Colorado Springs Smart Streetlights Pilot Project

February 2022

Panasonic

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Acronyms

AC – Alternating Current

AMI – Advanced Metering Infrastructure

The City – The City of Colorado Springs

ESCO – Energy Service Company

EV – Electric Vehicle

FC – Foot-candle

HID – High-Intensity Discharge

HPS – High Pressure Sodium

IoT – Internet of Things

LED – Light Emitting Diode

LG – Landis+Gyr

NIC – Network Interface Controller

NOAA – National Oceanic & Atmospheric Administration

NOC – Network Operations Center

O&M – Operations & Maintenance

QA – Quality Assurance

RTS – Return to service

SaaS – Software as a Service

SLA – Service Level Agreement

The team – Includes the City of Colorado Springs and Panasonic

VZ – Verizon

WAN – Wide Area Network

1. Executive Summary

The City of Colorado Springs ("The City") and Colorado Springs Utilities partnered with Panasonic (collectively, "the team") to test smart city technologies capable of integrating with streetlights owned by Colorado Springs Utilities. The team identified two priorities:

1. to pilot solutions that offer enhanced control of streetlights;
2. to pilot solutions that offer more granular measurement of snow accumulation and other weather-related information.

Streetlight Controllers

The City procured 50 streetlight controllers from Verizon, 40 streetlight controllers from Landis+Gyr, and each vendor's associated software platform to enable monitoring and controlling the streetlights. For these 90 streetlights, each vendor's software platform allowed the City to monitor the status of each streetlight luminaire, receive error notifications, set dimming schedules for energy savings, and more. The team found that the streetlight controllers and software platforms identified and notified the team of problems with the streetlights immediately, as those problems occurred. The team believes this ability could allow for improvements to streetlight crew response times for resolving those problems. The team also found that by applying dimming schedules, energy savings could be realized, anywhere from 1% - 51% compared to non-dimming LEDs. This energy savings percentage is based upon the pilot dimming schedule and other, more aggressive dimming schedule standards provided by the vendors which were not piloted.

Weather Stations

The City procured six weather stations from Campbell Scientific, as well as the Campbell Cloud data reporting dashboard. The weather stations were mounted on six different streetlight poles, one in each council district. All six of the weather stations included snow depth sensors, road temperature sensor, data loggers, battery backup, a weather enclosure, and mounting hardware. One of the weather stations included a solar panel and battery backup so that it could operate completely off-grid, and it also included a wind gauge and air temperature and relative humidity sensor. The remaining five weather stations were AC powered through the photocell power tap on the pole. The City found that data from the weather stations was comprehensive, but there were some inconsistencies as it relates to the use case that the City was exploring. Additional testing will be necessary before the City will determine whether or not to expand the weather sensor program.

2. Introduction: Smart Streetlighting & Smart Cities

2.1 Market Overview and Trends

In cities across the United States, there are over 41 million streetlights which serve a variety of purposes, including those outlined in Figure 1. As of 2020, approximately 45% of the streetlights across the country had been converted from the existing luminaires to LEDs. This conversion is largely due to decreasing LED fixture pricing, which may eventually reach price parity with non-LED fixtures according to a study by Northeast Group, see Figure 3 for more information. Decreasing HID manufacturing capacity will likely continue to place upward pricing pressure on legacy non-LED fixtures, a market that is primarily supported by entities owning large, established non-LED systems such as electric utilities and municipalities.

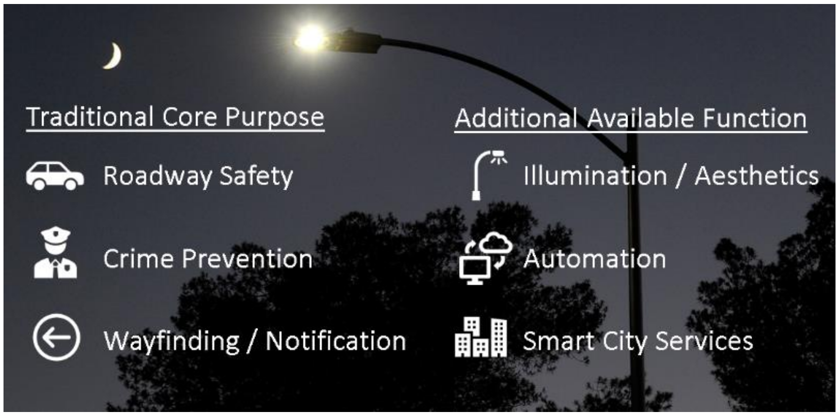


Figure 1. Functions of outdoor lighting

Figure 2. Benefits of LED

In addition to decreasing LED fixture pricing, other benefits of LED streetlights over non-LED streetlights, such as the benefits listed in Figure 2, have led municipalities to pursue LED conversions. Further, LEDs tend to have longer lifetimes, allow for better control of the lighting through the use of streetlight controllers, and provide a platform to facilitate the advancement of Internet of Things (IoT) technology as many of these IoT devices can plug into the top of LED fixtures or can be mounted to the streetlight riser pole. Given these enhanced community benefits, LED conversion will likely continue across the country, and could approach 100% of all streetlights over the next decade. See Figure 3 for general market pricing trends for LEDs and streetlight controllers.

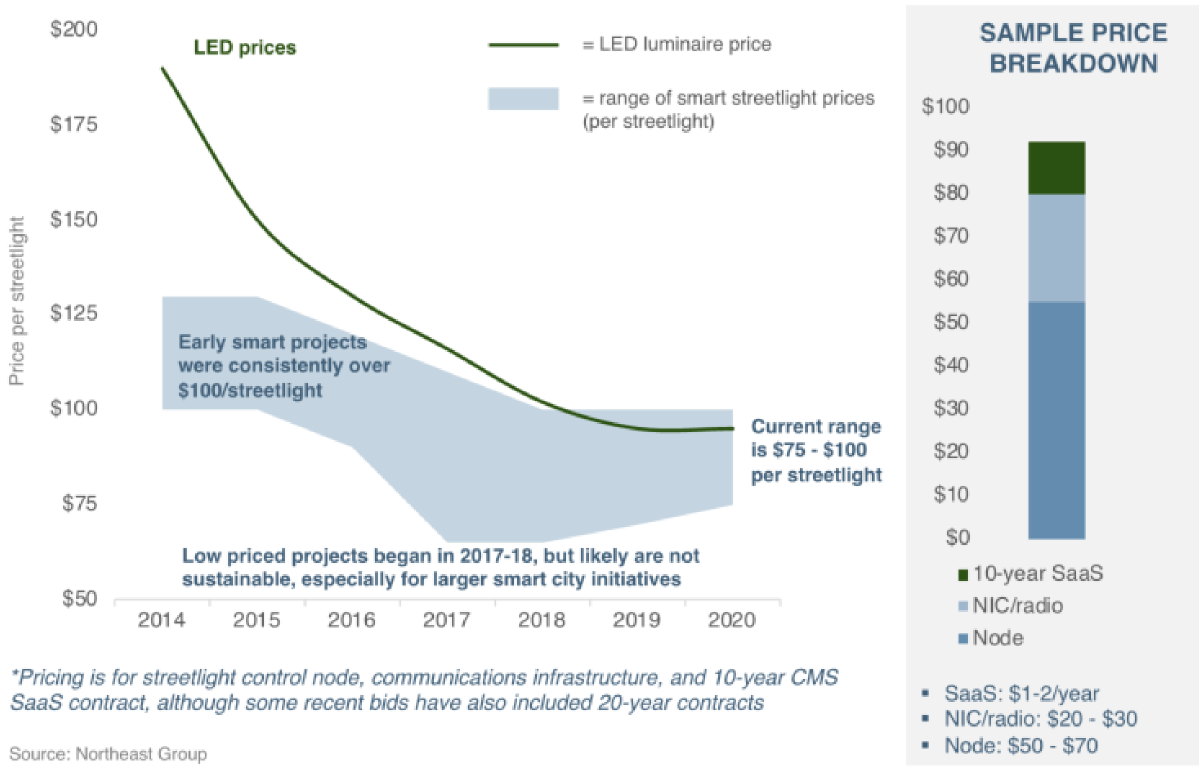


Figure 3. General market pricing for LED and controls. **Adapted from Northeast Group, LLC. (April 2020).** ***United States Smart Street Lighting & Smart Cities: Market Forecast (2020-2029), Vol. III.***

When evaluating the conversion of existing streetlights to LEDs, municipalities consider the payback period, or the time it will take to realize a return on investment, given the upfront cost of conversion compared to the yearly savings realized from reduced energy costs and reduced O&M costs. Payback periods typically range from four to 10 years depending on the energy and O&M savings. Many cities have achieved at least 50% energy savings, and sometimes up to 70% energy savings, by converting to LEDs. Those that have implemented streetlight controllers have typically seen an additional 10-20% in energy savings after implementing dimming schedules. Often, O&M savings exceed energy savings. Refer to Figure 4 for examples of energy savings and payback periods.

The jurisdictions shown in the "Energy Saving Examples" graph in Figure 4 realized an average of 66% savings through LED conversions, dimming, or both. In the case of the City, Colorado Springs Utilities owns the streetlight poles and offers a Cost of Service Study fee to the City. Given the methodology behind this fee calculation, it is unclear if energy savings from LED conversion and dimming schedules would result in direct cost savings for the City, and a deeper analysis of a large-scale LED streetlight conversion would need to be performed to verify ultimate savings that may result for the City.

The "Payback Period Examples" graph in Figure 4 shows several jurisdictions and the number of years it took to recoup their initial investment of LED conversion and controllers, with an average of less than seven years. The longer payback periods are often due to additional financing and overhead costs, sometimes associated with streetlight buybacks (i.e. when a city purchases the streetlights from a utility to gain ownership control of the system). Since the vast majority of cities do not own their streetlights, they are looking to buy back streetlights to lock in energy savings and increase revenue opportunities. In response, utilities are adding LED tariffs so cities can benefit from LED savings. Fortunately, a streetlight buyback scenario is not applicable and therefore would not impact the payback period in Colorado Springs since Colorado Springs Utilities owns the streetlights in the city.

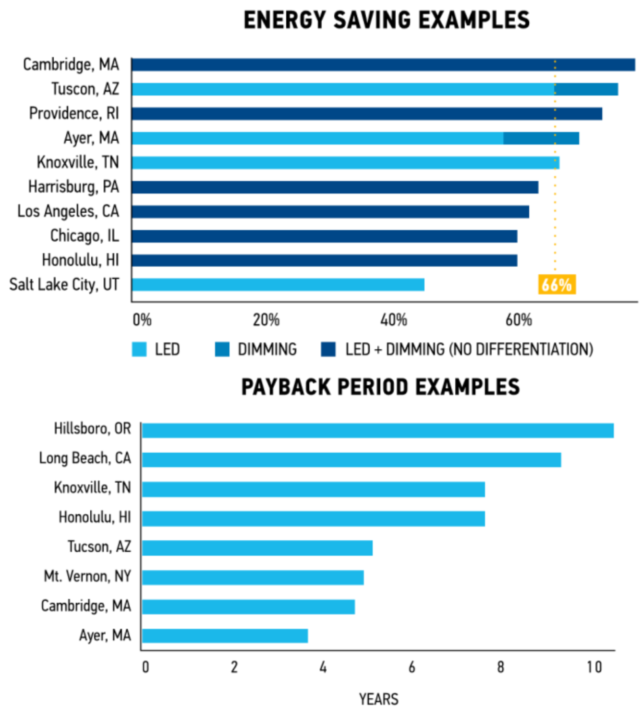


Figure 4. Municipal streetlight conversion examples - energy savings and payback. **Adapted from Northeast Group, LLC. (April 2020).** ***United States Smart Street Lighting & Smart Cities: Market Forecast (2020-2029), Vol. III.***

Other known qualitative benefits of LED conversion and adding streetlight controllers are shown in Figure 5. Streetlight controller benefits. These benefits are difficult to assign a monetary value to, but a rough estimate of $50 per controller has been included in the "Benefits" amount in Figure 6, which shows the 10-year cost benefit analysis for purchasing streetlight controllers.

Qualitative Benefits	Description
Improved safety and security	Better quality lighting and fewer burned out streetlights lead to lower crime rates and fewer traffic accidents
Fewer customer complaints	Customers no longer need to call in to report burned out streetlights (or day burning streetlights)
Environmental benefits	Fewer greenhouse gas emissions
Utility benefits	By adding nodes and communications to their rate base, utilities that own streetlights can earn a rate of return on the assets
Government rebates	Some rebates and grants may be available for energy saving projects
Additional smart city applications	Implementing network for smart streetlights can lay the groundwork for future smart city applications and reduce the cost of future applications (as network is already in place)

Figure 5. Streetlight controller benefits. **Adapted from Northeast Group, LLC. (April 2020).** ***United States Smart Street Lighting & Smart Cities: Market Forecast (2020-2029), Vol. III.***

The most efficient way to maximize payback would be to install the controller at the same time that the legacy fixture is replaced with an LED. With a current inventory of 27,055 streetlights in Colorado Springs, the team expects some installation costs would be incurred, but still believes the cost would be reduced from installing the controller while replacing legacy fixtures, rather than making two separate trips to the same streetlight. A rough estimate of $100 in cost savings is shown in the "Costs" amount in Figure 6.

Based on Figure 6, which shows the initial costs of streetlight controllers and the realized benefits seen in other cities, the team recognizes that the possibility exists for the benefits of the controllers to outweigh the costs. However, the team believes more cost benefit analysis is needed before confirming that the same cost benefit analysis would apply in Colorado Springs, see section 5 of this report for more information.

Figure 6. 10-year cost benefit analysis for streetlight controllers (per unit). **Adapted from Northeast Group, LLC. (April 2020).** ***United States Smart Street Lighting & Smart Cities: Market Forecast (2020-2029), Vol. III.***

Figure 7 outlines the costs, savings, and revenue opportunities other cities have realized by converting to LEDs and installing streetlight controllers. The team does not believe that all of these opportunities would be available in Colorado Springs based on current processes and structure of the streetlights system. For example, given the current inventory of streetlights in Colorado Springs, the team expects some controller installation costs would be incurred. Further, external smart city devices are not allowed on streetlights at this time, eliminating some of the revenue potential.

COSTS	SAVINGS	REVENUE
LED Luminaire: Currently averaging \$90-\$120 for 100W equivalent	**Energy:** Typically 50% or better from LED, plus additional 10-50% from controls	**Pole attachment fees:** Some smart city services will require sensor attachments to poles.
Streetlight node and comms network: Currently estimated at \$75-\$100 per streetlight (varies greatly based on network choice).	**O&M:** Fewer truck rolls to replace and monitor lights, fewer luminaire replacements, fewer customer service costs	**Services**: Selling smart city services to cities and other orgs. E.g. EV charging, pedestrian traffic counting, etc.
Installation: Cost of changing out luminaire (no additional cost if part of changeout schedule). No additional costs for installing controllers at same time.	**Avoided cost of HPS**: Over 20-year period, need to replace an HID 3x vs 1x for LED. LEDs anticipated to last 15+ years.	**Data**: Entities may be interested in purchasing data collected from smart city sensors. E.g. retailers purchasing foot traffic data.
Additional costs: One-off maintenance (pole adjustments, tree trimming), professional services, ESCO costs, etc.), debt servicing.	**Additional savings:** Improved safety and security, environmental benefits, etc.	

Figure 7. Costs, savings, and revenue opportunities for LED conversions. **Adapted from Northeast Group, LLC. (April 2020).** ***United States Smart Street Lighting & Smart Cities: Market Forecast (2020-2029), Vol. III.***

Many market data, projections, graphs, and insights in this section were provided by Northeast Group, LLC, "United States Smart Street Lighting & Smart Cities: Market Forecast (2020-2029) Vol. III." This study was produced from both primary and secondary research. Northeast Group researched all cities in the US with a population of over 100,000 (314 cities in total) to form the basis of its analysis. Northeast Group also conducted interviews with the majority of the leading smart streetlight communications and controls vendors. For both the survey and industry analysis, the authors conducted interviews with cities, municipalities, utilities, vendors, and state/federal government officials. Secondary research was conducted using a number of sources. Sample secondary sources included those from the US Department of Energy, publicly available utility and vendor reports, LED studies completed, press reports, and others. Northeast Group conducted a comprehensive analysis of the 314 largest cities in the US, with a combined population of nearly 95 million people, representing nearly 30% of the country's population. To date, this is the largest survey of its type to be conducted.

2.2 Smart City Applications

Streetlighting continues to be one of the most common entry points for smart city applications due to the ability to mount hardware on pole infrastructure ubiquitously located around a city, see Figure 8 for more examples of smart city applications involving streetlight attachments. Many streetlight controller vendors also offer a cellular connected smart city node that can be attached to the top of the streetlight, enabling communication for smart city applications. These nodes have integrated sensors for specific use cases, such as microphones, Bluetooth chips, or weather sensors. Smart city nodes that cannot attach to the top of the light are often able to be mounted on the streetlight riser pole.

Cities across the country are performing pilots utilizing these smart city nodes; emergency communication in Chicago, EV charging and small cell poles in Los Angeles, and parking monitoring in San Diego are just a few examples. Smart city hardware installations will likely move from pilot phases to larger scale deployments in the next decade as use cases and business models are proved out in the pilot projects. In addition, the rise of 5G small cell deployments has focused attention on attachment fees and highlighted the need for elegant device and pole integration.

The City and Colorado Springs Utilities have collectively identified several projects as part of the Smart Cities Strategy, a number of which are related to streetlights, such as the focus of this pilot, streetlight controllers and weather sensors.

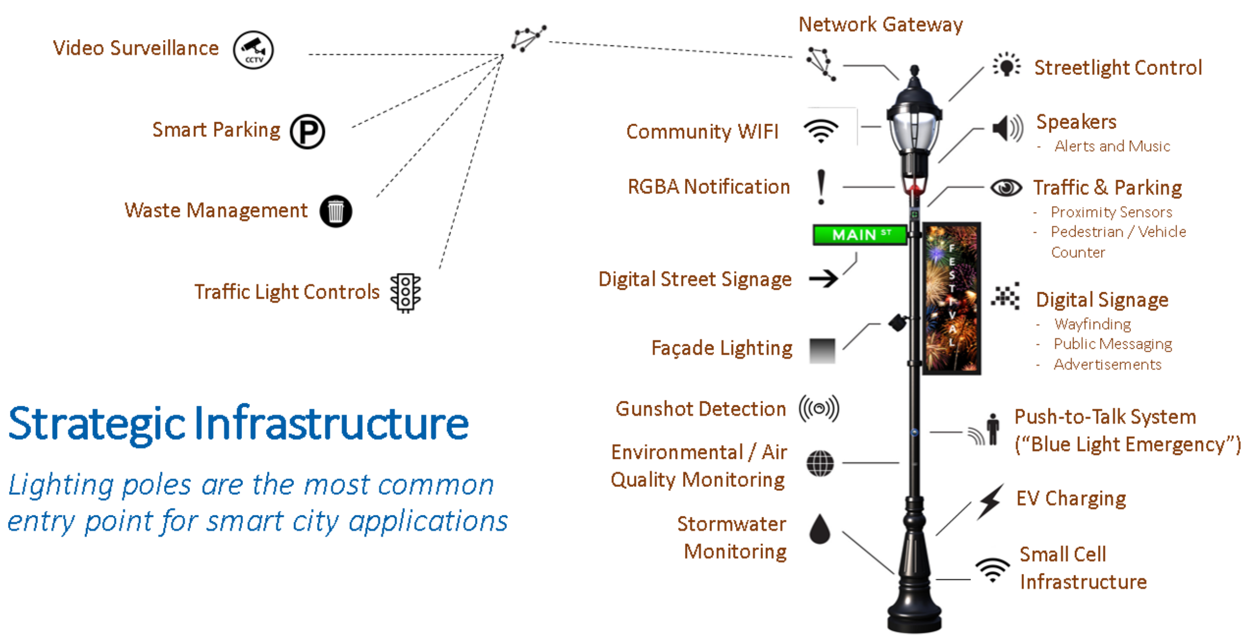


Figure 8. Examples of smart city applications

2.3 Existing Colorado Springs Streetlighting System

As of 2021, the Colorado Springs streetlighting system had 27,055 streetlights. Approximately 18% of the streetlights have been converted to LED (4,932), and the remaining 22,123 streetlights are non-LED. The streetlights are individually controlled by a photocell node on top of the light.

