The Business Case for Smart Street Lighting as the Smart City Network

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Owners and managers of street and area lighting need high quality, reliable information to support informed decisions about Smart Lighting and Smart City-related projects. Until now, most of this information has either been scattered across a vast number of academic studies, or websites with unsourced information and marketing-speak.

This article is intended to provide a supportable, accurate framework to help answer these questions: "Why should our organization care about Smart Street Lighting? What do street lights have to do with our Smart City vision?"

The Benefits of Smart Street Lighting

This paper is meant for those who build their own internal business cases or read them in the course of their work. It will show that :

- Moving street and area lighting from unmetered to metered rates and cut energy costs by 50% or more
- Enabling adaptive, standards-based lighting based can provide operational savings of up to 70%
- Smart lighting can extend the life of LED lamps by 60%-70%
- Smart lighting-enabled networks can reduce the cost of sensor and device operations by 60%-80%
- Smart lighting projects can have a typical project break-even of less than five years
- Smart Lighting provides 85%+ of the economic benefits versus LED retrofit projects
- A Smart City sensor project can provide 250%+ of LED retrofit project benefits

Additional non-financial benefits of Smart Lighting include a reduced impact on:

- Nighttime dark sky visibility
- Animal health, migration, and reproduction
- Human mental, physical, and behavioural health

Tondo's Smart Lighting system provides a complete and secure Smart City network and IoT ("Internet of Things") management platform based on interoperable, open standards technologies.

This standards-based approach enables cities to avoid being locked into proprietary vendor technologies and maximizes the useful life of a Smart City network.

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Can Dimming Street Lights Reduce Your Bill?

Although we have had the ability to dim street lights since 1977, it's not quite that simple.

The purpose of street and area lighting is primarily pedestrian and driver safety. For this we need standards bodies such as ANSI, CSA, and IEC to define the objective standards for what is safe. Otherwise we would have chaos, risk, and increased legal liabilities.

New standards for street and area lighting have been published between 2011 and 2021 that enable us to deliver safe, standards-based, *dimmable* lighting. Prior to 2021, dimming controls were based on proprietary methods with limited interoperability and were not able to deliver accurate standards-based illumination.

Metered vs Unmetered Electricity Rates

Utilities have historically delivered electricity for street lighting under an "unmetered" street light rate plan for municipalities. These rates assume that it is impractical or costly to meter individual lights or groups of cabinet-controlled lights. These rate plans typically calculate the input wattage for a luminaire (ballast + lamp), multiplied by the number of hours of darkness per month - which assumes "dusk-to-dawn" lighting.

These street light-specific plans are often "padded" at rates higher than the equivalent Commercial rate plan for the same electricity demand and consumption.

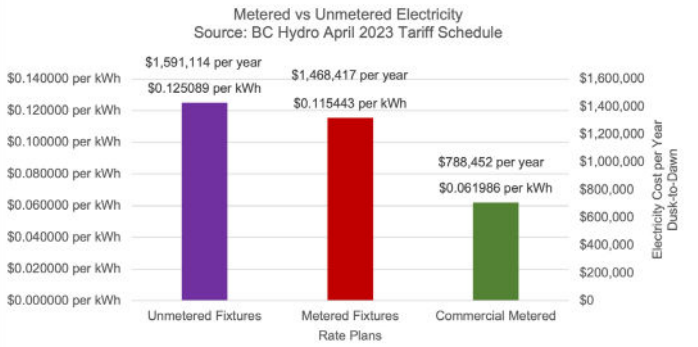

Figure 1: Unmetered vs Metered Electricity Costs

In the chart from Figure 1, we can see an 8% cost reduction moving from unmetered to metered street lighting. We can also see a 50% cost reduction moving to metered General or Large Customer electricity rate plans. This raises the question of whether some utilities are capturing unreasonable excess profits from street light rate plans.

In 2002, the American National Standards Institute (ANSI) published the C12.20 standard for accurate electricity metering. In 2018, ANSI published the C136.50 and C136.52 standards [14] for the accurate measurement of electricity of individual street lights. This facilitated new technologies to be incorporated into Smart Lighting systems that allow for metered street and area lighting.

