Street lighting in Wellington City

Making a case for adopting LED lighting

Introduction

The evolution of street lighting has reached a new level of efficiency and effectiveness with the development of technologies utilising light emitting diodes (LED) as their source of light. As this technology matures and the opportunity cost of waiting for future evolutions narrows there has been a slow but steady movement around the world towards adopting LED street lights.

This trend is largely driven by a desire to reduce energy and maintenance costs through the superior life offered by LEDs. Where existing technologies, such as the dominant high-pressure sodium street light, can last around 16,000 hours[1], manufacturers have used laboratory testing regimes to demonstrate a life expectancy of 100,000 hours for the LED counterpart.

Other benefits from LED technology are found in controlling light pollution, improved reaction times for road users through better colour differentiation and visibility leading to safer environments, greater levels of comfort and a whole-of-life benefit from the lack of toxic materials in LED lights.

LED lights are highly adaptable which enables the use of control systems to manage use. This results in increased efficiency and gives the user the ability to adopt other technologies enabling lights to be dimmed when the need for lighting no longer exists. Directional lighting; another strength of the LED street light; means energy is no longer consumed in lighting areas of less importance. Conversely this ability to produce highly focused lighting enables solutions to light areas that were previously too difficult to light due to the distribution flaws found in existing lighting units.

Running parallel to LED lighting is the ability to create ’smart’ networks – for example lights that report their own faults, or turn on the instant they are instructed to rather than after an ignition period. This can enable different approaches to be taken in lighting our topographically-challenging city. A truly networked street lighting system can be used to light different areas, suburbs or even street to different levels depending on the needs of that area – lighting can be used to channel pedestrians to and from public transport options before and after a sport event or concert for example.

This paper articulates the research carried out by Wellington City Council in investigating the procurement and adoption of LED technology, adaptive dimming, and asset and performance management control systems. It uses data collected about the existing lighting stocks, maintenance, renewal and upgrade programmes alongside the advantages and benefits shown to exist in LED lighting.

In advancing discussions on the benefits of changing the way Wellington City is lit it is suggested readers keep in mind why cities are lit and which cities have taken the opportunity to use lighting to benefit the wider community. Wellington has the potential to save significant amounts of money through efficient outdoor lighting – there exists even greater potential to the city if the lighting network’s true potential to the city is realised simultaneously.

[1] 3.8 years at an average of 11.5 hours of operation per day versus 23.8 years

Street lighting

A brief history

Street lighting is nothing new – providing light to enable travellers and pedestrians a safer passage dates back to early Greek and Roman civilisations. Over the centuries lighting technology and practices evolved and with the industrial age came the concept of purpose-built street lights.

The time for candles and oil had passed by the 19th century and gas lamps where eventually seen across the larger European cities as well as parts of the USA, South Africa and Australia. The first gas street lighting in New Zealand arrived in the mid-19th century but kerosene lamps were still used to allow safe navigation at night by illuminating bridges, culverts and drains.

By 1876 Christchurch boasted 152 gas lamps. Although far superior to previous lighting, their illumination and extent was still limited. The early systems required lamp lighters, but pilot lights were soon introduced, which lit the lamp when the gas was turned on centrally.

The street light usage was also not continuous: it was recorded the Wellington gas lights were “lighted on moonless nights only and then not later than twelve o’clock[2]”.

The next significant change was replacement of gas with electricity. In 1888 Reefton, on the West Coast, was the first town in the Southern Hemisphere to install electric street lights. Wellington followed a year later as the first Southern Hemisphere city with electric lights (one of the original street lights still stands at the intersection of Featherston Street and Lambton Quay)[3].

Lights were usually on from dusk to dawn, though some suburban areas extinguished them in the early morning. The new electric lights were significantly brighter than their predecessors with the first street lights being arc lamps.

By 1912 the incandescent lamp had been invented – these offered a longer life and easier maintenance – and before long most of the country’s cities and towns were using them.

As the country developed and grew there was a need for stronger and smoother roads – faster and larger numbers of motor vehicles in turn required much brighter lighting. Experiments were carried out with new bulbs to increase brightness which led to the development of sodium or mercury-vapour lamps.

In a similar fashion to the advantages of electric lights over gas, the new sodium or mercury lamps had the added advantage of using less power than their respective predecessors. From the 1950s fluorescent lights were also installed.

Wellington City Council called for tenders in 1964 to replace 5000 old lamps with modern fluorescent lights. The fluorescent lighting produces a cool bright white light, and the lamps have a very long life.

[2] *www.teara.govt.nz/en/streets-and-lighting*
[3] http://www.stuff.co.nz/dominion-post/capital-life/9621582/Lamp-commemorating-electric-lighting

Fluorescent was the predominant lighting used until the 1970s, when they began to be replaced by high-pressure sodium and metal-halide lights. By the 21st century most street lights in New Zealand were high-pressure sodium lamps. There were over 330,000 street lights across the country, running for more than 4000 hours each per year, consuming some $18 million[4] worth of electricity.