The City currently pays a fixed annual fee of $4,075,139 to Colorado Springs Utilities under a service level agreement (SLA) for operation and maintenance of the municipal lighting system. The SLA includes estimated productivity for the following:

1. ***Minor Maintenance****. On average, 4,216 streetlight components are replaced annually. Components include but are not limited to lamps, controllers, luminaires and fuses.*
2. ***Knockdowns****. On average, 246 streetlights are replaced annually due to third party damage.*
3. ***Feeds****. On average, 64 failed streetlight feeds are replaced annually. Aging infrastructure is reflected most in this category.*
4. ***Stolen Wire.*** *A maximum of 10% of the operations and maintenance budget is allocated to replacing stolen wire annually. There has not been any stolen wire in the last four years.*
5. ***New Lights in Previously Developed Areas*** *(Crime / Safety Lights). On average, 34 new lights are installed annually in previously developed areas and for public safety lighting. Lights in this category require approval from the City's Office of Innovation.*

As observed in cities across the country, Colorado Springs is currently converting all non-LED streetlights to LEDs, attaching smart cities devices and other equipment to streetlights, and encouraging co-location of small cells with streetlights.

Since 2018, Colorado Springs Utilities only purchases LED replacement fixtures and replaces all failed non-LED fixtures with LEDs. At this rate, the current estimated time until the entire streetlight inventory is converted to LED is between 10 and 15 years.

Colorado Springs Utilities currently allows municipal attachments to the streetlights. These attachments include smart city equipment procured by the Office of Innovation, parking optimization equipment from the City's Parking Enterprise, traffic operations equipment from the Public Works Department, and policing devices procured by Colorado Springs Police Department. All attachments are reviewed and approved by Colorado Springs Utilities prior to attachment to the poles.

The City and Colorado Springs Utilities collaborated on a small cell master license agreement and associated small cell design standards to regulate co-located small cells and streetlights.

3. Streetlight Controller Pilot Results

The City procured streetlight controllers from Verizon (VZ) and from Landis+Gyr (LG), as well as each vendor's associated software platform which enables monitoring and controlling of the streetlights.

3.1 Verizon Overview

VZ provided 50 streetlight controllers, project management services, implementation and provisioning services, and a one-year software subscription to their NetSense streetlight control platform. The total costs are shown in Figure 9.

Non-Recurring Charges		
SKU	Description	QTY
S80-000123	LIGHT SENSE 4G LTE 0-10V NEMA 120-277V	50
Total Non-Recurring Charges	$ 5,000.00	

Non-Recurring Services		
SKU	Description	QTY
IL-VES-PS-IE	Intel Lighting - Implementation Eng	8
IL-VES-PS-PM	Intel Lighting - Project Mgmt	4
IL-VES-PS-PROV	Light Sense node Provisioning Support	50
Total Non-Recurring Services	$ 1,843.50	

Custom Non-Recurring Fees		
SKU	Description	QTY
S07-000012-N	IL-LSn-Service-1yr, one time	50
Total Custom Non-Recurring Fees	$ 300.00	

Contract Summary	
Description	Cost
Total Non-Recurring Charges	**$ 5,000.00**
Total Non-Recurring Services	**$ 1,843.50**
Total Contract Term Monthly Recurring Fees	**$ -**
Total Contract Term Annual Recurring Fees	**$ -**
Total Contract Term Custom Non-Recurring Fees	**$ 300.00**
Grand Total	**$ 7,143.50**

Figure 9. Verizon Costs paid by City of Colorado Springs

All 50 streetlight controllers were installed on an existing LED streetlight. Of these, nine were 100W equivalent colonial (decorative) fixtures and the remaining were cobra head (roadway) fixtures; seven 100W equivalent, twenty-five 250W equivalent, and nine 400W equivalent. The locations of these controllers were spread out across all City Council districts, as shown by the green dots within the black circles in

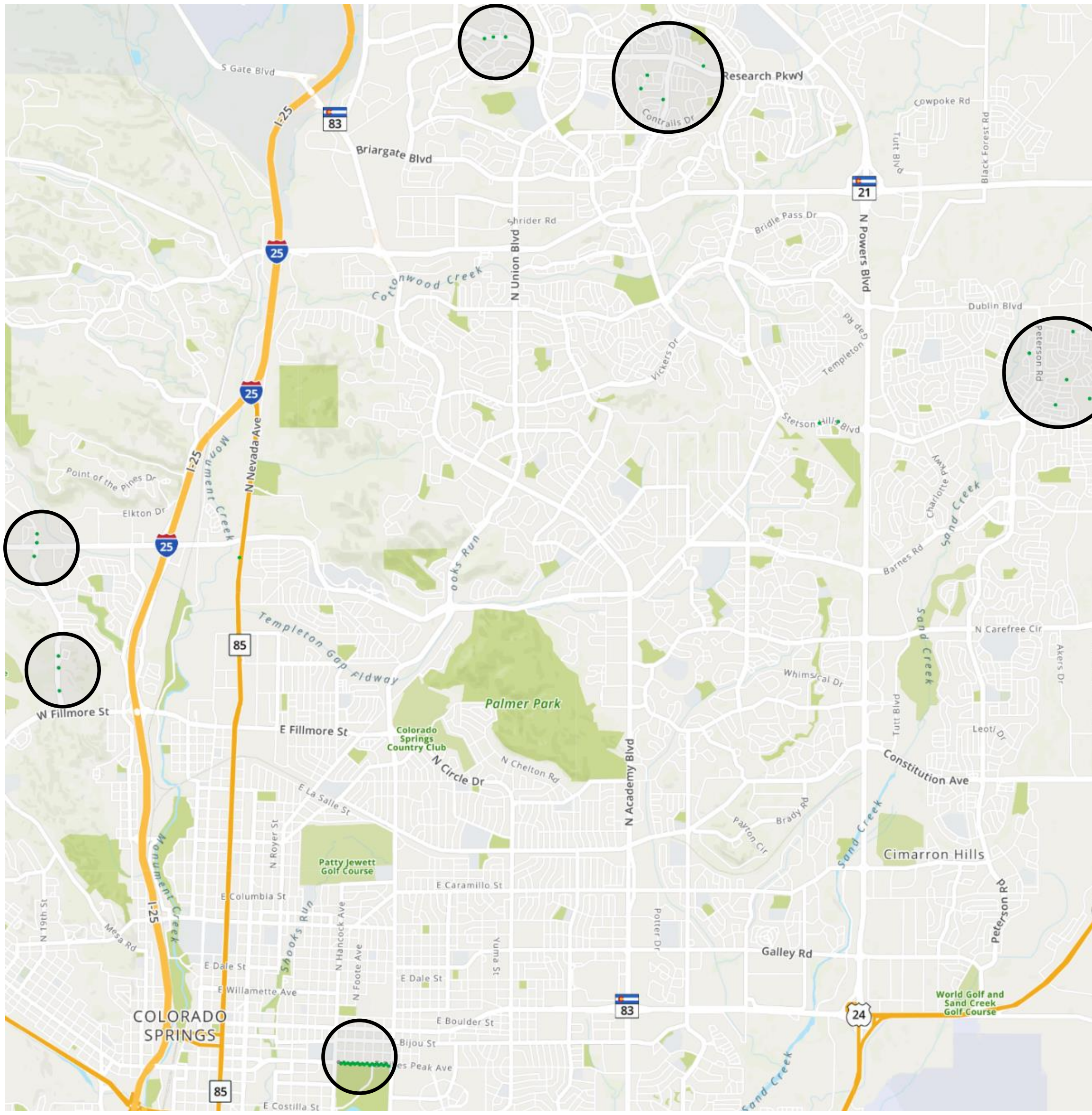


Figure 10. Verizon Controller Locations

The VZ streetlight controller enables users to monitor and manage streetlights on VZ's communication network. The controller incorporates VZ LTE CAT-M1 module, onboard GPS, temperature, and utility-grade metering sensors. Key features include:

- Cellular connectivity enables gateway-free installation
- Advanced 4G LTE CAT-M1 IoT technology
- Auto-commissioning with integrated GPS
- Simple plug-and-twist mounting to luminaires via existing NEMA 5- or 7-pin photocontrol socket (in accordance with ANSI C136.41)
- Advanced lighting control with onboard photocell and 0 to 10 V dimming
- Utility-grade energy measurement with metering Class 0.5 accuracy

- Measures and reports electrical and sensor data to NetSense platform
- Light Sense node connects to the network using highly secure, certification-based authentication and encryption for each device

For a more detailed product specification, see *Appendix: Verizon Streetlight Controller Product Sheet*.

The VZ streetlight controllers ("Light Sense node") communicate via 4G LTE cellular network with the NetSense cloud platform. This allows users to access and control the status of devices through the NetSense Lighting Application portal, which is VZ's customer dashboard. This high-level system architecture is shown in Figure 11.

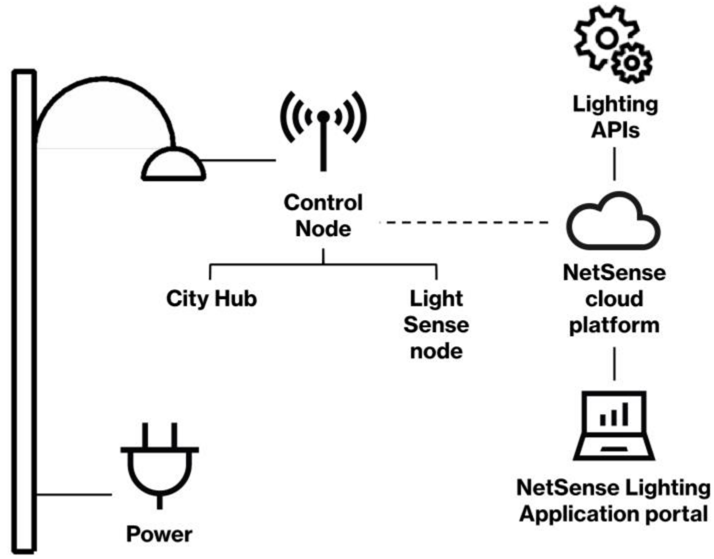


Figure 11. Example of Verizon System Architecture

NetSense has robust functionality, and each dashboard section is listed below, including a description of the functionality, as described in the user manual. The *Appendix: Verizon Dashboard Views* section may also be referenced for visual context.

1. ***Sites.*** *A site is a geographic area containing lighting nodes. Your NetSense Lighting Application may come pre-configured with one site, and over time, you may create other sites. You can optionally define a site by specifying a set of boundaries marked by geographic coordinates, i.e., latitude and longitude, known as a geo-fence.*

2. ***Nodes.*** *A single installed lighting device on a light pole represents a lighting node within the NetSense Lighting Application. These devices are referred to as lighting nodes or just nodes in the application and in this user guide. NetSense supports the lighting devices listed below:*

    a. *Core Node EX-C LTE: Has core lighting control features, including proximity dimming.*
    b. *Light Sense node: Has core lighting control features, optimized for scale and low communication costs.*
    c. *City Hub: Has core lighting control features and serves as a connectivity and power source for additional sensors and cameras.*

3. ***Groups.*** *The NetSense Lighting application has two types of groups for lighting nodes: lighting groups and organizational groups.*

4. ***Lighting Groups.*** *Unlike organizational groups, a node can only belong to ONE lighting group. Nodes are assembled into lighting groups for scheduling*

purposes as all nodes in a lighting group share the same schedule. Only lighting groups have schedules; organizational groups do not. When you first receive the NetSense Lighting Application, all nodes belong to the default lighting group, the Site Lighting Group. You can also create your own lighting groups. A node must belong to a lighting group.

5. ***Organizational Groups.*** *Organizational groups are flexible configurations of one or more nodes for which you can perform maintenance and other actions. For example, you can create an organizational group for all lighting nodes on the same circuit or in the same area. A lighting node can belong to multiple organizational groups.*

6. ***Schedules.*** *A lighting schedule dictates when a light turns on and off. You configure a schedule's timeline by time, by relation to sunrise/sunset, or automatically by the node's photocell sensor. In addition to scheduling when a lighting node goes on, you can set its brightness level, otherwise known as the driver level.*

7. ***Notifications and Alerts.*** *The NetSense Lighting Application reports on a number of alert types for maintenance that include but are not limited to the following:*

    a. *Power Fault Detection (PMAC failure) – The luminaire is consuming power under or over the expected threshold*
    b. *Stuck Relay – Node's relay is stuck in ON position and light is not turning off as scheduled.*
    c. *Device Disconnect – The device has not communicated with NetSense for an extended period.*
    d. *When the application receives any alert condition, it consults the default notification rules, or the rules that you have set, and sends email notifications as directed.*

8. ***Management Windows.*** *The NetSense Lighting Application includes two management-style windows to manage nodes (found under Management > Nodes) and groups (found under Management > Groups and Lighting > Groups). These windows present a wealth of information, share the same design and are generally manipulated in the same ways.*

9. ***Users and Roles.*** *The NetSense Lighting Application employs the following user role hierarchy; the Admin Users, Lighting Users, and Read Only Users.*

3.2 Landis+Gyr Overview

LG provided 40 streetlight controllers, one access point for network connectivity, SaaS services to access their dashboard, online training, and technical support services. Colorado Springs Utilities paid for the 40 controllers and the one access point. The City paid for the remaining items, as detailed in Figure 12 below.

Description	Quantity	Unit Price	Extended Price
Street Light Management Services			
SaaS Services	6 months	$1,135.00	$1,135.00
Online Training - 4-hour sessions	2	$300.00	$600.00
Landis+Gyr Technical Support Services	1	$9,250.00	$9,250.00
		Total	**$16,660.00**

Figure 12. Landis+Gyr costs paid by City of Colorado Springs

Of the 40 lamps that controllers were attached to, ten were LED and the remaining were HPS. Figure 13 shows these locations, which were bundled around the Colorado Springs Utilities Test Center.

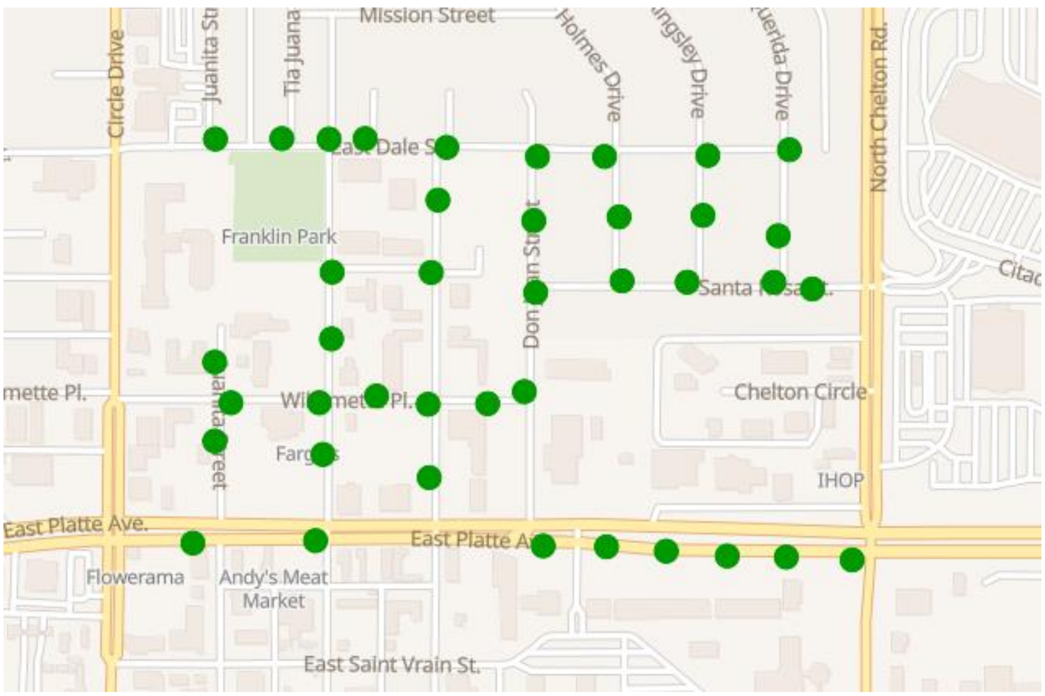


Figure 13. LG Controller Locations

The LG streetlight controller enables users to monitor and manage streetlights — both HPS and LED luminaires – on LG’s communication network. The controller incorporates LG’s Network Node, a fully functional, small IoT RF radio module capable of communicating on Wi-SUN compliant RF Mesh IPv6 or RF Mesh networks. Key features include:

- Luminaire health monitoring and outage detection

- Supercapacitor support for power outages
- Load-side accumulated energy, instantaneous current, voltage, power, and power factor
- GPS location—maps with streetlight visualization
- Dimming schedule creation
- Constant lumen output: ramp up power over time to maintain lumen efficacy
- Optional Feature - Advanced Metering Infrastructure (AMI) Network integration. The LG solution could bolster an AMI mesh network in areas where routing support is needed as they can serve as an additional router. A potential con is segregating the AMI data from streetlight data to ensure data security. The City and Utilities will need to discuss the cost to backhaul data on the AMI network. The network was not designed to include this additional data transfer.

For a more detailed product specification, see *Appendix: Landis+Gyr Streetlight Controller Product Sheet*.

The LG streetlight controllers communicate via wireless RF mesh with a gateway device, which is part of the WAN that connects to LG's Network Operations Center (NOC). This allows users to access and control the status of devices through the Smart Community Center, which is LG's customer dashboard. This system architecture is shown below in Figure 14.