In 2022, Measurement Canada published "E-38—Program for granting conditional permission to install and use street lighting luminaires with adaptive controls without the approval, verification and sealing of their embedded measurement technology", which provides a process for Canadian municipalities to realize the benefits of new energy measurement technologies that conform to ANSI C12.20, C136.50, and C136.52.

Energy measurement standards for luminaires are relatively new, and initially, it may require cities, Tondo, and utility providers to work together to ensure accurate savings are fully reflected on municipal energy bills.

In the case of the BC Hydro rates used in this example, their published Street Light Rates [2] that govern dimming of customer-owned street lighting requires a dimming control schedule to be submitted in advance for approval, and can only be changed twice per year. This is impractical when implementing an adaptive, dynamic dimming solution - clearly some utilities will need to update their street light rate plans to keep pace with the advancement of Smart Lighting control technologies and updated lighting standards.

Time of Use (TOU) Billing

Time of Use billing incentivizes utility customers to use less electricity during high-demand periods, and shift their use to lower-demand periods.

TOU tiered rates help the electrical utilities avoid brown-out, black-out, and manage their costs: electricity is a commodity and costs can fluctuate significantly on demand.

Although street and area lighting levels are independent of TOU - they are simply necessary based on dusk-to-dawn and traffic / pedestrian volume - being able to measure energy use and accurately reconcile energy consumption is an important capability for Smart Lighting systems.

LED Street Lights Still Use Energy

It's highly likely you've already developed a business case for an LED retrofit project, and it's either in-progress or completed. The case for LED retrofit is simple: a savings of approximately 35% in energy costs, a 4x longer lamp lifecycle, and a corresponding reduction in lamp replacement truck rolls.

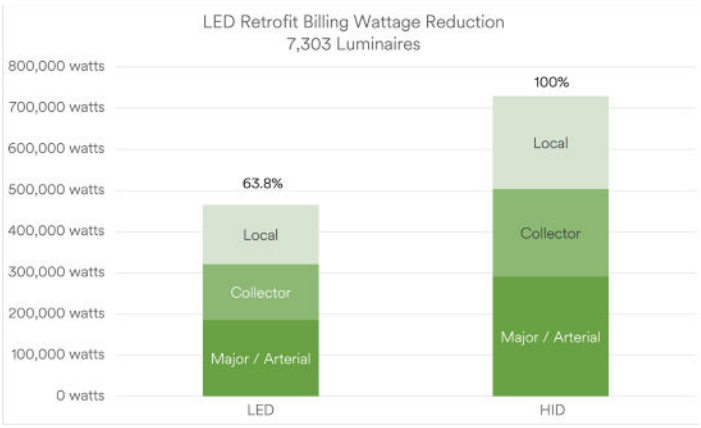

Figure 2: Electricity savings from LED retrofit projects

Dusk-to-dawn control wastes more than 60% of streetlight energy by providing light when it is not needed.

Today, most streetlights are controlled by "dusk-to-dawn" photocells or astronomical clocks to detect night-time conditions. The power to a light pole is most often controlled by wiring cabinets controlling groups of 15-20 street lights that turn the pole power on and off from a central point. When the sun goes down, a photocell or astronomical clock tells the cabinet to power the group of poles, and street lights provide light.

In some cases, a "50%" dimming control is used for a specific time period, such as midnight to 4am, providing 50% illumination between those periods.

Current lightings standards describe different levels of light according to pedestrian, driver, and cyclist traffic, interactions, road surface, light pole positions, and more. To implement standards-compliant street and area lighting, Smart Lighting controls are necessary.

Street Light Environments are Dynamic.

Dusk-to-dawn streetlight control or 50% midnight-4am dimming is not only wasteful, but it delivers sub-standard lighting when it cannot adapt to its environment, events, or demand:

- There are different types of streets serving different transportation needs: local streets, laneways, primary and secondary collectors, primary and secondary arterials, expressways, and freeways [5]
- Lighting demand changes based on volumes of vehicle, cyclist, and pedestrian traffic [9]

In some cases, municipalities use crude dimming levels according to designated times managed by an astronomical clock, such as dimming 50% at midnight to dawn. This approach may result in illumination that does not conform to current standards, and misses significant opportunities for energy reduction.