Reasons for street lighting

The Australian and New Zealand Standard *Lighting for Roads and Public Spaces* (NZ1158)[5] outlines that the performance criteria for road and public space lighting schemes can include any or all of three basic aims of:

a) Facilitating safe movement
b) Discouraging illegal acts and
c) Contributing to the amenity of an area through increased aesthetic appeal.[6]

Street lighting has social and economic benefits. Primarily the reason for providing street lighting has not changed from the historical precedents, that is, the increased safety of night time travellers and pedestrians. What has changed over the centuries and years are the volume of night-time traffic, the pace at which people move from point to point, the numbers of pedestrians and cyclists who share space with motor vehicles and the diversity of activities after dark.

Effective street lighting helps reduce criminal activities like car-crime and assaults. Further, high-quality lighting aids the use of CCTV cameras in that colours are more easily discernible. Effective lighting allows pedestrians and cyclists to identify potential risks at a greater distance, thus allowing for more decision-making time.

Providing quality lighting, including decorative and feature lighting, for key tourist, cultural and hospitality locations within a city has been shown to increase both local and visitor patronage while providing well-lit linkages enables increased mobility and interactions between public and alternative modes of transport.

For Wellington City Council the desired results from providing and maintaining street lighting assets are:

- improved road safety for motorists, pedestrians and cyclists
- reduced incidence of night-time crime
- improved perceptions of street safety and security
- increased leisure and commercial activity after dark
- increased walking, cycling and use of public transport
- community resilience through lighting solutions designed for specific environments (paths vs streets for example)

[4] *Now estimated to be about $30 million*
[5] ***Note:** AS/NZ1158 is made up of six parts each of which provides guidance on different aspects of street lighting and its application to different environments.*
[6] *AS/NZ1158.1.12005 page 2*

- lighting infrastructure that maximises efficiency, minimises maintenance and reduces the risk of excessively long outages
- best long-term value through suitable application of street lighting technologies
- minimised energy consumption.

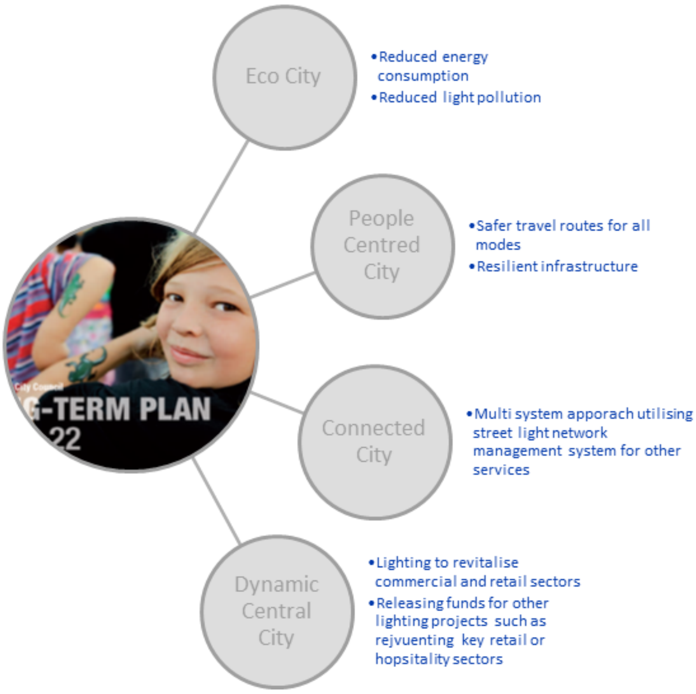
These expectations contain overlaps and to one extent or another most of the lighting technologies available today can provide for an element of success in one or two of the results listed above. Based on overseas experiences and research only LED lighting (solid-state lighting) offers the potential to cover the entire list with any real certainty.

Connections to the Long-Term Plan

Street lighting does not appear as a distinct item in recent planning documents – largely this is due to existing strategies being based only on maintenance and ongoing renewals. It also may be the quality and quantity of lighting was satisfactory given the performance and cost limitations associated with the existing stock – in other words there were no tangible benefits to be gained from investing heavily in technology that could not increase service levels and performance, reduce costs or save energy to a level where it was a financially-viable exercise.

This situation has now changed – evolving LED lighting technology along with the adaptive and intelligent controls mean we can look at the contributions street lighting can make towards the achievement of the city's aspirations.

Alongside are the four key areas in to which Wellington City Council is directing energies – alongside are the areas where street lighting can produce an impact.



Street lighting in Wellington

Existing street lighting

Wellington City Council operates just under 18,000 street lights – these light major and minor roads, pathways, access-ways, subways, through-paths, area lighting, amenity lighting and an element of decorative lights (such as the lights in the Norfolk pines on Oriental Parade).

The Council also has about 2400 lights on the waterfront between the Railway Station and Clyde Quay wharf, another 835 lights operated by the Council's Parks, Sports and Recreation unit, and a number of lights providing external lighting for buildings and property. These lights are not part of the street lighting portfolio.

Existing street lighting stock

Across the city and suburbs the street lighting stock is more variable (including manufacturer, design, wattage and type) than is desirable. To an extent this is due to legacy issues and maintenance/renewal programmes of the day that reflected the budgets and technology available to the Council officers and contractors at that time.

With an estimated 28[7] different light manufacturers and potentially 34 different levels of lighting output (wattage), providing a consistent level of service has become somewhat problematic.

Recorded in the database are around 100 different types of lamp technologies. Table 1 shows these broken down into the main subgroups and their respective average energy consumption.