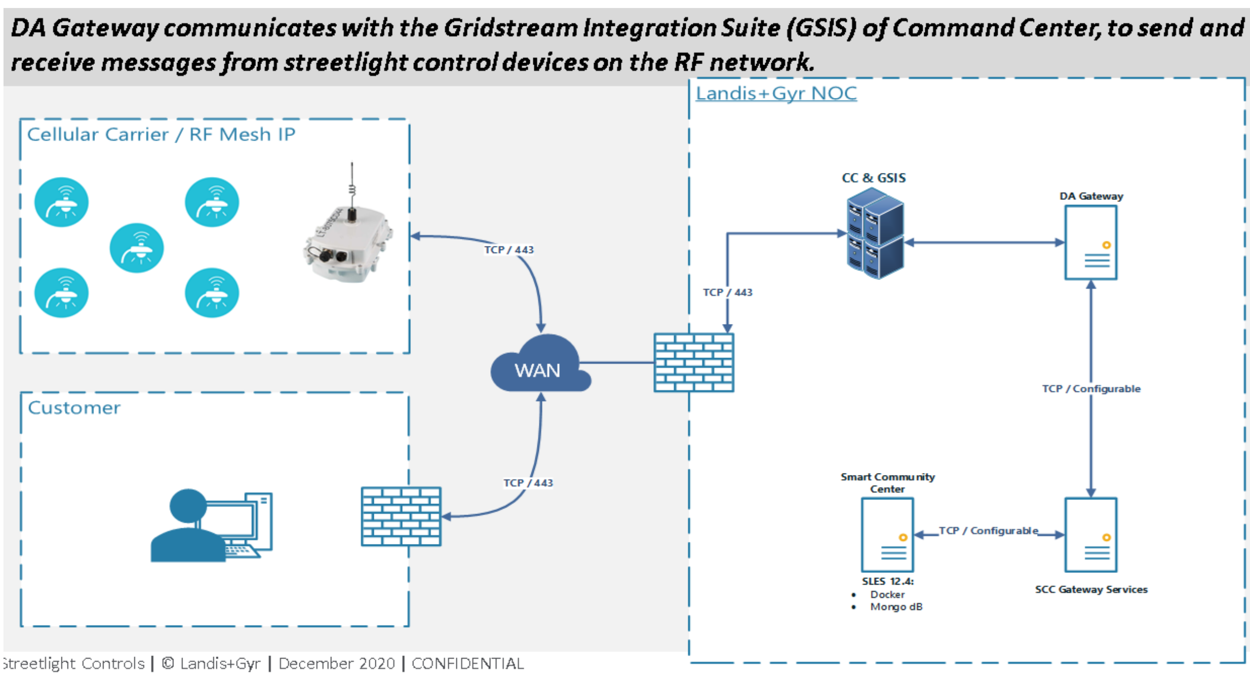


Figure 14. Example of the LG System Architecture

Smart Community Center has robust functionality. Each dashboard section and a description of its functionality is listed below. The *Appendix: Landis+Gyr Dashboard Views* section may also be referenced for visual context.

1. ***Dashboard Home.*** *The Home Page provides a dashboard view of the software available. The Home Page is customizable, and by default displays the*

following items: System Health Check, Status Trend (updated daily), Status Map, List of Open Tickets, Inventory Overview (number of Objects and Object Types), List of Latest Reported Active Failures

2. ***Inventories.*** *The Inventories section allows you to see an overview of the objects and geo groups in the format of a map and a filterable list. Both the Inventory Map and Inventory Lists provide more details about each object and allow for real time control as well as commissioning certain objects when necessary.*

    a. ***Inventory Map.*** *The Inventory Map section provides a map view of all the assets controlled by Smart Community Center. It provides all the asset editing functionalities to facilitate the various asset management workflows such as device creation, provisioning, relocating objects, cloning objects, create groups and networks, and import and export inventory.*

    b. ***Inventory List.*** *The Inventory Lists section allows to query the inventory of assets controlled by Smart Community Center in a very powerful and flexible way. You can create multiple inventory lists to answer very different needs such as List all the objects that are consuming more energy than they should, List the streetlights equipped with Sodium Lamps, List all streetlights that reported more than 5 failures in the last month. This application allows for bulk editing of thousands of devices at once as well as creating a favorite list, managing the Inventory state, trigging an immediate or delayed object commissioning, or performing a firmware update.*

3. ***Streetlight****. The Streetlight section allows you to see a real time display of the status of active streetlights as well as any errors or warnings. This section also describes which dimming programs each streetlight uses as well as the calendar those programs are on. The Streetlight section also provides the user with data analytics regarding the density of key values based on grouping.*

    a. ***Streetlight Status.*** *The Streetlight Status section offers a comprehensive graphical representation of all the incidents/failures reported from the fielded objects. This allows for a quick appreciation of the overall system state and provides all the history information for any given object. On this map, note that red dots represent Streetlight controllers that have a failure, orange dots represent Streetlight controllers that have a warning, and green dots represent Streetlight controllers that are fully operational.*

    b. ***Streetlight Schedulers.*** *In the Streetlight Schedulers section, you can create, view, and delete calendars that control the dimming programs that are implemented on each day of the year, view a more detailed breakdown of each dimming program and what it entails, and view a map of where streetlights with commissioned calendars are located.*

c. ***Streetlight Map Data Analytics.*** *In the Streetlight Map Data Analytics section, you can view different Geo Groups and the following factors are displayed on the map using a colors scale for the density of values: Lamp Level, RMS voltage, Active power, Power factor, Temperature.*

4. ***Reports.*** *In the Reports Section, reports can be created to summarize data based on inventory lists. Using widgets like the ones found on the home page, a report can be customized to display the information that the user chooses. This section also provides energy reports for each Geo Group that displays a summary of the information relevant to energy and energy consumption.*

   a. ***Reports Center.*** *In the Report Center section, you can click the Create an Inventory List button in the top left of the screen which prompts you to either create a control program from scratch or begin using a preexisting template. Clicking on the green plus button on the bottom right of the screen allows you to add a widget to the report. Clicking the cloud icon toward the top of the screen allows you to download a PDF version of the report.*

   b. ***Energy Reports.*** *In the Energy Reports section, you can see a graphical and numerical display of energy information of a Geo Group for a set time period. This data can be downloaded to a PDF file using the cloud icon in the top right of the screen. The graph can be edited to show years, months, weeks, or days using the graph period option.*

5. ***Data History.*** *The Data History section allows you to view various measurements and alerts for individual objects in the system over a chosen period.*

6. ***Real Time Control.*** *The Real Time Control section provides live data and information regarding each individual streetlight on the map.*

7. ***Maintenance.*** *The Maintenance section allows you to keep track of the errors and warnings that have occurred in each Geo Group and to create and filter through tickets using the Tickets Center.*

   a. ***Streetlight Maintenance.*** *In the Streetlight Maintenance section, you can see a list of objects and failures for each Geo Group.*

   b. ***Tickets Center.*** *The Tickets Center section allows you to view, create, and edit the tickets assigned to objects.*

8. ***Automation Center.*** *The Automation Center section allows you to set up automated commands that can complete various actions within the Smart Community Center.*

9. ***Drone Monitoring***. *The Drone Monitoring section provides a view that cycles through a list of objects, providing snapshot information and status. This view*

is particularly useful for monitoring a group of objects or presenting information.

10. ***User Settings.*** *The User Settings menu of the Smart Community Center allows you to manage your user profile as well as view the activity of other users.*

    a. ***Settings.*** *The Settings menu allows you to access the: User Profile, Users Management, Roles & Permissions, Geo Groups, Audit, Data Models.*

    b. ***Documentation.*** *The Documentation section is a helpful tool put together to help when using the Smart Community Center. Listed are the names of many of the pages and sections that make up the Smart Community Center as well as a general overview of what the Smart Community Center can do. Clicking on any of the names of SCC pages in this section will navigate you to a new page containing information and screenshots as examples describing the how to use the selected page effectively and efficiently.*

    c. ***Sign Out.*** *Clicking the Sign Out button from either the Home page or the sidebar will allow you to sign out of the program.*

3.3 Vendor Comparison

Figure 15 compares the product and service features of each vendor's solution14. The City's experience with installation and the product functionality is explained below.

Product and/or Service Feature	Verizon	Landis+Gyr
Hardware Cost (per Controller)	$100	$148
Software Cost (per Controller per year)	$6	$57
Total Non-Recurring Services Fee (Project Management, Implementation, Technical Support)	$2,144	$9,850
Luminaire health monitoring and outage detection	Yes	Yes
Utility-grade power monitoring: e.g. load-side accumulated energy, instantaneous current, voltage, power, and power factor	Yes	Yes
GPS location—maps with streetlight visualization	Yes	Yes
Schedule creation (Dimming, On/Off)	Yes	Yes
Constant lumen output: ramp up power over time to maintain lumen efficacy	No	Yes
Wireless Communication	Yes (Cellular)	Yes (RF Mesh)
Report Creation	Yes	Yes

Real Time Control	Yes	Yes
Strengthens utility AMI network	No	Yes
Gateway-free installation	Yes	No
Plug-and-twist mounting	Yes	Yes
Controller compatible with 7-pin fixtures	Yes	Yes
Auto-commissioning with integrated GPS	Yes	No
Automatic email alerts	Yes	No
Security Encryption	Yes	Yes
IP66/IP67 Rated	Yes/No	Yes/Yes
UL773 wet rated	Yes	No
Dimming Control	0-10VDC	0-10VDC / DALI

Figure 15. Streetlight Controller Vendor Comparison

Installation

Verizon: The streetlight controllers were installed by Colorado Springs Utilities on Wednesday, February 26th, 2020 and VZ was on standby to answer any questions. Colorado Springs Utilities did not report any installation difficulties. VZ saw all the 50 nodes in the NetSense platform the next day and upgraded all the devices to the newest firmware by the second day. Of the 50 devices, all of them associated to a pole from the GIS file except for one node - 015322000151598, north of pole number SLR09972 - CENTENNIAL BD. VZ was able to manually associate the node to the pole. The system was fully operational less than a week after install.

Landis+Gyr: LG provided a user training session to Colorado Springs Utilities as an overview of how to install the controllers. Colorado Springs Utilities performed the install on December 14th, 2020 and had to use three of the alternate pole locations, as they identified three without power. The following is a timeline of events after install:

- *December 15th, 2020*. All 40 streetlight devices in Command Center were in Discovered status. LG noted that they would monitor them until they go to Normal status (anticipated by next day).
- *December 17th, 2020*. All devices were still in Discovered status, except for two. A local team member was able to address this when they were at the Colorado Springs Utilities Test Farm. LG committed to have a field resource visit these devices and get them registered and to Normal status.
- *December 23rd, 2020.* All devices were in Normal status in Command Center. As such, LG was on track to have the integration complete, with Smart Community Center Software stood up by January 8.
- *January 13th, 2021*. LG experienced an access issue that prevented the SCC software from being stood up. LG treated this as a high priority issue.

- *January 29th, 2021*. The system was fully operational, six weeks after install.

In response to a request to explain the lag between install and system operation, LG provided the following explanation:

> *We can expect 2-4 weeks after install for the software to be setup and configured, generally. There are RFCs that need to occur on our side with some providing configuration information that are needed for the others, and thus there are dependencies. We're working on streamlining this process to be able to get everything stood up more quickly.*
>
> *It's generally not dependent on the size of deployment, though the process is slightly different when we use a Production instance of Smart Communities Center. If Springs opts for another deployment after this on a different Command Center environment, we would aim to start that process well before installation so there's less lag between install and software functionality.*

Product Functionality

Verizon: Throughout the course of the pilot, there were very few times when all 50 nodes displayed a green working status without either a warning, error, or disconnected status. Not every error resulted in the nodes failing to relay data to the team, and often a simple acknowledgement of the warning or error would clear the message. Below is a screenshot taken on March 10th, 2021, showing that 37 controllers were "working," seven controllers had an error message, and six were disconnected from sending data to the NetSense platform.

Figure 16. VZ NetSense Platform - Controller Status

Throughout the pilot, neither the City nor Colorado Springs Utilities deployed bucket trucks to check the health status of the pole, luminaire, and controller. Unfortunately, it is often not possible to pinpoint the exact causes of these errors and disconnections without deploying resources to the pole. Even so, the following list gives the possible reasons, as described by VZ technical support personnel:

> ***Power Meter Failure Alarm***. *When devices have the Power Meter Failure alarms, they cannot read any power sensor values like Main Power, Current, Voltage. Usually, this indicates a hardware fault, but these days, we are seeing few cases where it is not a real hardware issue and can be rectified by hard power cycling the node. So, uninstalling a node and installing it right back or cutting off power to the pole/fixture should correct this issue. We are working on a remote fix so that no on-site crew visit will be required in the future. But for now, power cycling is the way to fix the issue.*

> ***OverPower Alarm**. For the one device that I marked as non-dimming, it looks like this fixture doesn't dim even though the node is sending dimming signals to the fixture. To verify, I did a Manual Override of the light and set it to 50% driver level and then queried the Current Driver level along with the Main power reading, and at 50%, it was still consuming 129W of power. This can be because of the following reasons[:] wiring issue if the dimming wires in the fixture, bad dimming driver, [or lack of] proper contact between the dimming pins in the NEMA socket and the node (when node is not twisted all the way).*
>
> ***OverPower Alarm**. For this one, I would look at the description and the date of the alarm. The description says it is for Driver Level 73, which is not a driver level set for any of the schedules. That is an indication that this alarm was generated by mistake (we are working on future firmware releases to eliminate these kinds of alarm triggering). And the next thing I look at is the date. If the alarm was real, then it would get triggered every day and the date would reflect that. But in this case, the date indicates that the alarm has not been updated since 8/3/2020. That is another indication that this alarm is not real. So, you can go ahead and hit the Acknowledge button to clear the alarm.*
>
> ***Disconnected Alarm**. For disconnected nodes, again, I would look at the date. if the node is disconnected for less than 2 days, I wouldn't worry much about them as our nodes do check in every 4 hours with NetSense and if they miss 2 check-ins, they will be flagged as disconnected. They might miss the check-ins for a variety of reasons, but the nodes should be working as expected. If the nodes stay disconnected for more than 2 days, that would be when we might need to take some action, and that takes us to the next one.*
>
> ***Disconnected Alarm**. For this node, it has been disconnected for a while now. I remember that last time we talked while reviewing this site, I did mention this node that was disconnected for a while and that we need to verify that this node has power. Also, I checked the connectivity of the node on our network and it has been disconnected from the Verizon network since 7/7. In this case, it looks like the node has lost power. So, someone on-site needs to check that the fixture/node has power.*

It is also important to note that for the disconnected nodes, if they had power, they continued to operate on their regular schedule. If they were disconnected for a long period of time, they will fall back to photocell mode, which is how the existing streetlights without controllers attached are operating. Usually, if a node is disconnected for more than 2 days, it was indicative of a power issue.

Finally, the *OverPower* and *UnderPower* alarms did not clear by themselves, so they were manually acknowledged. The *Disconnected* alarms did clear by themselves when the nodes connected.

The City and Colorado Springs Utilities conducted a dimming test and measured the foot-candle (FC) levels at different driver levels. Overall, the test was successful; however, the team did run into a few issues with the controllers:

Pole 1472 on Pikes Peak Ave: When we adjusted the driver level to 45 and then attempted to increase the driver level to 50, the fixture remained at 45. We waited the 5-minute duration, but the fixture never reached a driver level of 50 throughout the 2-hour test and after we left. Now, the portal was displaying a driver level of 50, but our LED-compatible light level meter was showing readings at a 45-driver level.

Pole 1350 on Pikes Peak Ave: When we set the driver level to 65, the lighting level increased, but when we attempted to set the level to 50, it remained at 65. The portal was showing the driver level at 50 but based on our LED-compatible light level meter reading, it was registering much higher than 50. It was also apparent that the light was much brighter than the surrounding streetlights.

We also experienced a latency issue with the devices. When we changed the driver level of multiple streetlights at one-time, they did increase or decrease in real-time; however, when we attempted to change the driver level again, the lighting level change duration varied. Meaning one pole's lighting level would increase, then the next pole's lighting level would increase 5-10 minutes after, and so on.

In response, VZ offered the following potential causes:

1. *Recently, we have been having issues with our backend servers that is causing some unresponsiveness in NetSense. I would believe that you came across the same issue. And sometimes logging out and logging back in to NetSense can help when you cannot override lights as a workaround. There was also a minor upgrade that happened at around 10am PST and lasted less than an hour. But I am guessing your test was done during nighttime. I checked the 2 poles that you listed and today, it looks like they are responding fine. Both changed the driver levels in less than 10 seconds every time.*

2. *However, for Pole 1350, it looks like the fixture doesn't dim at all. The power usage is the same for all driver levels from 100, 50, 10 - about 130W. This is probably not a node issue but a fixture wiring issue, or the dimming pins of the node has no contact with the dimming pins of the NEMA socket. I would use the Monitor Current Values button in the Reporting page to verify that the fixture is behaving as expected once you manually override the lights by selecting Driver Level and Main Power for my sensors.*

3. *Another cause might be a bad network condition, but I am leaning more toward NetSense servers being slow.*

Landis+Gyr: There were some issues with giving dashboard login access to certain email domains, which LG could not solve before the end of the pilot.

The LG streetlight controllers sometimes displayed warnings, errors, or disconnected statuses. Not every error resulted in the nodes failing to relay data to the team, and often a simple acknowledgement of the warning or error would clear the message.

As with the VZ streetlight controllers, the LG streetlight controllers reverted to a photocell-controlled schedule when the streetlight controller failed.

The City and Colorado Springs Utilities did not conduct a dimming test with the LG streetlight controllers.

3.4 Streetlight Controller Findings

Scaling the smart streetlight pilot by accelerating the conversion of legacy streetlights to LED and deploying additional streetlight controllers would increase energy savings, allow for quicker identification of streetlight issues, and would allow for the realization of other qualitative benefits. Changes in existing O&M processes and staffing, and a more robust financial analysis would be necessary to realize the full impact of these benefits.

Operations and Maintenance

During the pilot, Colorado Springs Utilities discovered three lamps that did not have power during installation of the LG nodes. The LG portal identified a flickering streetlight, usually an indication that the lamp is failing. It is likely that some of the issues with the VZ nodes were also caused by lost power to the associated poles. Had streetlight controllers been installed at the time of these outages, the team would have more quickly known of the issues, rather than relying on residents' complaints. With changes to the existing O&M process and additional repair staff, the team could provide a quicker response, resulting in better service for streetlight customers.

Energy Savings – LED Replacement

There is clear energy savings potential, as confirmed by the pilot. The first aspect of energy savings potential comes from converting from non-LED luminaires to LED luminaries. As analyzed using the 2020 streetlight inventory, the City could reduce its energy usage by 40-50% by converting all its streetlight luminaires to LED luminaires.

Energy Savings – Dimming

The second aspect of energy savings comes from streetlight controller dimming capabilities. After the initial 40-50% energy savings by converting to LED, the City can reduce its energy usage an additional 1-51% (depending on diming strategy). The pilot tested two different dimming schedules in both vendor portals, labeled Schedule 1 and Schedule 2 in Figure 17.

Time	Schedule 1 (% of Max Driver Level)	Schedule 2 (% of Max Driver Level)
Sunset	100%	100%
11:00pm	100%	95%
11:30pm	100%	85%
12:00pm	95%	85%
1:00am	90%	85%
2:00am	100%	85%
2:30am	100%	95%
3:00am	100%	100%
Sunrise	0%	0%

Figure 17. Two dimming schedules were tested for both vendors

Schedule 1 was the most conservative and only realized 1% energy savings compared to an LED always at 100% driver level. Schedule 2 was also conservative but realized 3% energy savings compared to an LED always at 100% driver level. Schedule 2 is shown in Figure 18.