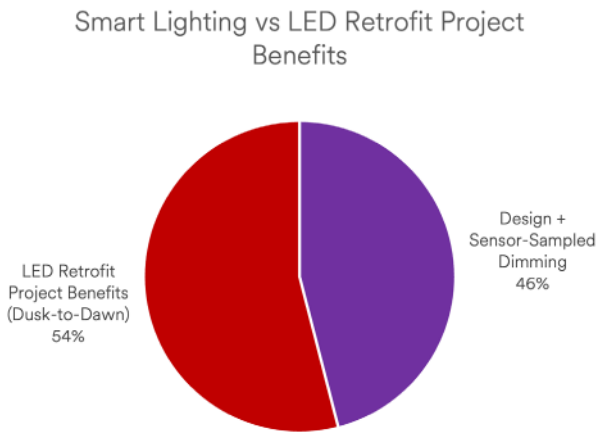

Figure 3: Comparing Smart Lighting vs LED Retrofit Project Benefits

- Vehicle, pedestrian, and cyclist traffic changes based on time of day, day of week, and the month of the year [15]
- Lighting demand can change for special or unexpected events
- Dusk-to-dawn hours vary significantly based on location [18]
- Weather, pole position, and pavement surface affects the quality of by as much as 240%[17]
- Intersections and crosswalks where pedestrians and vehicles interact have specific lighting requirements [5]

Lamp luminance output – even with LEDs – also degrades over time, changing the desired lighting levels. As a result, lamps are:

- Replaced earlier than their useful life
- Must be manually adjusted by dispatching field service calls
- Lighting is purchased over-illuminated at initial installation to compensate for degradation

Smart Lighting controls that deliver standards-based lighting on-demand offer significant opportunities for cost-reduction and improved lighting safety.

Solution: Smart Street and Area Lighting

Smart street lighting can adjust light levels according to:

- Roadway classifications set by standards and regulations, such as ANSI/IES RP-8-22 and Europe's EN 13201 standards
- Traffic, cyclist, and pedestrian volumes
- Ambient light levels
- Weather conditions
- Intersections and crosswalks
- Special or unexpected events
- Other safety and security considerations

By delivering standards-compliant lighting on-demand, Smart Lighting becomes a significant source of operational, maintenance, electricity, GHG savings - and safety.

How Can We Dim Street Lights Safely?

The short answer: by applying the established roadway lighting standards using Smart Lighting controls to roadway and pedestrian demand.

The primary purpose of street lighting is to provide safe and secure environments for drivers, cyclists, and pedestrians, particularly where they interact with each other. When demand drops, roadway lighting standards allow cities to consider lower illumination levels.

Let's walk through a case using the North American ANSI/IES RP-8-22 standard for roadway lighting and apply it to a city's real-world data. [1]

This Canadian city has a population of 92,000 people over a 20km sq. area, and has 7,303 street lights with 99.3% of them upgraded to LED lamps.

The chart in Figure 4 shows the city's share of roadway by ANSI/IES RP-8-22 standard classification type:

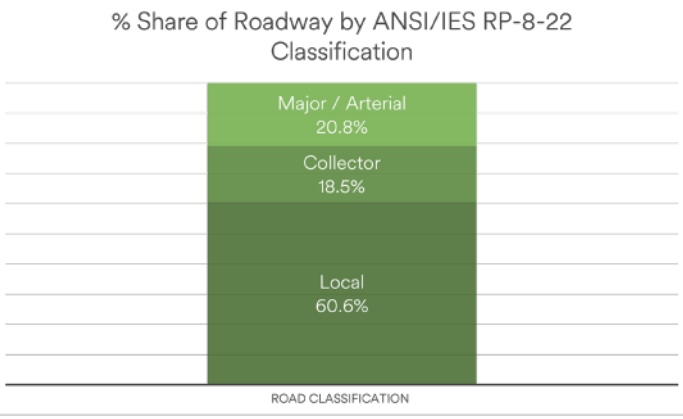

Figure 4: Share of roadways by ANSI/IES classification

From the chart we see 79.2% of this city's roadways are classified as Local, which typically experience lower traffic volumes and peak periods correlated to commuter and shopper traffic periods.

