems (voluntary) will continue to see low adoption rates unless high volume manufacturing drives down the cost considerably over time. NEEA should focus on the controls-only retrofit market to cut the cost down for the customers. Navigant recommends NEEA focus on buildings with high energy intensity and inefficient space utilization such as warehouses and offices to maximize the savings from LLLCs. NEEA should initially target buildings with no or manual controls due to higher savings potential and to avoid competition with existing controls.

To ensure robust results, as next steps, Navigant suggests that further investigation be conducted on how non-energy benefits can affect the penetration of LLLCs, quantify cost of installing LLLCs integrated with lighting fixtures, and finally evaluate, measure, and verify savings associated with LLLC systems.

1 Introduction

Over the past 10 years, lighting electricity consumption has decreased by nearly 10 percent (Navigant Consulting 2012a) largely due to utility efficiency programs educating consumers and incentivizing high efficiency commercial lighting measures (such as T12 to T8 retrofits, pulse-start metal halide lighting, etc.) Although lighting currently accounts for approximately 43 percent of northwest commercial building electricity use, claimable savings from some traditional commercial lighting measures will likely decrease in the coming years due to the saturation of the installed base with high efficiency light sources and recent Federal efficiency standards.

Thus many utility energy efficiency programs are looking to advanced lighting controls as the next opportunity for energy savings in the commercial sector. Despite efforts over the past 10 years to promote the adoption of these controls, in 2009 it was estimated that 76 percent of commercial lighting fixtures still remain on manual on/off switches in the Northwest (Cadmus Group 2009). Some barriers to adoption include cost, difficulty of installation and commissioning, inconsistent reliability, and poor end-user satisfaction. In addition, many high energy savings controls, such as energy management systems, require a large scale lighting retrofit in order install, a significant decelerator to the rate of adoption.

Consequently NEEA is investigating the potential market and benefits of luminaire-level lighting controls (LLLC), an integrated lighting control approach that combines multiple control schemes to potentially provide 50 to 60 percent energy savings with low installed cost, ease of retrofit in existing buildings, and performance compatible with high efficiency technology such as LEDs. LLLC is defined by the following capabilities:

- Dimming
- Distributed control at each luminaire[1] without the need of a central controller. The distributed system should make use of networking functionality to enable remote measurement and verification (M&V), remote diagnostics, and simplified maintenance.
- Local sensor inputs (and corresponding controls) for each luminaire including at a minimum an occupancy sensor, a light-level sensor, and energy metering.
- Standards-based integration to dimmable technologies (e.g. dimming ballasts, LED drivers, voltage regulation, etc.)

[1] The Illuminating Engineers Society Lighting Handbook and the 2011 National Electrical Code, Article 100, define a luminaire as, "a complete lighting unit consisting of a lamp or lamps together with the parts designed to distribute the light, to position and protect the lamps, and to connect the lamps to the power supply."

2 Research Objectives

Before initiating such an efficiency program, developing a market baseline for the energy savings measure is crucial in order to measure the future impacts of the program. Thus, NEEA contracted Navigant to develop a market baseline for LLLCs in the Pacific Northwest (PNW). This market baseline includes:

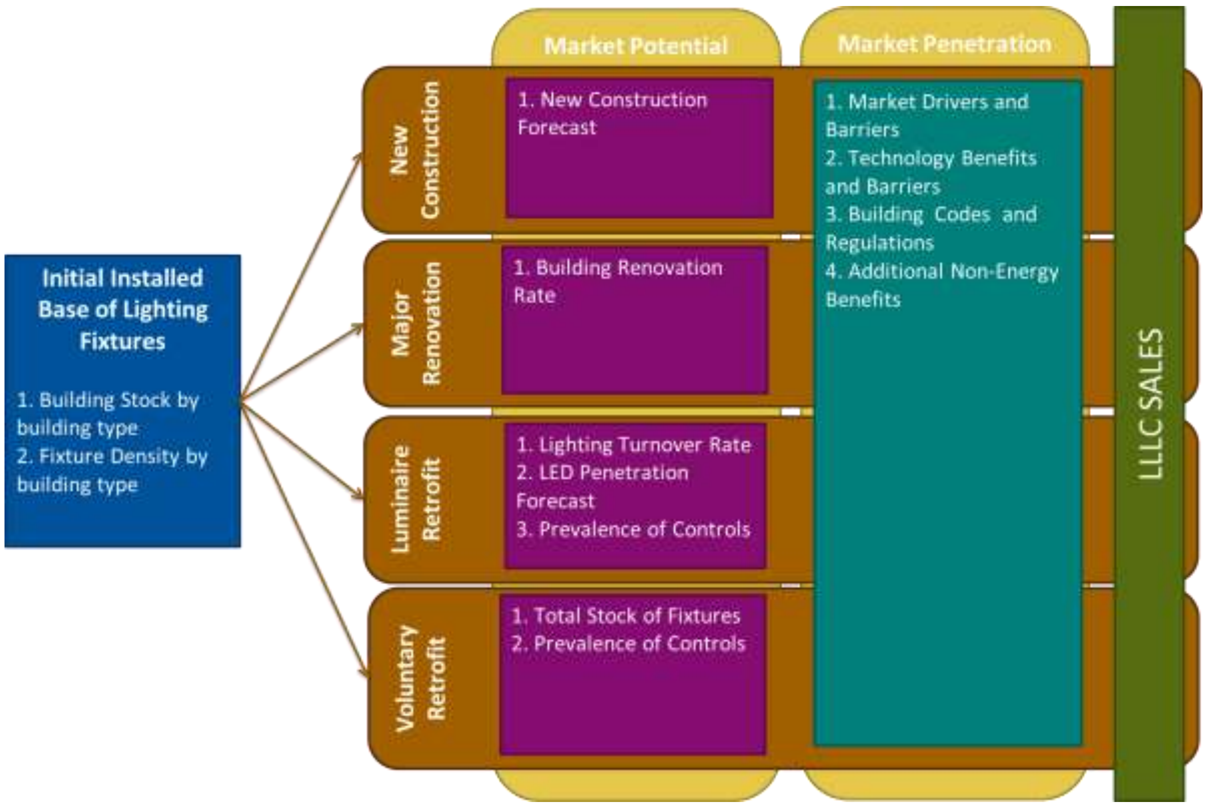
- A current estimate of the installed base and sales of LLLCs
- A current estimate of the total installed base of lighting fixtures in office buildings eligible for replacement/retrofit with LLLC
- A forecasted growth of the installed based and sales of LLLCs over a 20-year period

3 Methodology

In order to develop the advanced lighting controls market baseline, Navigant used a combination of primary research and secondary research. Figure 3-1 illustrates at a high-level Navigant's four-step approach to developing the baseline.

Step 1: Estimated the installed base of applicable fixtures for LLLCs. Major inputs to this calculation were the applicable lighting fixture density and the total building stock square footage in the PNW.
Step 2: Calculated the available market, or maximum market potential for LLLC penetration based on an analysis of various market segments (new construction, major renovation, luminaire retrofit, and voluntary retrofit). Inputs to the available market calculation included new construction forecasts, building renovation rates, LED penetration forecasts, and the existing prevalence of controls in commercial buildings.
Step 3: Estimated the portion of the available market captured by LLLC in each year, using Bass diffusion curves. These curves were based on an analysis of a variety of market drivers and barriers related to LLLCs.
Step 4: Developed a stock turnover model to track the sales and installed stock of LLLC in the Northwest. Each of the above-mentioned steps is described in further detail in the following sections.

Figure 3-1: Luminaire Level Lighting Control Market Baseline Approach



3.1 Building Stock and Installed Base

This section describes the approach Navigant used to compile data related to the currently installed base of lighting fixtures and controls in the PNW. This information is used to establish a 2013 market baseline for lighting fixtures and luminaire-level lighting controls (LLLCs). Once established, this baseline established is used to aid in forecasting future growth in the sale and installation of LLLCs and the corresponding market penetration.

3.1.1 Installed Base of Lighting Fixtures and Controls

This baseline study utilized data from the 2014 Commercial Building Stock Assessment (CBSA),[2] to construct an estimate of the 2013 stock of installed lighting fixtures and lighting controls in the Northwest region. The CBSA building type categories, listed below, are designed to be similar to those utilized by the Northwest Power & Conservation Council (NWPCC):

[2] At the time of publication of this report, the 2014 CBSA was still in progress of being completed. Navigant used draft outputs from approximately 50 percent of the total expected sample size for this baseline study.

- Office
- Retail
- K-12
- University
- Warehouse
- Grocery
- Restaurant
- Hotel
- Hospital
- Assembly
- Residential Care
- Other

The final dataset also represented a range of vintages (pre-2004 and post-2004), building sizes, and geographic areas of the PNW. The database housing the final CBSA dataset allowed for the data segmentation to be customized by the user based upon the building types described above as well as other building characteristics.

In addition to building characteristics, there are two main categories of data that were used in estimating the market baseline: lighting fixtures and control technologies. The CBSA dataset compiles data on all lighting fixtures surveyed onsite. For establishing the LLLC market baseline, based on interviews and an evaluation of commercially available LLLC products, Navigant determined that the applicable fixture types should include:

- Strip Lighting (Bare and Lensed)
- Pendant Mounts
- Surface mounts
- Recessed lighting

The prevalence of these fixture types was extracted and correlated with other CBSA data such as building type and square footage, to estimate fixture densities for use in the baseline model.

3.1.2 Commercial Building Stock Assessment Data Assumptions

For the most part, the data compilation and assumptions used in constructing the baseline are consistent with those used for the CBSA. However, Navigant made a few additional assumptions when extrapolating the CBSA sample data to the population of buildings in the region for the purposes of this baseline study. Listed below are additional assumptions beyond those already incorporated into the CBSA data:

- Due to limited CBSA data available at the time of the initial baseline analysis, K-12 schools and universities are assumed to have the same fixture densities. This can be updated as more university data becomes available via the CBSA.