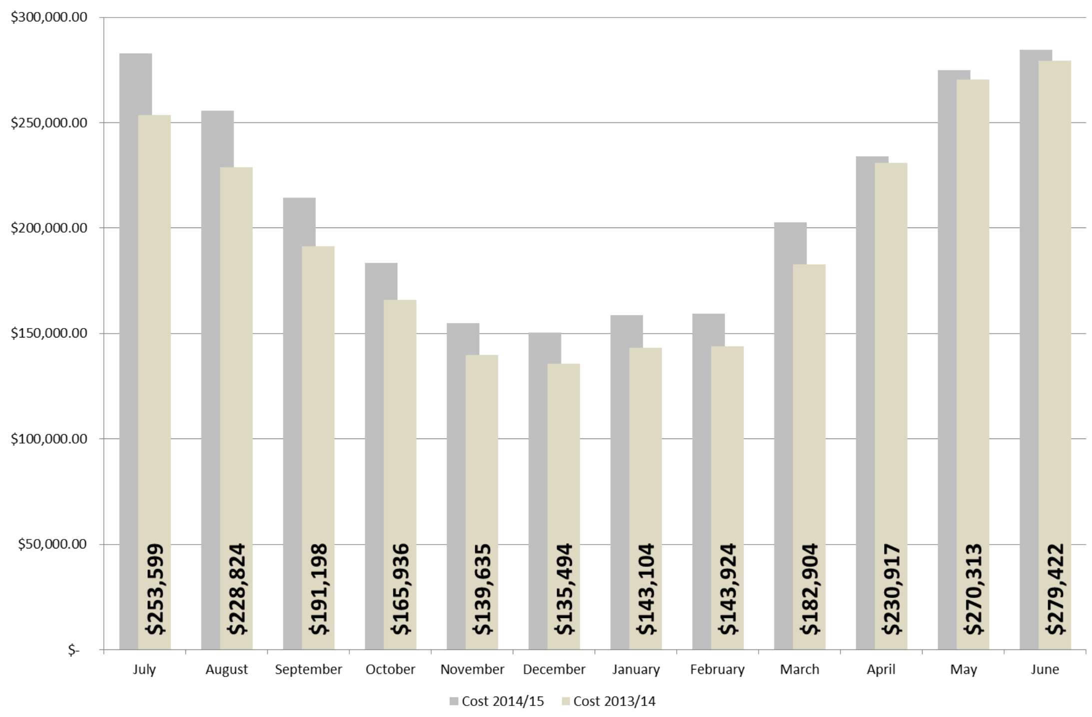
Technology	Network %	Tally	Total (W)	Total (kW)	Watts per unit (Ave)
HP Sodium	87.9%	15,749	1,764,105	1,764.11	112.01
Metal Halide	5.4%	976	138,454	138.45	141.86
Fluorescent	2.0%	362	22,603	22.60	62.44
Mercury Vapour	1.3%	232	16,591	16.59	71.51
LED	0.7%	117	4,093	4.09	34.98
Other	2.7%	478	21,326	21.33	44.62
Grand Total	100.0%	17,914	1,967,172	1,967.17	109.81

Table 1 - distribution of lighting technology in Wellington / average power consumption distribution by technology

Energy consumption and costs

In providing the existing street lighting service to the city we consume in the order of 7.3 megawatts of electricity at a cost of just over $2.36 million[8] a year. Without taking into consideration any increases in the electricity network costs or changes to the lighting stock, this price will increase to $2.55 million in 2014/15 due to the tariff structure in place between the Council and our existing electricity retailer.

[7] *Within the street lighting data base there are some gaps in the data – this may result in more manufacturers being identified as well as an increased number of different wattages.*
[8] *2013/14 financial year*



Of significance to any conversation about street lighting is an understanding of how the costs for operating the street lights are calculated for the different parties. In Wellington's case the electricity retailer is Contact Energy Limited - this is who the Council purchases the electricity from. The electricity network which supplies power to the street lights is owned and maintained by Wellington Electricity.

Agent / Charge	%	Per $1000	
Contact Energy - Energy	31.10%	$	311
Contact Energy - Administration	0.28%	$	3
Wellington Electricity - Fixed	11.74%	$	117
Wellington Electricity - Variable	56.48%	$	565
Electricity Authority - Variable	0.40%	$	4

Table 1 - agent/charge revenue distribution

Contact Energy pays Wellington Electricity to distribute the electricity consumed by their customer (the Council) and recovers this cost via the monthly power bill. The retailer also collects an administrative charge on behalf of the Electricity Authority (previously called the Electricity Commission) which is also recovered from the customer.

The graph alongside shows the distribution of costs to each party for every $1000 spent on powering Wellington's streetlights. This also shows the relationship between the fixed and variable components of the Council's street lighting power costs.

