U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

NEWLY INITIATED PROJECT:

The State of Connected Lighting

Potential Ways IoT Lighting Can Solve Everyday Problems[1]					
Retail	Healthcare	Offices	Transport	Outdoor	Leisure
Find products	Find equipment	Space utilization	Find parking	Monitor air quality	Test emergency lighting
Deliver promotions	Detect lines	Prioritize maintenance	Find wheelchairs	Monitor gunfire	Info in museums
Gamification	Monitor elderly/frail	Manage space	Detect suspicious cars	Weather	Guest rooms
Track customers	Wayfinding	Personalize space	Manage traffic	Maintenance	Shopping
Assist with shopping	Reduce theft	Deliver communications	Person detection	Site management	Space comfort

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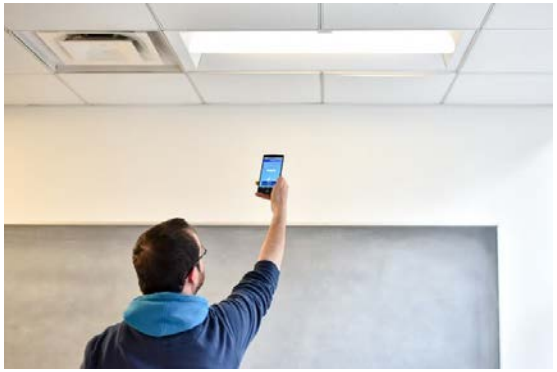


Project Summary

Timeline:

Start date: January 2018

Planned end date: September 2018

Key Milestones

1. Literature review: February 2018
2. Product matrix report: March 2018
3. Final report(s) of findings: September 2018

Key Partners:

U.S. General Services Administration (GSA) Proving Ground Program
Better Buildings Program Partners
Interior Lighting Campaign Partners

Budget:

Total Project $ to Date:

- DOE: $100K
- Cost Share: $N/A

Total Project $:

- DOE: $200K
- Cost Share: $N/A

Project Outcome:

Focus: Define capabilities of existing sensors and connectivity modules [needed for Internet of Things (IoT)], and how they are currently installed or upgraded in interior lighting fixtures in order to identify current capabilities, drawbacks and gaps, and technical/market barriers.

Driving Adoption of Technology Solutions [Multi-Year Program Plan (MYPP)]: *This supports CBI MYPP goal #3 - Prove with market leaders that, by 2020, it is possible to cost-effectively reduce average energy use in commercial buildings by at least 25% relative to 2010 levels.* This project helps determine if IoT lighting is a cost-effective energy saving solution in commercial buildings. Once we have an understanding about the state of the art and the state of the market for IoT lighting, we can focus on developing and validating its integration and other energy savings benefits.

Team

Linda Sandahl, Program Manager
28 Years PNNL experience. Successful track record in managing technology introduction projects and stakeholder engagement activities

Felipe Leon, Task Lead
4 years PNNL experience. Lighting Engineer with private sector product management and lighting product development experience

Michael Myer, Technical Guidance
11 years PNNL experience. Research expertise in SSL, daylighting, lighting controls, and codes & standards

Karsten Kelly, Research Support
2 years PNNL experience. 20 years of commercial hardware and software development, and system component testing

Resources/Synergies

DOE Solid-State Lighting (SSL) research and development team

- Connected Lighting Test Bed

Interior Lighting Campaign (ILC) supporters and participants

Federal Sector

- U.S. GSA Proving Ground
- Environmental Security Technology Certification Program

IoT Ready Alliance™

Illuminating Engineering Society

Challenge

≈20% electricity[2]

<$4 / ft^2 new construction[3,4]

Most equipment / ft^2

Problem Definition: IoT lighting has the potential to save significant energy in buildings, however the market is emerging and there is much uncertainty/questions surrounding current and expected IoT lighting capabilities and applications, including:

- High cost / monetization of IoT
- Sensor interchange
- Future proofing
- Legacy sensors
- Communication with other systems
- Cyber security

Solution: *Conduct analysis of lighting and IoT market to better understand the opportunities and address the barriers.*

IoT Lighting Applications and Potential

Analysis of Elements in a Building and IoT Support Suitability				
Building System	Power Available	Physical Platform for Sensor	Density Within Space	Coverage
Lighting	**Yes**	**Yes**	**High**	**Great**
HVAC	No	Yes	Low	Low
Electrical Receptacles	Yes	Yes	Medium	Low
Glazing	No	No	Low	Low
Doors	No	Yes	Low	Low
Furniture	No	Yes	Medium	Moderate
Stand-alone sensors	No	Yes	TBD	TBD

Potential Areas of Research

- ROI
- Security
- Data management
- Workforce Issues

Alternate Approaches

Stand-alone IoT devices

Approach

First stage – landscape assessment:

- Review literature (surveys, applications, issues)
- Review commercially available product listings (mostly internet searches)
- Engage in lighting IoT activities (IoT Ready Alliance, Illuminating Engineering Society) to learn from industry leaders
- Identify gaps in knowledge (products, applications)
- **STATUS: Complete - Document out for external review**

Second stage – manufacturer & end user interviews:

- Assess how issues (e.g., security, ROI, future proof) are being addressed (or level of concern)
- Fill in gaps in knowledge from the literature review (e.g. specialized products, future sensors/applications) to assist with informing manufacturers, product developers, and users
- **STATUS: In progress – compiling list and making connections**

Future work:

- Conduct lab testing for functionality and energy (savings/use) – included in core lab call proposal
- **STATUS: Designing future work**

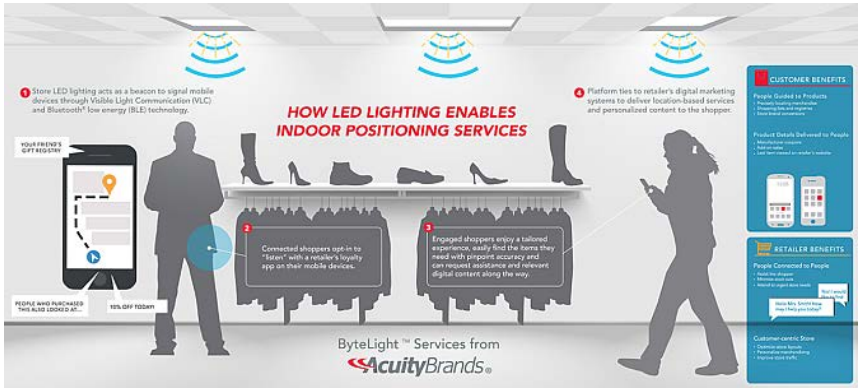
Progress and Remaining Work (early stage research)

Type	Milestone/Deliverable Progress	Due Date	Status
Literature Review	Scoping Research objectives defined; literature review complete and existing information clearly and concisely outlined to initiate future research	1/22/18	Complete
Product Matrix Outline	Identify and document key IoT products/solutions in lighting, focusing on sensors and connectivity modules; determine gaps	2/9/18	Complete
Draft Report	Deliver draft report *Internet of Things Capabilities Research: Literature Review and Product Matrix*, including product matrix, and existing gaps in knowledge to DOE and Inter-laboratory Working Group	3/22/18	Complete
Email	Draft list of key research questions for manufacturer and end user interviews submitted to DOE	5/18/18	
Data	Complete manufacturer Interviews: Coordinate with SSL team to identify manufacturer questions based on literature review and product matrix, and conduct manufacturer interviews	7/15/18	
Data	Complete User Interviews: Coordinate with Better Buildings Alliance members and others interested in IoT lighting solutions	8/15/18	
Draft Report	Supplement the draft IoT report with manufacturer and end user interviews. Report will be relevant to both manufacturers and end-users	9/13/18	
Final Report	Final Report for publication. Informs additional R&D	3 weeks following DOE feedback	
Email	Recommended next steps for IoT lighting research delivered to DOE	10/26/18	

Approach: Products and Applications

Review Industry Press / Products[5,6]

Review Applications / Benefits



Manufacturer Interviews

enlighted

current powered by GE

signify

LUTRON

AcuityBrands.