- Due to limited CBSA data available at the time of the initial baseline analysis, Hospitals and residential care are assumed to have the same characteristics. This will be updated as more hospital data becomes available via the CBSA.

- Extrapolations were performed based on sampled square footage rather than total building square footage, with the exception of excluded subspaces (see next bullet).
- Some subspaces sampled through the CBSA were excluded for consistency with CBSA building floor area assumptions. These subspaces generally include parking, residential, manufacturing, and industrial subspaces within a larger commercial building.
- Subspaces for which no control data was collected are assumed to have no controls.
- Lighting controls were grouped into three overall categories based on the mapping outlined in Table 3-1 below.

Table 3-1: Lighting Controls Grouping

Lighting Control Type	Description	Control Group
EMS-S	Automatic Sweep Controls with EMS System	Networked Controls
EMS	EMS System (w/o automatic sweep)	Networked Controls
DS	Daylight Sensing, Details Unknown	Other Sensors
DS-SS	Daylight Sensing, Single-Step Dimming	Other Sensors
DS-MN	Daylight Sensing, Multiple Stepped Dimming	Other Sensors
DS-CD	Daylight Sensing, Continuous Dimming	Other Sensors
DIM	Dimming (non-daylight)	Other Sensors
EGR	Egress control 24/7	Other Sensors
OS	Occupancy sensors	Other Sensors
T	Timeclock (electronic or mechanical)	Other Sensors
OTH	Other	Other Sensors
MCB	Manual - circuit breaker / central switch	None or Manual Sensors
MS	Manual - wall switch	None or Manual Sensors
MB	Manual - bi-level	None or Manual Sensors
N	None (continuous)	None or Manual Sensors
Un	Unable to determine	None or Manual Sensors

3.1.1 Extrapolating to the Existing Stock of Buildings

After lighting, controls, and building data were extracted from the CBSA dataset, Navigant extrapolated these findings to the estimated stock of buildings in the PNW. As the 2014 CBSA was still in the process of being completed, Navigant chose to utilize the NWPCC estimates from the *Sixth Northwest Conservation and Electric Power Plan* (Northwest Power and Conservation Council 2010) for square footage by building type in the PNW.

Once the 2014 CBSA is completed, Navigant recommends that floor space estimates from the 2009 CBSA conducted by Cadmus be utilized to produce estimates of the current building stock in the region. The square footage data should be extrapolated forward to 2013 by accounting for new construction and demolition rates, using data available from FW Dodge where applicable.

With an estimate of the building stock established, Navigant performed a stratified extrapolation in order to match buildings in the CBSA dataset with the comparable set of buildings in the regional population. Key characteristics that buildings are matched on include primary economic use and square footage. Navigant calculated levels of statistical confidence and precision on the estimates of the installed base of lighting and lighting controls in the region as described above and the extrapolations to the regional building population.

3.2 Available Market

After developing the installed base of applicable lighting fixtures and existing controls, the next step was to determine the available market for penetration of LLLCs, or maximum market potential. As LLLC products can be sold as either an integrated component of a new luminaire or fixture or a retrofit component to an existing luminaire, Navigant considered four market segments, listed in Table 3-2, as contributing to the available market for penetration of LLLC:

Table 3-2: Market Segments by Solution Types

Market Segment	Luminaire Integrated Solution	Retrofit Solution
New Construction	✓	
Major Renovation	✓	
Luminaire Retrofit	✓	
Voluntary Retrofit		✓

While other events (such as lamp replacements or group ballast replacements, upon burnout) could potentially instigate the purchase of LLLCs, these market segments were not evaluated separately, but rather included in the voluntary retrofit market. Navigant developed occurrence rates associated with each of these events based on a combination of technical and market data (both at a regional and national level), discussed below. Then, Navigant applied (i.e., multiplied) these occurrence rates to the applicable fixture base to determine the available market for penetration of LLLC. In addition, for the luminaire retrofit and voluntary retrofit market segments, Navigant also accounted for the competition of LLLC with other preexisting control systems installed in buildings. Each of these market segments is discussed in further detail below.

3.2.1 New Construction

New construction, defined as new commercial buildings built, involves the new installation of fixtures and building control systems. LLLCs installed in this market segment will likely be integrated into the new luminaire purchased or will supplement the installation of other high efficiency lighting. To determine new construction rates, Navigant utilized the *Sixth Northwest Conservation and Electric Power Plan* (Northwest Power and Conservation Council 2010) new construction and existing building floor space forecasts through 2030. Navigant used the ratios between new construction floor space and existing building floor space by building type and trended forward these ratios to 2034.

3.2.1 Major Renovation

Major lighting renovation is defined as the redesign of an existing building's lighting, including replacement of fixtures (not necessarily 1 for 1) and installation of new controls systems. Similar to the new construction market segment, in major renovation it is assumed that LLLCs will be installed in tandem with a new luminaire. To determine major lighting renovation rates, Navigant relied on nationally-based assumptions developed for the Department of Energy (DOE) in Navigant's *Energy Savings Potential of Solid-State Lighting in General Illumination Applications* (Navigant Consulting 2012b) report. In this report, it is assumed that 5% of buildings are renovated each year. This represents an approximate building turnover cycle of 20 years. Navigant applied these rates to installed fixture base of each building type.

3.2.2 Luminaire Retrofit

Luminaire retrofit refers to the replacement of an existing fixture or luminaire with a new luminaire. This market segment, distinct from a major renovation of a building, accounts for the retrofitting of existing fixtures to LED luminaires as LEDs increase in efficacy, reduce in cost, and gain greater market penetration into the commercial sector. The inherent controllability of LED technology combined with their expected increased market penetration was noted during interviews as a significant opportunity for future growth of LLLCs. To determine the rate of LED luminaire retrofits, Navigant utilized LED penetration rates in the retrofit market from DOE's *Energy Savings Potential of Solid-State Lighting in General Illumination Applications* (Navigant Consulting 2012b) report. These penetration rates were then multiplied by the installed base of applicable fixtures in the PNW to arrive the total available market for LLLC in the luminaire retrofit market segment.

3.2.3 Voluntary Retrofit

A voluntary retrofit, or controls only retrofit, is an LLLC purchase not instigated by any other lighting purchase event. It is solely initiated by the customer's interest in LLLC due to its benefits, and thus is applicable to the entire installed base of fixtures. This market segment assumes that LLLC are being installed as a retrofit solution or add-on technology rather than integrated into a new luminaire. Navigant assumes that the total installed fixture base (not undergoing any of the lighting turnover events described above) represents the maximum market potential for voluntary retrofits.

3.2.4 Accounting for Competition with Other Control Types

In accurately modelling the adoption of LLLC it is important to consider the entire landscape of lighting control options available to consumers. In addition to conventional control technologies (such as independently installed occupancy sensors, daylighting, and dimming systems), other advanced or networked control technologies are available today. As evidenced by the draft

CBSA data, in 2013, approximately 19 percent of applicable commercial fixtures are already networked, often through an energy management system (EMS). Interviews with manufacturers indicated that LLLC represents only a subset of the future possibilities of advanced lighting controls.

When considering the dynamics of LLLCs and these other controls co-existing in the market, Navigant assumed that forecasts of other lighting control systems being installed into new buildings or buildings undergoing major renovation (e.g., photosensors, occupancy sensors, EMS) will not compete with LLLC, but rather supplement LLLC. Therefore, it is assumed that the entire new construction and major renovation markets are available for penetration of LLLC.

In contrast to the new construction and renovation market segments, Navigant assumed that the existing prevalence of controls in buildings will affect a consumer's likelihood to adopt LLLCs in the luminaire retrofit and voluntary (or controls only) retrofit scenarios. This is based on the assumption that buildings with existing controls systems will already be experiencing some moderately reduced energy consumption. Thus, the electricity savings and return on investment from retrofitting their building with LLLC will be reduced as well, ultimately retarding the penetration of LLLC.

To account for this slowed penetration effect, Navigant first forecasted the prevalence of controls in commercial buildings (grouped into three categories: no or manual controls, non-networked controls, networked controls) using building controls trends found in Navigant Research's advanced lighting controls market reports (Navigant Research 2013b) and in historical CBSA (Cadmus Group 2009; Kema-Xenergy Inc. 2004) controls penetration estimates. Next, Navigant developed separate discounts, based on interviews, to the available market calculation for buildings with non-networked lighting controls and networked lighting controls. Lastly, Navigant reduced the available market of the "luminaire retrofit" and "voluntary retrofit" markets using the assumed discount values.

3.3 Market Penetration

This section describes the approach Navigant used to estimate this market penetration. The rate of market penetration is subject to certain market barriers, including, but not limited to, acceptance and availability of the technology. Typically, these barriers only apply to new market entrants, such as LLLC technologies, as it is these technologies that may initially be unknown to consumers or may not be readily available to purchase. As a product establishes itself on the market, however, benefits are communicated by word-of-mouth to the consumer base, manufacturers are able to ramp up production capacity, and stocking distribution channels emerge. To simulate this lag effect on newer technologies, the baseline forecast model applies a Bass technology diffusion model to the market share predictions. The Bass diffusion model is a widely recognized marketing tool used in technology forecasting which effectively slows the rate of technology adoption based on the time necessary for consumers to become aware of and adopt a new lighting control technology.

Navigant developed two separate diffusion curves for each building type to capture distinctive market characteristics of each market segments identified in Section 3.1. Navigant used a single diffusion curve for the market segments that represent a luminaire integrated installation of LLLCs (new construction, major renovation, and luminaire retrofit) as they encapsulate the same market barriers, economics and stimulations. Navigant applied a separate diffusion curve for voluntary retrofit market as it involves different drivers and economics. To develop the diffusion curves for the luminaire-integrated markets, Navigant used a combination of research on the historical and projected diffusion of comparable technologies and data received from manufacturer interviews. Navigant first identified a list of comparable and established technologies (lighting and non-lighting), shown below, that could potentially inform the development of an LLLC specific diffusion curve.

