MEMORANDUM for the Northwest Energy Efficiency Alliance

Incremental Cost of Luminaire Level Lighting Controls (LLLC)

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Executive Summary

This memorandum provides an estimate of the incremental cost of luminaire level lighting controls (LLLC). Specifically, we estimate the additional equipment and labor costs incurred by installing LEDs with LLLC as compared to LEDs with no controls. We segmented LLLC products into two overarching categories based on their differing features and price points, nominally called “clever” and “smart” systems. “**Clever**” systems are defined as an LLLC which meets basic DLC QPL requirements (high-end trim, dimming, occupancy sensors, and photocells) and are “plug and play” fixtures. A “**smart**” system includes all “clever” capabilities but can also analyze and communicate energy and non-energy data to inform decision making processes for a wide variety of Internet of Things (IoT) use cases such as space utilization, HVAC optimization, and retail asset tracking. An emerging product category is a type of **“clever-hybrid”** system between smart and clever that includes a standalone gateway and provides additional functionality such as energy monitoring.

This study found an incremental cost of $53 for clever systems, $75 for clever-hybrid systems and $136 for smart systems above a standard LED luminaire retrofit. However, there is a wide range in prices, with clever systems quoted as low as $43 per fixture. Figure 1 depicts the costs of each component estimated in the study for clever and smart systems. For clever systems, roughly 99% of the incremental cost is due to the fixture itself, with only a small fraction going towards programming. For smart systems, the fixture accounts for 86% of the incremental cost, while programming and additional system components that enable data collection make up the rest of the cost. This reflects the additional IoT use cases that smart systems provide beyond energy savings.