Next, when we look at the vehicle traffic volumes during Dusk-to-Dawn periods, we can also see from the chart in Figure 5:

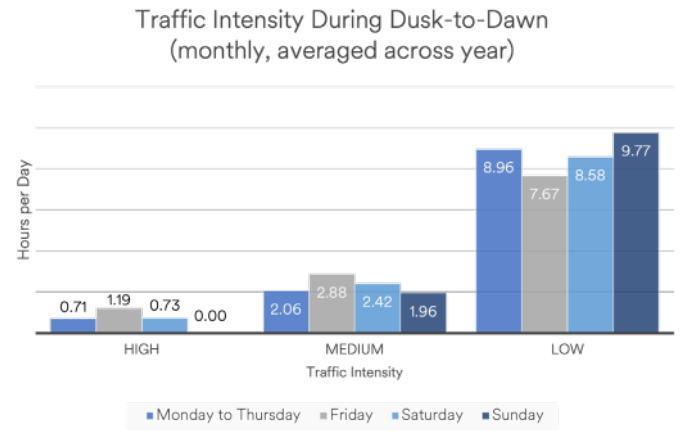

Figure 5: Traffic volumes during dusk-to-dawn periods

In this example, the high traffic periods in this city that require maximum lighting levels represent only 10% of dusk-to-dawn hours. Approximately 80% of hours are low-traffic periods.

- Most traffic volumes are low traffic periods
- Demand changes for each day of the week

As a result, lighting standards provide for lower lighting levels where there is a lower probability for pedestrian-vehicle interaction.

In the chart in Figure 6, we see an example of the required luminance level for a Local road depending on the volume of pedestrians - high, medium, or low volumes.

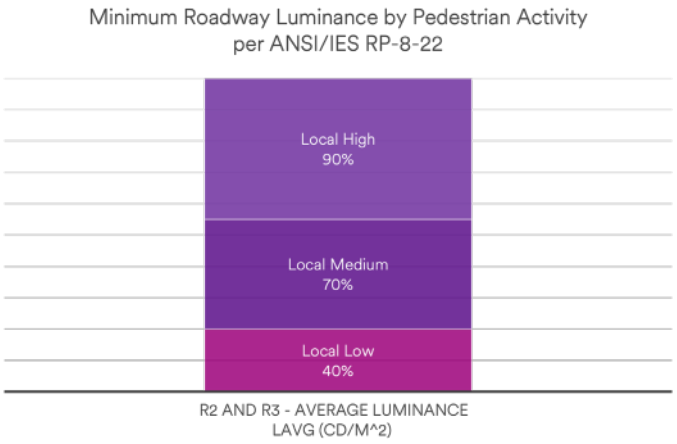

Figure 6: Minimum luminance levels for a Local roadway classification

Smart Street lighting enables lighting designers, engineers, and a city's operations team to deliver standards-based lighting levels based on the unique composition of their city's roadway system.

When we put all this data together, we see that 60% of the city's roadway lighting can be dimmed 75%-80% of evening hours by as much as 80% of the time compared with peak hour demand.

Not All Street Light Dimming is Equal

There are several methods of dimming available [6, 7, 8] with Tondo's Smart Lighting system and the savings factors from several academic studies were used in our business case:

- **Design-Based** – based on dimming-enabled photometric design
- **Statistical** – based on historical traffic volumes with all days of week equal
- **Statistical Categorization** – based on historical traffic volumes, each day of week is unique
- **Sensor Sampled** – sensors used to sample traffic volumes in in 15-minute intervals

Lighting designers and engineers can utilize software applications such as DIALux to design street lighting projects according to North American and European/ UK standards.

Smart Lighting controls enable cities to easily apply and maintain these designs where lamps and

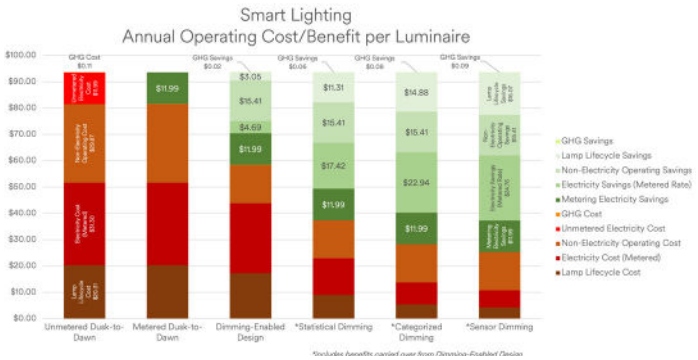

Figure 7: Costs & benefits by lighting control method

luminaires have different lighting characteristics, respond to traffic pattern changes, and adjust output according to lamp luminance that degrades over a lamp lifecycle.

