Sustainability Through Streetlights: Why Smart LED Streetlights are the Gold Standard for Measurable Carbon Reduction

Cities are responsible for of approximately 75% of man-made carbon dioxide (CO2) emissions. More than 1,000 cities around the globe have pledged to take rigorous, immediate action to halve emissions by 2030, and a growing number of cities are now mandated under local, state, or national carbon-reduction policies. To meet their goals, cities need to prioritize projects that are truly impactful and quick to implement.

Renewable energy is an important part of the solution, especially given the costs have dropped below those of coal-fired generation in most countries. But growing demand for electricity and obstacles to the pace of development means that cities cannot rely on renewables alone to meet their carbon-reduction goals. This leaves two strategic options to close the gap: sequestering CO2 away from the atmosphere (carbon capture) and managing demand (energy efficiency).

Governments and industry are putting money into early carbon capture projects, but the solutions are immature and expensive, costing as much as US$40-100 per ton to capture concentrated carbon sources (e.g. steel production) and US$134-342 for diluted sources (e.g. direct air capture), not to mention the costs and risks of transport and long-term storage. In comparison, energy efficiency projects are much more mature and attractive, with well-established precedents and strong returns on investment (ROI) through existing market structures. The challenge with demand-side projects, however, is that their impact can be difficult to measure and verify, leaving them open to claims of "green washing" or even fraud.

But one project type generates large, quantifiable boosts in energy efficiency. Cities around the globe are upgrading their old, inefficient streetlights with light emitting diodes (LEDs) and smart control systems. Streetlights consume 15-40% energy use in an average city and up to 60% energy use in an average municipality. LED streetlights with smart controls can:

- save millions in electricity and maintenance costs,
- reduce energy and associated (scope 2) carbon emissions by up to 80%, and
- provide verified carbon-reduction figures that satisfy the most rigorous 24/7 accounting methods.

This paper explains why LED streetlights are the low-hanging fruit for urban carbon reduction, and why no streetlight upgrade investment is complete without smart lighting controls.

IMMEDIATE BENEFITS AROUND THE GLOBE

Paris was one of the first major cities to install smart LED streetlighting. In 2015, the famous City of Lights upgraded nearly 200,000 streetlights with LED luminaires, networked lighting controls (NLCs), a wireless communications platform, and a central management system (CMS) capable of controlling and measuring dynamic lighting schedules. Following the success of the program, the entire country began making the switch. Since 2016, France has replaced more than a third of its 7 million streetlights and is on track to complete them all by 2030, the same year the country has pledged to reduce carbon emissions by 40%.

Christchurch, New Zealand, is completing a similar streetlight modernization project, upgrading 45,000 legacy streetlights with longer-lasting and more-efficient LED luminaires and smart lighting control systems. The project is an important part of the city's goal to achieve carbon neutrality by 2045 and is expected to save the city NZ$2.1 million annually in electricity and maintenance costs.

A typical LED deployment averages two years for a city with 100,000 lights, and the upgrades begin delivering benefits on day one. The immediate impact and clear ROI of LEDs are driving rapid adoption, and 90% of global streetlights are projected to be LEDs by 2031 (see graph).

The evidence is clear that upgrading to LED bulbs alone cuts energy consumption by about half compared with legacy bulb technologies. **But only upgrading the bulb leaves considerable value on the table. Adding smart-lighting control**:

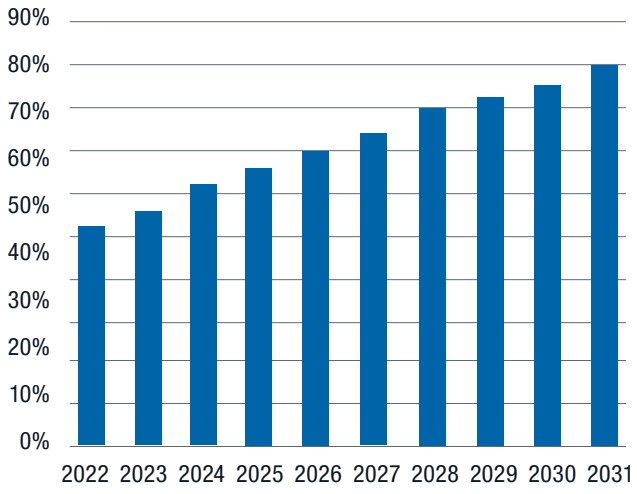
1. boosts energy savings by an additional 10% to 30%,

2. enables simple, real-time measurement of electricity consumption and carbon reductions, and

3. establishes technology infrastructure for expansive equity and smart-city initiatives.