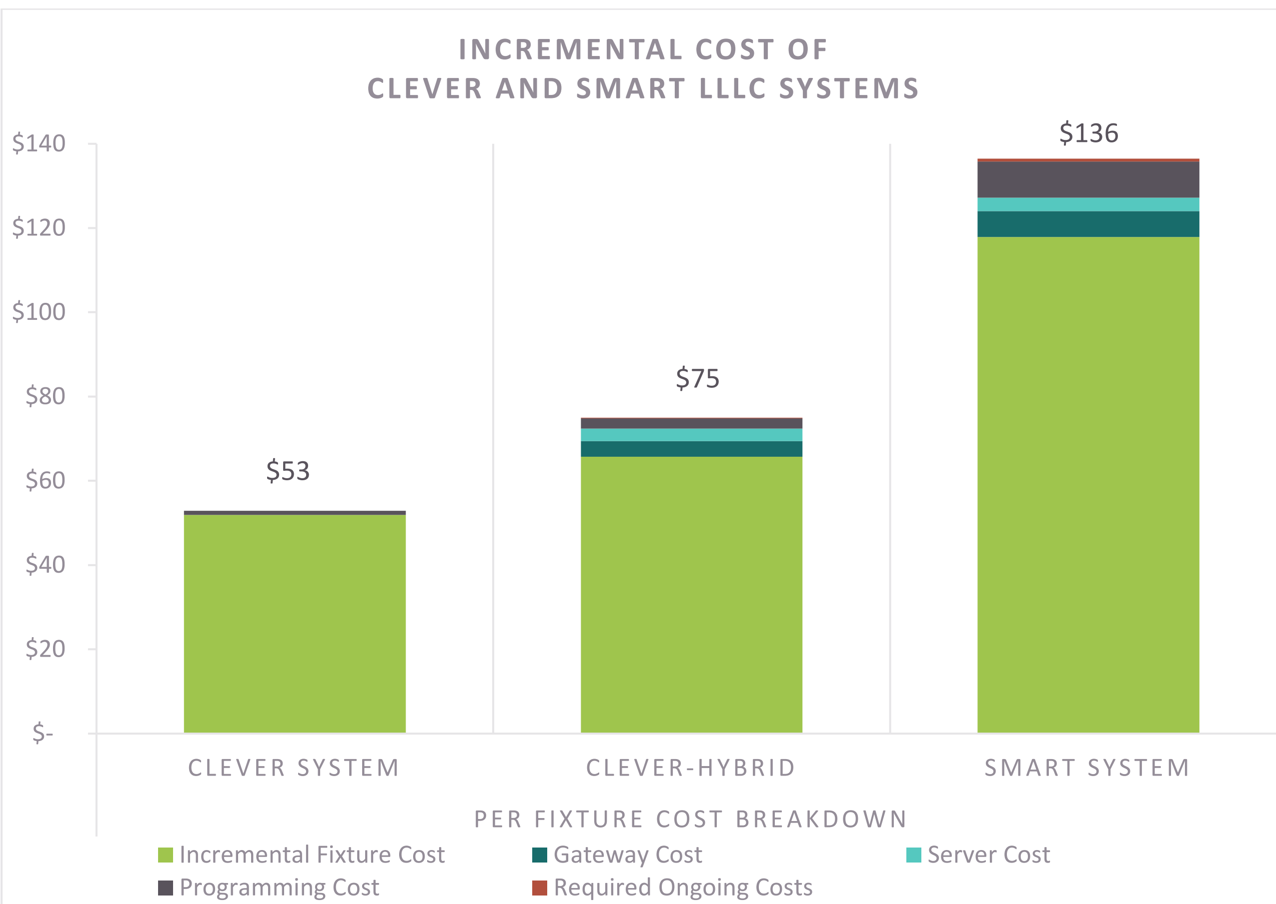

Figure 1 The per fixture cost breakdowns for clever, clever hybrid and smart systems

The study interviewed a total of fifteen contractors, manufacturer representatives, and manufacturers to collect twenty project cost estimates based on prototypical office buildings for sixteen different clever and smart systems. In addition to equipment prices, different cost components of LLLC were collected, such as installation labor costs or the cost of gateways. We used this data to estimate the total costs for the entire installation and then divided by the assumed number of fixtures to calculate costs on a per fixture basis.

Due to the different functionalities and purchasing decisions for clever and smart systems, it is important to recognize the difference in both incremental cost but also the distinct market segments of clever and smart LLLC systems when comparing them.

1. Introduction

LED luminaires are increasingly prevalent in commercial applications and are predicted to represent over 70% of the linear lighting fixture market by 2030.[1] The long lifetime and low overall wattages of these LED luminaires (also referred to as LED fixtures) creates a stranded savings opportunity because, once installed, it is highly unlikely that LED luminaires will be retrofitted with controls during their remaining useful life, eliminating the opportunity for deeper energy savings for roughly the next ten years.

Luminaire level lighting controls (LLLCs) are controls and sensors directly attached and/or integrated within an individual lighting luminaire in a space. LLLCs provide control capabilities for each fixture, such as occupancy and vacancy sensing, daylight harvesting, high-end trim continuous dimming, and combinations of each. The granularity of detection and control afforded by LLLC maximizes the potential for customization of lighting services and deep energy savings.

LLLCs were included in less than 1% of the LED luminaires installed in 2016, despite controls representing 45% of the lighting fixture market's potential savings.[2] The large savings potential for LLLCs is particularly true for linear fixtures, where controls represent 69% of energy savings potential. Key adoption barriers for LLLCs include the lack of customer or contractor awareness and the incremental cost of installing a fixture with controls above a standard retrofit, despite the significant additional savings opportunities. This memo provides a comparison of the incremental cost of both smart and clever systems relative to an LED luminaire base case.

LLLC systems can be informally classified as "clever" or "smart". A **clever** system is defined as an LLLC which meets basic DLC QPL requirements (high-end trim, dimming, occupancy sensors, and photocells) and are 'plug and play' fixtures which require little or no additional programming costs upon installation. A **smart** system includes all 'clever' capabilities, but it can also analyze and communicate energy and non-energy data to inform decision making processes for a wide variety of IoT use cases beyond analytics above the standard requirements, such as space utilization, HVAC optimization, and retail asset tracking.

An emerging product category is a type of **'clever-hybrid'** system between smart and clever that includes a standalone gateway and provides additional functionality such as energy monitoring.

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[1] Navigant. 2014. Energy Savings Forecast of Solid State Lighting in General Illumination Applications. http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/energysavingsforecast14.pdf

[2] https://energy.gov/sites/prod/files/2017/08/f35/led-adoption-jul2017_0.pdf

Table 1 The "clever", "clever-hybrid" and "smart" LLLC offerings examined in this study. Blank cells indicate that the manufacturer does not have an LLLC offering of the specified type and commas indicate multiple offerings of the specified type.