List of similar technologies include:

- Occupancy Sensors
- Programmed Start Ballast
- Electronic Ballast
- Photosensors
- Dimming Ballasts
- Smart Thermostats
- Energy Management Systems (EMS)
- Digital Addressable Lighting Interface (DALI)
- Security Cameras
- HVAC Static Pressure Sensors
- HVAC Air Flow Sensors
- HVAC Temperature Control Sensors
- Personal Comfort Systems
- Smart Meters
- GPS
- EnergyStar TVs
- EnergyStar Laptops
- Wi-Fi

Navigant then evaluated each of the above technologies across a variety of technology characteristics that might affect adoption. These evaluated characteristics are listed below:

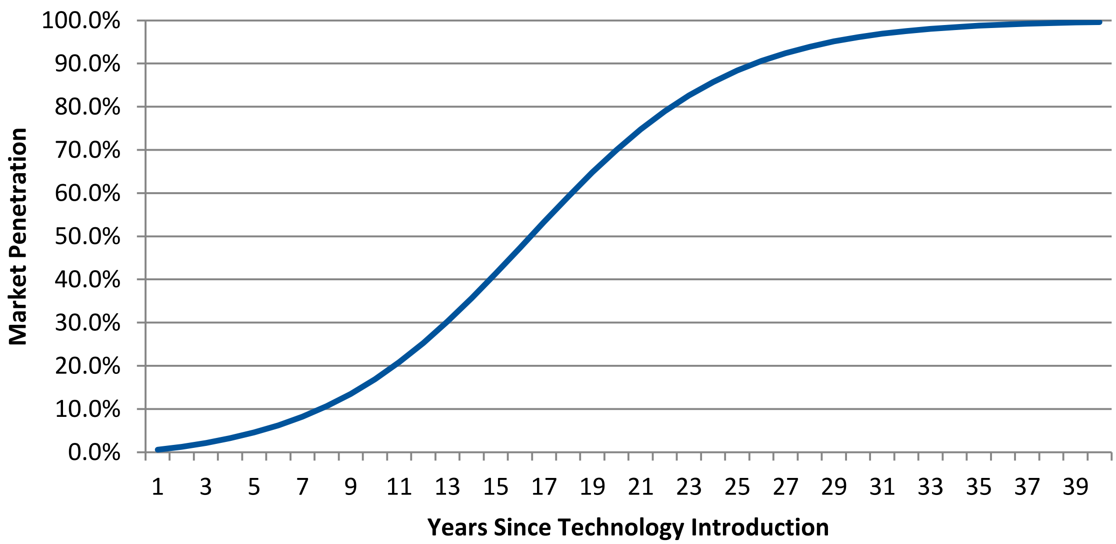
Table 3-3: Evaluated Characteristics

Technology Characteristics	**Applicable Market**
Sensor	Retrofit
Distributed	Replace on Burnout
Fixture level/per occupant level	New Construction
Personalized	
Wireless/network	**Technology Benefits**
Intelligent	Energy Savings
Includes Hardware	Energy Management
SAAS	Commissioning/Failure Detection
Easy to Install	Space Utilization
High labor cost %	

Add-on	**Data Availability**
Cost Effectiveness	Market Maturity
Durable/Long lifetime	Market Saturation
Commercial	Data Sources

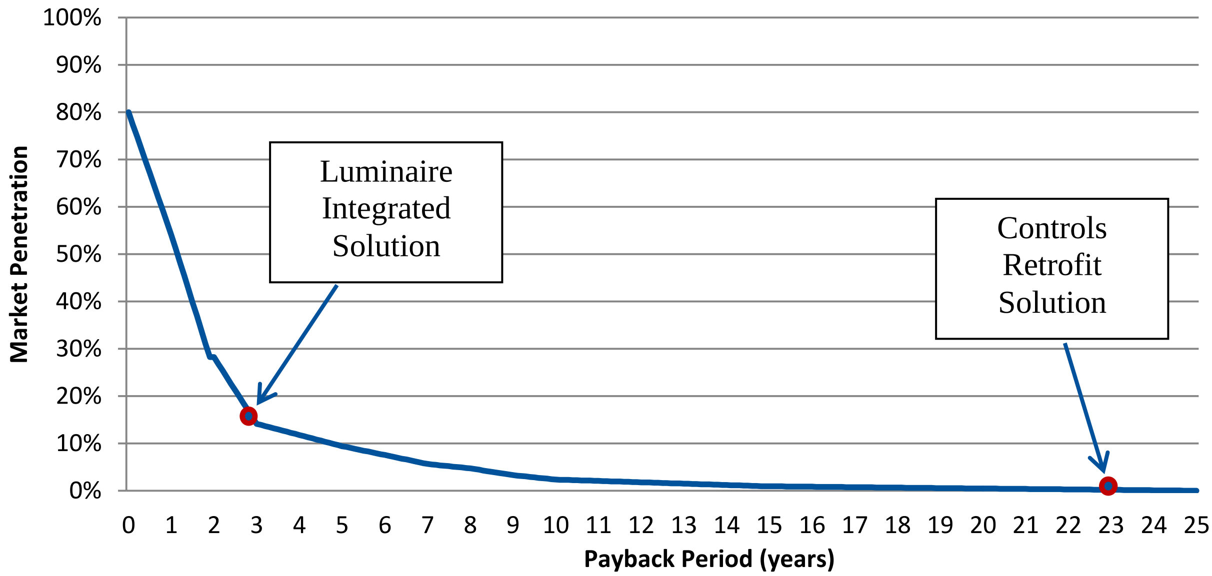
Navigant selected the top scoring technologies to derive a diffusion curve for LLLC. The resulting technologies that provided input into the LLLC diffusion curve were: occupancy sensors, photosensors, dimming ballasts, and DALI. Penetration data for these technologies was based on historical sales data and Navigant Research's market reports (Navigant Research 2013a; Navigant Research 2013b). Navigant then aggregated each of these technologies' diffusion characteristics into one diffusion curve approximating the expected market penetration of LLLCs. Navigant used feedback from interviews with manufacturers to calibrate its approximation of the expected market penetration. The LLLC diffusion curve derived in this analysis is shown in Figure 3-2.

Figure 3-2: LLLC Technology Diffusion Curve for Luminaire Integrated Markets



To derive a diffusion curve for the voluntary retrofit market Navigant investigated the relative economics of installing an LLLC system integrated with a luminaire versus as a controls-only retrofit. Based on interviews, manufacturers claimed that when installing a LLLC in tandem with a high efficiency (e.g., LED) luminaire, the payback period to the customer could range from 1 to 3 years. In contrast, based on a proof of concept study (New Buildings Institute 2013) conducted on the Enlighted controls-only retrofit product, the average simple payback period (equipment and installation costs divided energy cost savings) was approximately 23 years. Therefore, to develop a diffusion curve for the voluntary retrofit market, Navigant scaled down the luminaire-integrated LLLC diffusion curve (Figure 3-2) by the ratio of market penetrations calculated from a commercial buildings payback acceptance curve, developed by Arthur D. Little, Inc. (Navigant Consulting 2010), and shown in Figure 3-3.

Figure 3-3: Commercial Payback Acceptance Curve



As a last step to determining the market penetration of LLLCs, Navigant assumed LLLC introduction years for each building type based on interviews. Table 3-4 shows the introduction years used in this study. Further discussion on the roadmap of LLLCs in various building types can be found in section 4.1.5.

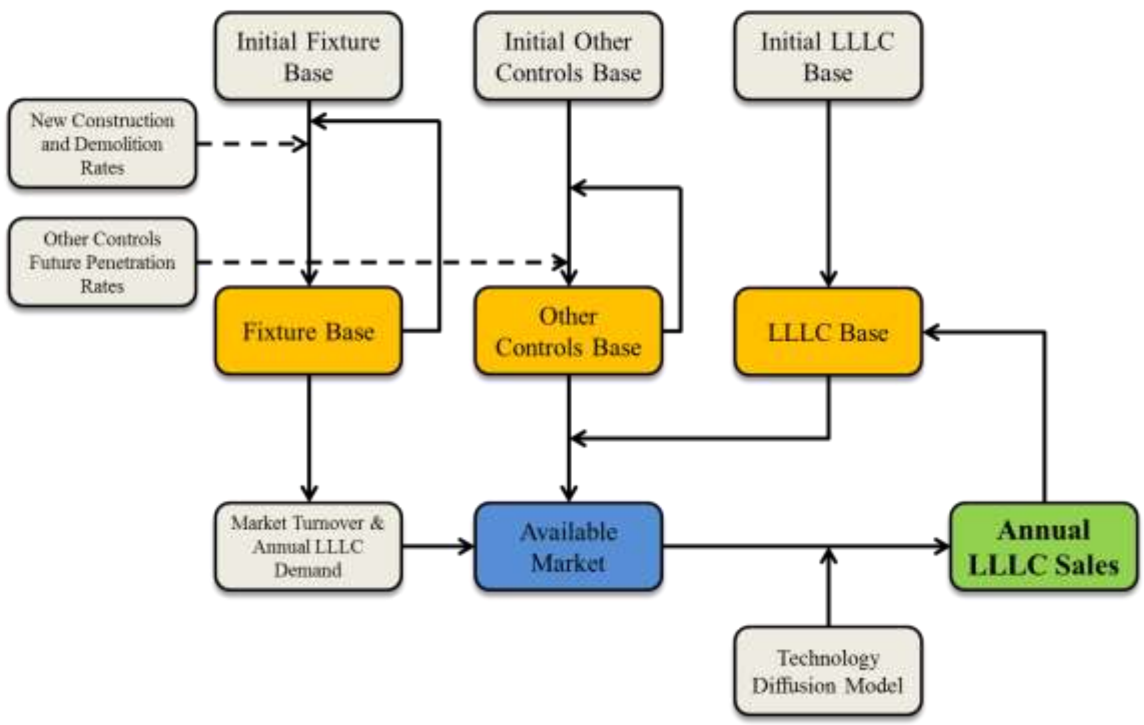
Table 3-4: Assumed Introduction Years for LLLC

Building Type	Introduction Year
Office	2011
Retail	2014
Schools	2013
Warehouse	2009
Grocery	2015
Restaurant	2015
Hotel	2015
Hospital	2015
Assembly	2015
Other	2015

3.4 Baseline Forecast

This section describes the approach Navigant used in developing the 20-year market baseline forecast. Navigant developed a stock turnover model (as shown Figure 3-4) that uses the installed stock estimates developed in Section 3.1, then applies the applicable market rates described in Section 3.1 to determine the available market, and finally forecasts sales of LLLCs in each year based on the market penetration curves derived in Section 3.3. These sales then feed into the installed stock in the following year. The primary outputs of this forecast are installed stock and sales of LLLCs by building types in each year with focus on office buildings.