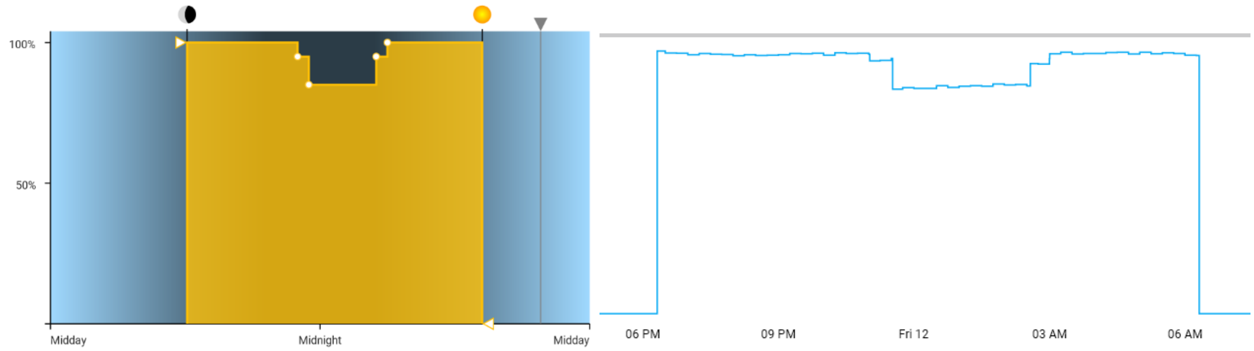
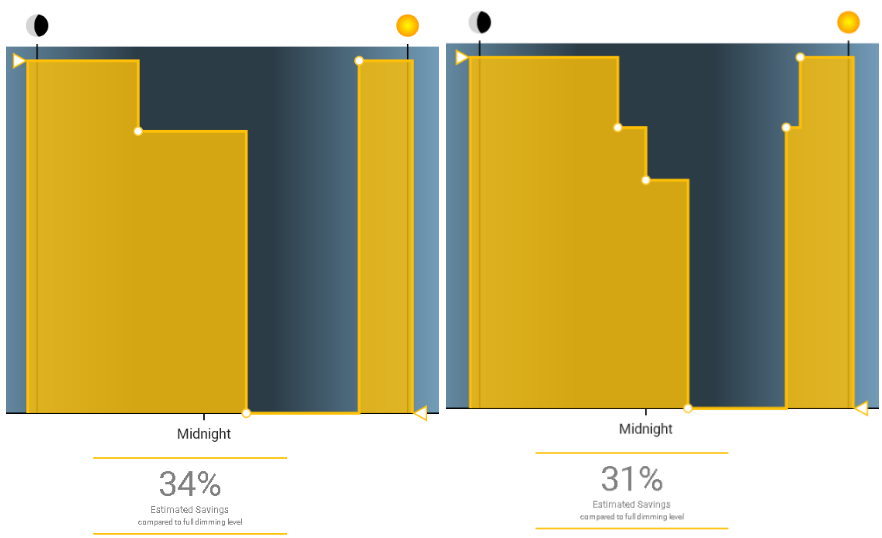


Figure 18. L: "Schedule 2" dimming schedule. R: Actual power usage data

If more aggressive energy savings are desired, dimming schedules can be updated. For instance, the LG portal has example savings programs included in the Schedulers section of their portal. These would realize diming savings between 25-51% compared to an LED always at 100% driver level, as shown in Figure 19.



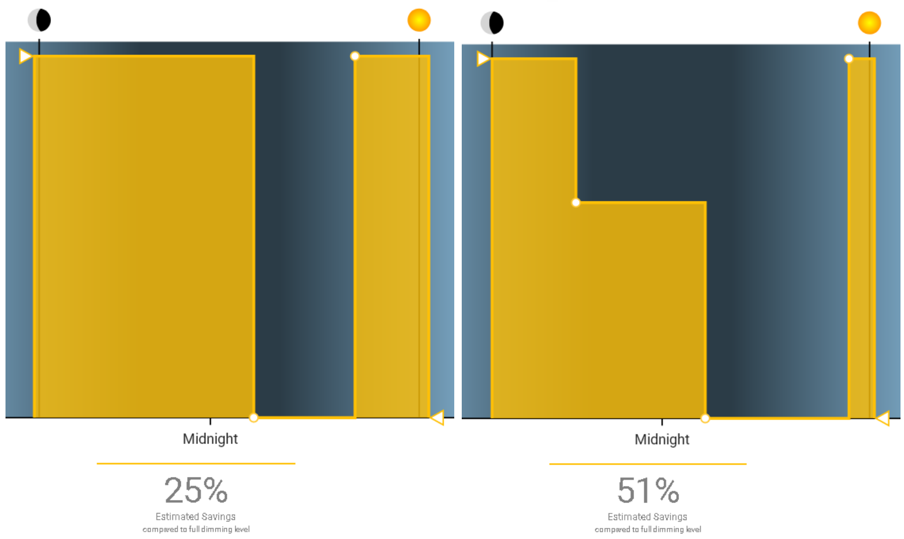


Figure 19. Example aggressive energy saving dimming schedules

Qualitative Benefits

There are also numerous potential qualitative benefits to controllable streetlights that are harder to monetarily quantify, but the team sees significant value in these benefits as well.

a. Reduction of citizen complaints about streetlight outages per year
b. Decrease in traffic accidents
c. Reduction of crime
d. Annual value from granular ability to control any/all lights (PD, EMS, etc.)
e. Enhanced customer service (reflects on the City)
f. Supporting "Dark Sky" advocates
g. Reducing installation of light shields
h. Potential decrease in insurance premiums
i. Value of leveraging an existing smart city platform and monetization potential of smart city use cases
j. Asset management for Colorado Springs Utilities (preventative maintenance)
k. Asset management for City (managing citizen requests for City)
l. Consistent lighting quality (consistent lumen output)

4. Weather Station Pilot Results

4.1 Vendor Overview and Installation Summary

The City procured six weather station from Campbell Scientific, as well as the Campbell Cloud data reporting dashboard. The weather stations were mounted on six different streetlight poles, one in each council district. The locations of the weather stations are shown in Figure 20.

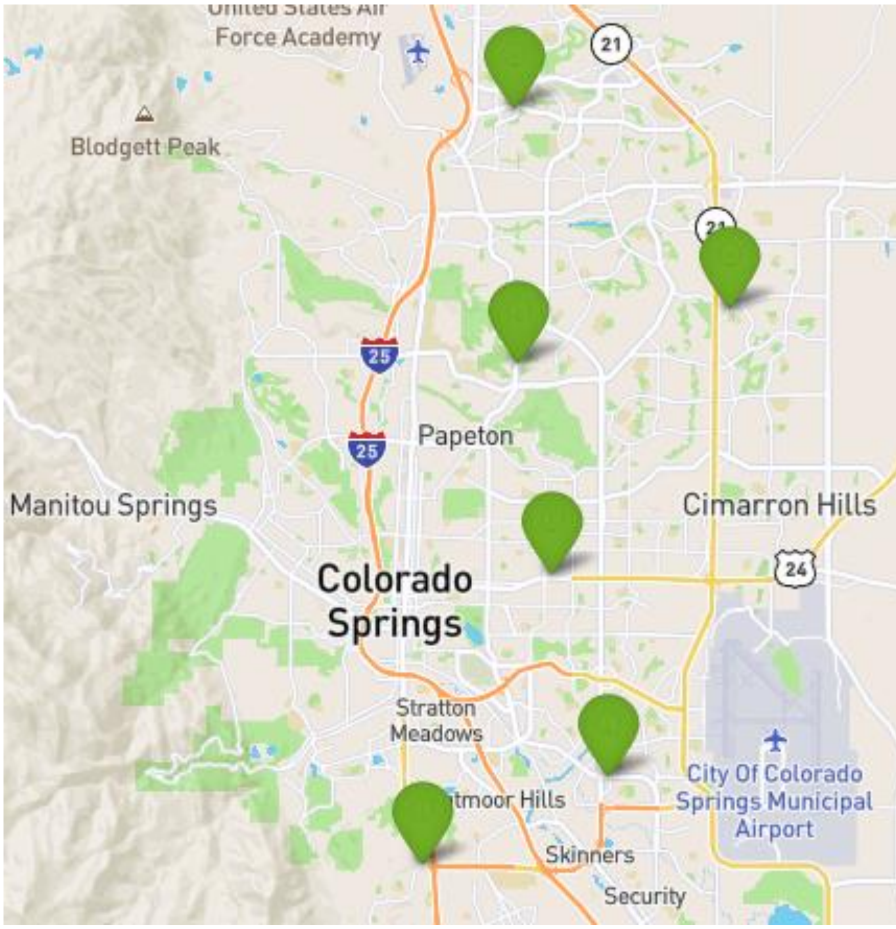


Figure 20. Weather station locations.

All six of the weather stations included snow depth sensors, road temperature sensor, data loggers, battery backup, a weather enclosure, and mounting hardware. One of the weather stations included a solar panel and battery backup so that it could operate completely off-grid. This one also included a wind gauge and air temperature and relative humidity sensor. The remaining five sensors were AC powered through the photocell power tap on the pole. The section titled *Appendix: Weather Station Mounting Details* shows how these weather stations were mounted on the poles, and the section titled *Appendix: Campbell Scientific Product Sheets* includes the component specifications.

The City used Narwhal Group for installation services. The turn-key cost of the install, including material, was $74,365. Install occurred Monday, August 10th through Friday August 14th, and no installation issues were noted. Traffic permits and barricades were needed for the work. Figure 21 shows a representative install site:

Figure 21. Example weather station pole-mount site

4.2 Functionality, Accuracy, and Data

The team spent a lot of time understanding hardware functionality, sensor accuracy, and data reporting, as outlined below. The final sub-section is a comparison of weather events as reported by both the traditional weather services and the Campbell weather stations.

Hardware Functionality

There were few issues with the hardware. All weather stations indicated "Normal Operations" during the entire pilot, including the grid-isolated solar powered station. This means that the data loggers were always powered and reporting data from the sensors.

The District 1 station, though, had been showing troubling data from the surface temperature sensor for over a week. It was believed to be a hardware issue with the Campbell device since the instrument was showing classic signs of failing. The device was reporting data and receiving power from the station; however, the data being reported was far from reality. Since the device included a four-year warranty, it was mailed back to Campbell Scientific for evaluation. It was mailed on February 24th, and Campbell mailed back a replacement unit on March 12th after it completed the evaluation. Even though the device was under warranty, the City had to pay a fee for a contractor to uninstall, ship, and reinstall the device.

Sensor Accuracy

The sensors were all mounted on the poles at 10 feet above grade, which is the minimum height allowed by Colorado Springs Utilities to avoid tampering from below. The snow depth sensor accuracy is 0.04% of the mounting height, which equates to +/- 0.75" for our installation. This means that the weather stations are not accurate enough for light snow fall events or desired granularity below 1" but are sufficient for measuring large snow fall trends. There are other considerations when determining accuracy readings, which are outlined below:

1. Accuracy gets better as surface becomes more uniform, such as after snowfall events once the snow settles. If there is grass or other vegetation, consider installing a concrete pad beneath the surface.
2. Any movement underneath the sensors will affect readings, such as pedestrians, cars, or wildlife. Piling snow on sidewalks underneath the sensors will lead to false readings.

The best locations are completely undisturbed areas, with no human access. Unfortunately, this is not possible in a city environment, especially when the goal is to measure snow depth and surface temperature directly on the streets.

Data Reporting

The Campbell Cloud webpage to view the data went down in early November and was offline for over a week. The Campbell technical team was able to create a ticket and the data display was repaired, after which the webpage was accessible without any issues. In addition to this isolated issue, there were a few recurring issues that made the data hard to interpret.

1. **Issue 1.** There were often gaps in raw data for snow depth, so that no data was shown in the portal. These gaps ranged from anywhere from 15 minutes to a whole month.
2. **Issue 2.** There were often abnormal spikes of snow depth data, anywhere from 40" to 100" of snow within 15 minutes, which was never realistic based on actual snow conditions.

For **Issue 1** above, the data gaps or the "no data available" messages are due to QA thresholds set between 0 inches and 300 inches for the snow depth measurement (which were set according to NOAA standards). For the time periods when the station data went negative, the data was excluded from display in the Campbell Cloud. For instance, data would go negative when the readings are within the +/- ¾" threshold and there is no snow on the ground.

To remedy the issue the program would have to be updated with a correct offset so that the sensor is reading 0 when there is no snow on the ground. Because this would require a site visit with a contractor, the other preferred option was to change the QA rules to include negative readings to a certain depth so that they would be displayed instead of a gap or "no data available".

For **Issue 2** above, the majority of those spikes were measurements of 100" or greater, and when aggregated over time averages, they displayed in the cloud as smaller peaks trending over time (for example, a measurement of 100" at one time and 0" one hour later averages to 25" over 15 minute increments). To avoid this, QA thresholds were set to 99" so that those measurements were excluded.

For both issues, it is important that the data user and operator are aware of how they affect readings so not to draw incorrect conclusions.

Weather Event Analysis

This sub-section is a comparison of weather events as reported by both the traditional weather services (through the NOAA weather station) and the Campbell weather stations at each council district. Figure 22 shows snow depth historical data for weather events that occurred during the pilot.

Date	Reading	NOAA Site	District 1	District 2	District 3	District 4	District 5	District 6
12/29/20	Snow depth	3.3”	2.7”	1.6”	2.7”	ND	2.5”	3.6”
01/10/21	Snow depth	2.5”	1.7”	1.2”	ND	ND	1.9”	2.5”
01/11/21	Snow depth	1.5”	0.5”	1.8”	ND	ND	1.5”	2.4”
01/26/21	Snow depth	3.5”	1.3”	3.3”	3.1”	0.0”	3.6””	1.9”
01/27/21	Snow depth	4.5”	0.8”	3.7”	3.0”	0.0”	2.7”	2.4”
01/28/21	Snow depth	2.5”	0.6”	4.2”	2.9”	1.7”	2.1”	2.3”
02/14/21	Snow depth	2.0”	1.5”	3.0”	3.1”	0.0”	1.9”	2.0”
02/15/21	Snow depth	2.5”	3.3”	5.6”	3.4”	0.6”	2.0”	5.0”
02/16/21	Snow depth	2.0”	ND	2.9”	2.8”	2.4”	2.0”	2.7”
02/17/21	Snow depth	1.5”	ND	5.0”	3.7”	0.0”	4.3”	2.5”
02/18/21	Snow depth	2.5”	ND	5.9”	2.1”	0.0”	5.4”	3.5”
02/19/21	Snow depth	2.0”	ND	ERR	2.9”	0.7”	4.5”	4.6”
02/25/21	Snow depth	6.5”	ERR	4.6”	2.5”	0.0”	5.0”	1.8”
02/26/21	Snow depth	3.0”	ERR	5.1”	3.9”	3.0”	4.0”	2.2”
03/14/21	Snow depth	5.0”	ERR	4.2”	4.3”	2.8”	3.4”	4.2”
Values indicate peak depth for the given date. ND: no data. ERR: data error.								

Figure 22. Snow depth historical data

The NOAA station cited in Figure 22 is located at an elevation of 5735 feet and has a latitude of 38.7425 deg N and longitude of -104.7251 deg W. This is near the junction of I-25 and Mesa Ridge Pkwy approximately equidistant between the District 3 and District 4 Campbell weather stations.

As can be seen by the data in Figure 22, the snow depth in each district is varied during the same snow events, proving that snow accumulation is more of a granular event than can be captured by the existing weather service station locations.

4.3 Weather Sensor Findings

Each of the six weather stations cost an average of approximately $12,000 once installed. The results of the data will be shared with City leadership and regional stakeholders to see if this information is beneficial regarding snow days or delayed starts. If the information is useful for decision making, the City may consider adding more weather stations across the city. This will give better context to the snow depth trends in the portal, but also help determine if the granularity of the data would affect operations (or whether existing NOAA forecast data is enough). Finally, the potential operator should clearly understand the shortcomings of the platform (e.g. accuracy levels and activity interference under the sensors) to determine whether the solution is attractive. If a specific payback is needed, the team should consider the following items in determining the value proposition and ROI:

1. Potential cost reduction due to avoided equipment deployments. This cost reduction could come from materials (vehicle fuel and salt) and/or any contractor or salaried employee costs for time spent driving.
2. Potential capital costs avoided for future vehicle replacement if vehicles can be used less.
3. Potential for improved deployment efficiency to prioritize areas that accumulate snow more quickly

Further assessment of the snow depth historical data from this pilot will assist the City in determining if there would be any cost reductions or value captured through the utilization of the weather station solution.

5. Smart Streetlights Pilot Project Conclusions

As stated in the Executive Summary of this report, the City identified two priorities for the Smart Streetlights Pilot:

1. to pilot solutions that offer enhanced operational efficiency and control of streetlights;
2. to pilot solutions that offer more granular measurement of snow accumulation and other weather-related information.

Through the pilot, the City, Colorado Springs Utilities, and Panasonic fulfilled these priorities and based on the data collected during the smart streetlights pilot, the following assumptions have been made:

1. **Accelerating the conversion of legacy streetlights to LED would result in energy savings. This supports previous research and findings of the City and Colorado Springs Utilities.**

   The City could reduce its energy usage by 40-50% by converting all its non-LED streetlight luminaires to LEDs. Changes in the existing payment structure would be necessary to realize the full benefit of energy savings. The City and Colorado Springs Utilities leadership will continue to collaborate on policies and strategies regarding the scalability of LED conversion based on financial and operational impacts and benefits.

2. **Deploying additional streetlight controllers and implementing more aggressive dimming schedules than those piloted during this project would increase energy savings.**

   The City could reduce its energy usage an additional 1-51% depending on dimming schedules used, based on the estimated savings provided by the vendors for dimming schedules not piloted during this project. Changes in the existing payment structure would be necessary to realize the full benefit of energy savings.

3. **The notifications received from the streetlight controllers may result in improved response times to problems.**

   Changes in the existing O&M processes and additional repair staff would be necessary to realize the full benefit of streetlight controller notifications. City and Utilities staff should discuss whether O&M processes could be modified to include resolving notifications from streetlight controllers.

4. **Further data analysis and consideration will be needed regarding using the weather sensors to support calling snow days or delayed starts.**

   Further assessment of the snow depth historical data from this pilot will assist the City in determining if there would be any cost reductions or value captured through the utilization of the weather station solution. If the information is useful for decision making, the City may consider deploying additional weather stations across the city.

The team also realized some limitations of scaling the smart streetlight controllers piloted in this project. These limitations include:

1. **Surge Protection** – The streetlight controllers do not meet CSU's minimum specifications (2000 Joules) for surge protection. Colorado Springs Utilities recommends that further investigation on these devices is required to determine if such equipment can meet existing standards, or if it would be applicable to define a waiver from the standards.
2. **Scaling** – The streetlight controllers only fit in the approximately 21,000 cobra head fixtures and the approximately 300 pendant fixtures, which represent approximately 77% of the streetlight inventory. The streetlight controllers do not fit into the approximately 6,400 colonial fixtures without a modification to the cupola lid, nor the approximately 1,300 acorn fixtures, which are the primary streetlights in downtown Colorado Springs. The inability to fit the streetlight controllers to 23% of the streetlights limits the capability to realize the benefits of the streetlight controllers outlined in this report.
3. **Cost** – The cost of a Dark to Light (DtL) photocell, which is CSU's current standard, is $22.44 with a warrantee of 10 years and an expected useful life of 20 years. In comparison to the DtL photocell, the cost of a streetlight controller is $148.00 for LG and $100.00 for VZ, or approximately five times the cost of a photocell. An additional significant expense comes from the annual software cost of approximately $6 per node per year, an annual software cost of approximately $162,000. Additionally, part of the bottleneck for O&M for streetlights is due to staffing levels, which would be a significant additional cost to factor into the cost of the project. Further, because of the current structure of the City and Utilities Cost of Service Study to determine the cost of energy consumption for streetlights, it is unclear if energy savings from LED conversion and dimming schedules would result in direct cost savings for the City. A comparison of the total cost of the streetlight controller compared to the total cost savings realized would be beneficial to the team prior to expanding the program.
4. **Changes to Operations and Maintenance Processes** – One question that was not answered during the pilot is which entity would administer and monitor the software. It is recommended that the team further refine expectations and desired objectives related to streetlight controllers prior to adoption of streetlight controllers as a standard.
5. **Data Governance** – The report does not present significant reference to data governance. Data governance is the process of managing the availability, usability, integrity, and security of the data in enterprise systems, based on internal data standards and policies that also control data usage. Effective data governance ensures that data is consistent and trustworthy and does not get misused. Existing photocells simply turn on the streetlight at dusk and turn off the streetlight at dawn. Moving to a streetlight controller device with an accompanying software platform that tracks hundreds of attributes regarding condition assessment, luminaire monitoring, outage detection, etc. represents an entirely new business model. Many questions remain regarding data governance, including: Who owns the data? Who maintains the data? What are the processes, roles, policies, and standards to ensure the quality and security of the data?