GOOEE

End-User Interviews

- Interior Lighting Campaign supporters
- Better Buildings Alliance members
- Targeted users (e.g., Target)

Approach: Products and Applications

Literature Review:

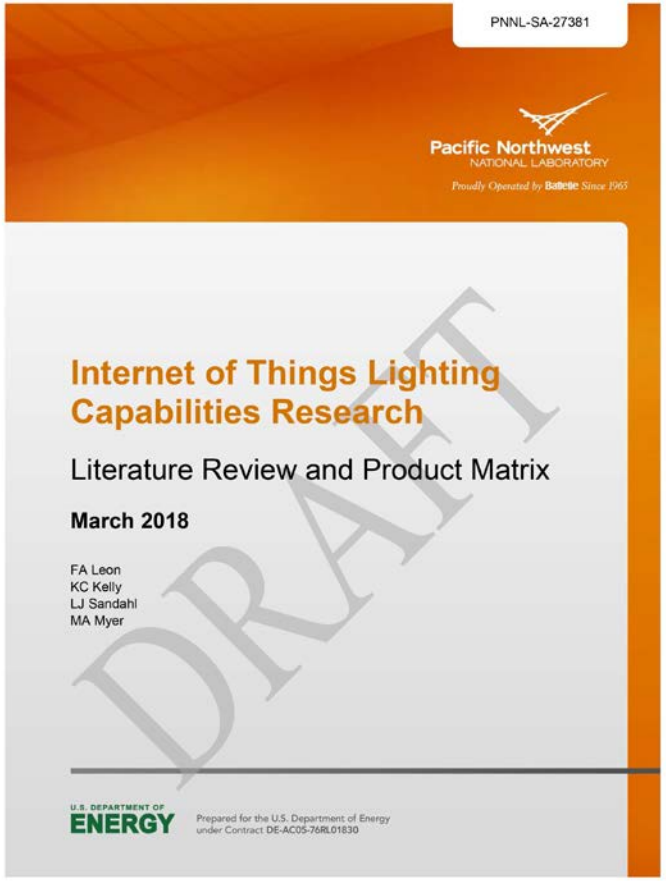
- Sources: trade press, industry websites, presentations and webinars, reports, and conference papers
- General areas encountered – products, applications, capabilities, and concerns (e.g., security, privacy)
- Typical cost information

Product Matrix (primarily from product literature):

- Sensors, modules, and applications/services
- What connectivity protocols offered?
- What encryption specified in data sheets?
- What control features / types of sensors offered?
- What is the power source for sensor? What is the power draw?
- Alternate (non-lighting) approaches

Interviews (to be completed):

- Identify gaps in knowledge
- What technology being used that we did not encounter?
- What are the connectivity methods post install?
- Why not moving beyond legacy sensors?
- What are the approaches taken?
- How do specifiers create competitive bids?



Progress – Key Literature Review and Product Matrix Findings

Sensors

Manufacturer	Product Code	Installation	Motion	Photosensor	Other	Tunable White	Bluetooth / Zigbee / WiFi / Wired / Other
Enlighted	SU-4E-01	In / On Fixture, ceiling tile	Digital PIR	Light Pipe / Photosensor Array	Temperature	Yes	BLE 4.0
Eaton	LumaWatt Pro	In / On Fixture	Digital PIR	Light Pipe / Photosensor Array	Temperature		BLE 4.0 and Wired
Acuity	nLight AIR rES7	In / On Fixture	Digital PIR	Photosensor			BLE 4.0 and 802.15.4
Helvar	Active+ Sense	In/On Fixture	PIR	Photocell			
Intelligent Lumen	Intelligent Sensor Buildings	In / On Fixture	PIR	Photocell	Temperature		BLE and 802.15.4