Figure 3-4: Illustrative Baseline Forecasting Methodology



3.5 Interviews and Supplemental Market Research

There is no current survey of lighting controls in the Pacific Northwest region that gives specific data on the current adoption of LLLC. Therefore, to build an accurate estimate of current adoption rates, and to forecast those rates into the future, Navigant conducted a series of interviews to gather a wide range of perspectives from various market actors. Discussions with current vendors of LLLC solutions were critical to estimating the number of these systems that have already been sold to customers in the region. In order to get an accurate picture of how LLLC will fare in the future, Navigant talked with vendors of both LLLC solutions and other lighting control solutions, as well as with trade associations.

Navigant created an interview guide specific to each category of stakeholder. Questions relevant to each stakeholder's experience with LLLC and lighting controls helped steer the interviews to touch on all of the relevant trends and factors that are expected to influence future adoption rates. Manufacturers of lighting controls were asked about their current products and anticipated technological developments, as well their expectations for building codes, regulations, marketing trends, and other factors that they see affecting the adoption of LLLC. Trade associations can be valuable collectors of information, and so were asked about trends that they are witnessing amongst their members. A sample manufacturer interview guide can be found in Appendix A.

Through the interviews that Navigant conducted, a broad view of the various factors that affect LLLC adoption was captured. In addition to the general trends of this industry, the following specific pieces of data were informed by information gained through the interview process:

- The percentage of currently installed networked controls that qualify as LLLC
- The portion of the installed base that should be considered penetrable by LLLC, based on whether existing lighting systems include no controls, sensors only, or networked controls
- The shape and speed of the projected adoption curve of LLLC

4 Key Findings

4.1 Interviews and Supplemental Market Research

While CBSA data and existing information on the current installed base of luminaires and lighting controls was critical to the formation of Navigant's baseline model, information from interviews and other supplemental market research helped paint a broader picture of the numerous trends that will affect the adoption of LLLC in the future.

4.1.1 Commercial Controls Market Trends

The market for lighting controls in commercial buildings has expanded and transformed dramatically in recent years. Demand for local controls, such as occupancy sensors and photosensors, as well as networked controls, is on the rise as adoption rates of light-emitting diode (LED) lighting begins to climb and controls technology improves and becomes less expensive. Building owners and managers, many of whom have become accustomed to the idea of centrally monitoring and managing their heating, ventilation, and air conditioning (HVAC) systems, are beginning to expect the same level of control from their lighting systems.

The broad expectation by manufacturers and customers alike is that smarter lighting control systems will proliferate widely in the coming years. There is less agreement, however, on whether those smarter controls will follow the path of LLLC or that of another control strategy.

Not surprisingly, manufacturers who focus on LLLC solutions are optimistic that this type of control will continue to gain a larger and larger share of the market, while manufacturers who focus on other types of lighting control strategies expect LLLC adoption to be more limited. Navigant expects many different types of strategies to be present in the commercial market for the foreseeable future, and has incorporated numerous perspectives into a baseline model that predicts that rate of LLLC adoption absent utility programs.

4.1.2 Networked Lighting Controls Market Segmentation and Products

Many of the manufacturers interviewed for this project discussed the widely differing success of LLLC in different commercial building segments. Warehouse and manufacturing buildings were seen as one of the best candidates for this type of lighting control, since the luminaires used have high wattages and long run-times. Together, those factors increase the energy consumed by each luminaire, thus increasing the savings achievable by advanced lighting control strategies and reducing the payback periods. Outdoor lighting, regardless of the type of building it is associated with, is another example of an application that uses high wattage fixtures with longer run-times. Lighting control companies such as Digital Lumens and Daintree have therefore focused on the high bay and outdoor lighting used in these building segments, and have seen greater success here than in other building segments.

The next best target for LLLC solutions appears to be office buildings, conference centers, schools, and gymnasiums. Paybacks are generally not as good as high bay applications, but can still be attractive depending on factors such as usage patterns and electricity prices. In addition to energy savings, office buildings can benefit from sensors that can track the use of individual spaces and provide feedback for space optimization plans. Another key feature of the office segment is a focus on occupant comfort. Luminaires that can be controlled individually, based on localized conditions, can often provide a better user experience than lighting that is centrally controlled or controlled via a more remote set of sensors. Multiple vendors described occupant frustration with sweep-type systems that require occupants to manually turn lights back on if they work late, and a common experience with occupancy sensors is the need to wave arms or move closer to the sensor to trigger lights back on. Individual sensors can minimize those types of problems.

Retail and hospitality buildings are expected to adopt LLLC solutions slower than other commercial building segments. These buildings use light to attract customers and emphasize products, and owners are thus loathe making any changes in lighting control that might affect sales. One exception is big box retails, where the incentives are more similar to high bay applications, since individual luminaires consume a comparatively high amount of electricity.

4.1.3 Market Drivers

Building codes were cited by many interviewees as being a primary driver in the adoption of lighting controls in general, and LLLC solutions specifically. Codes such as ASHRAE 90.1-2010 require the use of occupancy sensors and daylight sensors in a wide range of space types.

The ASHRAE code does not specifically require luminaire level control, but a couple of manufacturers noted that complying with code requirements is getting harder to do with room-level or conventional control systems. Washington and Oregon are much more stringent on multi-zone daylighting than other states, creating a further incentive to use LLLC solutions. California's Title 24 was also cited as a major driver. While this code also does not mandate control at the luminaire level, the extensive requirements do mean that the cost premium between code minimum and LLLC is much smaller. While California is outside of NEEA's region, the state is generally seen as a leader in this type of code, with states in the Pacific Northwest likely to adopt similar codes if they are seen as successful.

Demand response was brought up by a couple of manufacturers as a driver for networked control at the luminaire level. Utilities are likely to have a large interest in lighting systems that can be controlled remotely and automatically, and that involve individually dimming luminaires. Such systems could respond instantly to load shedding events, with minimal impact on building occupants. While some interviewees saw this as a potentially large driver for LLLC moving forward, other interviewees were more cautious, pointing out that with LED lighting and advanced controls, the amount of power consumed by lighting systems is dropping to a point where it may not be as valuable as a demand response strategy. In a separate report, Navigant has forecast that the number of commercial buildings participating in demand response programs will grow at a compound annual growth rate (CAGR) of 16.5% from 2011 to 2018 and will reach 1.4 million sites globally by 2018.

Energy savings were cited as a key driver for some LLLC installations, and less important in others. In buildings with high wattage lights that run for long hours, the energy savings from individually optimizing every luminaire can be significant. In building with lower wattage lights, or lights that are not used for as many hours, the energy savings from an LLLC solution may be so small that payback periods stretch for twenty years or longer. In those cases, the non-energy benefits of an LLLC are a far more significant driver. During the interviews, the difference in energy savings between LLLC systems and other types of occupancy-based systems were discussed. In a typical zone-based system, one occupancy sensor might control eight or more luminaires. If only one person is present in that zone, all but one or two of those luminaires could be shut off in an LLLC system.

Non-energy benefits are an important sweetener for decision makers considering LLLC solutions, especially in situations where the energy savings alone do not make a compelling case. Some non-energy benefits provide real monetary savings, such as a reduction in maintenance costs. An intelligent lighting control system can record the run-time of lamps, predicting when they will require replacement so that groups of lamps can be replaced at the same time rather than one-by-one. This can lead to especially large savings in building areas where lights are difficult to reach, such as tall atriums that may require special equipment to be set up to access the lights. Other non-energy benefits are not tied directly to monetary savings, but can improve occupant comfort and user experience. For example, as more spaces are required by code to adopt some level of occupancy-based control, an LLLC system can provide a granular level of sensing that ensures that lights remain on around every person in a space. Similarly, a granular level of daylight sensing ensures that lights are dimmed to the appropriate level for every location within a space, rather than dimming one part of a room too far because another part of the room is receiving more natural light. These types of comfort-based benefits are especially important in office buildings, where salary costs almost always dwarf energy costs, and retaining top personnel can be critical. In addition, LLLC provide a unique source of data as to occupancy for security or space utilization purposes.

Ease of design and installation was cited by the company Enlighted as a key reason that customers chose their LLLC system. With sensors and intelligence in each luminaire, an LLLC system does not require each occupancy sensor and photosensor to communicate with a specific group of luminaires. The Enlighted system was specifically designed to be installed by electricians or even facility managers, rather than specialists. This can save time and reduce labor costs, as well as give building owners the confidence that any future changes to their lighting systems or room layouts will not require expensive visits from a company technician. In fact, "ease of system management" was the number one reason Enlighted customers gave on a survey for why they selected an Enlighted system.