As a result of the pilot, the City will pursue several next steps related to streetlights. These next steps include:

1. **LED Conversion** – The City and Colorado Springs Utilities will research and implement methods to increase the rate of LED conversions. This may include being more proactive and expedient on converting existing streetlight luminaires to LEDs, or a future solicitation for a third-party energy performance contractor to convert all existing luminaires to LEDs.
2. **Other Smart Streetlight Use Cases** – The City will research and implement additional smart city applications that can be attached to streetlights. These applications include air quality monitoring, pedestrian and bicycle counting, and public Wi-Fi.

6. Appendix: Verizon Streetlight Controller Product Sheet

Data sheet

Add smart, full-featured controls to your street lights.

Light Sense node for Intelligent Lighting

Light Sense node is designed to convert LED fixtures into intelligent focal centers, providing actionable insights that go far beyond illumination and mere granular lighting control. Our Smart Communities solutions and cloud-based IoT services are now at your fingertips.

Main features.

- Cellular connectivity enables gateway-free installation
- Advanced 4G LTE CAT-M IoT technology
- Auto-commissioning with integrated GPS
- Simple plug-and-twist mounting to luminaires via existing National Electrical Manufacturers Association (NEMA) 5- or 7-pin photo-control socket in accordance with American National Standards Institute (ANSI) C136.41
- Advanced lighting control with on-board photocell and (voltage) 0-10V dimming
- Utility-grade energy measurement with metering Class 0.5 accuracy
- Measures and reports electrical and sensor data to NetSense® Lighting Application

Advanced 4G LTE IoT CAT-M IoT connectivity
No additional networking equipment is needed to deploy with 4G LTE connectivity. Fast, reliable, and nationwide 4G LTE connectivity from Verizon Wireless allows for gateway-free deployment.

Lighting control
Light Sense node is connected to incoming AC mains and the LED driver/standard ballast. This direct connection provides on/off control and performance monitoring of the luminaire. Luminaire dimming control follows the 0-10VDC dimming standard.

Onboard sensors
Light Sense node sensors include: GPS, photocell, utility-grade power metering and temperature.

Security
Light Sense node connects to the network using highly secure, certificate-based authentication and encryption for each device.

Certifications
Underwriters Laboratories (UL), Federal Communications Commission (FCC)

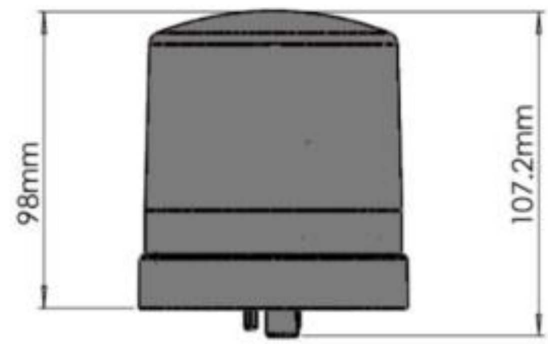
verizon

Product specifications

Order code	S80-000123
Communication	
Communication	Cellular (4G LTE) Lightweight machine-to-machine (LwM2M) protocol
LTE frequency bands	LTE band 4 and 13
Cellular data rate	LTE CAT-M
Security	
Encryption	DTLS1.2 PSK with 256-bit AES encryption
Power and electrical	
AC input voltage	120-277V/60Hz
Node power consumption	1.0W Typical (1.2W max)
Surge rating	6KV/3kA ANSI C136.2
Energy measurement	Metering accuracy ANSI C12.20 Class 0.5 (relevant sections), Pulse LED Support for energy measurement
On-board sensors	Photocell, GPS, power metering, temperature
GPS accuracy	3m (clear open sky)
LED Luminaire Control	
Ballast rating	E-Ballast and Standard/HID Ballast* rating of 5A max at 120V/277V 60Hz
Dimming control output	0-10 VDC
Photocell	
Operating levels	ANSI C136.10 Turn-on typical at 16 Lux, turn-off typical at 24 Lux, (On:Off ratio of 1:1.5)
Physical	
Mounting	Twist-lock National Electrical Manufacturers Association (NEMA) photo-receptacle (ANSI C136.41) 5-wire/7-wire receptacle
Weight	0.6 lbs
Color	Light gray
Dimensions	107.2 mm height x 88.6mm diameter
Environmental and compliance	
Water ingress	IP66, UL773 wet rated
Vibration	3G vibration per ANSI C136.31 2010
Operating temperature	-40C to 55C
Relative humidity operating range	5% to 95% non-condensing
Certifications	UL, FCC
Region of certification and LTE operation	USA

** For Standard/HID Luminaires support the luminaire must have main AC entry SPD rated at ANSI C136.2-2018 20kV/10kA*

Mechanical dimensions



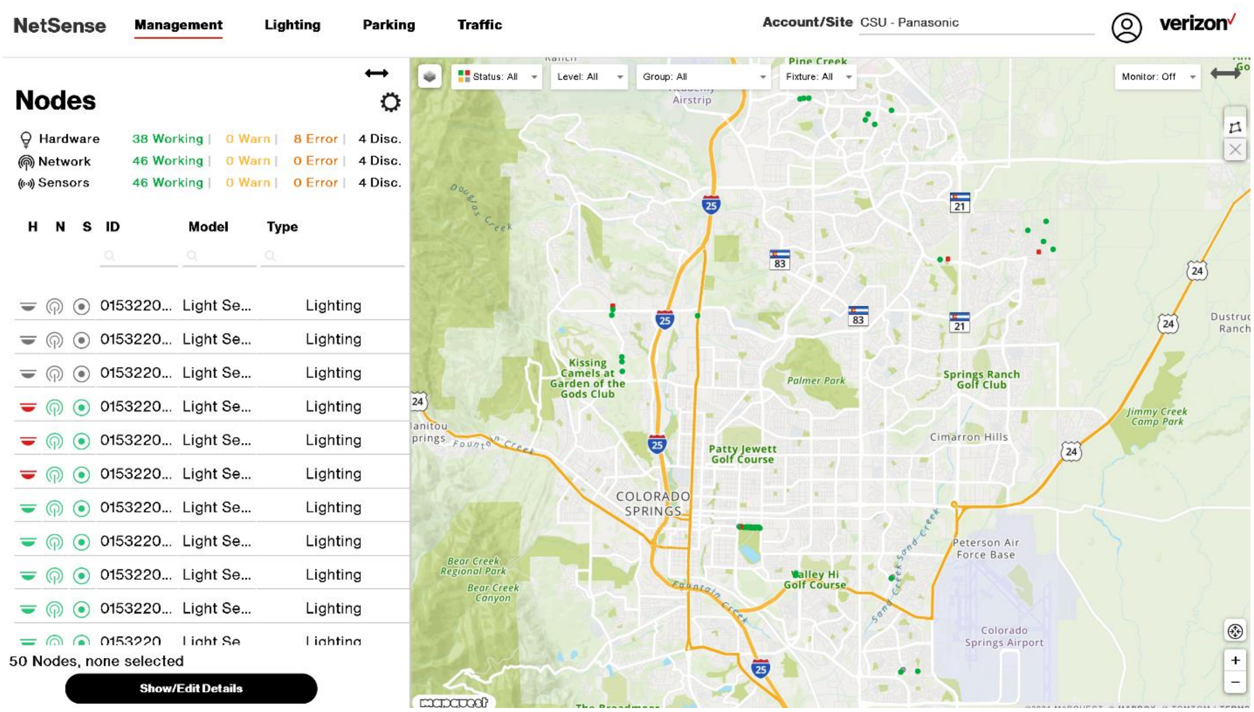
Units: mm

Ordering information

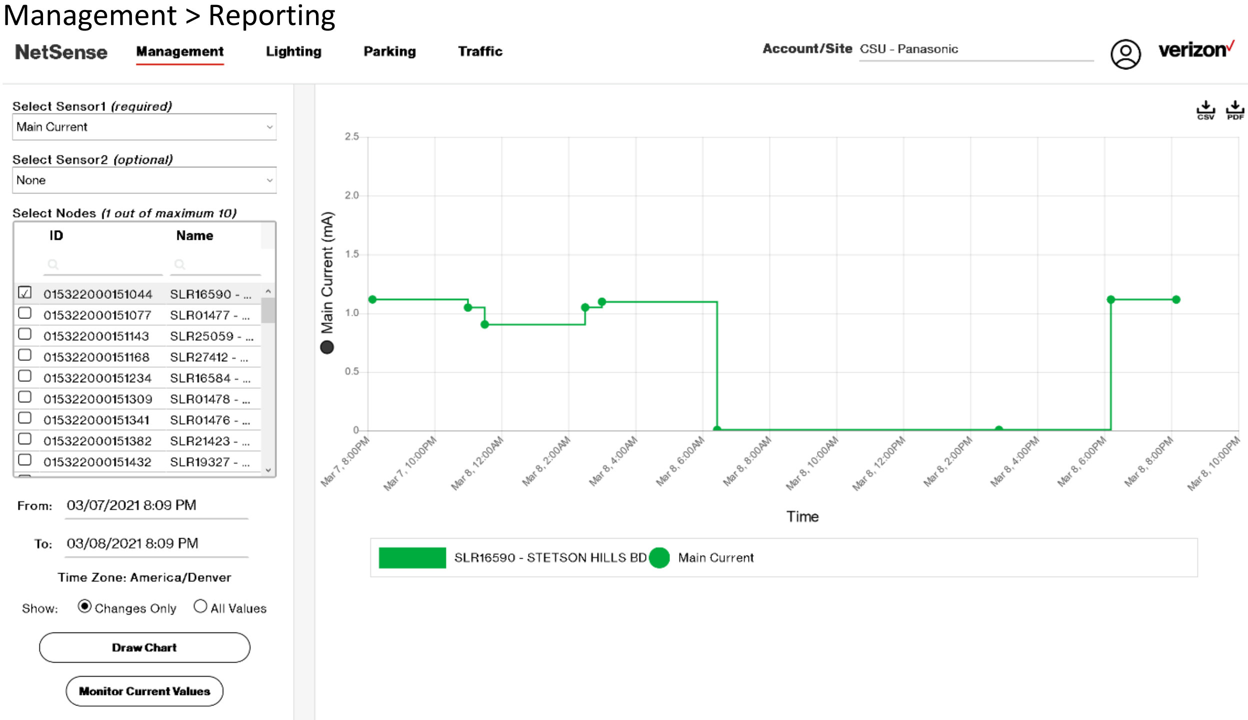
Order code	Description
S80-000123	Light Sense node, 4G LTE, 0-10V, NEMA, 120-277V

7. Appendix: Verizon Dashboard Views

Management > Nodes:



Management > Reporting



Management > Notifications

NetSense | **Management** | **Lighting** | **Parking** | **Traffic** | **Account/Site** CSU - Panasonic | verizon

Notifications

Active

Name	Active	Description	Type	Action

Alerts

Name	Type	Severity	Description	Node	Date & Time	Action
Device Disconnected	Disconnect	Critical	Node Disconnected fr...	01532200015...	05:14:01 PM 03/08/21	
Power Meter Failure	PowerMeterFailure	Critical	Power meter chip non...	01532200015...	02:45:21 PM 03/08/21	
Device Disconnected	Disconnect	Critical	Node Disconnected fr...	01532200015...	07:35:43 AM 03/08/21	
Power Consumed Ove...	OverPower	Critical	Consuming more pow...	01532200015...	01:00:06 AM 03/08/21	
Power Consumed Ove...	OverPower	Critical	Consuming more pow...	01532200015...	01:00:04 AM 03/08/21	

Lighting > Groups:

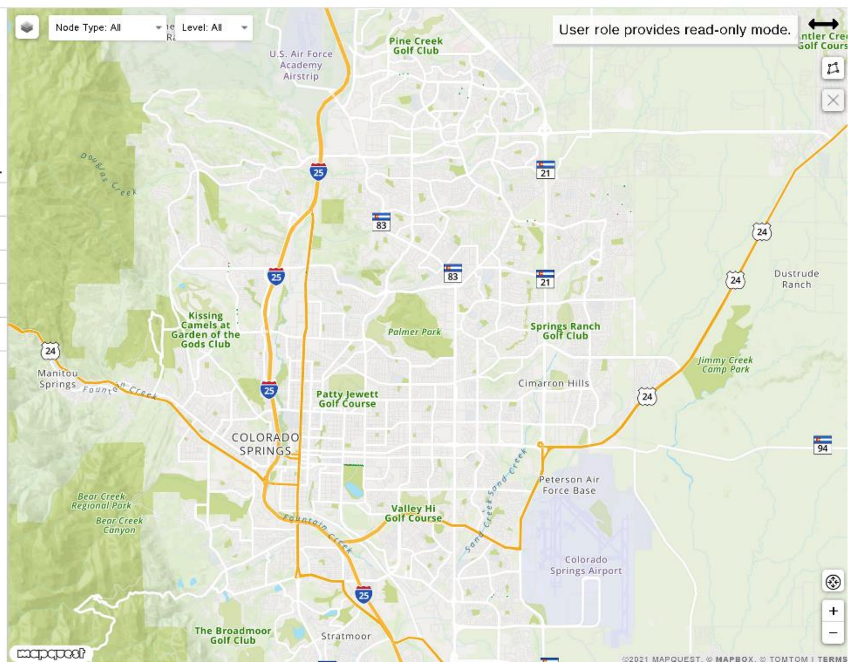
NetSense | **Management** | **Lighting** | **Parking** | **Traffic** | **Account/Site** CSU - Panasonic | verizon

Groups

Type	Name	Description
	UnderInvestigati...	Nodes have some data los...
	CSU Cobrahead...	
	Site Lighting Gr...	Default site lighting group
	Pikes Peak LG	Light in Pikes Peak Ave
	CSU Colonial LG	
	CSU LG	Lights excluding those in ...

6 Groups

Show/Edit Details



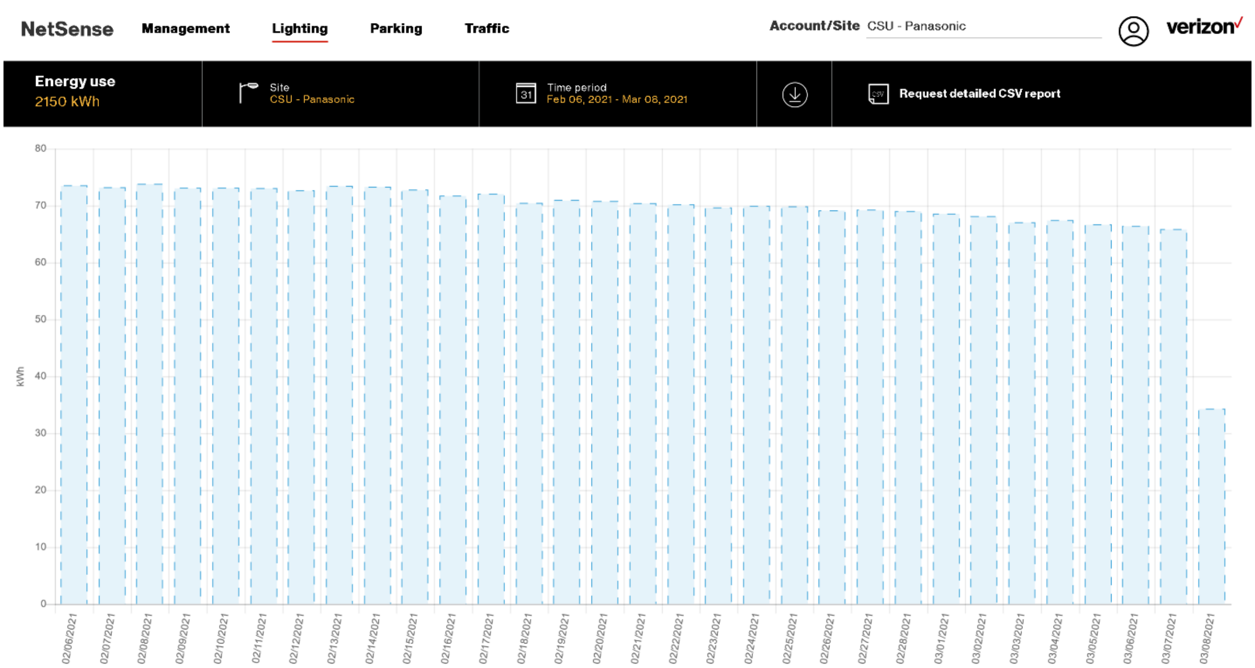
Lighting > Schedules:

NetSense Management **Lighting** Parking Traffic Account/Site CSU - Panasonic verizon

Schedules

Name	Description
Sunrise/Sunset with Dimming points	
Colonial Photocell with Dimming points	Fixtures with 0-10V driver
Cobrahead Photocell with Dimming point	Fixtures with 0-8V Driver
Default schedule	Default site schedule
Schedule with Dimming Points	
Sunrise/Sunset Schedule	Basic Sunrise/Sunset schedule

Lighting > Energy:



Lighting > Fixtures:

NetSense Management **Lighting** Parking Traffic Account/Site CSU - Panasonic verizon

Fixtures

Add Fixture

Type	Name	Description
	100W COBRA HEAD	100W COBRA HEAD with 0-8V driver
	100W COLONIAL	100W COLONIAL with 0-10V driver
	250W COBRA HEAD	250W COBRA HEAD with 0-8V driver
	400W COBRA HEAD	400W COBRA HEAD with 0-8V driver

8. Appendix: Landis+Gyr Streetlight Controller Product Sheet

Street Light Management

Enabling Smart Cities and Utilities through Intelligent Lighting Management Solutions

The Landis+Gyr Street Light Management Solution enables our customers to monitor and manage street lights — both High Pressure Sodium (HPS) and LED luminaires – on Landis+Gyr's communication network. The controller incorporates Landis+Gyr's Network Node, a fully functional, small IoT RF radio module capable of communicating on Wi-SUN compliant RF Mesh IPv6 or RF Mesh networks. As part of our Gristream® Connect IoT portfolio, Landis+Gyr's Street Light Controller and Management Software serve as a foundation for other smart city applications, while vastly improving energy and operational efficiencies.