In short, NLCs are small hardware modules in each luminaire that can enable greater functionality, electricity metering and networked communications with back-office software systems. Read on to learn how smart controls deliver more benefits and

PERCENT OF LED'S CONVERTED GLOBALLY



1. How Smart Controls Boost Carbon Savings

Smart streetlighting systems enable proactive management strategies that result in deeper cost and emissions savings than can be achieved with LED bulbs alone. For starters, the systems automatically detect "day burners" — malfunctioning lights that stay on during the day, wasting energy. Maintenance teams can receive immediate alerts to repair or replace a light that begins wasting energy by staying on during the day.

Control systems also allow the brightness levels of LED streetlights to be adjusted dynamically, like a dimmer switch in a house. Dimming generates a big boost in energy savings, because decreasing the luminosity of LEDs reduces electricity consumption. The brightness of LEDs is not a straight-line function of electricity consumption, so a minor reduction in brightness actually results in a significant efficiency gain (see graph). With smart controls, luminosity can be set lower for an individual light or for groups of lights. They can also be scheduled to dim — perhaps in the middle of the night — when the fewest number of residents are active. Or they can be scheduled to burn longer and brighter on weekends, game nights, or in conjunction with other events. **Lights can even be automated to dim marginally when the cost or carbon intensity of power generation exceeds a predetermined threshold**.

Smart streetlighting systems also enable the reduction of energy waste through adaptive controls. In these instances, lights are typically paired with motion sensors so that LEDs remain dimmed until pedestrian, bike, or vehicle traffic enters the vicinity.

Smart control systems also generate net savings through constant light output (CLO). It is well understood that the output from streetlights inevitably decreases as luminaire's age and accumulate grime. To maintain adequate levels of light, maintenance crews typically must replace aging luminaires early or clean them in the field. This solution requires many carbon-intensive truck rolls and countless hours of labor. But smart streetlighting systems with CLO gradually boost the LED output over time to maintain the same level of luminosity. For example, a new LED streetlight can be configured to operate at 80% brightness level (still emitting a sufficient and safe level of light) on the day it is installed, and then increase the brightness level by 2% each year for the next 10 years. While requiring a marginal increase in electricity consumption, the carbon and cost impact of CLO is less than that of extensive maintenance work.

Smart control systems also offer significant operational benefits beyond just the reduction of truck rolls that occurs when cities switch to longer-lasting LED technology. Salt Lake City, Utah, reported that its system was equivalent to having another full-time employee, because of the reduced number of service calls, streamlined maintenance processes, and improved asset management. Similarly, the city of Tempe, Arizona, reported that its LED conversion project was paying for itself in reduced truck rolls alone, and numerous cities noted that residents were happier because they no longer had to call and report outages. Christchurch, New Zealand, had almost 6,000 fewer work orders between 2019 and 2023 after installing its smart streetlights, and the city's maintenance costs decreased by approximately $1.2 million.

FOUR BIG BOOSTS FROM SMART LIGHTING

SMART STREETLIGHTS BY AND FOR CHICAGO

LOCATION: **Chicago, Illinois**

POPULATION: **~2.75 million** (3rd largest city in U.S.)

PROJECT SIZE: **~290,000** LED streetlights with smart controls

ANNUAL EMISSIONS SAVINGS: **134,600** metric tons (estimated)

ESTIMATED COST SAVINGS: **$100 million** over the first decade

In 2022, the City of Chicago completed the bulk of a project to replace its hazy orange high-pressure sodium (HPS) streetlights with smart LED streetlights. “The main reasons for the project were carbon reduction and a better quality of life for residents,” said Art Rodriguez, Deputy Commissioner, Chicago Department of Transportation. “It addresses climate change and air quality for future generations, plus the brightness of the LEDs has changed the perception of neighborhoods in a way that feels safer.”

Chicago has a goal to reduce its carbon dioxide emissions 62% by 2040, and the State of Illinois is aiming for net-zero emissions by 2050. With metering at every luminaire and real-time carbon calculations built into the central management system (CMS), the city knows exactly how much the project has saved: 134,600 metric tons of CO2 and $8.7 million annually on electricity as of September 2022. Plus, the regional electric utility, ComEd, gave the city almost $37 million in additional rebates over the first five years of implementation.

In addition to the resource savings, the smart streetlighting has been a “game changer” for operations, according to Rodriguez. Previously, the city received 1,000 streetlight-related complaints to its 311 system every week and relied on these and field inspections to discover outages. “Now, even with staff limitations, we find and fix outages before we even receive a complaint sometimes,” he said. “The system has allowed us to dispatch more efficiently, and it’s definitely cut down on our operational costs.”

In step with the streetlighting implementation, Rodriguez’s department has eliminated paper-based operations. Dispatchers use the CMS to prioritize and group work orders to further increase the department’s effectiveness, and work crews receive mobile failure alerts with work orders, 311 ticket data, GIS location and circuitry information needed for repairs.