4.1.4 Market Barriers

Long payback periods were consistently cited as the largest barrier to greater adoption of LLLC. Paybacks vary depending on the specifics of a lighting system and local energy prices, but average systems often do not pay for themselves for more than twenty years. While many customers are enthusiastic about the non-energy benefits of smart lighting control systems, they still expect to see decent returns on their investment. Twenty years is far too long to make this an attractive investment. There are, however, a number of caveats to this conclusion. Prices for sensors and networking equipment continue to fall, reducing upfront costs. A high portion of LED lamps sold in the coming years are expected to come with built-in dimming control and even wireless networking control, further reducing the cost premium of LLLC systems. The adoption of LEDs is also expected to lead to high replacement rates of older technology luminaires. The cost premium for LLLC systems is lowest when a customer is already replacing lights, especially when upgrading to LEDs, so a number of manufacturers noted that this will be an ideal time to market such lighting control systems.

Complexity is another leading barrier to any advanced lighting control system. While LLLC promises to provide a simpler control scheme that minimizes commissioning and maintenance, the current reality is that many users feel overwhelmed by the options and features that are available, and often opt for simpler systems. Managers of commercial buildings may also not have the expertise to address any problems that may arise, thus steering decision makers away from systems that are perceived as too complicated.

Lighting designers may also act as a barrier to the adoption of LLLC. While the inclusion of a lighting designer should enable a construction or retrofit project to deal with the complexity problem described above, interviews suggested that many lighting designers oppose this control strategy. If the lighting in a room includes decorative features such as wall washers the throw light on individual walls, a lighting designer might not want each luminaire to dim differently than others and negatively affect the intended aesthetic.

Cybersecurity is becoming a concern for building owners as they contemplate ever more sophisticated building control systems. A lighting control system that provides granular detail on occupancy and possibly other metrics could expose a worrisome amount of information should the system be hacked. Lighting controls vendors interviewed for this report described the security protocols that are built into their systems. However, with examples of cybersecurity breaches coming up frequently in the news, building owners may be reluctant to install systems that could be perceived as a risk.

4.1.5 Introduction Year

A critical reference point for the baseline analysis is the year in which each building type has begun or will begin to adopt LLLC in significant numbers. During the interviews, this question was asked of both manufacturers of LLLC solutions. The years listed in Table 3-4 represent the best estimate of these introduction years, based on responses to our interviews. It should be noted that these are not intended to be the year in which the very first LLLC system was installed in each building category, but rather the year in which a trend of adoption began or when that trend is expected to begin. These values were used as the starting point for the adoption curve for each category.

4.1.6 Baseline Adoption

A second key metric for the baseline analysis is the current and expected adoption rate of LLLC systems. Navigant discussed expectations for adoption rates with both manufacturers and industry associations. While an analysis of price and payback and other considerations was also conducted, the advice received from these industry experts was quite valuable in setting expectations as to how quickly LLLC systems can be expected to proliferate in the absence of utility incentive programs. Not surprisingly, there was a mix of responses, with vendors of LLLC systems having more optimistic views and vendors of competing lighting control systems having lower expectations. The optimistic views see market that is growing at an accelerating rate and quickly penetrating into new building types. The more cautionary view sees many examples of spaces where LLLC is not expected to be practical, and also points to the increasing adoption of other competing strategies for intelligent lighting control. This range of views was used to inform and validate the adoption curve that Navigant used for projecting future sales of LLLC systems.

4.1.7 Key Recommendations for Utility Programs

Addressing the number one barrier to LLLC, that of cost, was seen as the number one recommendation for utilities seeking to increase adoption rates. Even if the incentives do not reduce payback periods to the two-to-five-year range that many commercial customers seek, a rebate that pays for some portion of the system will make a customer much more likely to choose an LLLC system. As one manufacturer put it, customers like to see that they are already a portion of the way towards funding a system before having to find the budget for the remainder of the cost. This type of cost reducing incentive program is seen as driving adoption much faster than restrictive building codes, which can easily become watered down or overly complicated.

4.2 Northwest Installed Base of Fixtures and Controls

The installed base of fixtures is a critical element to determine the available market for penetration of LLLCs, while the installed base of controls is indicative of existing market characteristics and penetration of controls. This section outlines the 2013 installed base of fixtures and characteristics of controls market.

The installed base of fixtures is calculated on a per-building type basis as the product of total floor area, and the applicable fixture density by building type for the Northwest region. Table 4-1 outlines the installed base of fixtures used in this study.

Table 4-1: Northwest 2013 Fixture Characteristics

Building Type		Total Floor Area (million sqft.)	Applicable Fixture Density (per sqft.)	Installed Applicable Fixtures
Office	Large Off	284	0.0086	2,153,433
Office	Medium Off	128	0.0086	970,210
Office	Small Off	150	0.0086	1,138,416
Retail	Big Box	130	0.0094	1,184,634
Retail	Small Box	241	0.0094	2,187,999
Retail	High End	60	0.0094	547,000
Retail	Anchor	116	0.0094	1,056,102
K-12	K-12	257	0.0105	2,551,012
University	University	129	0.0105	1,274,724
Warehouse	Warehouse	406	0.0041	1,426,561
Grocery	Supermarket	52	0.0165	844,843
Grocery Other	Minimart	22	0.0165	360,239
Restaurant	Restaurant	50	0.0109	491,693
Hotel	Lodging	167	0.0083	1,032,405
Hospital	Hospital	71	0.0087	594,320
Hospital Other	Other Health	157	0.0087	1,315,295
Assembly	Assembly	225	0.0079	1,588,020
Other	Other	425	0.0103	4,293,225
Total/Weighted Average		3,070	0.0088	25,010,129

According the CBSA data, warehouses have the single highest total square footage area in the Northwest region. However, combining the four types of retail space and two types of grocery space, the overall retail category accounts for just over 20% of the total building area in the region. The combined office building types represent the next largest category in the region, with just under 18% of the total square footage.

Warehouses have the lowest applicable fixture density, almost two and half times less than the weighted average for the region, while groceries have the highest applicable fixture density with 0.017 per sqft, in other words, one fixture for every sixty square feet. Schools have the second highest fixture density with approximately 0.011 per sqft, meaning one fixture for every ninety square feet.

As for the total installed applicable fixture base, offices and schools represent more than one-third of the market; however, their existing controls base characteristics and willingness to adopt LLLC vary significantly resulting in varied market penetrations of LLLC in the future.

Another key input into the analysis was the existing base of installed controls. As discussed earlier, Navigant categorized fixtures into three groups related to their control scheme: No controls, Non-Networked controls, Networked Controls. Table 4-2 presents the 2013 prevalence of controls in commercial buildings in the PNW.

Table 4-2: Northwest 2013 Controls Characteristics

Building Type		Fixtures with Networked Controls	Fixtures with Non-networked Controls	Fixtures with No Controls
Office	Large Off	28%	9%	63%
Office	Medium Off	28%	9%	63%
Office	Small Off	28%	9%	63%
Retail	Big Box	43%	5%	52%
Retail	Small Box	43%	5%	52%
Retail	High End	43%	5%	52%
Retail	Anchor	43%	5%	52%
K-12	K-12	.9%	16%	75%
University	University	9%	16%	75%
Warehouse	Warehouse	3%	2%	73%
Grocery	Supermarket	6%	18%	77%
Grocery Other	Minimart	6%	18%	77%
Restaurant	Restaurant	2%	3%	95%
Hotel	Lodging	<1%	11%	89%
Hospital	Hospital	1%	9%	90%
Hospital Other	Other Health	1%	9%	90%
Assembly	Assembly	14%	13%	73%
Other	Other	18%	10%	72%
Weighted Average		18%	12%	70%

Another key input to the baseline study is the current installed base of LLLC. As the market is emerging and is currently relatively fragmented amongst several manufacturers, this data was difficult to ascertain with a high degree of accuracy. However, based on interviews, Navigant estimates the 2013 installed base of LLLC as presented in Table 4-3.

Table 4-3: Northwest 2013 LLLC Installed Base

Building Type		Total Cumulative Diffusion by 2013	# of Fixtures with LLLCs
Office	Large Off	2%	26,591
Office	Medium Off	2%	11,980
Office	Small Off	2%	14,057
Retail	Big Box	0%	0
Retail	Small Box	0%	0
Retail	High End	0%	0
Retail	Anchor	0%	0
K-12	K-12	1%	8,282
University	University	1%	4,138
Warehouse	Warehouse	5%	37,553
Grocery	Supermarket	0%	0
Grocery Other	Minimart	0%	0
Restaurant	Restaurant	0%	0
Hotel	Lodging	0%	0
Hospital	Hospital	0%	0
Hospital Other	Other Health	0%	0
Assembly	Assembly	0%	0
Other	Other	0%	0
Total		1%	102,602

According to CBSA 2014 data, offices have the highest existing prevalence of fixtures with networked controls, while warehouses, hotels and hospitals have the lowest. This is contradictory to Navigant's interview findings, which indicated warehouses have been one of the early adopters of LLLCs technology. Therefore, Navigant used the data from the interview findings and manufacturers' press releases for warehouses to estimate the existing installed base of LLLCs in warehouses. Navigant also assumed LLLCs are introduced to warehouses in the Northwest region and other such building types earlier than other building types based on the interview findings and naturally occurring market effects from other regions.

It is worth mentioning that even though some building types did not have a large installed base of fixtures with networked controls, they also did not have a many buildings with no controls whatsoever because they have non-networked sensors installed such as occupancy sensors. Warehouses are a good example of this, where there is substantial integration of sensors but not of networked lighting controls. This will pose a challenge to installing LLLC systems in these spaces, where managers may believe they are already capturing most of the savings that are possible through the use of lighting controls.

Navigant estimated the installed base of LLLCs in the Northwest region by extrapolating the interview results and manufacturers' press releases to the Northwest region, which resulted in total of 18,000,000 sqft. covered area by LLLCs, which is equal to approximately 100,000 unit sales to date for the region. Navigant estimates the 2013 installed base of LLLC as presented in Table 4-3.