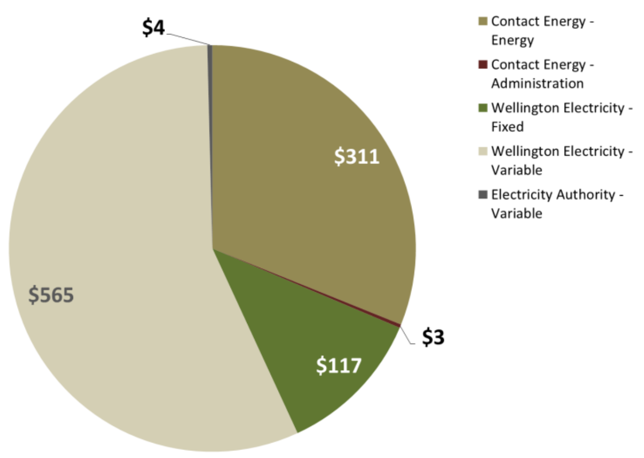


Figure 1 - energy cost distribution

Variable costs versus fixed costs

The way in which the Council pays for its street lighting electricity costs can seem somewhat complicated at first. The structure, shown in the table, is made up of fixed and variable components which are then applied to various elements of the street lighting network, the hours of operations, regulatory requirements or direct cost recovery. In the case of the 'energy' costs the tariff is further complicated with different rates applying to different hours and months of operation.

These elements are significant to the Council due to their ability to affect any future investments in upgrading the lighting technology. In seeking greater efficiencies and better lighting solutions the global trend is moving towards the adoption of solid-state lighting. Commonly manifested as LED lights the technology is enabling street light operators to significantly reduce their power consumption though the lower power requirements of the new technology.

As will be discussed later in this document, additional development of LED street lighting now makes adaptive lighting more viable which in turn can significantly reduce power consumption further. For Wellington City Council this is of particular interest due to the fact a major portion of our spending on street lighting is demand-driven - based on kilowatts. In short, if the Council can reduce the number of kilowatt hours (variable costs) we consume, we can reduce the overall cost.

Maintenance and renewals programmes

Maintenance of the existing street lighting stock is largely reactive – although regular patrols are used to identify faults on arterial routes, the majority of faults are reported by residents. This reflects the practices seen around the world where the street lighting network is effectively 'dumb'.

The existing technology is susceptible to weather-related faults which with a relatively short life span (relative to LED lights) results in an ongoing process of replacing or repairing bulbs, ignition and electrical controls and protective shields.

With a transition to LED technologies there is proportional reduction in the maintenance costs due to the longer life of the asset – effectively a high-pressure sodium light will be replaced between 4 and 6 times during the same lifespan of a high-quality LED luminaire.

Additionally, with high levels of weather protection, there is no need to replace shields and drive systems which means a reduction in patrols, turnouts, replacement parts and traffic management.

The only maintenance expected to continue is a small number of faults, occasional washing with a low pressure water blaster from the ground (mobile operation) coupled with a pole/outreach arm inspection programme.

Existing lighting strategies

Although Wellington City Council does not have a formal street lighting strategy there was an attempt in 2010 to establish a formal approach to outdoor lighting. Advanced by the *Wellington City Lighting*

Strategy is an approach that identifies the benefits of good lighting but unfortunately focuses almost exclusively on decorative and amenity type lighting.

It is suggested that this strategy document is evolved into an actionable Council plan to incorporate street lighting, pathway and access-way lighting that is aligned with lighting in open spaces, Council housing and property operators. It would also enable the Council to work with property owners, developers, retailers, businesses and the hospitality industry to collectively provide lighting that delivers vibrancy as well as safe and efficient navigation.

Making changes to how we light Wellington

Wellington City Council, in achieving the aspirations of the LTP and *Towards 2040* strategy, can make considerable advances through the adoption of LED street lighting. In reducing the Council's carbon footprint through reduced energy consumption and street lighting-related maintenance the Council has a real opportunity to help Wellington become the one of the first cities in the southern hemisphere to replace its entire lighting stock with energy-efficient lights.

Taking an additional step, the City Council has the ability to be a world leader in sustainability through the adoption of adaptive lighting in its residential streets – furthermore in adopting adaptive technologies, the Council has the ability to significantly improve street lighting while simultaneously reducing energy consumption further.

With intelligent lighting management systems included in a street lighting upgrade the ability to enable the street light to communicate a fault to maintenance contractors removes the need for residents to advise the Council a streetlight is not working thus reducing the delay in fixing faults significantly.

Solar-powered street lights

While solar-powered street lights have been developed there are very small numbers in use for metropolitan lighting. In Wellington the cost of installing such technology where there is existing infrastructure is too high in comparison to LED technologies.

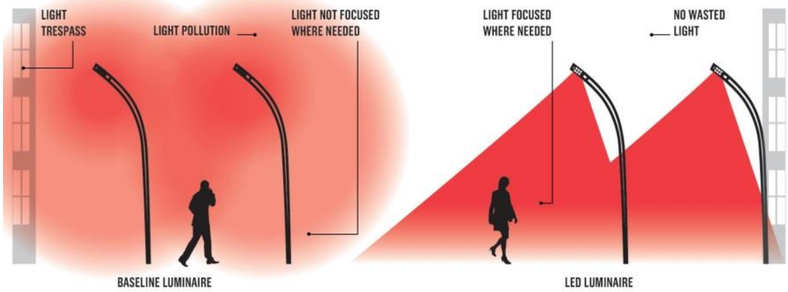
Where there is no existing infrastructure to support a need for lighting – for example on isolated pathways with no nearby power source – solar-powered options are being explored. To date there have been only three solar-powered lights installed across the city.