Controllers / Gateways

Manufacturer	Product Code	Installation	Ballast / Driver Control	Dimming	Bluetooth / Zigbee / WiFi / Wired / Other
Gooee	SR / DALI Dongle	In Fixture	Phillips SR DALI	DALI	BLE Mesh
Douglas Lighting Controls	Bluetooth Fixture Controller and Sensor	In / On Fixture	Relay	0-10V	BLE Mesh
RAB	Lightcloud Controller	In / On Fixture	Relay	0-10V	2.4GHz Mesh (unknown)
Hubbell	PowerHUBB Node	In / On Fixture			PoE
Eaton	WaveLinx Relay Switchpack	In / On Fixture	Relay	0-10V	Zigbee

Applications

Manufacturer	Product Code	Device Support	Browser Support	Local / Cloud	Energy Mgmt	Indoor Positioning	Space Utilization	Asset Tracking	Other	SDK	API
Acuity	Atrius Navigator	Phone	No	Cloud	No	Yes	No	No		Yes	
Acuity	Atrius Spaces		Yes	Cloud			Yes				
Molex	Transcend Lighting Management System				Yes		Yes				
Enlighted	IoT Platform			Mixed	Yes	Yes	Yes	Yes	HVAC		
Cree	SmartCast Manager	PC, Tablet		Mixed	Yes	No	No	No	Color Tuning		Yes

Initial Findings

Sensors:

- Most sensors utilizing passive-infrared (PIR) for motion / occupant detection
  - PIR is a legacy sensor
  - Few utilizing new sensor technologies for motion / occupancy

Products:

- Many made-to-order / possible vaporware?
- Alternate (non-lighting) approaches
- Outdoor market seems more standardized and advanced than interior market

Connectivity:

- Common connectivity (in ranked order):
  - Bluetooth / BLE / mesh most common
  - 802.15.4
  - Wired, PoE
  - Zigbee

Market Speed:

- Companies are quickly buying new products and developing new sensors

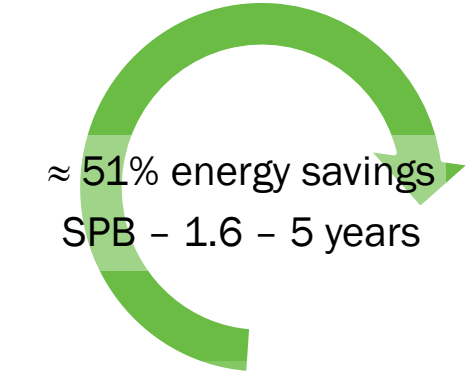
Draft Research Questions (based on initial findings):

- What are the sensing technologies of the future to enable enhanced functionality in lighting products?
- What energy benefits can be realized through new, or more precise, sensing technologies?
- To what degree can an IoT socket-in-the-sky infrastructure speed up the adoption of high efficiency luminaires (i.e., the upgrade of the luminaire is no longer simply an investment in energy savings, but rather an investment in future capabilities)?
- If lighting will become the platform for IoT integration into the building, what is your vision of the platform?
- Are IoT devices and sensors incorporating BACnet into connectivity?
- How are the IoT devices interacting with other building systems?
- How to handle IoT device energy usage? Always in standby ? Always drawing full power?