ENHANCED SAFETY FEATURES

- Luminaire health monitoring and outage detection
- Supercapacitor support for power outages

IMPROVED OPERATIONAL & ENERGY EFFICIENCIES

- Improved energy and asset management
- GPS location—maps with street light visualization
- Dimming schedule creation
- Constant lumen output: ramp up power over time to maintain lumen efficacy

METROLOGY CAPABILITIES

- Load-side accumulated energy, instantaneous current, voltage, power, and power factor

COMPONENTS

- Landis+Gyr street light controller with integrated Network Node
- Command Center 7.1 MR3 or later
- Street Light Management Software

ENHANCED SAFETY FEATURES | IMPROVED OPERATIONAL & ENERGY EFFICIENCIES | METROLOGY CAPABILITIES | COMPONENTS

LandisGyr.com

Landis+Gyr
manage energy better

Street Light Management

ENHANCED SAFETY FEATURES | IMPROVED OPERATIONAL & ENERGY EFFICIENCIES | METROLOGY CAPABILITIES | COMPONENTS

PRODUCT SPECIFICATIONS

FCC Class B Device

CONTROLLER SPECS	
Dimensions of Controller	Diameter 3.5" (88mm), Height 3.6" (92mm)
Voltage	120-277V (50-60 Hz)
Material	Lexan™ SLX Polycarbonate
Ingress Protection	IP67, IP66
Temperature Rating	Operational -40°C to 60°C Storage -40°C to 85°C
Compatibility (General)	LED, HPS, and induction to a max load of 6A
Compatibility (Luminaire with ANSI C136.41 standard receptacle)	All Features supported by LED luminaires with 5 and 7 pin All features except dimming is supported on 3 pin HPS luminaires
Dimming Method	Complies with 0-10V DC (IEC60929) and DALI (IEC62386)
Dimming Ramping Process	Dimming in gradual steps every 6 seconds (e.g. 100% to 20% = 102 seconds)
Dimming Schedule	Daily or weekly recurring schedule with ability to schedule a special event, in 1 minute incraments with 1% resolutions
On / Off Trigger	Photo sensor for local lilght detection (selectable) with GPS based astronomical dawn/dusk back up
Dawn / Dusk Levels	On: 2.5 foot candles (fc) Off: 3.9 foot candles (fc) Configurable over the air

RADIO SPECS	
Frequency Range	902 to 928 MHz
Supported Data Rates	RF Mesh (N500): 9.6, 19.2, 38.4, 115.2 kbps RF Mesh IP (N550): 50, 150, 200 kbps
Output Power	High Min: 25, Typical: 26, Max: 27 dBm
Receiver Sensitivity	9.6 kbps Min: -114, Typical: -112, Max: -110 dBm 19.2 kbps Min: -112, Typical: -110, Max: -108 dBm 38.4 kbps Min: -110, Typical: -108, Max: -106 dBm 115.2 kbps Min: -102, Typical: -100, Max: -98 dBm 50 kbps Min: -107, Typical: -105, Max: -103 dBm 150 kbps Min: -99, Typical: -97, Max: -95 dBm 200 kbps Min: -98, Typical: -96, Max: -94 dBm

GET IN TOUCH

For more information and nationwide warranty terms, visit us at LandisGyr.com or call at 678-258-1500.

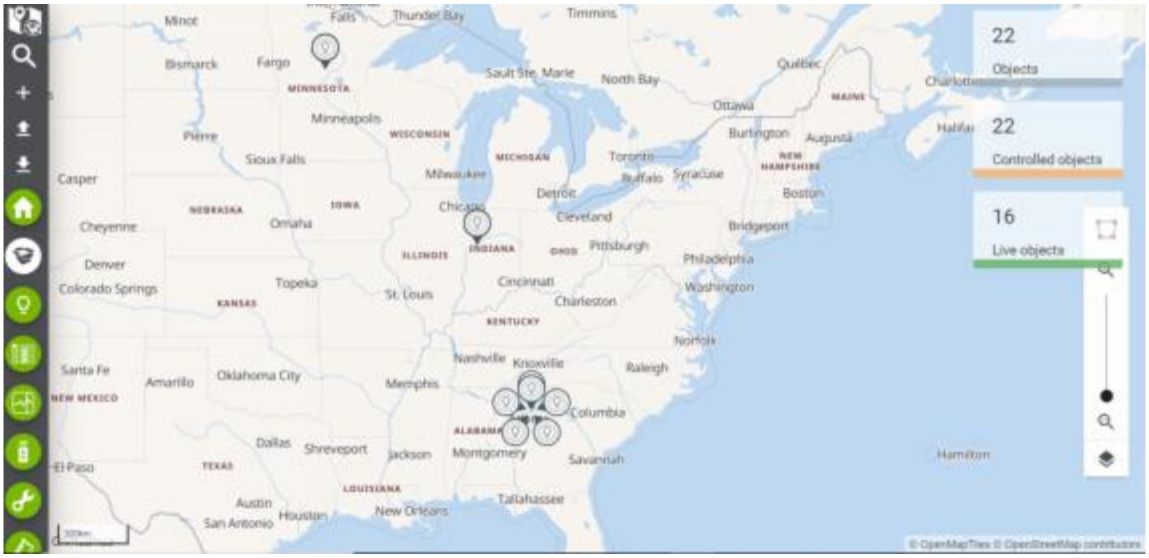
LandisGyr.com

LET'S BUILD A BRIGHTER FUTURE TOGETHER

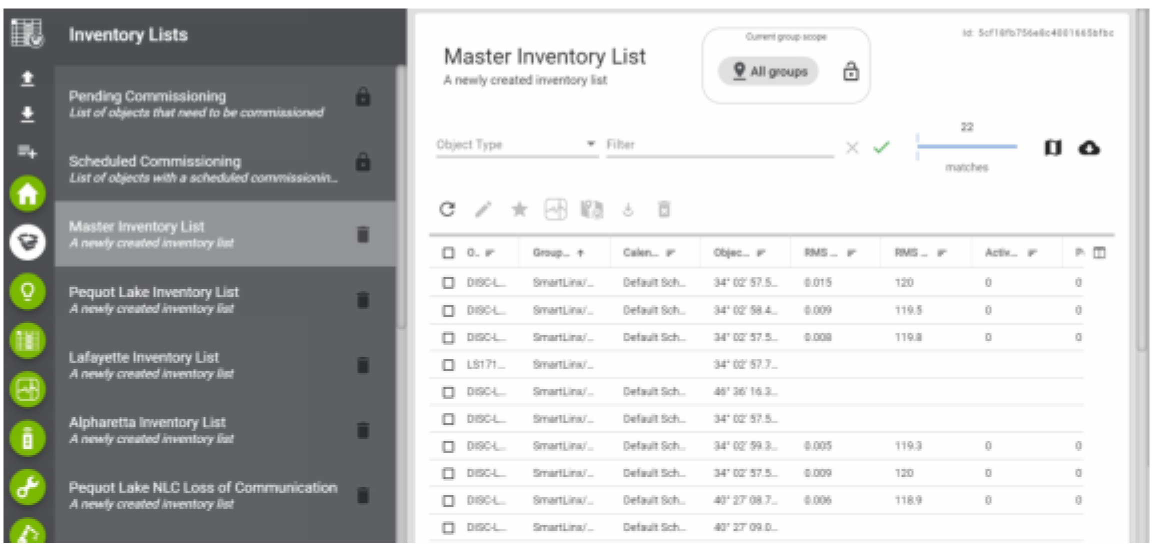
Since 1896, Landis+Gyr has been a global leader of energy management solutions. We've provided more than 3,500 utility companies all over the world with the broadest portfolio of products and services in the industry. With a worldwide team of 1,300+ engineers and research professionals, as well as an ISO certification for quality and environmental processes, we are committed to improving energy efficiency, streamlining operations, and improving customer service for utility providers.

9. Appendix: Landis+Gyr Dashboard Views

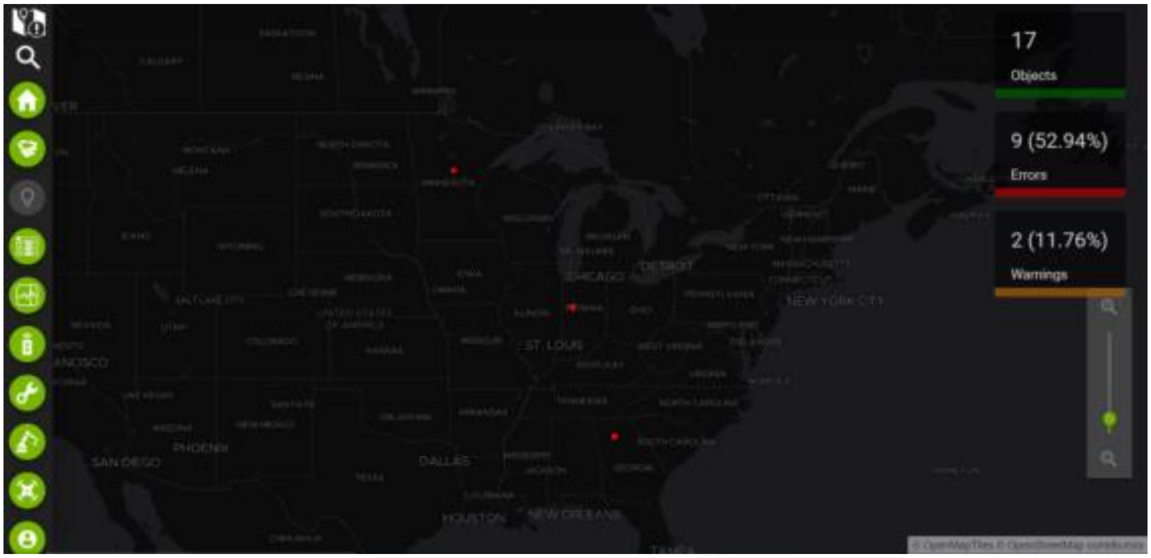
Inventory Map:



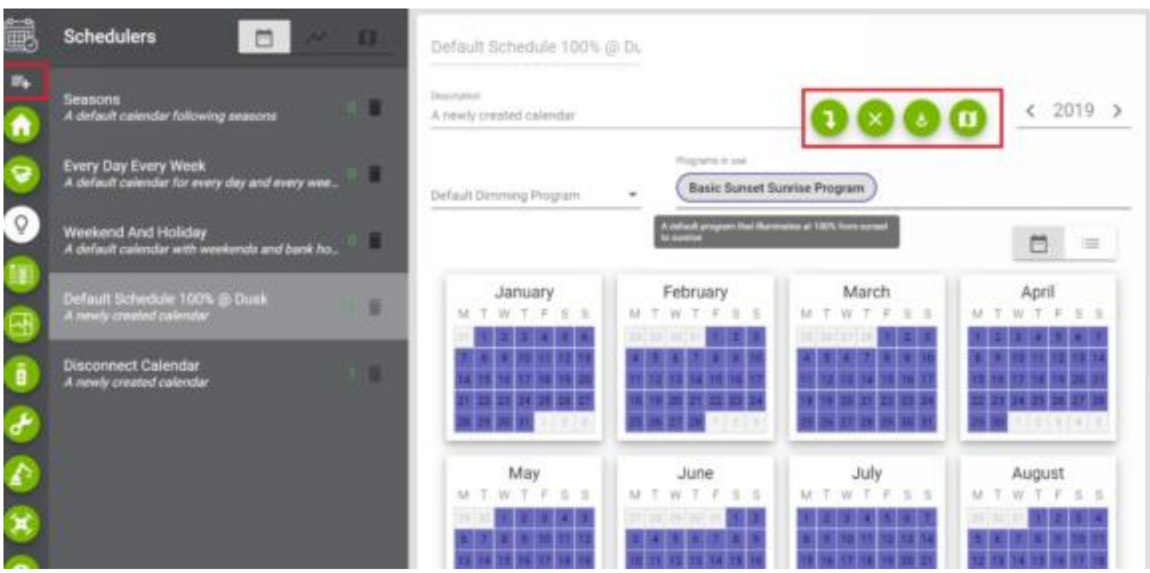
Inventory List:



Streetlight Status:

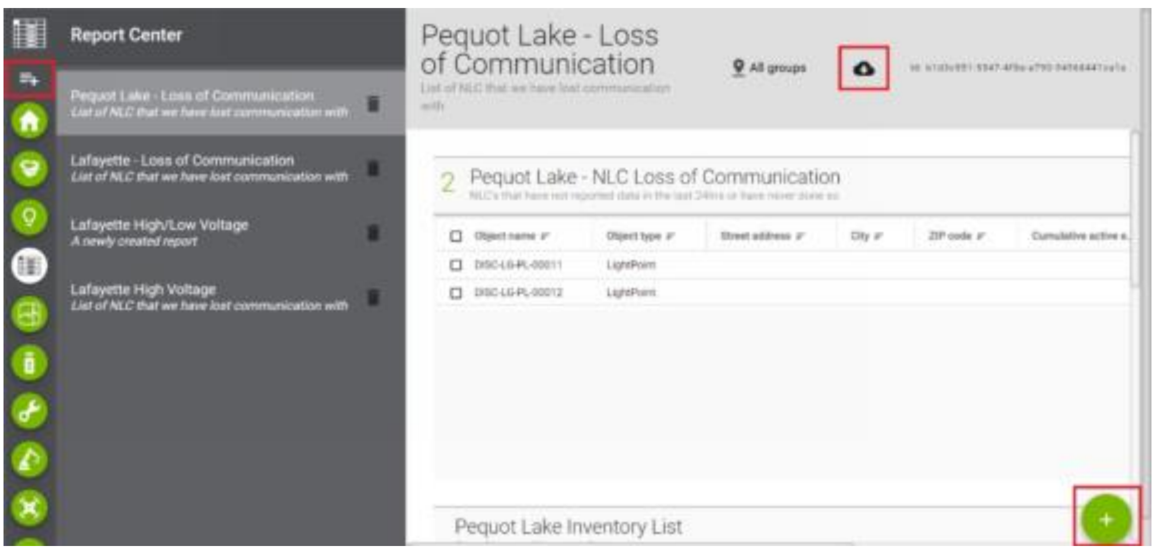


Streetlight Schedulers:



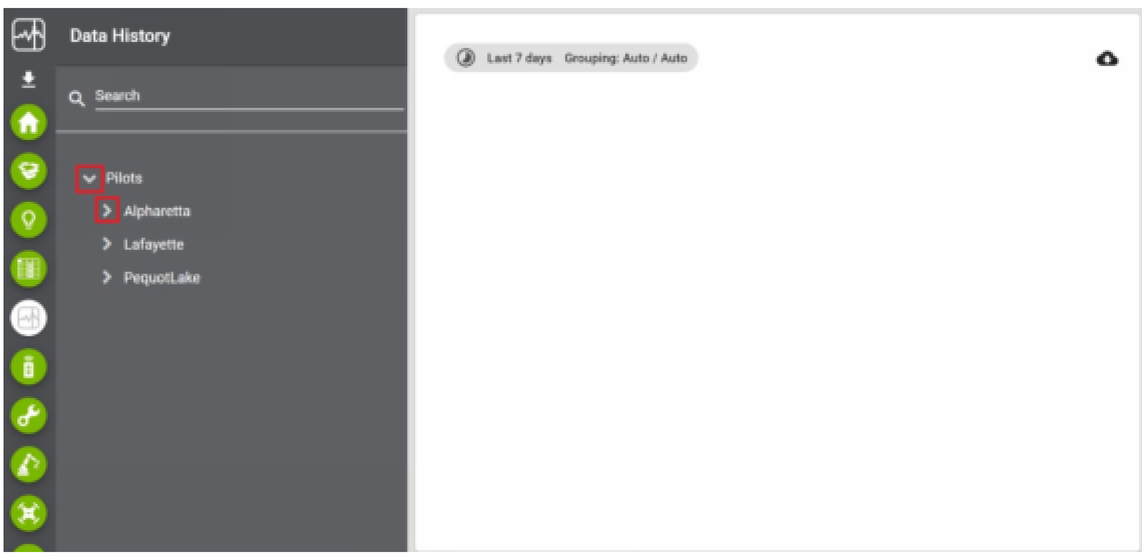
Streetlight Map Data Analytics:

Report Center:

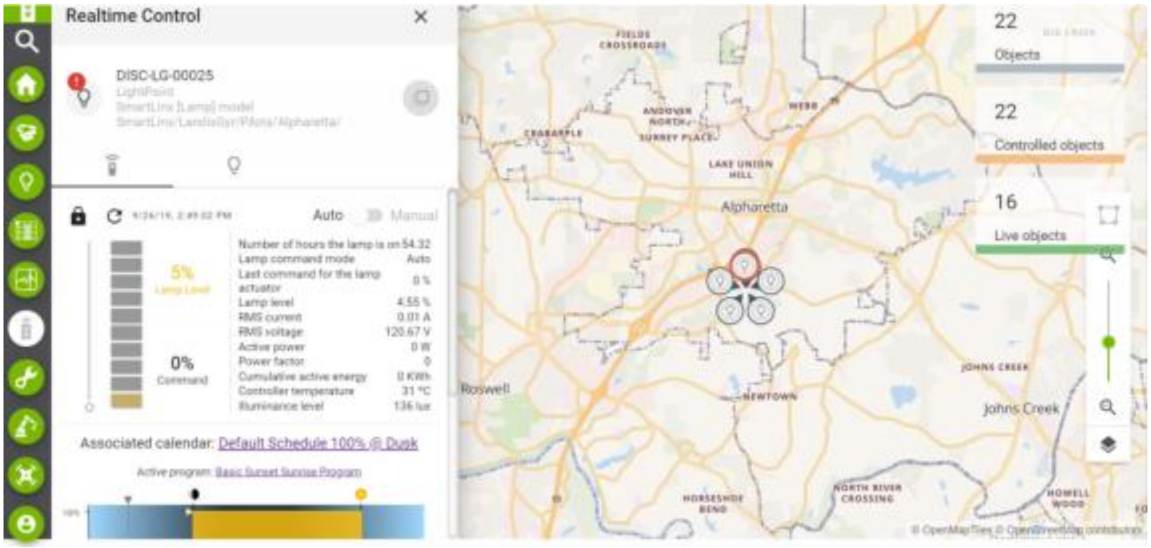


Energy Reports:

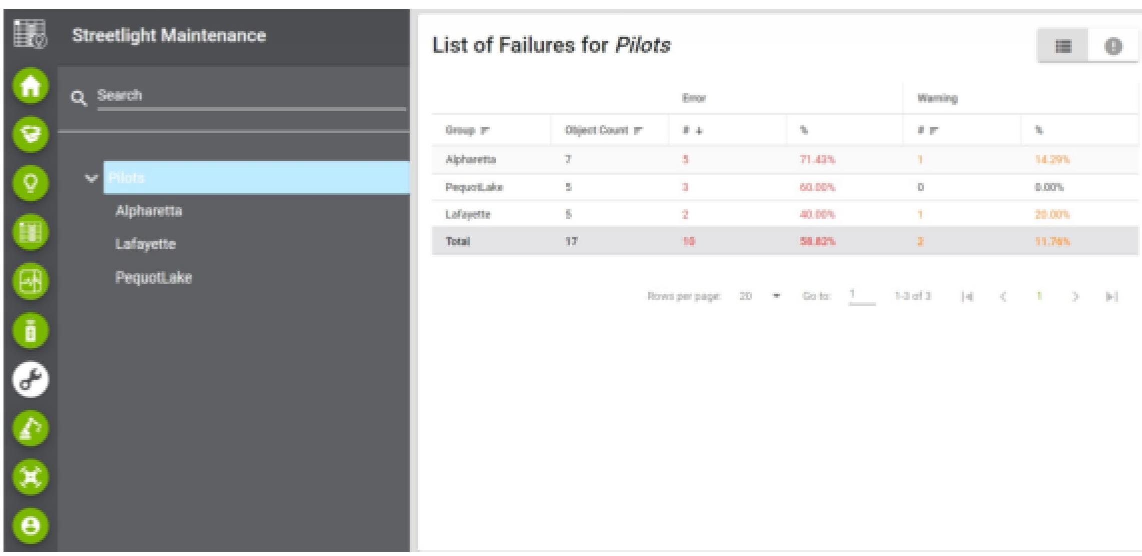
Data History:



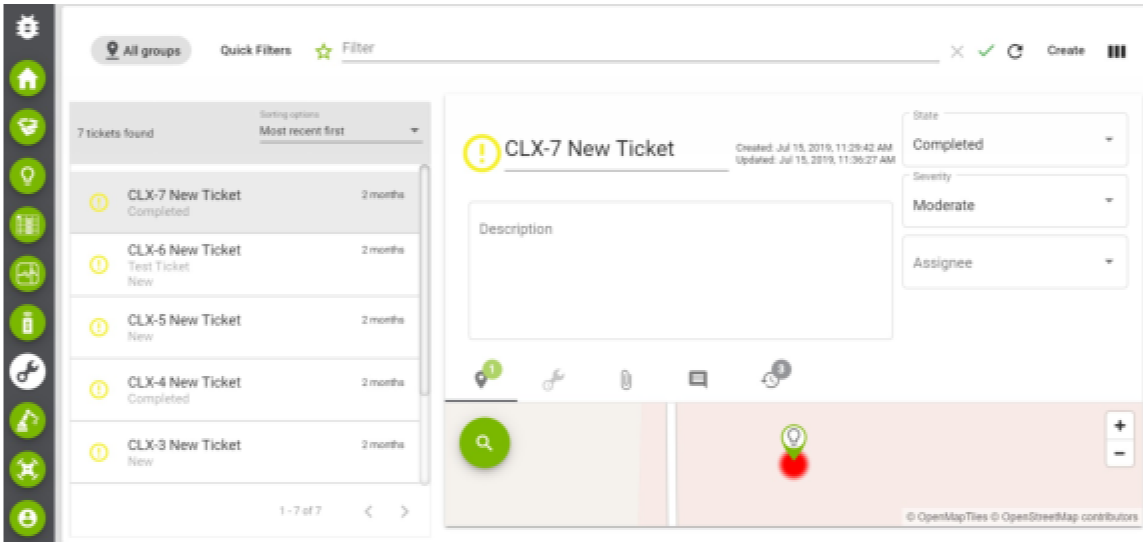
Real Time Control:



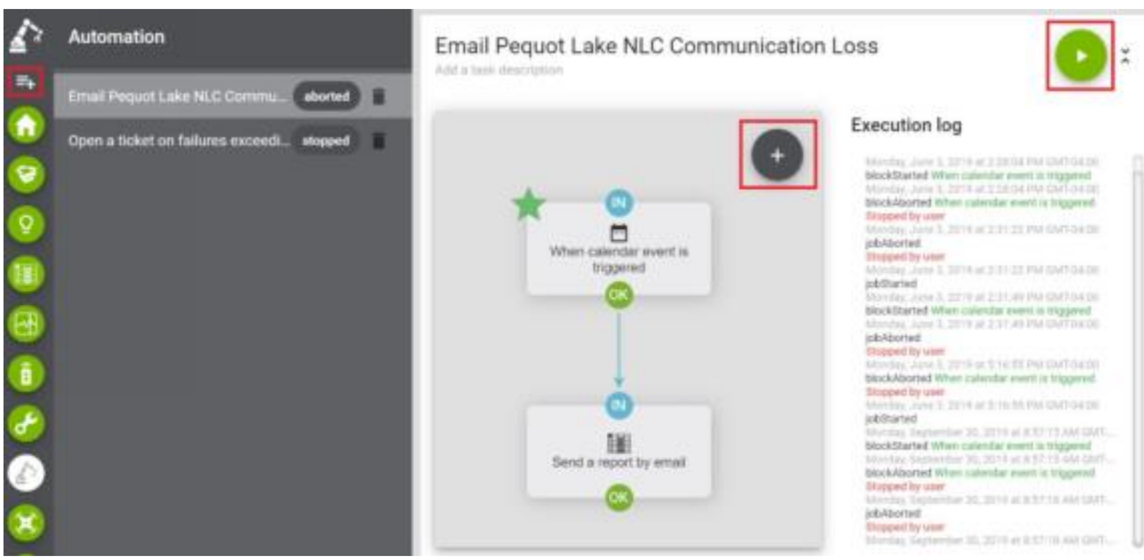
Streetlight Maintenance:



Tickets Center:



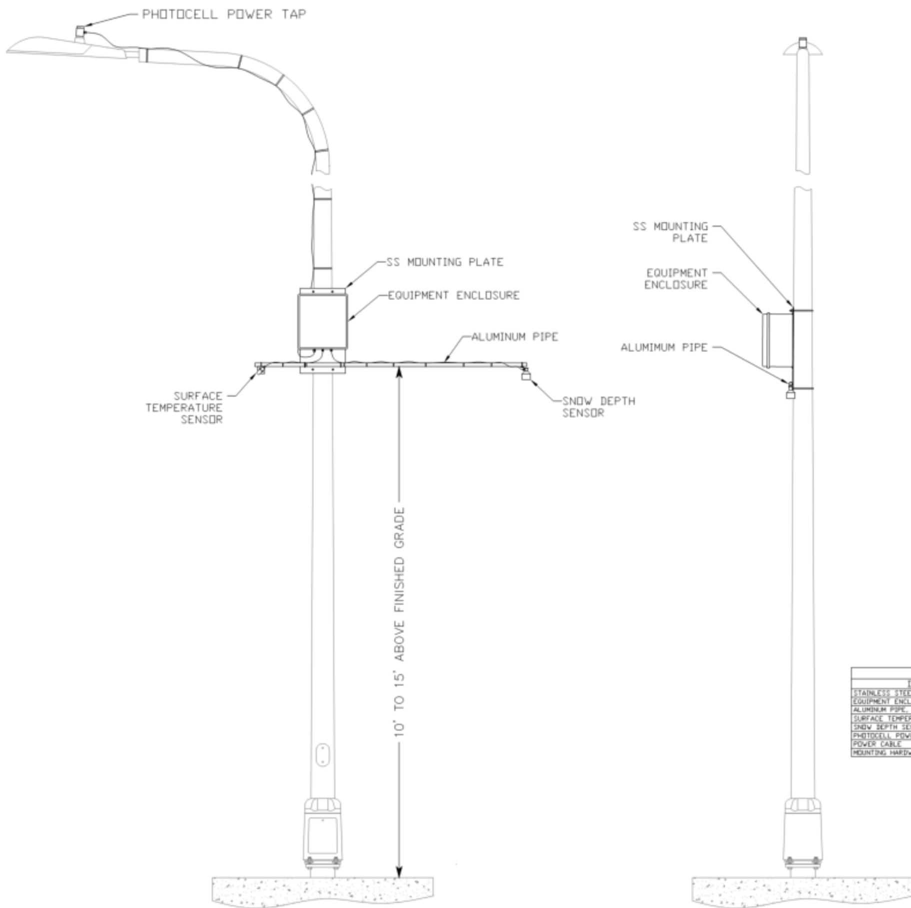
Automation Center:



Drone Monitoring:

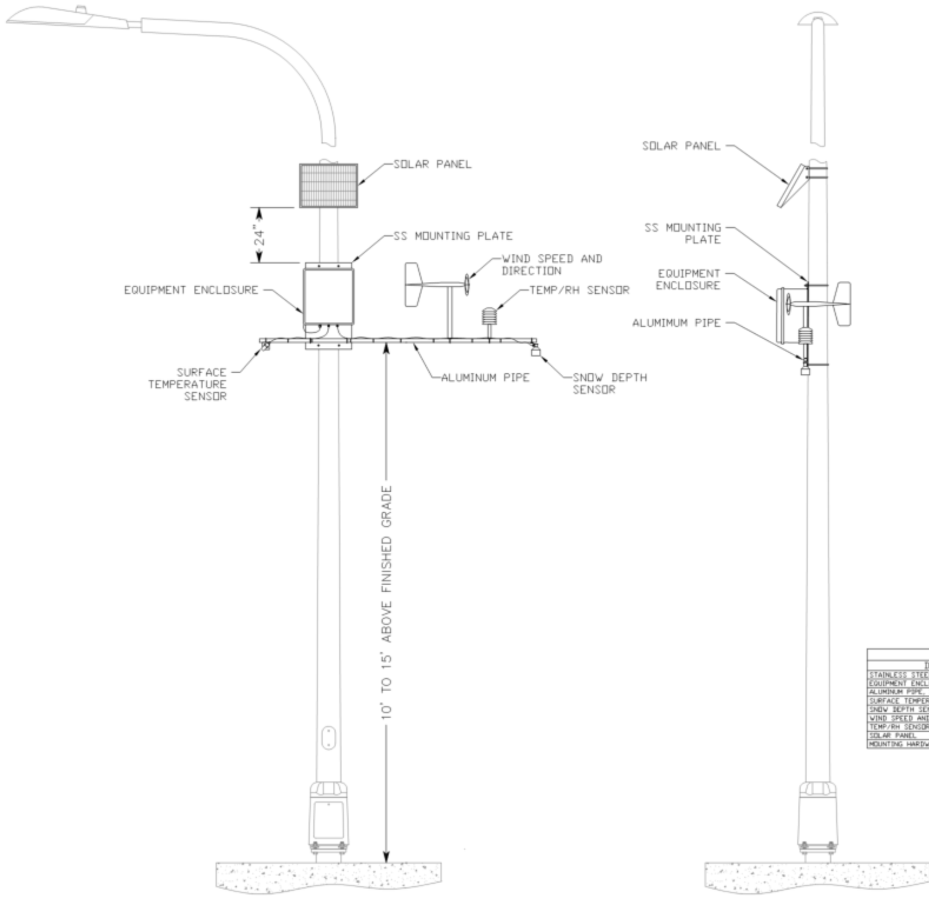
10. Appendix: Weather Station Mounting Details

Mounting details for “lite” station without solar panel and wind sensor:



DIMENSIONS AND WEIGHTS		
DESCRIPTION	DIMENSIONS (IN.)	WEIGHT (LBS.)
STAINLESS STEEL MOUNTING PLATE	30 x 16 x 0.1875	26.5
EQUIPMENT ENCLOSURE	19.5 x 17.5 x 10.5	18.2
ALUMINUM PIPE, SCHEDULE 40	1.315Ø x 96	4.8
SURFACE TEMPERATURE SENSOR	0.9Ø x 2.4	1.5
SNOW DEPTH SENSOR	3.0Ø x 4.0	1.4
PHOTOCELL POWER TAP	2.6Ø x 4.0	0.5
POWER CABLE	0.6Ø x 300	5.9
MOUNTING HARDWARE	N/A	1.5

Mounting details for “heavy” station with solar panel and wind sensor:



DIMENSIONS AND WEIGHTS		
DESCRIPTION	DIMENSIONS (IN.)	WEIGHT (LBS.)
STAINLESS STEEL MOUNTING PLATE	30 x 16 x 0.1875	26.5
EQUIPMENT ENCLOSURE	19.5 x 17.5 x 10.5	22.6
ALUMINUM PIPE, SCHEDULE 40	1.315ø x 96	4.8
SURFACE TEMPERATURE SENSOR	0.9ø x 2.4	1.5
SNOW DEPTH SENSOR	3.0ø x 4.0	1.4
WIND SPEED AND DIRECTION SENSOR	22.4 x 15.7 x 7.1ø	2.2
TEMP/RH SENSOR	4.9ø x 5.6	2.5
SOLAR PANEL	19.7 x 16.6 x 2.0	10.6
MOUNTING HARDWARE	N/A	2.5

11. Appendix: Campbell Scientific Product Sheets

PRODUCT

CAMPBELL SCIENTIFIC
WHEN MEASUREMENTS MATTER

CR300
Measurement and Control Datalogger

Compact Data Logger

Ideal for small applications

Overview

The CR300 is a multi-purpose, compact measurement and control data logger. This small, low-cost, high-value data logger offers fast communications, low power requirements, built-in USB, and excellent analog input accuracy and resolution. The CR300 can measure most hydrological, meteorological, environmental, and industrial sensors. It concentrates data, makes it available over varied networks, and delivers it using your preferred protocol. It also performs automated on-site or remote decision making for control and M2M communications. The CR300 is ideal for small applications requiring long-term remote monitoring and control.

The CR300 series includes Wi-Fi, cellular, or the following radio options for different regions:

- CR300-RF407: US and Canada
- CR300-RF412: Australia and New Zealand
- CR300-RF422: Europe

Note: Campbell Scientific does not recommend the CR300 for use as a PakBus router in networks with more than 50 devices. Large arrays or string variables may also reach memory limits. For such applications, a CR1000X Measurement and Control Datalogger is recommended.

Benefits and Features

- Connects directly to a computer's USB port
- Differentiates even slight changes in data values with higher resolutions measurements (24 bit Adc)
- Provides simple serial sensor integration and measurement with SDI-12 and/or RS-232
- Supports full PakBus networking
- Includes embedded web page for direct connection via web browser

Specifications

-NOTE-	*Additional specifications are listed in the CR300-Series Specifications Sheet.*

Operating Temperature Range	-40° to +70°C (standard) *Non-condensing environment*
Case Material	Powder-coated aluminum

For comprehensive details, visit: www.campbellsci.com/cr300

Analog Inputs	6 single-ended or 3 differential (individually configured)
Pulse Counters	8 (P_SW, P_LL, C1, C2, and SE1 to SE4)
Voltage Excitation Terminals	2 (VX1, VX2)
Communications Ports	》USB Micro B 》RS-232
Switched 12 Volt	1 terminal
Digital I/O	7 terminals (C1, C2, P_SW, and SE1 to SE4) configurable for digital input and output. Includes status high/low, pulse width modulation, external interrupt, and communication functions. Exception: The SE4 terminal doesn't do external interrupt.
Input Limits	-100 to +2500 mV
Analog Voltage Accuracy	》±(0.04% of measurement + offset) at 0° to 40°C 》±(0.1% of measurement + offset) at -40° to +70°C 》Accuracy specifications do not include sensor or measurement noise.
ADC	24-bit
Power Requirements	16 to 32 Vdc for charger input (CHG)
Real-Time Clock Accuracy	±1 min. per month
Internet Protocols	Ethernet, PPP, RNDIS, ICMP/Ping, Auto-IP(APIPA), IPv4, IPv6, UDP, TCP, TLS, DNS, DHCP, SLAAC, NTP, Telnet, HTTP(S), FTP(S), SMTP/TLS, POP3/TLS
Communication Protocols	PakBus, Modbus, DNP3, SDI-12, TCP, UDP, and others
Warranty	3 years (against defects in materials and workmanship)
CPU Drive/Programs	80 MB serial flash
Data Storage	30 MB serial flash
Idle Current Drain, Average	1.5 mA (@ 12 Vdc)
Active Current Drain, Average	》5 mA (@ 12 Vdc for 1 Hz scan with 1 analog measurement) 》23 mA (@ 12 Vdc with processor always on)
Dimensions	13.97 x 7.62 x 4.56 cm (5.5 x 3.0 x 1.8 in.) Additional clearance required for cables and leads.
Weight	242 to 250 g (0.53 to 0.55 lb) depending on communication option selected

CR300-RF407 Option

Radio Type	Frequency Hopping Spread Spectrum (FHSS)
Output Power	5 to 250 mW (user-selectable)
Frequency	902 to 928 MHz (US, Canada)
RF Data Rate	200 kbps
Receive Sensitivity	-101 dBm
Antenna Connector	RPSMA (External antenna required; see www.campbellsci.com/order/rf407 for Campbell Scientific antennas.)
Idle Current Drain, Average	12 mA (@ 12 Vdc)
Active Current Drain, Average	< 80 mA (@ 12 Vdc)

CR300-RF412 Option

Radio Type	Frequency Hopping Spread Spectrum (FHSS)
Output Power	5 to 250 mW (user-selectable)
Frequency	915 to 928 MHz (Australia, New Zealand)
RF Data Rate	200 kbps
Receive Sensitivity	-101 dBm
Antenna Connector	RPSMA (External antenna required; see www.campbellsci.com/order/rf412 for Campbell Scientific antennas.)
Idle Current Drain, Average	12 mA (@ 12 Vdc)
Active Current Drain, Average	< 80 mA (@ 12 Vdc)

For comprehensive details, visit: www.campbellsci.com/cr300

CAMPBELL SCIENTIFIC
Campbell Scientific, Inc. | 815 W 1800 N | Logan, UT 84321-1784 | (435) 227-9120 | www.campbellsci.com
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PWENC16/18

Prewired Enclosure, 16 x 18 inches

Saves Work, Prevents Errors

Factory-installed and tested wiring by experienced technicians

Overview

The PWENC16/18 is a prewired, weather-resistant enclosure that is 16 in. wide and 18 in. tall. It starts with the same enclosure used for our ENC16/18, but then is factory configured with up to 19 connectors that are attached to the data logger or peripherals within the enclosure. Sensors with the appropriate connector are simply attached to connectors on the outside of the enclosure. The PWENC16/18 includes a basic measurement program (created in ShortCut) for the -PW products sold as part of this system. If a more advanced custom data logger program is required for additional sensors, communications, control, or other needs, an extra fee will be incurred.

Benefits and Features

- Weather resistant to protect instruments
- Backplate designed so that Campbell Scientific components mount easily and securely
- Combines flexibility with ease of use
- Eliminates the task of wiring sensor leads into the data logger's terminal strips
- Reduces wiring errors by inexperienced field technicians who are unfamiliar with the equipment
- Shortens deployment time
- Allows each enclosure in a large network to be similar to the other enclosures
- Customized options may be purchased
- White, UV-stabilized enclosure reflects solar radiation—reducing temperature gradients inside the enclosure without requiring a separate radiation shield

Detailed Description

The PWENC16/18 can house one data logger, power supply, and one or more peripheral (depending on the peripheral's footprint). You order the sensors, data logger, power supply, and communication peripherals separately. Compatible sensors, peripheral cables, and solar panels have a –PW extension.

The PWENC16/18 is shipped with the 7363 enclosure supply kit that consists of desiccant, a humidity indicator card, cable ties, wire tie tabs, putty, grommets, screws, and PVC coupling. Connectors, communication ports, and the enclosure mounting bracket are chosen as options. (See Ordering Info on the web page.)

The PWENC16/18 can be mounted to any of our tripods or towers, or to a user-supplied pipe.

Note: Refer to the Ordering Info on the web page for standard configurations. Nonstandard configurations must be special ordered. It is considered a nonstandard configuration when using a different type, size, or location for any connector, communication port, conduit, cable entry seal, or antenna bulkhead (contact Campbell Scientific for more information).

Specifications

Color	White (Reflects solar radiation, reducing temperature gradients inside the enclosure without using a separate radiation shield.)
Construction	Fiberglass-reinforced polyester enclosure with door gasket, external grounding lug, stainless-steel hinge, and lockable hasps
Enclosure Classification	NEMA 4X (before being modified)
Dimensions	45.7 x 40.6 x 22.9 cm (18 x 16 x 9 in.) internal 43.8 x 38.7 x 25.2 cm (17.3 x 15.3 x 9.9 in.) internal under the lid space 49.5 x 44.4 x 27 cm (19.5 x 17.5 x 10.6 in.) external
Weight	7.7 kg (17 lb)

PRODUCT

SR50A-L

Sonic Distance Sensor

Rugged acoustic distance sensor

Typically used for snow depth or water depth measurements

Overview

The SR50A is a rugged acoustic sensor for measuring the distance from the sensor to a target. This sensor is typically used for snow depth or water depth measurements, but it is well-suited for other uses.