Photometric Design-based dimming is intended to be used together with one of the three adaptive traffic-based dimming methods: Simple Statistical, Categorized Statistical, or Sensor-Based.

These four methods of Smart Lighting-enabled dimming are compared in the chart in Figure 7, along with Dusk-to-Dawn and operating costs for:

- Electricity use based on metered and unmetered rates [2]
- GHG footprint measured in CO2 equivalents and available carbon credits [3,4]
- Increased lamp lifecycle [10, 16]
- Reduced luminaire maintenance truck rolls [11, 12, 13]

In the chart above from Figure 7, we can see the components of the business case for Smart Lighting controls, and the significant impact they have on the total cost of managing street and area lighting.

Reducing Street Light Maintenance Costs

Managing street and area lighting is a lot of work.

It is regulated by safety authorities at the state/ provincial and national levels, and subject to regulatory standards. Maintenance involves both routine and non-routine maintenance activities. These routine activities include:

- Inspection, testing, cleaning, lubricating, and performing minor repairs as needed
- Regular visual inspection as part of the replacement of lamps
- Replacement of luminaires and lamps according to expected lifecycles
- Testing for voltage and current leakage that can put the public or wildlife at risk

However, there are a number of non-routine activities that include investigating:

- Wire down
- Pole down
- Power supply down
- Power supply failure
- Wiring faults
- Energization of surfaces

- Vandalism
- Faulty lamp or luminaire
- Electricity theft

The transition from older high intensity discharge (HID) lighting to LED lighting only addresses the routine maintenance activity of replacing lamps.

Tondo's Smart Lighting controllers are designed to identify:

- Faulty luminaires
- Pole down from tilt
- Damage to pole or luminaires from weather, vehicle collision, or vandalism
- Wiring faults at installation time or degradation over time
- Electricity theft
- Power quality that can indicate risk to the public

For the purpose of this business case, we wanted objective third-party data without using our own assumptions.

Studies have shown [11, 13, 21] that Smart Lighting can save up to 50% in lighting maintenance costs post-LED retrofit and provide faster response and improved public safety.

There were a number of studies that suffered from problems in their methodology. We looked for:

- Real world measurements
- Completeness and scope of analysis
- Published date
- Detailed cost analysis using real-world city data

The assumptions used in this paper are hyperlinked to the source data and documented in the section, "Citations and Sources" on page 15.

To this point, the business case should be obvious for Smart Lighting. This brings us to the question of, "What is the value of Smart Lighting as the platform for a Smart City sensor network?"

The Street Light-Enabled Smart City Network

There are many definitions of what a Smart City is, and the definitions continue to evolve. However, a fair summary of those Smart City definitions is a city that:

- Supports operational efficiencies through technology-based automation
- Supports economic growth through the provision of technology infrastructure
- Supports citizen satisfaction with high-availability self-service for city services
- Supports community development through education, sharing resources
- Supports citizen engagement through connection with city representatives and voting
- Decreases the human impact of growing urbanization on our environment and wildlife
- Improves safety and security
- Supports equal access to city resources for all citizens

A Smart City uses technologies and innovation to reduce the impact of urban growth on our environment and improve service efficiencies, citizen engagement, community development, education, and economic growth for the benefit of all citizens and businesses.

You Can't Have a Smart City Without Smart Lighting

Before a Smart City vision can be realized, cities need a cost-effective, secure, wireless, city-wide communications platform ("network"). This will use a variety of sensors and devices to support Smart City process automation and efficiency.

Street lighting is the natural platform for the Smart City network:

- Street lighting is everywhere there are infrastructure assets, people, and vehicles
- Street poles are pre-wired for power

- Streetlight poles are high up in the air for optimal wireless network position
- Streetlight poles are convenient locations for a wide range of sensors and devices
- Streetlight poles are co-located to underground city infrastructure
- Connection standards already exist to connect network controllers to street lights

Tondo's Smart Lighting creates a secure, open standards-based city-wide network. This enables control over lighting, and also enables cost-effective connectivity for wireless sensors and devices that support Smart City goals.