Manufacturer	Clever	Clever-Hybrid	Smart
Acuity Brands		nLight Air 2.0	
Cree, Inc.	SmartCast® Technology		
Eaton		Wavelinx	LumaWatt Pro
Current, GE (Daintree)			Controlscope
Digital Lumens			Lightrules, SiteWorx
Enlighted Inc.			Enlighted
Lutron Electonics		Vive™ wireless	
Philips	SpaceWise, EasySense		Interact
Leviton		Intellect Room Controls	
Magnum		OPUS	
Xeleum	Xi-Fi		
RAB			Lightcloud

2. Methods

This section provides an overview of the definition, methods, and assumptions utilized in identifying incremental cost of each cost component of fixture integrated controls.

2.1 Definition of incremental cost

For the purposes of this analysis, we defined incremental cost as the difference between the cost of installing an LED fixture with LLLC and one without controls. Specifically, the base case (no controls) is defined as a retrofit scenario in which 2x4 fluorescent troffers are replaced with LED luminaires. The incremental cost of ‘Smart’ and ‘Clever’ systems is defined as the difference between their respective costs and the base case.

2.2 Cost Components

Clever and smart system components are typically differentiated by the smart systems’ need for additional network infrastructure. The cost of clever systems is made up of the following components:

- The difference in cost between an LED luminaire with and without built-in LLLC functionality (i.e., “incremental fixture cost”)
- Labor cost of controls setup/programming
- Devices required to install and commission the system (configuration tools)
- Support services (e.g. phone support, on-site programming, sensor layout and tuning, etc.)

In addition to the components of clever systems, the cost of smart and clever-hybrid systems may also include:

- Gateway(s)
- One-time or ongoing licensing fees for the controls network
- Server cost or hosting fee for data storage
- Software one time and subscription fees
- Asset tracking hardware and service fees

Table 2 The typical components contributing to the cost of the LLLC products.

Cost Type	Cost Component	Applicable to this Product Type?		
		Clever	Clever -hybrid	Smart
Equipment	Incremental Fixture Cost	Yes	Yes	Yes
	Configuration tool[3]	Yes	Yes	Yes
	Gateway	No	Yes	Yes
	Asset Tracking	No	No	Yes
Licensing	One-time or On-Going Cost	No	Yes	Yes
	Software Subscription Fee	No	No	Yes
Labor	Programming[4]	Yes	Yes	Yes
	Support Services	Yes	Yes	Yes

2.3 Data Collection Methods

The project team collected data by conducting outreach to 30 contractors, manufacturer representatives, and manufacturers, which yielded price estimates for 20 data points on 16 controls system brands from a total of 15 sources (two contractors, eleven manufacturers, and two manufacturer representatives). In all cases, parties were explicitly asked for the cost to the end use customer.

Table 3: Count of LLLC data points, sources, and brands collected by market actor.

Market Actor Data Source	Count
Manufacturer	15
Manufacturer's Representative	3
Contractor	2
Total	**20**

The data collected was divided into three system types: clever, clever-hybrid, and smart, for which 4, 7, and 9 data points were collected respectively. The data points, number of sources, and brands are shown by system type in Table 4 below.

[3] While early versions of smart and clever systems included standalone configuration tools, virtually all systems now configure tool using a smart phone app. The configuration tool is still an option in half of the systems.
[4] Programming involves configuring the control system so fixtures, control devices, and sensors can accurately communicate with each other and send control signals to the appropriate luminaires.

Table 4: Count of LLLC data points, sources, and brands collected by system type.

System Type	Data Pts.	Sources	Brands
Clever	4	3	3
Clever-Hybrid	7	7	6
Smart	9	8	7

2.4 Data Analysis Methods

The team collected 20 price estimates, broken out by each cost component, for 4 clever systems, 7 clever-hybrid systems, and 9 smart systems. Data collected for each fixture included the minimum, maximum, and average (mean) cost estimate on a per fixture basis.