Initial Findings

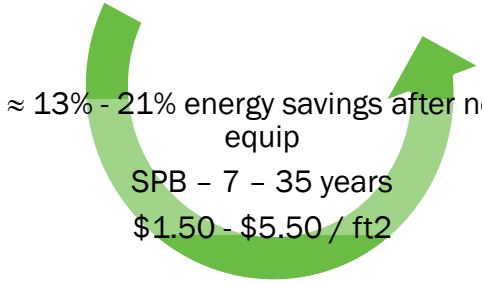
Data from Field Evaluations[7,8]						
	Site	Equipment Savings	Controls Savings	Total	Cost/ ft²	SPB (years)
Field Evaluations	Manufacturing	50%	16%	66%	$1.54	7
	Office	64%	3%	67%	$5.72	15
	Medical Office	29%	33	62%	$3.03	7
	Retail	30%	36%	66%	$0.80	7
	Office	43%	27%	70%	$4.66	13
GPG Field Evaluations	Zone 3	18%	31%	49%	$4.61	39
	Zone 4	58%	19%	77%	$5.04	40
	Zone 5	50%	29%	79%	$5.71	26
	Zone 6	35%	29%	66%	$5.30	38
	Zone 7	46%	10%	56%	$6.62	35
	Entire Site	41%	21%	62%	$5.47	35

Analysis for a 5-Year SPB[8]			
Pre LPD	Post LPD	Rate	Cost/ft²
1.00	0.48	$0.07	$0.62
2.50	0.48	$0.07	$1.99
1.00	0.48	$0.13	$1.15
2.50	0.48	$0.13	$3.69



New Equipment

Lighting Controls



IoT

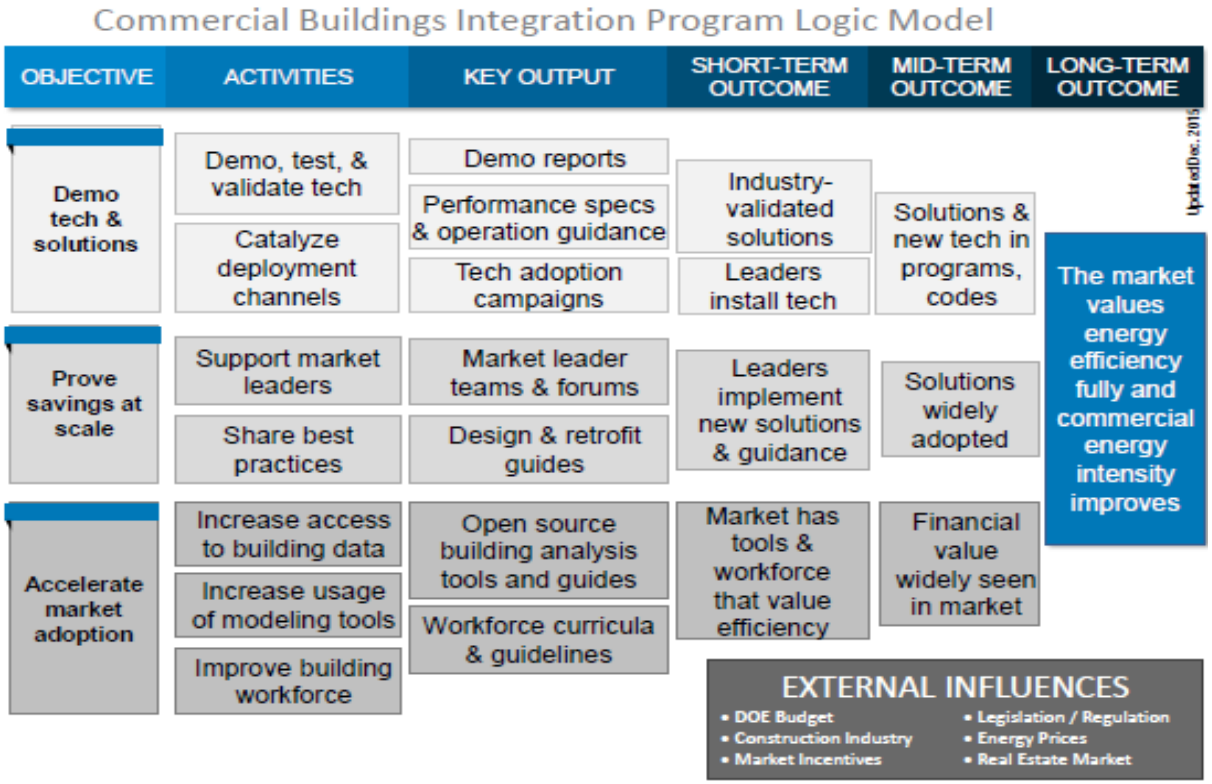
Impact

Contribution to Energy Efficiency:

- Add efficiency gains by moving to LED systems since its not just collateral savings
- IoT-enabled lighting applications offer collateral energy savings potential:
  - Integration into HVAC (5-20% savings)
  - Space utilization efficiencies (savings are not well documented, but they are real)

Contribution to BTO Goals:

- **MYPP Goal: #3 -** *Prove with market leaders that, by 2020, it is possible to cost-effectively reduce average energy use in commercial buildings by at least 25% relative to 2010 levels.*



Stakeholder Engagement

Key stakeholders include manufacturers of IoT and building owners/managers

- Interior Lighting Campaign participants/supporters
  - 169 supporting organizations (lighting manufacturers, ESCOs, energy efficiency organizations and others who support high efficiency lighting. We have contacts with these groups and can engage them in discussions.
  - 74 participants who own or manage facilities that have or are planning high efficiency lighting system upgrades. We engage them to learn about their experiences.
- Better Buildings Alliance Lighting and Electrical Technology Research Team members
  - Periodic teleconferences and webinars with large building owner/managers who are interested in high efficiency lighting technology
- Participate in standards and related activities
  - IoT Ready Alliance
  - Illumination Engineering Society (e.g., 2016 Strategic Research Plan[10])
  - NEMA

Future research expected to include laboratory and field testing evaluations which will include increased involvement from building owners/managers, utilities, and manufacturers

Remaining Work: IoT Integration and Use Investigations

- Gather data about sensors/devices (in process), including connection methods
- Study interchangeability between various IoT devices/components and lighting equipment
- Study solutions for easier IoT device installation into fixtures
  - Draw on other programs / field evaluations as well
- Study compatibility of current sensor performance to proposed IoT