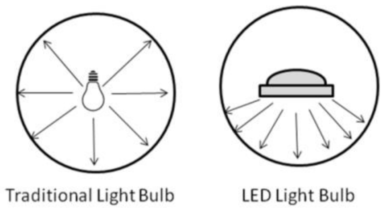
LED technology

A light-emitting diode (LED) is an electronic device that produces light when an electrical current is passed through it. The wavelength (or colour) of light emitted depends on the materials from which the LED is made. LEDs are available in many colours, including red, blue, amber and green. The LEDs used predominantly in general lighting applications are 'phosphor converted blue' LEDs - blue diodes covered with a layer of yellow phosphor. The phosphor absorbs some of the blue light, and emits yellow light. When the unabsorbed blue light mixes with the yellow light it creates what the eye perceives as 'white' light.

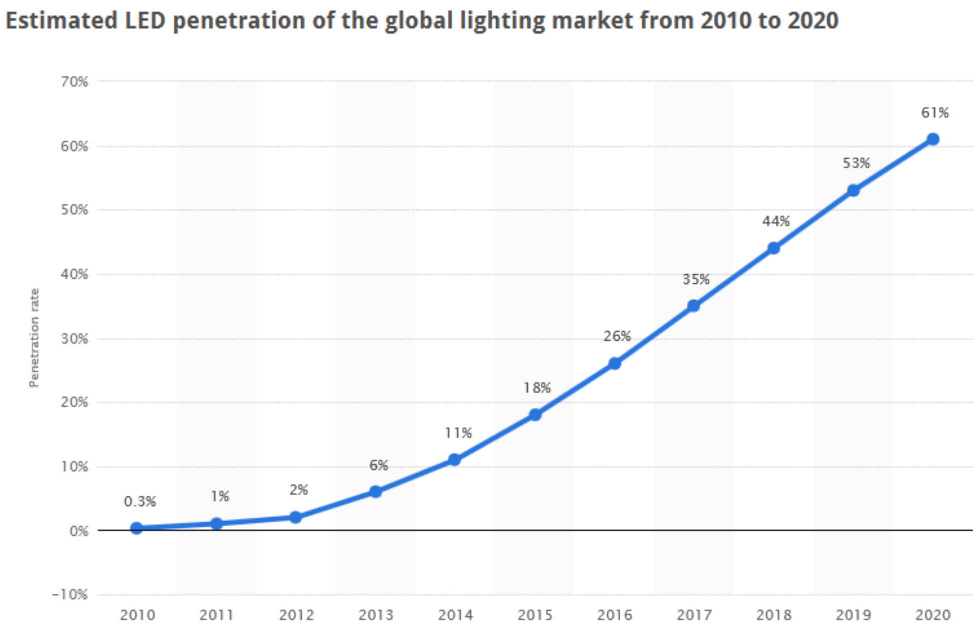
It should be noted that LED technology is not new - it has its history in low-powered lights that have appeared for a long time as Christmas lights or signal lights within many electronic devices. The radical change has been in the increased efficacy of high-powered LED units. Although additional and unexpected benefits such as reduced graffiti or reduced street crime are yet to be fully qualified by local authorities that have transitioned to LED lighting technologies, the key drivers for change are:

- Reduced energy consumption
- Reduced maintenance costs due to long lifetimes
- Environmentally friendly as they do not contain toxic materials (e.g. mercury)
- Desired lighting levels provided instantly with no warm up period needed
- No production of ultraviolet light (which attracts insects)
- Less light pollution (or 'spill') as light is emitted directionally, rather than as a diffused glow (picture 1)
- Lighting output is controllable - allowing for dimming or adaptive management
- High colour rendition index - enabling improved recognition of different colours (good for CCTV)
- Reduced glare.





Picture 1 - light distribution comparison



Graph 1 - LED market growth 2011-2016 (source: statista)

The graph above shows the speed with which LED street lights will achieve dominance in the marketplace – this has been documented as being is due to the many benefits seen to be available through the adoption of LED lighting as well as their ongoing reduced relative cost.

LED Magazine predicts the LED lighting share of the industry to grow from $1.75 billion to more than $3.25 billion in 2016.

Control systems

Control or central management systems offer tele-management options for monitoring, controlling, metering and diagnosing outdoor lighting and further enhance the benefits of LED lighting. The ability of the LED to respond instantly to commands, its lower power consumption (relative to equivalent lighting solutions) and the manner in which the light is produced make intelligent systems a valuable addition to the technology. Basic central management systems will enable our street light operators to have faults reported instantly to a central system or communicate it to a maintenance provider, with crews able to respond based on system information. The days of residents telling the Council their street light has not been working for weeks should be little more than a memory.

Critical to realising the best level of return on any investment in the city's street lights is the requirement to be able to report exactly how much energy is being consumed by each and every light. With the right level of control, we will be able to present our electricity retailer with a monthly report providing an exact account of our consumption – it will remove lights that are not working as they will not have consumed any power, it will take into account any reduction in consumption from some lights coming on later than others – even to the extent that some lights may come on or go off earlier or later than other lights within the same suburb or even street.

Control systems can also be used to manage events – in Auckland, as with other cities that have adopted LED lights around key venues, there is an ability to increase the lighting levels around Eden Park before and after a major event. This enable people to arrive and leave the event in safety but also enables pedestrian traffic to be directed in a manageable fashion towards public transport and parking infrastructure.

If suitable protocols are in place there is no reason that emergency services cannot request for task-specific lighting levels - brighter for some events, darker for others. Via a central control point an operator could possess the technology to increase or reduce the level of lighting to a street or larger area through a desktop computer or mobile device. This technology could also be used to support community events held over the darker months of winter.