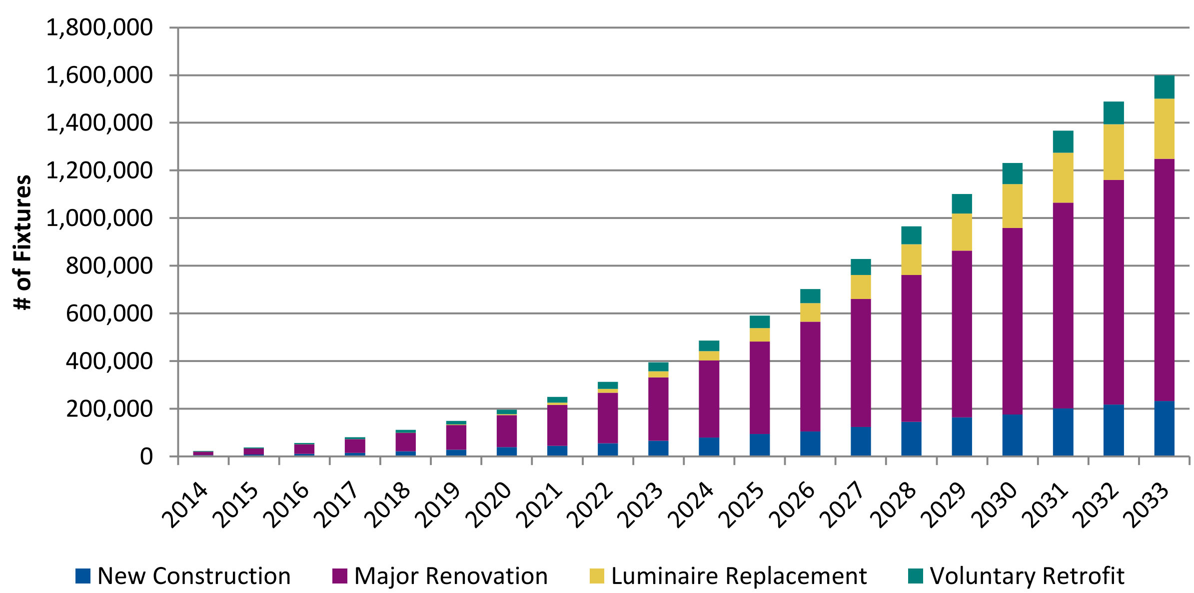
Office buildings, warehouses and schools have been the early adopters of LLLC type technologies; therefore, Navigant distributed the installed base of LLLCs to these three building types based on the spread of the LLLC adoption rates from the LLLC diffusion curve.

4.3 Baseline Forecast

Navigant developed a market baseline forecast model that forecasts the sales of LLLCs in each year by four market segments and by building types. These sales then feed into the installed stock in the following year to output the Northwest region installed base forecast of LLLCs for the 20-year analysis period.

Based on the baseline forecast developed, Navigant expects that annual LLLC sales, shown in Figure 4-1, will increase rapidly in the first 10 to 15 years, and then reach an inflection point as the market becomes more saturated with networked controls technologies. Navigant forecasts that the sales will grow at an average compound annual growth rate (CAGR) of 37% for the first 10-year period and at a CAGR of 15% for the next 10-year period, with 20-year average of 25%. The largest markets for LLLCs reside in the office buildings and warehouses.

Figure 4-1: Annual LLLC Sales



The majority of the sales will come through the major renovations, accounting for approximately 67% of the sales in 2023. The second largest share of the sales will come from the new construction market with 17% in 2023, followed by voluntary retrofits and then luminaire retrofits. Table 4-4 provides the annual LLLC sales projections by market share. As presented in Table 4-4, the results of this forecast indicate that the share of sales from luminaire retrofits market will increase, while the share of sales from other market sectors will decrease over the time. This effect is due to an increase in the LED penetration rates used in this analysis, which is assumed to be the major reason that instigates luminaire retrofits.

Table 4-4: Annual LLLC Sales by Market Share

	2018	2023	2028	2033
New Construction	20%	17%	15%	15%
Major Renovation	69%	67%	64%	63%
Luminaire Retrofits	1%	7%	13%	16%
Voluntary Retrofits	10%	9%	8%	6%

Most manufacturers' preferred way of presenting sales of LLLCs is with the total floor area these controls serve[3]. Appendix B illustrates the annual LLLC sales in square feet by building type. Navigant used only applicable floor area to convert sales into floor area coverage, which warranted results to be consistent with the manufacturer's calculations. For instance, if a space did not have any applicable fixture type as defined in Section 3.1.1, it was excluded from the density calculations to prevent overestimating the building floor area the controls serve since those spaces would have never installed LLLCs.

Figure 4-2 and Table 4-5 provide insight into share of annual sales coming from each building type. The annual sales amount for each building type depends on three factors:

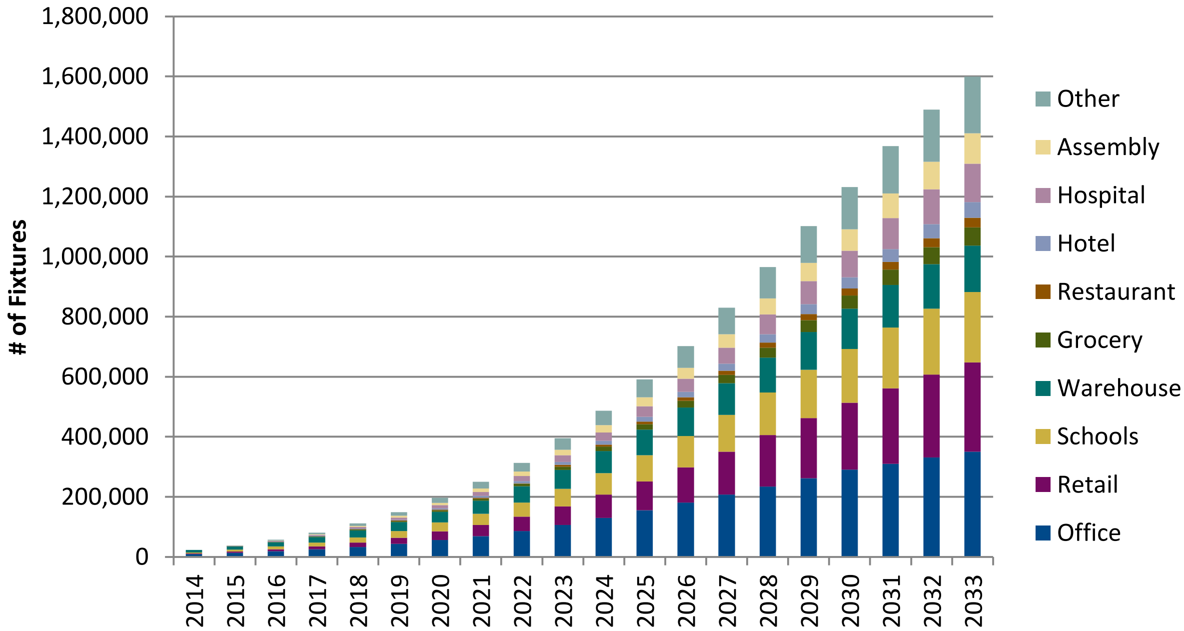
- **Introduction Year:** The year LLLC technology is introduced to a building type, which is derived from a combination of interview findings and Navigant's market intelligence. The earlier the LLLCs are introduced to a building type, the faster the adoption will be based on the penetration curves, which Navigant developed to demonstrate the effects of consumer awareness and willingness.

- **Number of Applicable Fixtures:** The number of applicable fixtures determines the available market for each building type for penetration of LLLCs.

- **Existing prevalence of controls:** The existing prevalence of controls and the expected penetration of non-LLLCs controls to different building types reduce the available market size for each building type as they compete with LLLCs.

[3] http://enlightedinc.com/press/enlighted-crosses-25-million-customer-square-feet-mark/

Figure 4-2: Annual LLLC Sales by Building Type



As seen in Table 4-5, office buildings and warehouses represent more than 43% of the sales in 2023, while groceries, restaurants, hotels and hospitals combined represent less than 12% of the sales in 2023. The share of sales that come from offices and warehouses will decrease as they become more saturated, and the share of sales that come from other building types will increase as they catch up with offices and warehouses over time.

Table 4-5: Percent of Annual Sales by Building Type

	2018	2023	2028	2033
Office	30%	27%	24%	22%
Retail	13%	16%	18%	19%
Schools	16%	15%	15%	15%
Warehouse	21%	16%	12%	10%
Grocery	2%	3%	3%	4%
Restaurant	1%	1%	2%	2%
Hotel	2%	2%	3%	3%
Hospital	5%	6%	7%	8%
Assembly	3%	5%	5%	6%
Other	7%	9%	11%	11%