Socket

J-Box

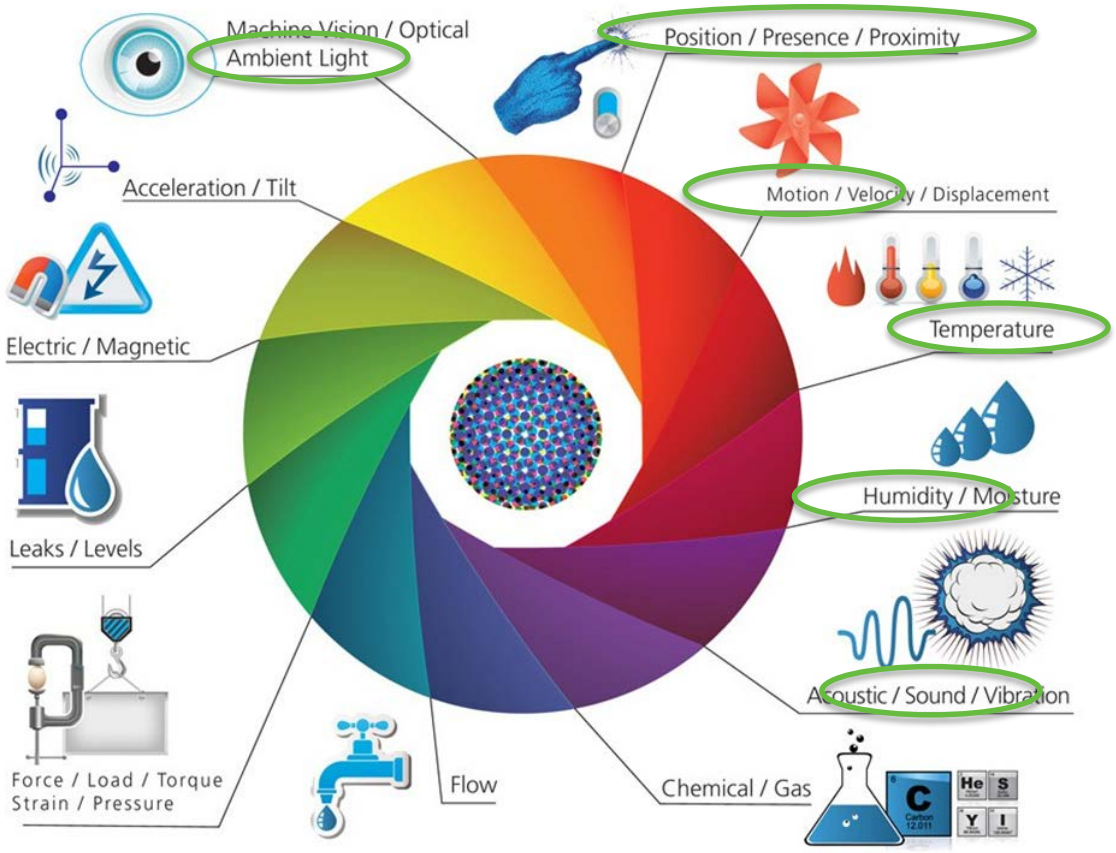
NEMA 7-pin

Cellphones

USB

Thank You

IoT Sensor Technologies[11]



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Reference Slides

1. 30 ways IoT lighting can solve everyday problems (*Lux Guide to Lighting*) < http://luxreview.com/article/2017/10/30-ways-iot-lighting-can-solve-everyday-problems>
2. Trends in Lighting Commercial Buildings. EIA. CBECS 2012 < https://www.eia.gov/consumption/commercial/reports/2012/lighting/>
3. RS Means Electrical Cost Data. 2016. 39th Edition
4. Wireless Advanced Lighting Controls Retrofit Demonstration. Lawrence Berkeley National Laboratory. <https://www.gsa.gov/cdnstatic/Wireless_Advanced_Lighting_Controls_Retrofit_Demo_FINAL-508-062915.pdf>
5. Image credit: Samsung
6. Image credit: Nedap
7. Compiled from case studies and draft report for DOE-sponsored field evaluations related advanced lighting controls
8. [DRAFT] Internal report for GSA about Fort Worth, TX facility
9. Internet of Things Lighting Capabilities Research [DRAFT] Pacific Northwest National Laboratory. 2018
10. http://media.ies.org/docs/research/IES_2016_Strategic_Research_Plan.pdf
11. Image credit: Postscapes and Harbor Research IoT Sensor Technologies < http://postscapes.com/what-exactly-is-the-internet-of-things-infographic/)

Project Budget

Project Budget: $200K
Variances: No variances
Cost to Date: $53K
Additional Funding: No additional funding sources

Budget History					
FY 2017 (past)		FY 2018 (current)		FY 2019 – (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
0	0	$100K	0	$100K	0

Project Plan and Schedule

Project Schedule												
Project Start: January 2018	Completed Work											
Projected End: September 2018	Active Task (in progress work)											
	Milestone/Deliverable (Originally Planned)											
	Milestone/Deliverable (Actual)											
	FY2018				FY2019				FY2020			
Task	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)
Past Work												
Deliverable: Workplan approved by DOE; quarterly updates												
Deliverable: Draft report - Internet of Things Capabilities Research: Literature Review and Product Matrix												
Current/Future Work												
Deliverable: Research questions for manufacturer and end user interviews delivered to DOE												
Milestone: Supplemental interviews complete												
Deliverable: Quarterly updates (go/no go)												
Deliverable: Final report complete												
Deliverable: Recommended next steps for IoT lighting research delivered to DOE												