Per fixture costs were estimated using two prototypical office buildings: 40,000 square foot office building for clever systems and a 100,000 square foot office building for smart systems. The difference in estimated building size is due to the distinct applications between the two systems: clever systems are primarily intended for smaller office buildings that do not have dedicated facilities managers and are less likely to purchase a more expensive smart system, while smart systems are typically purchased by large organizations seeking to leverage the data collected by the lighting controls system for a variety of Internet of Things (IoT) use cases such as space utilization, asset tracking and energy monitoring. Table 5 and Table 6 provide an overview of the assumptions used to calculate costs for the building prototypes.

Labor estimates were based on a 2015 LBNL study, which found values ranging from $30 to $100/hr. Based on LBNL's study, this report assumes labor rates of $50/hr. and $100/hr. for programming clever and smart systems, respectively. The $50/hr. rate for clever systems reflects their ability to be programmed by facilities managers or contractors, while the smart systems typically require programming by manufacturers or manufacturer's representatives. The assumption that LLLC systems operate for 5 years is derived from the Design Lights Consortium's (DLC) requirement that LED luminaires and networked lighting controls must have a minimum warranty of 5 years. The estimated operational lifetime is reflected in ongoing annual fees, applicable to some smart systems. Total building costs were divided by the assumed total number of fixtures to calculate per fixture cost estimates.

Table 5. Building prototype, installation, and labor assumptions (clever).

Value	Meaning	Source
40,000	Square feet of lit space	Input
85	Square feet / fixture	LBNL 2015
471	Fixtures / building	Calculated
5	Years of Operation	DLC QPL Requirements
$50	Hourly rate for programming	LBNL 2015

Table 6. Building prototype, installation, and labor assumptions (smart).

Value	Meaning	Source
100,000	Square feet of lit space	Input
85	Square feet / fixture	LBNL 2015
1,176	Fixtures / building	Calculated
5	Years of Operation	DLC QPL Requirements
$100	Hourly rate for programming	LBNL 2015

3. Results

This section details the study findings of incremental cost for both clever and smart systems.

Incremental Cost of Clever LLLC systems

The average total incremental cost for clever systems is $53 per fixture, with a range from $43 to $63. The average incremental fixture cost (controls adder) for adding clever controls to a fixture is $52, which represents only 26% of the total luminaire + controls cost, where the 74% remaining is attributed to the luminaire itself. In comparison, the average incremental fixture cost for clever-hybrid systems was $66, representing 29% of the total luminaire + controls cost. Despite this difference in incremental fixture cost, the luminaire + controls cost for clever and clever-hybrid systems is very similar, $207 and $220 respectively. Therefore, the average incremental fixture cost for adding controls is 27% larger for clever-hybrid systems, but the luminaires + controls cost is only 6% larger for clever-hybrid system.

As expected, programming is a small fraction (2% for clever and 3% for clever-hybrid) of total project cost due to the relatively straightforward process. See average costs for components of clever systems in Table 7 and incremental per fixture cost breakdown for the 40,000 sq. ft. office building prototype in Figure 2 below.

Table 7. Per Fixture Cost of the clever LLLC Products, including cost breakdown and variability.

	Average	Min	Max	Systems w/ Component
Cost Components				
Incremental Fixture Costs ($/fixture)	$52	$43	$60	4
Programming cost ($/node)	$1	$0	$3	4
Average Per-Fixture Costs				
Incremental Fixture Cost	$52	$43	$60	4
Gateway Cost	$0	$0	$0	0
Server Cost	$0	$0	$0	0
Programming Cost	$1	$0	$3	4
Required Ongoing Costs	$0	$0	$0	1
Total Incremental Cost	$53	$43	$63	4
Project Costs				
Startup cost - 40,000 sq. ft. building	$94,422	$64,765	$122,460	4
Startup cost (per sq. ft.)	$2	$2	$3	4