Because the speed of sound in air varies with temperature, an independent temperature measurement is required to compensate the distance reading. A simple calculation is applied to initial readings for this purpose.

Note: Campbell Scientific recommends model SR50A-316SS-L for marine environments.

Benefits and Features

- Wide operating temperature range
- User-selectable options for output
- Compatible with most Campbell Scientific data loggers

Detailed Description

The SR50A was designed to meet the stringent requirements of measuring snow depth and water depth, and it uses a multiple echo processing algorithm to help ensure measurement reliability.

SDI-12, RS-232, and RS-485 output options are available for measuring the SR50A. Campbell Scientific's MD485 interface can be used to connect one or more SR50A sensors in RS-485 mode to an RS-232 device. This can be useful for sensors that require lead lengths that exceed the limits of either RS-232 or SDI-12 communications.

The SR50A replaced the SR50 in March 2007. The newer SR50A is smaller and has different output options than its predecessor. The SR50AH is available with a heater option for locations where rime ice is a problem.

Specifications

Measurement Time	< 1.0 s
Measurement Range	0.5 to 10 m (1.6 to 32.8 ft)

For comprehensive details, visit: www.campbellsci.com/sr50a

Output Options	SDI-12 version 1.3, RS-232, RS-485 (output options selected by configuring internal jumpers)
Baud Rates	1200 to 38400 bps (RS-232, RS-485 modes)
Power Requirements	9 to 18 Vdc (typically powered by data logger's 12 Vdc power supply)
Beam Acceptance	~30°
Resolution	0.25 mm (0.01 in.)
Accuracy	±1 cm (0.4 in.) or 0.4% of distance to target (whichever is greatest). Requires external temperature compensation.
Operating Temperature Range	-45° to +50°C
Compliance	CE Compliant
Length	10.1 cm (4.0 in.)
Diameter	7.5 cm (3 in.)
Cable Weight	250 g (8.2 oz) for a 4.57-m (15-ft) cable
Weight	》375 g (13.2 oz) without cable 》1.0 kg (2.2 lb)

Maximum Cable Length

-NOTE-	*Cable lengths greater than 60 m require a heavier gage wire if the power supply drops below 11 Vdc.*
SDI-12	60 m (196.9 ft)
RS-232	30 m (98.4 ft) Baud rates ≤ 9600 bps
RS-485	300 m (984.3 ft)

Power Consumption

Active	250 mA (typical)
Quiescent SDI-12 Mode	< 1.0 mA
Quiescent RS-232/RS-485 Modes	》< 2.0 mA (> 9600 bps) 》< 1.25 mA (≤ 9600 bps)

For comprehensive details, visit: www.campbellsci.com/sr50a

PRODUCT

CAMPBELL SCIENTIFIC
WHEN MEASUREMENTS MATTER

SI-111SS

Infrared Radiometer with Standard Field of View

Determine an Object's Surface Temperature

No physical contact necessary

Overview

The SI-111SS, manufactured by Apogee, is a precision infrared radiometer that determines the surface temperature of an object without physical contact. It measures both the subject's surface temperature and the sensor-body temperature. A Campbell Scientific data logger uses these measurements to calculate the correct temperature of the subject.

This radiometer features an IP67-rated, marine-grade 316L connector that allows the user to easily swap sensors for recalibration or to replace damaged cables.

Benefits and Features

- Compatible with most Campbell Scientific data loggers
- Measures surface temperature continuously in the field
- Provides road surface, plant canopy, soil surface, snow surface, and water surface temperature measurements
- Avoids influencing the temperature, providing more accurate measurements
- Ideal for providing spatial averages
- Rugged construction—two temperature probes housed in an aluminum body with a germanium window

Detailed Description

The SI-111SS consists of a thermopile, which measures surface temperature, and a thermistor, which measures sensor body temperature. The two temperature sensors are housed in a rugged aluminum body that contains a germanium window.

Both the thermopile and the thermistor output a millivolt signal that most of our data loggers can measure. The data logger uses the Stefan-Boltzman equation to correct for the effect of sensor body temperature on the target temperature. The corrected readings yield an absolute accuracy of ±0.2°C from -10° to +65°C.

Field of View (FOV)

The SI-111SS has a 22-degree half-angle field-of-view (FOV). The FOV is reported as the half-angle of the apex of the cone formed by the target (cone base) and the detector (cone apex). The target is a circle from which 98% of the radiation viewed by the detector is being emitted.

For comprehensive details, visit: www.campbellsci.com/si-111ss

Specifications

Input Power	2.5 V excitation (for thermistor)
Response Time	< 1 s (to changes in target temperature)
Target Temperature Output Signal	60 µV per °C difference from sensor body
Body Temperature Output Signal	0 to 2500 mV
Optics	Germanium lens
Wavelength Range	8 to 14 µm (corresponds to atmospheric window)
Field of View (FOV)	22° half angle
Operating Temperature Range	-55° to +80°C
Operating Relative Humidity Range	0 to 100% RH
Cable Description	4.5 m (14.76 ft) twisted, shielded 4-conductor wire with Santoprene casing, ending in pigtails
Absolute Accuracy	±0.5°C (-40° to +70°C) ±0.2°C (-10° to +65°C)
Uniformity	±0.3°C (-40° to +70°C) ±0.1°C (-10° to +65°C)
Repeatability	±0.1°C (-40° to +70°C) ±0.05°C (-10° to +65°C)
Diameter	2.3 cm (0.9 in.)
Length	6 cm (2.4 in.)
Weight	190 g (6.7 oz)

For comprehensive details, visit: www.campbellsci.com/si-111ss

PRODUCT

HygroVUE5

Digital Temperature and Relative Humidity Sensor

Designed for General Meteorological and Other Data Logging Applications

Overview

The HygroVUE™5 Temperature and Relative Humidity Sensor is designed for general meteorological and environmental monitoring applications. It utilizes the SDI-12 communications protocol to communicate with any SDI-12 recorder, simplifying installation and programming. The sensing element is easily changed in the field, reducing downtime and calibration costs. It is the entry-level sensor in the HygroVUE™ line of relative humidity and temperature sensors.

Benefits and Features

- Uses a combined, pre-calibrated digital humidity and temperature element
- Field-changeable element for fast, on-site recalibration
- Digital SDI-12 output, allowing long cables with no added errors
- Simple data logger programming
- Low power consumption
- Wide operating voltage
- Rugged design with potted electronics
- Compact size for smaller radiation shields

Detailed Description

The HygroVUE™5 sensor has a user-replaceable chip element that incorporates both a temperature sensor and an RH sensor. Each element is individually calibrated with the calibration corrections stored on the chip.

Electronics within the HygroVUE™5 control the measurement made by the sensor element, apply temperature and linearization corrections to the readings, and present the data via SDI-12 to a data logger.

A stainless-steel mesh filter minimizes the effects of dust and dirt on the sensor, while allowing air exchange around the sensor element and reducing the chance that condensation remains inside the filter cap. A small PTFE membrane filter is bonded to the surface of the element, which prevents any finer dust or mold from directly influencing the measurement.

The sensor housing is designed to withstand permanent exposure to all weather. It fits into a range of radiation shields, including compact shields such as the RAD06 6-Plate Solar Radiation Shield.

For comprehensive details, visit: www.campbellsci.com/hygrovue5

For improved reliability, the sensor is factory fitted with a fixed length of cable, and the sensor body is then potted to completely seal the electronics and cable joint. A range of cable lengths is available.

Specifications

Sensor Element	SHT35 derivative (specially coated for reliability)
Calibration Traceability	NIST and NPL standards
Supply Voltage	7 to 28 Vdc
Warm-up Time	Sensor is normally powered all the time. If power is switched off, allow 1.8 s for sensor to power up.
Main Housing Material	White PET-P
Housing Classification	IP67 (electronics housing)
Sensor Protection	Outer glass-filled polypropylene cap fitted with a stainless-steel mesh dust filter with nominal pore size of < 30 µm. The sensor element is fitted with a PTFE protective film with a filtration efficiency of > 99.99% for particles of 200 nm or larger size.
EMC Compliance	Tested and conforms to IEC61326:2013
Calibration	The sensor element is individually calibrated during manufacture.
Diameter	12.5 mm (0.49 in) at sensor tip, maximum 16 mm (0.63 in) at the cable end
Length	115 mm (4.52 in) sensor only, without cable

Maximum Current Drain

Quiescent	50 µA typical
During Measurement	0.6 mA (takes 0.5 s) typical

Temperature Measurement

Operating Range	-40 to +70°C
Accuracy	±0.4°C (over the range -40 to +70°C) ±0.3°C (over the range -20 to +60°C)
Long-Term Drift	< ±0.03°C per year
Reported Resolution	0.001°C
Repeatability	0.04°C Values are 3 standard deviations of 25 measurements at constant temperature.
Response Time	130 s (63% response time in air moving at 1 m/s)
Units	Degrees Celsius

Relative Humidity Measurement

Measurement Range	0 to 100% RH
Accuracy (at 25°C)	±3% (over the range 80 to 100% RH) ±1.8% (over the range 0 to 80% RH)
Additional Errors at Other Temperatures	< ±1% RH (over -40 to +60°C)
Short-Term Hysteresis	< ±1% RH
Long-Term Stability	±0.5% per year (maximum drift in clean air conditions)
Reported Resolution	0.001% RH
Repeatibility	0.05% RH Values are 3 standard deviations of 25 measurements at constant humidity.
Response Time with Filter	8 s (63% response time in air moving at 1 m/s at 25°C)

	Weight	Dimensions	Compatible Sensors[a]	Mounts to	Features
41003-5A | 10-Plate Naturally-Aspirated Solar Radiation Shield with Band Clamp 	0.6 kg (1.3 lb)	plate diameter: 11.9 cm (4.7 in) height: 20.3 cm (8.0 in)	107[b], 108[b], 109[b], HMP60[c], CS215[c], 43347[d], EE181[e]	CM500-series poles or user-supplied with a (1.05 in) to 5.1 cm (2.4 in) OD	» Naturally shades and protects sensor
RAD10 | 10-Plate Naturally-Aspirated Solar Radiation Shield with Double-Louvered Design 	1.0 kg (2.2 lb)	plate diameter: 12.3 cm (4.8 in) height: 20.8 cm (8.2 in)	HMP60, CS215, 083E, 43347	crossarm, mast, or user-supplied pipe with a 2.5 cm (1.0 in) to 5.3 cm (2.1 in) OD	» Improved sensor protection from driving rain, snow, insect intrusion » Lower self-heating
RAD10E | 10-Plate Naturally-Aspirated Solar Radiation Shield with Double-Louvered Design 	1.0 kg (2.2 lb)	plate diameter: 12.3 cm (4.8 in) height: 20.8 cm (8.2 in)	EE181, HMP60[f]	crossarm, mast, or user-supplied pipe with a 2.5 cm (1.0 in) to 5.3 cm (2.1 in) OD	» Improved sensor protection from driving rain, snow, insect intrusion » Lower self-heating
41005-5 14-Plate Naturally-Aspirated Solar Radiation Shield 	~1 kg (~2 lb)	plate diameter: 11.9 cm (4.7 in)	HMP155A	crossarm, mast, or user-supplied pipe with a 2.5 cm (1.0 in) to 5.3 cm (2.1 in) OD	» Naturally shades and protects sensor
RAD14 | 14-Plate Naturally-Aspirated Solar Radiation Shield with Double-Louvered Design 	1.1 kg (2.5 lb)	plate diameter: 12.3 cm (4.8 in) height: 27.4 cm (10.8 in)	HMP155A	crossarm, mast, or user-supplied pipe with a 2.5 cm (1.0 in) to 5.3 cm (2.1 in) OD	» Improved sensor protection from driving rain, snow, insect intrusion » Lower self-heating
43502-L | Fan-Aspirated[g] Solar Radiation Shield 	1.1 kg (2.5 lb)	length: 33 cm (13 in) diameter: 20 cm (8 in)	43347 RTD probe or other sensors with up to 2.5 cm (0.9 in) diameter	crossarm, mast, or user-supplied pipe with a 2.5 cm (1.0 in) to 5.3 cm (2.1 in) OD	» Shades and draws ambient air past sensor for more accurate measurements

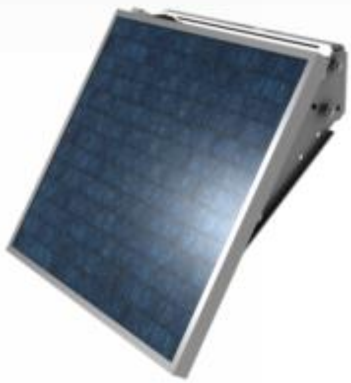
[a] Only currently-available sensors are listed. Refer to our website for compatibility with retired sensors.
[b] The 41322 adapter is required to install a 107, 108, or 109 probe in a 41003-5 or 41003-5A.
[c] For the HMP60 and CS215, the 41322 adapter can be used to mount the sensor in the lower part of the 41003-5 or 41003-5A. Alternatively, a 41381 extension tube and the 6637 hex plug can be used to mount the HMP60 or CS215 in a higher part of the shield; this configuration also requires the 18278 cable.
[d] The 27251 hex plug is required to install a 43347 RTD in a 41003-5 or 41003-5A radiation shield.
[e] The 28415 adapter is required to install an EE181 in a 41003-5 or 41003-5A radiation shield.
[f] The 33560 extension tube is required to install an HMP60 in the RAD10E radiation shield.
[g] The 43502 requires 12 to 14 Vdc. Its blower uses 500 mA.

PRODUCT

CAMPBELL SCIENTIFIC
WHEN MEASUREMENTS MATTER

SP20

20 W Solar Panel



Overview

The SP20 is a 20 W solar panel. It is often used for system configurations that have higher-than-average power requirements, or in higher elevation and latitude locations. It connects to Campbell Scientific power supplies and battery bases to recharge the battery, and it allows unattended operation of systems in remote locations that are far from ac electrical sources.

Benefits and Features

- Supplies electrical power in locations where ac power is unreliable, expensive, or not available
- Recharges the sealed rechargeable battery of a PS150, PS200, BP12 (requires CH150 or CH200), BP24 (requires CH150 or CH200), CR3000, CR5000, CR6, or CRVW3

Detailed Description

The SP20's 15-ft cable has stripped and tinned leads that connect to the PS150, PS200, CH150, CH200, or battery base of the CR3000, CR5000, CR7, CR9000X, CR6, or CRVW3. A 788 connector must be soldered onto the solar panel leads to use the SP10 with a 21XL rechargeable base.

Included mounting hardware consists of two part no. 17492 U-bolt and matching nuts. The U-bolt has a 5.398 cm (2.125 in.) space between the U-bolt legs. This hardware allows the solar panel to be mounted to a 0.75-1.5 in. IPS pipe [25.4-50.8 cm (1-2 in.) OD].

Specifications

-NOTE-	*Solar panel characteristics assume 1 kW m^{-2} illumination and 25°C solar panel temperature. Individual panels may vary up to 10%. The output panel voltage increases as the panel temperature decreases.*
Cable Description	20 AWG, 1-twisted pair
Maximum Peak Power	20 W

For comprehensive details, visit: www.campbellsci.com/sp20

Maximum Allowable Wind Gust Speed	*Note: The wind ratings are for solar panels with the indicated mounts and do not account for strength of tower or tripod.* 44 m s^{-1} (99 mph) Standard mount 58 m s^{-1} (130 mph) Extended mount
Guaranteed Minimum Peak Power	18 W
Current at Peak	1.19 A
Voltage at Peak	16.8 V
On-board Regulator Included	No
Cable Length	4.572 m (15 ft)
Dimensions	50.0 x 42.2 x 5.1 cm (19.7 x 16.6 x 2 in.)
Weight	4.4 kg (9.6 lb)

PRODUCT

CAMPBELL SCIENTIFIC
WHEN MEASUREMENTS MATTER

03002-L
Wind Sentry Set

Reliable, Competitively Priced

Good, all-purpose wind set

Overview

The 03002, manufactured by R. M. Young, measures wind speed and direction with a three-cup anemometer and a wind vane mounted on a small crossarm. It interfaces directly with your Campbell Scientific data loggers, so no signal conditioning is required.

Benefits and Features

- Compatible with most Campbell Scientific data loggers
- Designed for continuous, long-term, unattended operation in adverse conditions
- Small size, simplicity, and rugged construction provide a quality instrument for a modest price
- Ideal for wind profile studies
- Compatible with the LLAC4 4-channel Low-Level AC-Conversion Module, which increases the number of anemometers one data logger can measure
- Campbell Scientific version uses shielded bearings, which lowers the anemometer's starting threshold
- Compatible with the CWS900-series interfaces, allowing it to be used in a wireless sensor network

Detailed Description

The 03002 uses a cup wheel assembly to measure wind speed. Rotation of the cup wheel produces an ac sine wave that is directly proportional to wind speed. The frequency of the ac signal is measured by a data logger pulse count channel, then converted to engineering units (mph, m/s, knots). Campbell Scientific's version uses shielded bearings, which lowers the anemometer's threshold.

Wind direction is sensed by a potentiometer. With the precision excitation voltage from the data logger applied to the potentiometer element, the output signal is an analog voltage that is directly proportional to the azimuth angle of the wind direction.

Specifications

Operating Temperature Range	-50° to +50°C (assuming non-riming conditions)

For comprehensive details, visit: www.campbellsci.com/03002-wind-sentry

Height	32 cm (12.6 in.)
Crossarm Length	40 cm (15.7 in.) between instruments (center-to-center)
Mounting Diameter	34 mm (1.34 in.); mounts on standard 1-in. IPS pipe

Wind Speed (Anemometer)

Range	0 to 50 m/s (0 to 112 mph)
Gust Survival	60 m/s (134 mph)
Sensor	12-cm diameter cup wheel assembly, 40-mm diameter hemispherical cups
Accuracy	±0.5 m/s (1.1 mph)
Turning Factor	75 cm (2.5 ft)
Distance Constant	2.3 m (7.5 ft) 63% recovery
Starting Threshold	0.5 m/s (1.1 mph)
Transducer	Stationary coil (1300 ohm nominal resistance)
Transducer Output	AC sine-wave signal induced by rotating magnet on cup wheel shaft 100 mV peak-to-peak at 60 rpm (6 V peak-to-peak at 3600 rpm)
Output Frequency	1 cycle per cup wheel revolution (0.75 m/s per Hz)
Cup Wheel Diameter	12 cm (4.7 in.)
Weight	113 g (4 oz)

Wind Direction (Vane)

Mechanical Range	360°
Electrical Range	352° (8° open)
Settling Time	20 ms
Sensor	Balanced vane; 16 cm turning radius
Accuracy	±5°
Damping Ratio	0.2
Delay Distance	0.5 m (1.6 ft) 50% recovery
Starting Threshold	》0.8 m/s (1.8 mph) with 10° displacement 》1.8 m/s (4 mph) with 5° displacement
Transducer	》1.0% linearity 》Precision conductive plastic potentiometer (10 kohm resistance) 》Life expectancy is 50 million revolutions. 》Rated 1 W at 40°C, 0 W at 125°C.
Transducer Excitation	Requires regulated dc voltage. (15 Vdc maximum)
Transducer Output	Analog dc voltage proportional to wind direction angle with regulated excitation voltage supplied by the data logger
Vane Length	22 cm (8.7 in.)
Weight	170 g (6 oz)

For comprehensive details, visit: www.campbellsci.com/03002-wind-sentry

CAMPBELL SCIENTIFIC
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