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"Lighting poles represent strategic infrastructure for smart city development, thanks to their capillarity, connectivity and electrification."
The evolution of the street lighting market, Arthur D. Little S.A., October 2019

Smart Cities Need Sensors

Smart Lighting directly and materially reduces the human impact of growing urbanization on our environment and wildlife:

- Reduced energy use and GHG footprint
- Reduced sky-glow that impacts human health, animal and bird migration and reproduction
- Improved aesthetic and scientific research value of a dark night-time sky

Operational efficiencies, economic growth, improved safety and security, and citizen self-service delivery for Smart Cities depends on better information - faster.

Sensors and other connected devices help cities gather accurate and timely data to more effectively manage critical infrastructure and support service delivery:

- Transportation
- Flood control
- Water quality
- Gas or fluid leak detection
- Sanitation services
- Parking occupancy
- City asset theft or vandalism
- Air quality
- Public safety and first-responder resource management
- Infrastructure health and degradation

Most sensors today require proprietary technologies and multiple stand-alone platforms for managing devices and data.

These approaches present two major risks for cities:

1. An economic hold-up problem locking cities into purchasing devices through that vendor. There are few examples of vendors who have decreased their SaaS prices as they have gotten larger and increased their economies of scale.

2. A technical hold-up problem locking cities into purchasing devices that are compatible with a proprietary technology platform. There are few examples of proprietary technologies that have survived after open standards have been established.

With an open, standards-based network and open, standards-based management platform, the city is not locked in to a specific vendor's products.

Controlling Smart City Sensor Deployment Costs

Let's look at a manhole cover use-case as an example. Why manhole covers instead of water quality, gas leak detection, storm drain levels, or many other use-cases? This article in the New York Times caught my eye recently: Where have all the manhole covers gone? .

Manhole sensors can cost hundreds or in some cases, thousands of dollars, with additional monitoring fees charged monthly. When the number of sensors is relatively low, the operational costs of these sensors are not always noticeable. SaaS or monitoring costs from $10 to $50 or more per sensor per month charged by some vendors create barriers to scale.

The city that was used for street and lighting data in this article [1] has 7,303 standard light pole street lights, 2,537 city street blocks, and 269 crosswalk-marked intersections. The city also has 4,060 sewer manholes and 3,444 storm drain manholes for a total of 7,504 manholes – more manholes than street lights.

The value of a Tondo Smart Lighting-enabled Smart City network for sensor and device connectivity is based on the costs of the network offset by the operating cost savings from street lighting.

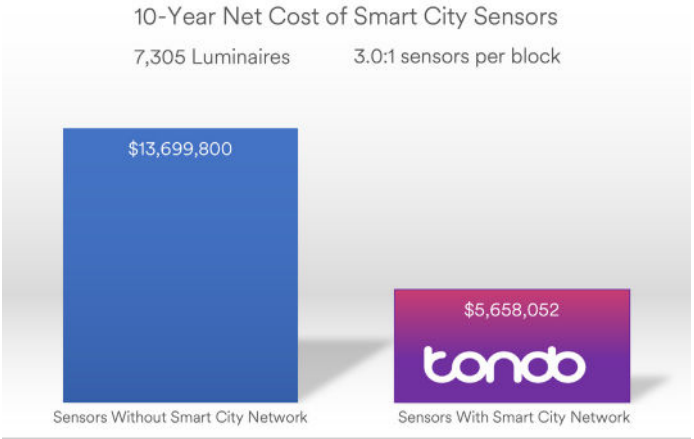

Figure 8: Sensor deployment costs on a Smart Lighting-enabled network

Using an assumption of $10.00 per month in SaaS costs per sensor for a competitor's proprietary or independent sensor network, this chart shows the 10-year net cost difference vs a Smart Lighting-enabled sensor solution.