As the strengths of LED lighting become more apparent there has been an increase in the technologies available to support and enhance its application. One of the more exciting areas of this is the potential for adaptive street or outdoor lighting.

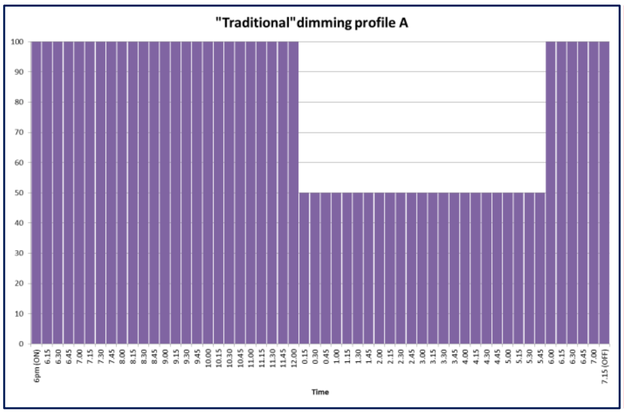
Adaptive lighting

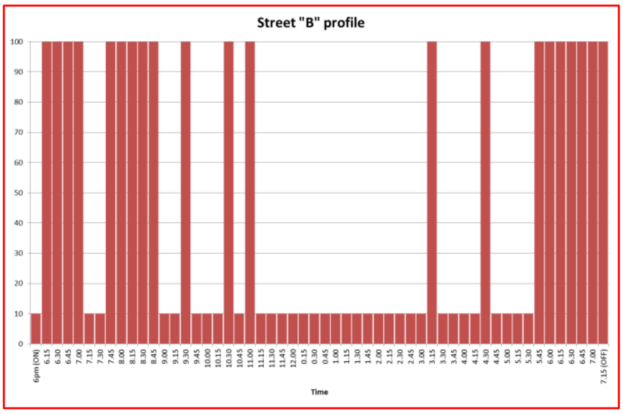
Adaptive lighting, to put it simply, uses technology to moderate the amount of light used to suit the purpose to which it is being applied. In the realm of street lighting this means lights can be dimmed or turned off when there is no need to provide lighting. The ability to run a large percentage of the city's street lights at a reduced level when there is nobody requiring the benefits of street lighting offers two significant and immediate benefits.

First, there is an obvious ability to increase power savings by not running lights at a high output level when they don't have to be. Second, as LED lights operate better at lower temperatures an LED light operating at a reduced power setting will last longer – this means the projected lifespan of the unit can be increased thus reducing the capital outlay (or depreciation) in replacing the asset.

As LED lights have an ability to respond instantly to on/off instructions there is little concern the correct amount of light not be available when needed – furthermore in contrast to some of the dimming programmes adopted thus far in LED upgrades the use of adaptive lighting guarantees to provide the same level of service to a motorist, pedestrian or cyclist regardless of whether they are using the city's streets during an arbitrarily determined 'peak' or 'off peak' period

This means rather than adopting a 'traditional' dimming profile (refer below) which effectively reduces the level of service to achieve savings the adoption of an adaptive system ensures the right amount of light is available for all pedestrians, cyclists and motorists.





Picture 2 traditional vs. adaptive dimming

Tvilight – CitySense and CityManager

A Netherlands company, Tvilight, has devised what seems to be the most viable adaptive option to reach the market so far. Using a passive infra-red (PIR) sensor attached to each pole a light can be turned up from a dimmed setting when a pedestrian, cyclist or motorist approaches and then after a programmed time the light will return to its dimmed state.

The CitySense system, shown in the image below, can enable lights to be configured in a way that increases lighting outputs progressively with movement and collectively greatly increases the energy savings potential for the city.

Picture 3 - Tvilight's CitySense system in operation

Alongside CitySense sits CityManager – its web-based software for remote monitoring, management and control of street lighting infrastructures. The software is directly coupled, although not proprietary, to CitySense through the internet and features remote programming and modification of settings of individual and groups of streetlights, context-specific lighting levels to reflect local conditions such as weather changes, special events and emergency situations as well as analytical tools to allow the use of exact data for energy savings/consumption, detection patterns and lamp failure detection.

Like more basic systems it is also capable of reporting faults. As the system is based on an open platform it can be developed to allow an interface with hardware from other providers (e.g. traffic and local weather monitoring).

Unlike other systems currently available the CitySense approach does not require cameras or any other intrusive mechanism to enable the city to maintain a high level of service in providing street lighting services.

Built from marine-grade materials the PIR receiver (shown above) is built to survive in hostile environments and is resilient to UV and the effects of aggressive coastal conditions. Should a reviver fail, its default position will automatically instruct the lighting unit to go to full power, this default setting will then be detected by the CityManager system enabling a replacement unit to be sourced or repairs carried out.

Currently a full trial of the Tvilight systems is being planned – this will see about 250 LED lights monitored over a period of time suitable to gather sufficient evidence of their performance. As an indication the following data from recent traffic count surveys has been used to assess what effect CitySense would have had on the power consumption of a light in five different settings across the city.