Beyond the operational and environmental benefits, Chicago’s project also contributed to the local economy. All of streetlight luminaires were manufactured in Chicago and installed with local labor, trained by Rodriguez and his staff. “From start to finish, this has been by and for Chicagoans,” he said.

Currently the City is considering moving its city water meters onto the same communication network as the streetlights, and the network is being used to test air quality sensors and applications.

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-Art Rodriguez, *Deputy Commissioner, Chicago Department of Transportation*

2. How Accurate Measurement Enables Verification and Decision-Making

The top 50 emissions offset projects on the global market are largely "junk," according to a recent investigation by The Guardian and researchers from Corporate Accountability. "In our analysis, a project was classified as likely junk if there was compelling evidence, claims or high risk that it cannot guarantee additional, permanent greenhouse gas cuts among other criteria," the news outlet explained.

The Guardian investigation highlights the pressing need for verifiable carbon reductions. With the increasing urgency of reduction timelines and millions in government funding and carbon finance on the line, decision-makers need the assurance of quantifiable results. But accurate carbon measurement isn't that simple.

Systems, economies, and cities are in constant flux. Behavior patterns of commuters, for example, change with the weather and impact carbon emissions. The carbon intensity of commodities also changes with suppliers and different processing methods. Plus, new technologies — like renewables — come online, and annual grid-emissions factors aren't updated to reflect the new mix. These are just some of the reasons monitoring and verifying carbon reductions with static calculations is challenging, if not impossible.

The conventional method for estimating carbon reductions from streetlight upgrades is a perfect example of the difficulty. Historically, cities or agencies multiplied the difference in wattage ratings between the old and new bulbs by the estimated hours of operation of all the upgraded luminaires. Then that very large number was multiplied by the yearly average carbon intensity of the state- or country-wide power mix to arrive at an estimated reduction figure. This calculation model has been used extensively to validate the general efficiency gains of LED streetlighting. But it is far from accurate (or useful) for important reasons.

First, hours of operation can only be loosely estimated due to differing control schedules and the automation of some lights via photocells. Second, LEDs with dimming capability often function at reduced power levels (as explained in the section above). Most importantly, the carbon intensity of power supplies can vary by up to 20% based on the types of fuel in use from one moment to another. Finally, even if the margin of error with a static measure was acceptable for stakeholders, the frequency would also be a problem. Manual audits are time-consuming projects that might be completed once a year, at best — far from the frequency needed to satisfy measurement and verification (M&V) purposes and inform strategic decision-making.

Smart streetlighting systems can calculate and report real-time reductions for LED streetlights, individually or in aggregate. Some NLCs provide revenue-grade electric metering at each luminaire, and the central management system (CMS) matches the time of consumption with carbon intensity figures from the electricity provider or environmental agency. The system then tallies, tracks, and reports the results to meet the various needs of stakeholders.

In addition to verifying savings for government-funded programs, carbon finance markets, or utility rebate programs, streetlighting systems with real-time carbon accounting allow cities to optimize their dynamic lighting decisions. The CMS can supply the granular or holistic data analysis needed to test dimming schedules and weigh the environmental and budgetary impacts against public-safety needs.

The systems can also measure consumption and calculate associated emissions for other equipment spread throughout the city. This can be done by hardwiring signs, security systems, electric vehicle (EV) chargers, 5G antennas, or other devices to luminaires with smart controls, which are capable of metering electricity consumption by other devices. Or it can be achieved through software integrations with the CMS to calculate emissions generated by other city-owned assets. With this capability, the CMS becomes a strategic tool for centralized tracking of a city's progress toward climate and energy goals, and it can provide insights into the effects of seasonal changes, holidays, city events, construction, and policies. It also can be used for revenue generation and billing.

3. How Streetlight Networks Expand the Possibilities for Smart Cities

Smart LED streetlighting also provides the infrastructure to address other urban issues that result in higher carbon emissions and lower quality of life by providing an industrial IoT (IIoT) network platform for additional smart city sensors. For example, day-time temperatures in poorer urban neighborhoods are often hotter than more affluent areas of a city, according to the U.S. Environmental Protection Agency (EPA). This intra-urban heat island effect is caused by "the uneven, inequitable spread of landcovers in the urban landscape, leading to more heat-absorbing buildings and pavements and fewer cool spaces with trees and greenery." It is also an example of the overlapping causes and effects at the intersection of energy, climate, and equity.

In addition to health impacts, residents of these areas suffer financially because of the heat island effect, and the impacts will continue to worsen, if left unaddressed. About 30% of all U.S. households report difficulty paying their energy bills or cooling their homes, which is more difficult in hotter neighborhoods and in less energy-efficient buildings. Low-cost temperature sensors deployed on every city block can help urban planners detect and address heat islands and help policy makers implement and measure the effectiveness of equity programs, like weatherization grants.