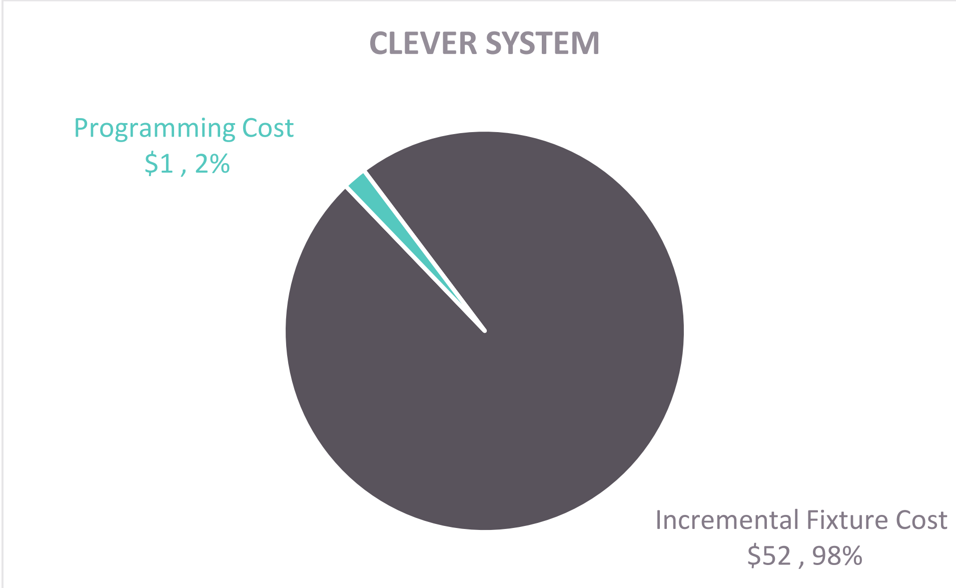

Figure 2. The cost breakdown of clever LLLC systems on a per-fixture basis.

The average total incremental cost of clever-hybrid systems was $75, with a range from $42 to $155. Clever-hybrid systems differ from clever systems due to their additional programming fees, gateway, and server costs. Programming and gateway costs vary significantly depending on the brand of the system. This is true for both cases where programming costs apply for clever-hybrid and smart systems.

The clever-hybrid programming cost estimates vary significantly, from $0-6/node, where the average clever-hybrid programming fee is $2/node. Programming fees may vary due to variation in configuration tool user-friendliness and contractor familiarity with the system.

The average clever-hybrid gateway cost collected was $729, where the minimum gateway cost was $230, and the maximum was $3,200. The variation in gateway cost is loosely dependent on the number of gateways required for the system. This ranged from 1-7 gateways for a 40,000 sq. ft. building, where the projects that required fewer gateways had more expensive gateway costs. The overall gateway cost for a 40,000 sq. ft. building averaged $1750, ranging from $1000 to $3200.

Table 8 below summarizes the clever-hybrid system cost estimates collected, including both the cost of components and overall project fees. Additionally, Figure 3 describes the incremental per fixture cost breakdown for the prototype 40,000 sq. ft. office building with fixture integrated LLLC.

Table 8. Per Fixture Cost Estimates of the clever-hybrid LLLC products, including cost breakdown and variability. Note that because systems are sold as a package, the total minimum or maximum cost of each incremental component may not add up to the total minimum quote provided by an individual market actor.

	Average	Min	Max	Systems w/ Component
Cost Components				
Incremental Fixture Costs ($/fixture)	$66	$35	$130	7
Programming Cost ($/node)	$2	$0	$6	7
Gateway Cost ($/gateway)	$729	$230	$3,200	7
Server Cost ($/server)	$3,233	$2,200	$5,000	3
Average Per-Fixture Costs				
Incremental Fixture Cost	$66	$35	$130	7
Gateway Cost	$4	$2	$7	7
Server Cost	$3	$5	$11	3
Programming Cost	$2	$0	$6	7
Required Ongoing Costs	$0	$0	$1	2
Total Incremental Cost	$75	$42	$155	7
Project Costs				
Startup cost - 40,000 sq. ft. building	$110,373	$46,602	$211,002	7
Product lifetime ongoing costs	$1,485	$0	$2,970	2
Startup cost (per sq. ft.)	$3	$1	$5	7