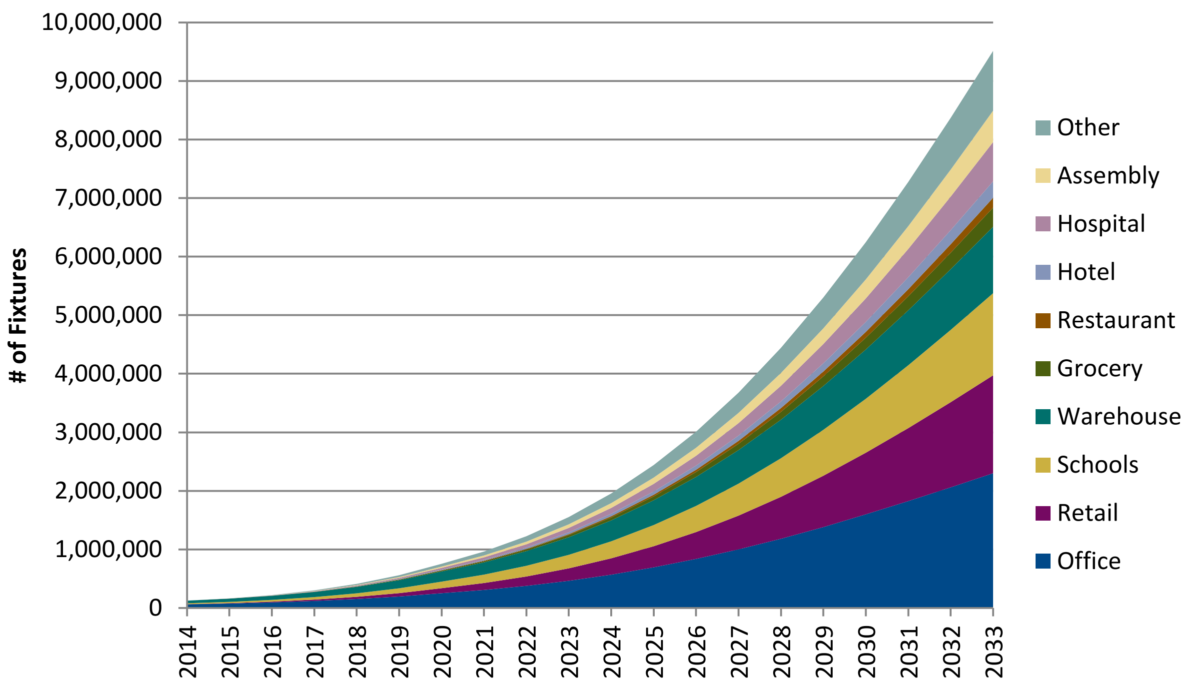
However, as illustrated in Table 4-6, the annual sales as a percent of the total floor area by building type hardly exceeds 6% of the total building floor area at any year. Navigant predicts, only about 1.5% of the total floor area in the Northwest region will install LLLCs in 2023.

Table 4-6: Annual Sales as a Percent of the Total Floor Area by Building Type

	2018	2023	2028	2033
Office	0.7%	2.0%	4.1%	5.7%
Retail	0.3%	1.2%	3.2%	5.5%
Schools	0.4%	1.3%	3.2%	5.2%
Warehouse	1.3%	3.0%	5.0%	6.1%
Grocery	0.2%	0.9%	2.8%	5.1%
Restaurant	0.2%	0.9%	2.8%	5.2%
Hotel	0.2%	0.7%	1.9%	3.6%
Hospital	0.2%	1.0%	2.7%	5.0%
Assembly	0.2%	1.0%	2.6%	4.6%
Other	0.2%	0.9%	2.5%	4.6%

Navigant developed the LLLC installed base for the PNW by feeding annual sales into the installed stock of the following year, accounting for building renovations and demolitions in future years.[4] Figure 4-3 shows the LLLC installed base over 20 years by building type. This figure represents Navigant's baseline forecast in absence of any utility intervention.

Figure 4-3: LLLC Installed Base by Building Type



[4] Navigant assumed major renovation rates will apply to the installed LLLC base only after 2020.

Figure 4-4 presents the share of the total applicable fixtures that is captured by LLLCs compared to other networked controls over the next 20 years. As seen in the Figure 4-4, LLLCs will penetrate into only a small portion of the market until 2023, and then they will pick up resulting in 34% of the market in 2033, as shown in Table 4-7. LLLCs will account for 20% of the networked lighting controls by 2023, and 60% of the networked lighting controls market by 2033. Buildings such as offices, that have higher initial prevalence of networked controls (see Appendix B); have more resistance to adoption of LLLCs in the retrofit market segments, which reduces the available market for penetration of LLLCs.

Other or no controls area represents non-networked sensors such as occupancy sensors, manual controls such as switch relays, and no controls. Navigant projects the installed base of these types of controls will decrease in the next 20 years; however, it will not fully diminish due to market barriers and customer reluctance to adoption of advanced technologies.

Figure 4-4: Installed Base by Controls

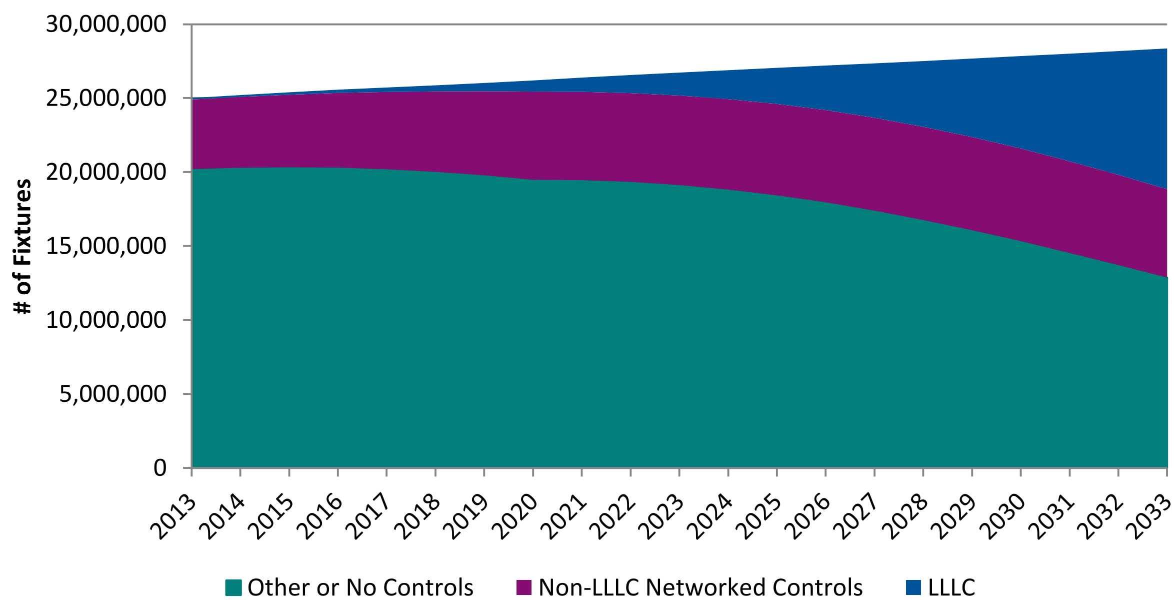


Table 4-7: Percent of Installed Base by Controls

	2018	2023	2028	2033
LLLC	2%	6%	16%	34%
Non-LLLC Networked Controls	21%	23%	23%	21%
Other or No Controls	77%	71%	61%	45%

5 Caveats and Limitations

There are a number of important caveats and limitations associated with the results of these forecast and modeling efforts. For this study, behavior of the market, limitations in data available and high levels of forecasted market penetration are key uncertainties. Impact of exogenous variables (such as changes to gas prices, weather, and federal codes) were not examined in this study. Uncertainties specific with this study include the following:

- Current CBSA 2014 data is limited and not fully updated. In several cases Navigant made estimates to fill the gap at the building type level data. Navigant also excluded parking spaces in installed fixture base estimates due to limited data. While the best available data was utilized, it may not reflect the actual market characteristics of the Northwest region.

- Data on the competition among controls is limited. While Navigant used its market intelligence to account for competition, it may not represent the actual behavior of the customers.

- The resulting voluntary retrofit market size is based on payback ratio between controls-only retrofit and lighting integrated retrofit. As it is highly sensitive to this payback ratio, it may be underrepresented or overrepresented due to uncertainties in the payback calculations.

- Data on the non-energy benefits impact is limited. While Navigant qualitatively account for the non-energy benefits, further study is required to quantify the non-energy benefits.

Some uncertainties would suggest that the baseline is lower than estimated while others could suggest baseline is higher than estimated. While multiple uncertainties exist, Navigant used the best data available at the time of publication.

6 Recommendations

Through conducting this baseline study and interviewing several market players, Navigant has extracted the following recommendations for NEEA and utilities considering pursuing an initiative focused on increasing the deployment of LLLCs in the PNW:

- New construction and major renovation markets represent high potential in the early years without utility intervention; therefore, NEEA should focus on the retrofit markets which have high market potential but where payback periods are very long

- Supplement LED retrofit programs to include education and additional incentives associated with installing LLLCs

- Target buildings with high energy intensity and inefficient space utilization such as warehouses and offices to maximize the savings from LLLCs

- Increase customer awareness through marketing and communicating technology benefits
- Communicate non-energy benefits where customer satisfaction is more important such as in restaurants, hotels, groceries, and hospitals
- Initially target buildings with no or manual controls due to higher savings potential and to avoid competition with existing controls
- Design building codes that require advance lighting controls to accelerate adoption of LLLCs

7 Further Work

In addition, Navigant has identified the following areas of additional work that NEEA and other utility partners can pursue to refine the estimates in this baseline study:

- Update CBSA inputs, and include parking spaces to density and controls base calculations in order to represent the actual market characteristics of the Northwest region
- Demonstrate and quantify the additional energy benefits of LLLCs compared to non-LLLC networked controls
- Study how non-energy benefits can affect the penetration of LLLCs
- Quantify cost of installing LLLCs integrated with lighting fixtures
- Conduct further analysis on ROI of luminaire integrated and control installations
- Survey customer willingness to adopt LLLC if they have,
    - Non-LLLC Networked Controls (e.g. EMSs, etc.)
    - Other Sensors (e.g. occupancy sensors, photosensors, etc.)
    - No or Manual Controls (e.g. switches, etc.)
- Evaluate, measure, and verify savings associated with LLLCs across an utility program

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Appendix A Interview Guide

Luminaire Level Lighting Controls: Market Baseline Study

Interview Guide

January 2014

1. Are you aware of any studies showing the current adoption rate of LLLC or other advanced lighting controls within the Northwest or broader U.S. markets?

2. Please describe recent trends you have observed in the sale of lighting controls within commercial buildings, in the Northwest and across the U.S.

3. Can you share information on your total sales of lighting controls, by control type, within the Northwest or U.S. markets? Do you have estimates of your market share within these regions?

4. Does your company currently sell an LLLC product, or have plans to do so in the future?

5. What percentage of your commercial lighting control sales are designed to function in a networked lighting control system? What portion of lighting control sales utilize distributed intelligence versus centralized intelligence?