Temperature sensors are just one example of hardware that can be networked via the communications infrastructure established by and for smart streetlighting. Air quality and noise sensors are other examples where data collection can inform programs that improve equity and quality of life in step with city goals.

Smart streetlight infrastructure can also be used to develop other smart-city services. Some cities are using their smart smart streetlights as mounting locations for pedestrian counters, smart cameras, and other intelligent devices. In addition, EV chargers, wi-fi, outdoor speakers, emergency call buttons, and LED displays are also networked through the system and monitored to support decision-making. Christchurch is considering similar use cases, and may begin using the communications network to backhaul meter data for its electric utility.

Paris has used its system to pilot use cases for environmental monitoring, smart parking, smart water metering, and EV charging. "Each time we want to experiment with a new application, we can plug it into the network very easily," said Frédéric Galloo, chairman of EVESA, the organization overseeing

NOT JUST FOR BIG CITIES

The benefits of smart streetlighting systems are not unique to major metropolitan districts. Smaller cities can just as easily benefit from the cost savings, carbon accounting, and infrastructure backbone, as evidenced by projects underway in these three cities:

FUENGIROLA IN ANDALUSIA, SPAIN
(population: 75,000)

BOULDER IN COLORADO, USA
(population: 108,000)

KITCHENER IN ONTARIO, CANADA
(population: 257,000)

OUR SOLUTION

Itron's comprehensive smart lighting and city solutions provide real-time, endpoint management and control over an intelligently connected network leveraging mesh, cellular and more. Orchestrated by Itron's CMS is an end-to-end solution that delivers all the capabilities needed to enable deep energy savings, accurate carbon accounting, and smart-city and equity-based programs. Itron's solution consists of the following key components:

Management: Itron's CMS is a single single pane of glass solution that manages lighting controller configurations, luminaire controls, failure alerts, performance analysis as well as smart city devices.

Control: Networked lighting control (NLC) devices for external mounting on an mounting on an ANSI or Zhaga socket or internal mounting in decorative fixtures. Compatible NLCs are manufactured by Itron and certified third-party manufacturers.

Connectivity: Communication modules in every NLC form a resilient, intelligently connected network across entire communities. The network leverages robust mesh and cellular technologies for seamless connectivity across multiple applications, sensors, and infrastructure devices. Itron's Network Services can manage all network operations and firmware/ software upgrades from our 24x7 Network Operations Center, allowing for clients to focus on the needs of lighting or smart-city management rather than networking.

Sensors: Additional IoT sensors and devices can be connected to the Itron solution to enable use cases in traffic and highway monitoring, air quality control, waste management, EV charging, water management and others. These sensors are connected through various technologies, including RF mesh, cellular, or cloud-to-cloud.

Integration: Flexible integration options for connecting third-party applications to the CMS via Northbound RESTful APIs or for connecting to different field networks via southbound TALQ or MQTT interfaces.

Expertise: Itron leverages decades of experience in delivering end-to-end networked solutions for utilities and cities of all sizes. As a global leader in this space, Itron excels in bringing utilities and cities together, fostering collaboration to expand benefits across entire communities. Our focus is to enable municipalities and utilities to optimize energy use, enhance public safety, and improve overall quality of life, driving digital transformation.

THE TAKEAWAY

Transitioning to LED streetlights generates immediate, substantial carbon reductions and solid ROI. Adding smart controls to the project deepens the emissions and cost savings and lays the foundation for expanded services. But, for the best ROI, the smart controls need to be installed at the time of upgrading to avoid the additional labor costs of a follow-up deployment. A single deployment generates significant operational, energy savings, and community benefits (see figure below).

Itron is committed to helping our customers build practical business cases that work for their unique infrastructure and stakeholder requirements. To discuss the customized benefits of a smart LED streetlighting project in your community, contact Itron.

Reduce O&M Expenses

- More efficient field ops w/ real-time asset info
- Lower call volume w/ proactive maintenance
- Avoided litigation w/ real-time asset info
- Better asset management and billing

O&M Savings[1]

5% to 15% per year

Save Energy

- Avoided day burners w/ proactive maintenance
- Reduced energy usage w/ "constant light output" dimming
- Add'l energy savings with adaptive and dynamic lighting schemes

Energy Savings[2]

10% to 30% per year

Capture Additional Benefits

- Improved customer satisfaction and fewer customer complaints
- Reduction in traffic accidents
- Reduction in crime
- Reduction in GHG emissions
- Near-term opportunities for new, smart city revenue streams

Additional Benefits

$25 to $75 per light per year

1 Avoided patrols and field surveys, avoided call center calls with proactive maintenance, and more efficient field operations with accurate, real-time asset info
2 Standard L70 dimming for overprovisioned lights, day burner identification and prevention, and the option for additional dimming, as demonstrated in Europe

To learn more visit itron.com

We create a more resourceful world

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