	Totals	Severn	Priscilla	Black Rock	Duthie	Fitzpatrick
Total Operation (minutes)	27,329	5,940	4,560	5,250	6,330	5,250
Minutes on Full	7,281	2,174	1,235	807	2,280	785
Minutes dimmed	20,048	3,766	3,325	4,443	4,050	4,464
Dimmed %	73.4%	63.4%	72.9%	84.6%	64.0%	85.0%
Vehicle count (#)	12,367	4,229	1,754	1,011	4,394	979
Consumption (kWh)						
70w (HPS)	1,913.1	415.8	319.2	367.5	443.1	367.5
30w (LED)	819.9	178.2	136.8	157.5	189.9	157.5
25w (LED)	683.2	148.5	114.0	131.2	158.2	131.2
30w LED with Tvilight	278.6	76.5	47.0	37.5	80.5	37.0
14w LED with Tvilight	152.1	39.8	25.6	22.4	42.0	22.2
Savings						
HPS to LED (30w)	57.1%					
HPS to LED (25w)	64.3%					
30w LED with Tvilight	85.4%	81.6%	85.3%	89.8%	81.8%	89.9%
14w LED with Tvilight	92.1%	90.4%	92.0%	93.9%	90.5%	94.0%

Table 2 - effects of LED and adaptive lighting (Tvillight CitySense) on sample streets

Although it may not be necessary or beneficial to adopt adaptive lighting across all of the city's streets there is sufficient evidence to suggest residential areas would be well suited to this approach.

Impacts from changing the way we light the city

As discussed above, the benefits of LED lights in their street lighting application are numerous. The more significant benefits are discussed below but it should be noted that although it is relatively straightforward to predict savings in energy and energy costs there is a risk that the energy sector may respond to reduced revenue by increasing their charges.

Energy savings

In 2013/14 Wellington's street lights consumed 7.33 megawatts of electricity at a cost of $2.36 million. With the adoption of LED street lights this figure can be reduced by at least 50% and potentially closer to the 70-80 per cent range if adaptive lighting technologies are applied.

The following table shows the most common lights within the current lighting stock and the assumed LED replacement alongside (it should be noted that the 'assumed' wattage of the LED is conservative). The table represents almost 90% of the city's street lighting stocks.

Current Wattage	No.	Consumption (w)	LED	New consumption (w)	Saving
50	173	8,650	25	4,325	50.00%
70	10,277	719,390	25	256,925	64.29%
100	554	55,400	40	22,160	60.00%
110	487	53,570	40	19,480	63.64%
150	4,100	615,000	60	246,000	60.00%
250	451	112,750	100	45,100	60.00%
400	61	24,400	120	7,320	70.00%
Totals	16,103	1,589,160		601,310	62.16%

Table 3 - assumed wattages of LED placement lights

Economic benefits

Quantifying the savings potential achievable through a change to LED lighting technologies is relatively straightforward in terms of energy savings. As can been seen below a 50% reduction in consumption will result in a direct savings of $1.03 million – based on current tariffs a 75% reduction in energy consumption will achieve savings of $1.5 million.

	Energy Costs	Line Charges		Administration Charges	Electricity Authority Levies	2013/2014 Totals
		Variable	Fixed			
Direct lighting costs	$ 735,657	$ 1,335,901	$ 277,782	$ 6,551	$ 9,380	$ 2,365,270
45% reduction in load	$ 405,979	$ 737,262	$ 277,761	$ 6,551	$ 5,177	$ 1,432,730
50% reduction in load	$ 369,207	$ 670,598	$ 277,806	$ 6,551	$ 4,708	$ 1,328,870
55% reduction in load	$ 332,442	$ 603,739	$ 277,768	$ 6,551	$ 4,239	$ 1,224,739
60% reduction in load	$ 295,674	$ 536,977	$ 277,782	$ 6,551	$ 3,770	$ 1,120,754
65% reduction in load	$ 258,906	$ 470,215	$ 277,782	$ 6,551	$ 3,301	$ 1,016,755
70% reduction in load	$ 222,138	$ 403,454	$ 277,782	$ 6,551	$ 2,830	$ 912,755
75% reduction in load	$ 185,369	$ 336,692	$ 277,782	$ 6,551	$ 2,359	$ 808,754
80% reduction in load	$ 147,365	$ 267,787	$ 277,782	$ 6,551	$ 1,875	$ 701,360

There are also savings to be made in the maintenance budgets with the focus shifting from maintaining or replacing bulbs, fuses and gear trays to one of inspecting and washing LED lights every four or five years and replacing poles and outreach arms.

Maintenance

The Council spends $300,000 each year on maintaining the parts of the existing network that would be replaced by LED street lights – additional funding covers the replacement of poles and outreach arms.

The following table outlines potential savings based on reducing maintenance by 80% - leaving funds to operate the central management system, keep the lights clean and renew or replace poles and outreach arms (based on a 30-year life cycle).

It should be noted that the savings shown are based on a complete replacement programme – scenarios indicate savings across different roll-out periods are shown on page 20.

It should also be noted that subsidies received from NZTA will also be affected by a reduction in energy consumption and opex and capex spending. These calculations are included in Appendix 1.