6. We are trying to determine average payback periods for LLLC and other advanced lighting control products. Do you have estimates for average consumer costs, savings, and payback periods for your lighting control products?

7. What percentage of your sales of the following luminaire types are sold with integrated sensors?

    - Recessed
    - Surface Mount
    - Pendant Mount
    - Task Lighting

8. Please discuss your expectations for the adoption of LLLC and other advanced lighting controls over the next 10-20 years. What percentage of the available market do you expect to adopt LLLC, and how quickly?

9. Our preliminary forecasting for LLLC shows the following adoption rates and sales estimates. Comment on whether you find these reasonable

2018 – XX% adoption. $XX in annual sales [with definition for sales #]
2028 – XX% adoption. $XX in annual sales [with definition for sales #]

10. Which commercial buildings types will adopt LLLC and other advanced lighting controls most quickly? What factors specific to different building types will affect adoption rates?

11. Is there a comparable technology whose adoption rate you would expect to be similar to that of LLLC?

12. Please discuss the relative likelihood of a commercial customer adopting LLLC or other advanced lighting controls in conjunction with the following events:

    - New Construction / Major Renovation
    - Ballast/Lamp Failure
    - Voluntary Retrofit

13. What technological developments do you expect over the next 10-20 years that will affect the adoption of LLLC?

14. What regulatory changes in the coming years might affect the adoption of LLLC and other advanced lighting control techniques?

15. Can utility intervention increase LLLC market penetration in the commercial sector? What factors make for a successful program?

16. What other factors might impact the adoption of LLLC in the coming years?

Customer Focus:

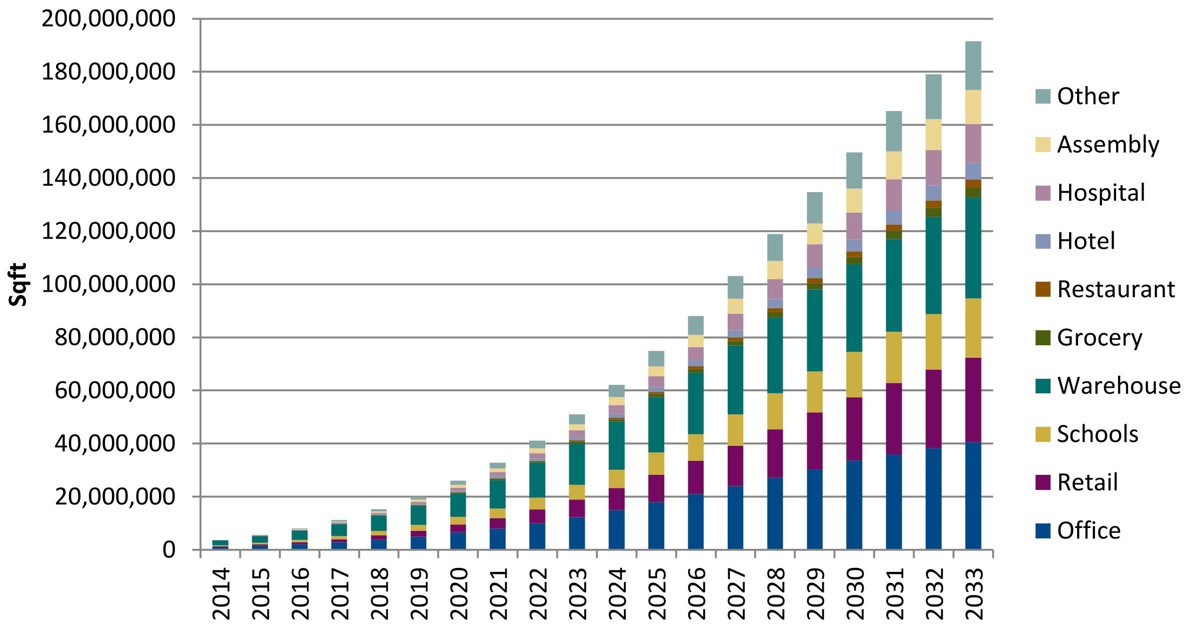
17. How do commercial customers select lighting controls? In what parameters are they most interested? Do they weigh energy savings, cost savings, safety, or lighting esthetic more heavily? Are there other non-energy benefits customers look for?

18. What customer feedback on advanced lighting controls have you received or otherwise become aware of? It is generally favorable or negative?

19. What are the major barriers to adoption of advanced lighting controls (e.g., acquisition, installation, compatibility, consumer education)?

Appendix B Annual LLLC Sales by Building Type in Square Feet

Figure B-1: Annual LLLC Sales by Building Type in Square Feet



Appendix C Office Buildings

Figure C-1: Annual LLLC Sales (Office)

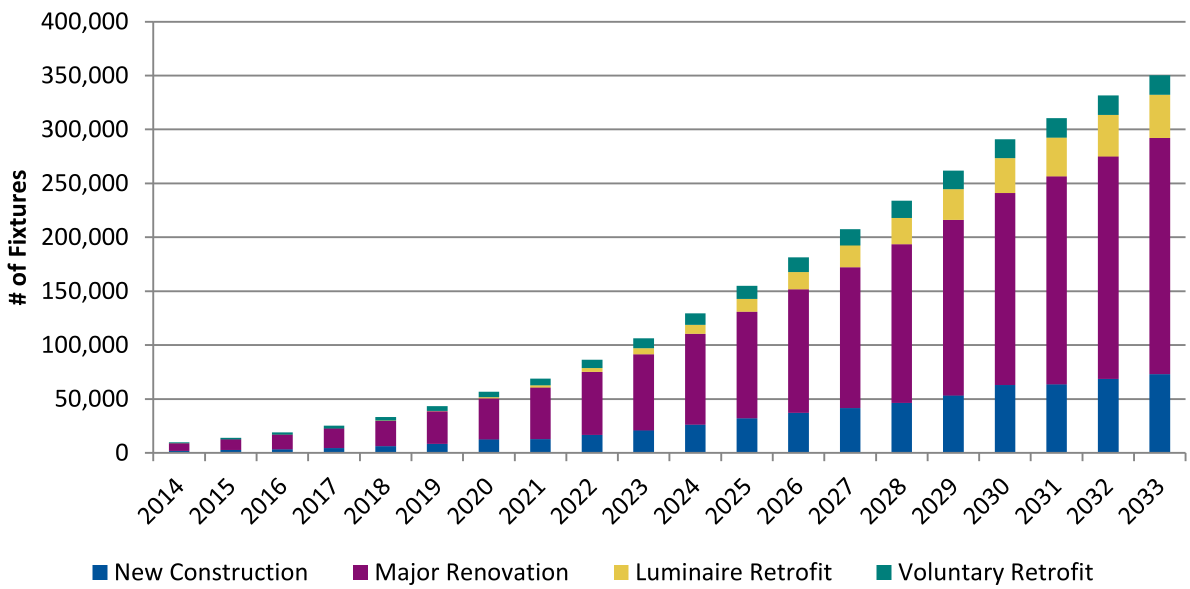


Table C-1: Annual LLLC Sales (Office) by Market Segment

	2018	2023	2028	2033
New Construction	19%	20%	20%	21%
Major Renovation	70%	66%	63%	62%
Luminaire Retrofits	1%	5%	10%	12%
Voluntary Retrofits	10%	9%	7%	5%

Figure C-2: Installed Base of Controls (Office)

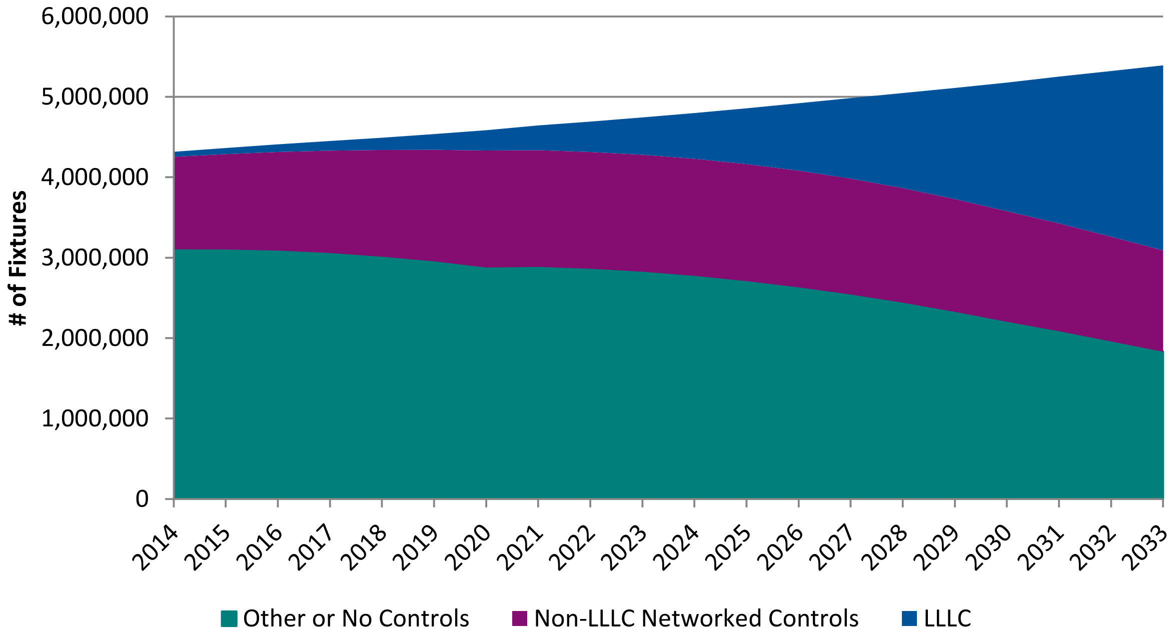


Table C-2: Installed Base of Controls (Office) by Controls

	2018	2023	2028	2033
LLLC	3%	10%	23%	43%
Non-LLLC Networked Controls	30%	31%	38%	23%
Other or No Controls	67%	59%	44%	34%