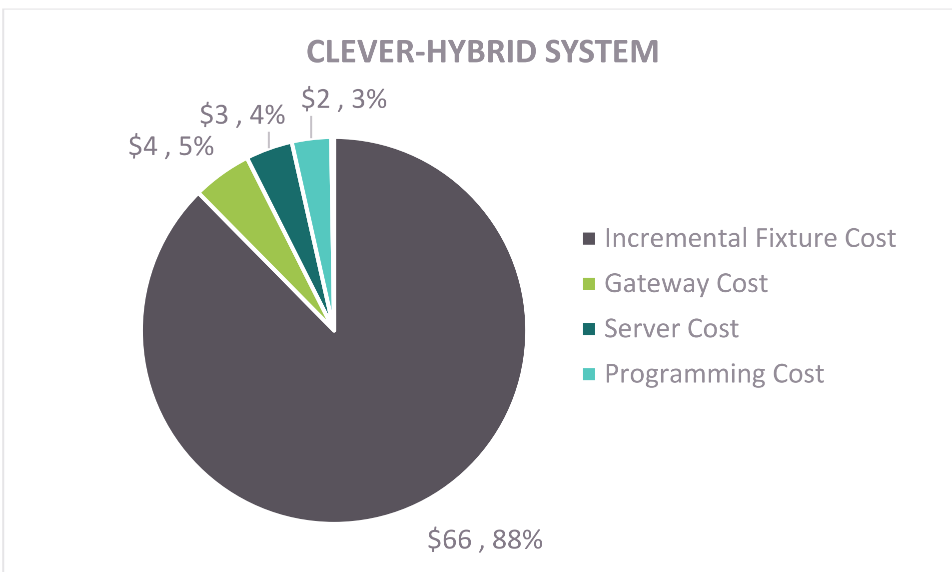

Figure 3 The incremental cost breakdown of clever-hybrid LLLC systems on a per-fixture basis.

Incremental cost of Smart LLLC systems

The incremental cost for smart systems was roughly $136 per fixture, with a range from $104 to $230. This wide variation is likely due to the differentiation in services that these various smart systems provide, as well as contractor familiarity and installation volume, and the fact that these are quoted prices rather than an actual project bid.

Due to their increased complexity, smart systems contain additional cost components such as gateway costs and ongoing costs that are typically not present in clever systems. The incremental fixture costs were more than twice as large for smart systems ($136) as clever systems ($53), but clever hybrid systems fell between the two price points ($75), closer to the clever systems cost. The main driver of difference in cost is that smart systems often require additional components to clever systems, including gateways, servers or hosting fees, and additional programming. As expected, programming time for smart systems varies widely. The average programming cost is $9/node but can be more accurately described by two main cost buckets: one third of data points collected suggest programming fees of ~$20/node whereas the remaining two thirds of smart systems data suggests only ~$3/node. Programming fees for smart systems vary significantly in form. Some programming is performed by a contractor on an hourly rate, while other programming may be performed by a manufacturers' in-house field team for a much larger fixed price, which includes a guarantee of programming quality and often also includes support services in the cost.

Smart system gateways cost an average of $607 but vary significantly from a minimum of $125 to a maximum of $2,200. An average of 13 gateways are required for a 100,000 sq. ft. building, ranging from a minimum of 6 to a maximum of 24.

Table 9 below describes the cost components and project overall cost for a smart system installed in a 100,000 sq. ft. building and Figure 4 represents the incremental per fixture cost breakdown for the 100,000 sq. ft. office building prototype.

Table 9. Per Fixture Cost Estimates of the smart systems with fixture integrated LLLC products, including cost breakdown and variability. Note that because systems are sold as a package, the total minimum or maximum cost of each incremental component may not add up to the total minimum quote provided by an individual market actor.

	Average	Min	Max	Systems w/ Component
Cost Components				
Incremental Fixture Costs ($/fixture)	$118	$100	$210	9
Programming cost ($/node)	$9	$1	$25	9
Gateway cost ($/gateway)	$607	$125	$2,200	9
Server cost ($/server)	$4,786	$0	$11,000	7
Average Per-Fixture Costs				
Incremental Fixture Cost	$118	$100	$210	7
Gateway Cost	$6	$2	$11	9
Server Cost	$3	$0	$4	7
Programming Cost	$9	$3	$5	9
Required Ongoing Costs	$1	$0	$0	2
Total Incremental Cost	$136	$105	$230	9
Project Costs				
Startup cost - 100,000 sq. ft. building	$334,355	$276,631	$532,505	9
Product lifetime ongoing costs	$17,200	$0	$0	2
Startup cost (per sq. ft.)	$4	$3	$5	9

Note: The cost of the gateway per fixture is calculated by multiplying the cost of the gateway by the number of gateways required per fixture.