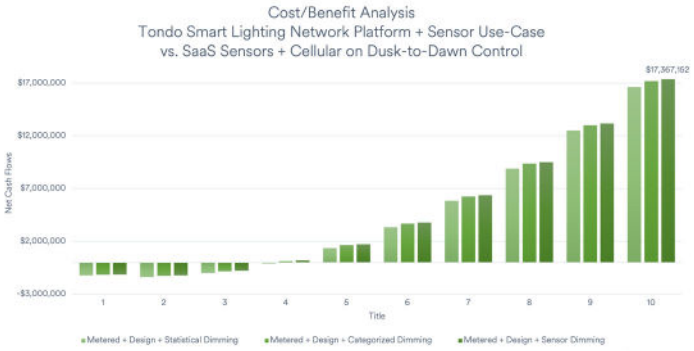

Figure 9: 10y cash flows for a Smart Lighting-enabled sensor solution

In Figure 9, a cash-flow positive Tondo's Smart Lighting solution for 7,303 luminaires and 2,537 city blocks offsets the cost of the Smart City network, showing a project IRR of 13.8% without including savings from sensor deployment, and 52.6% when including sensors.

The break-even for Smart Lighting only is 4.5 years, and this drops to 4 years with a three sensor-per-city-block project - and avoids over $17m in future costs.

The Business Case for Smart Lighting as the Smart City Network

If you've read all the way through, congratulations - hopefully this information has been helpful for you.

The biggest barrier to reducing energy costs, operating costs, and the GHG footprint of our energy use is reliable information.

The key takeaways from this case are:

- New generation Smart Lighting solutions such as Tondo's may enable cities to move lighting from unmetered to metered rates and cut their energy costs by 10% - 50%
- Smart Lighting can enable cities to deliver standards-based lighting according to demand, resulting in a savings of as much as 70%
- Network-controlled Smart Lighting has been shown to reduce non-electricity management and operating costs of managing street lighting by 50%
- The reduction in electricity use from adaptive dimming also extends the life of LED lamps by as much as 70%
- To cost-effectively enable a Smart City strategy, cities require secure, standards-based wireless networks for sensors and devices to operate on.
- Tondo's Smart Lighting controllers include a secure city-wide wireless network platform that can reduce the cost of sensor and device operations by 50% - 80%
- A Tondo Smart Lighting project provides a positive cash flow budget benefit and typically less than 5-year project break-even.
- When compared with an LED retrofit project benefit, a Tondo Smart Lighting Network project can provide 2.8x the benefits.

A Tondo Smart Lighting-enabled Smart City sensor network will provide municipalities with significant long-term value, and establish their platform for Smart City enablement.

If you have questions or comments for us on this article, please contact us through the Contact Us form on our website at www.tondo-iot.com.

About the Author

Marissa Wright is the Vice-President of Strategy and Markets for Tondo. She has over 40 years of experience in the technology sector, and earned her MBA in 2013 from Simon Fraser University in British Columbia, Canada.

Marissa is an active angel investor, and through her own consulting practice, advises companies on business growth strategies based in Vancouver, Canada.

For more information, questions, or comments on this paper, you can contact Marissa at marissa@tondo-iot.com or on LinkedIn

Methodology, Sensitivities, and Assumptions

This article is based on a comprehensive economic model developed internally at Tondo that uses a city's ArcGIS data, Google Maps data, and established street lighting standards to accurately assess the costs and benefits of Tondo's Smart Lighting and Smart City network projects. However, there are a number of assumptions and input values that may cause significant changes to these predicted values.

Sensitivities for this business case include but are not limited to:

- Cost of electricity and rate plan
- Composition of lighting assets, luminous efficacy, and input wattage
- Costs of CO2 carbon credits
- Additional project management, provisioning, and configuration costs
- Cost of third-party software integration
- Any custom software or hardware development required in a project
- Capital costs of specific sensors
- Sensor deployment costs
- Lighting controller installation costs
- Number of luminaires
- Crosswalk-based intersections
- Number of streets for each road surface and classification
- Currency conversion rates between Canadian and U.S. dollars, if applicable
- Assumptions for sensor ratio to number of city blocks used in the case
- SaaS cost assumptions for proprietary sensor solutions used in the case
- Non-standard lighting and practices required for implementation
- Assumption that all lighting assets support dimming control

Although it is not practical to cover all aspects of our business case model in this article, our internal model does allow for us to tailor these and other assumptions for a specific use-case.

If you are interested in having your city's data used to produce a similar cost-benefit analysis of your own Smart Lighting and Smart City Network initiative, please contact us through our website and we would be happy to help.

Citations and Sources

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