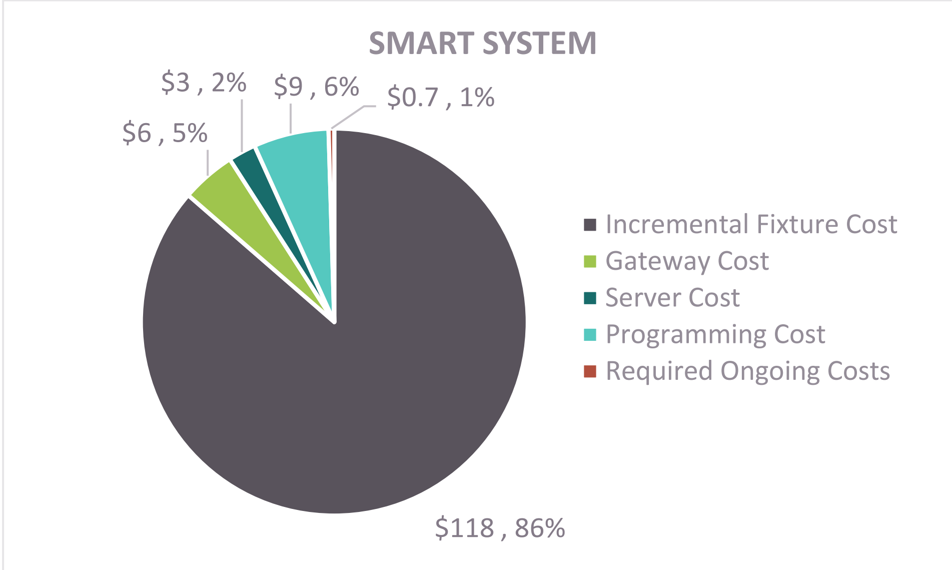

Figure 4 The per fixture cost break down of smart systems with fixture integrated LLLC's.

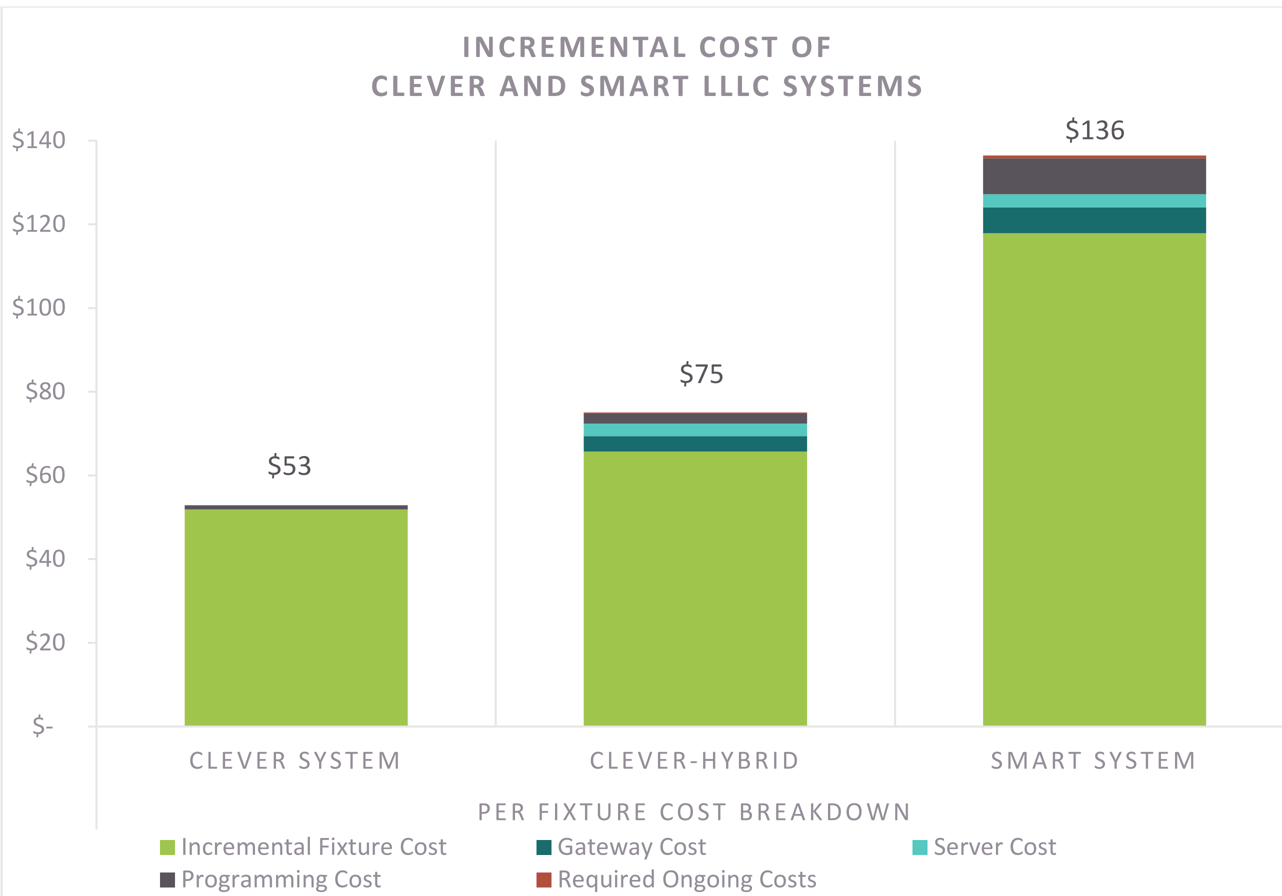

Figure 5 Overall cost breakdown of clever, clever-hybrid and smart systems on a per-fixture basis.

4. Comparison to Previous Work

To track the progress of the luminaire market in terms of LLLC cost and integration, the results of this study were compared to those from a previous study conducted in Q3 2017. The 2017 study focused on characterizing the programming, one-time/ongoing costs, gateway and incremental fixture costs for two categories, “clever” and “smart” systems. The 2017 study gathered 21 price estimates for each cost component (11 for clever and 10 for smart systems) using interviews with 7 manufacturers, 3 manufacturers reps, and 4 contractors as well as anonymized distributor pricing data from the Cadeo Group based on 4 distributor interviews they performed on behalf of NEEA. The 2017 study focused primarily on segmenting LLLC products into two overarching categories based on their differing features sets and price points, nominally called “clever” and “smart” systems.

The 2017 study found an average incremental cost of $68 for clever systems and $107 for smart systems. The 2017 study did not explicitly separate clever and clever-hybrid systems for the analysis, so clever and clever-hybrid 2018 results are averaged for the sake of this 2017 to 2018 study comparison. Additionally, the 2017 study did not characterize server cost, so the server cost has been removed from the below 2018 estimates for more accurate comparison. The combined clever and clever-hybrid average incremental cost in the 2018 study was $65, ranging from $37 to $144. Additionally, the smart system incremental cost from this year’s study was $133. Therefore, the combined clever system incremental cost decreased slightly by 4% and the smart system incremental cost increased by 24% as shown in Table 10 below. This shift in price point may be due to split priorities in the controls market: a focus on creating the most economical and approachable controls solutions in the clever system market vs. an effort to create a system with the most functionality and software ease of use in the smart system market.

Table 10. Incremental Cost (per fixture) for clever and clever-hybrid combined (clever combined) systems and smart systems in 2017 and 2018, as well as percent change from 2017 to 2018.

Incremental Cost (per fixture)					
Year	**2017**	**2018**			**Percent Change**
System	Average	Average	Min	Max	Average
Clever combined	$68	$65	$37	$144	-4%
Smart	$107	$133	$105	$226	24%

5. Next Steps

To further refine these cost estimates, it is suggested to further investigate incremental costs by obtaining additional data from contractors (improving customer pricing accuracy) and obtaining data from actual project invoices (which tend to be lower than the bid estimates collected from general estimates due to their competitive nature). However, this type of project cost data is typically difficult to obtain unless projects participate in utility incentive programs.

Additionally, the 2018 study did not explicitly address external sensors, switch costs, and other system-specific widgets. An additional study may explore the costs associated with this auxiliary hardware as well.

An additional study is recommended for 2019 as clever, clever-hybrid, and smart product categories continue to mature and the product value propositions are refined.

Appendix

See accompanying Excel spreadsheet for:

- All cost estimates from literature review and interviews
- Details on interviewees and the information they provided
- Calculation of average per component costs
- Calculation of per building costs
- Calculation of per fixture costs