	2013/2014 Totals	OPEX	CAPEX		Overall Lighting Costs	Potential savings
			Renewals	Upgrades		
Direct lighting costs	$ 2,365,270	$ 531,000	$ 904,455	$ 68,077	$ 3,349,273	
45% reduction in load	$ 1,432,730	$ 53,100	$ 180,891	$ 68,077	$ 1,632,779	$ 1,716,494
50% reduction in load	$ 1,328,870	$ 53,100	$ 180,891	$ 68,077	$ 1,528,919	$ 1,820,353
55% reduction in load	$ 1,224,739	$ 53,100	$ 180,891	$ 68,077	$ 1,424,788	$ 1,924,484
60% reduction in load	$ 1,120,754	$ 53,100	$ 180,891	$ 68,077	$ 1,320,804	$ 2,028,469
65% reduction in load	$ 1,016,755	$ 53,100	$ 180,891	$ 68,077	$ 1,216,805	$ 2,132,468
70% reduction in load	$ 912,755	$ 53,100	$ 180,891	$ 68,077	$ 1,112,804	$ 2,236,469
75% reduction in load	$ 808,754	$ 53,100	$ 180,891	$ 68,077	$ 1,008,803	$ 2,340,469
80% reduction in load	$ 701,360	$ 53,100	$ 180,891	$ 68,077	$ 901,409	$ 2,447,863

Table 4 - potential savings showing all components.

Payback calculations

Although the total price for a full rollout of LED street lights and their associated controlling systems cannot be determined until an approach is made to the marketplace, a simple payback calculation has been completed across a range of assumed prices.

Best estimates available to us indicate a good-quality luminaire designed to last at least 20 years will cost in the range of $350-350 - adding a control system may add another $150 per luminaire and adopting an adaptive dimming system (Tvlight for example) an additional $330 per unit.

Depending on the extent of technology applied, the quality of lights adopted and the desire of the Council to maximise energy savings, the simple payback period ranges from 4.2 – 9.2 years.

The following table shows the payback periods for the three amounts ranging from $9 million to $19.6 million (being the best case, mid-range and worst case pricing assumptions) against the savings indicated above (a full table of payback periods is shown in Appendix 2).

	Energy savings						
	50%	55%	60%	65%	70%	75%	80%
$ 9,000,000	4.9	4.7	4.4	4.2			
$ 14,400,000	7.9	7.5	7.1	6.8			
$ 15,150,000				7.1	6.8	6.5	6.2
$ 19,650,000				9.2	8.8	8.4	8.0

Table 5 - payback periods

Disposal costs

In replacing the existing lighting assets there will also be a cost in disposing (physical removal, destruction or recycling and financial write-off) of the existing lighting assets. The overall cost of this key pricing component can vary if the opportunity is taken to replace other componentry at the same time. For example this could see cables, outreach arms or fuses being included (or not) in any rollout programme.

This element should be calculated based on net current value and included in the total cost or value of ownership scenarios and shown separately when overall project costs are established.

Levels of service

With LED technologies it is possible to direct lights very accurately which means that less light is being wasted – this we believe will in turn enable the Council to provide a better level of street lighting across the city than provided now. Historic pole placements have meant some areas of the city are not well lit – with LED lighting getting more and more efficient it is now feasible to install additional lights and still maintain significant energy savings.

An example of this has been demonstrated in Mariri Road and Boundary Road in Kelburn where nine high-power sodium lights totalling 747 watts (each being 83 watts) were replaced with 11 LED lights totalling 163[9] watts thus achieving a reduction in energy consumption of 75%.

In this installation the Wellington City Council became the first council in New Zealand to trial the award-winning[10] NXT luminaire from Canada (right) – although the light is only rated at 14 watts feedback from the street's residents has been very good with favourable comments received on both the volume and quality of light.

Picture 4 - LED Roadway NXT luminaire

With the ability to use powerful yet highly-efficient lights it will now be possible to light some of the harder to reach corners and dark spots previously considered unreachable. With the use of photocell technology and exploiting the on/off capabilities of LED lights it will also be possible to light streets the instant a predetermined level of light has been reached. This will mean that energy savings are maximised and light is available when needed.

Other benefits

In addition to those already discussed LED street lights offer the following benefits.

- Higher efficiency and low light pollution due to directional light:

  As LED lights are very directional street lights with a lower lumen output can replace conventional lamps with a higher output. The light emitted from the LED lamp is directed downwards, spread throughout the entire area it covers. This means that a lower amount of light is needed to properly illuminate the area.

[9] NOTE: In this installation 10 lights of 14w were used in conjunction with a 21 w light (10x14 + 1x23)
[10] In 2014 the NXT was named as "Best in Class" (Roadway – Local Residential) in the 2013 Next Generation Luminaires Outdoor Lighting Competition as judged by the Illuminating Engineering Society, the U.S. Department of Energy and the International Association of Lighting Designers.

- Reduced light pollution, which can affect the mood of human beings, navigation in birds and insects, animals' lifecycles and flowering in plants. Also no ultraviolet radiation is emitted from the LED street lamps.
- Reduced light depreciation

  The loss of brightness or lumen depreciation is slower over the life of an LED lamp than that of sodium or other types of lamp. Not only does the LED have a longer lifespan than the conventional lamp, but it stays brighter longer than other lamps thus reducing the need to replace lights as often.

- Better operating characteristics

  LED lights operate at lower temperatures, are not sensitive to low temperature and unaffected by on-off cycling. This makes them safer and more efficient in cold environments.

- Resilience

  These bulbs are shock- and vibration-resistant making them the best choice for places like bridges or windy environments.

- Dark-sky friendly

  Because of the directional light, light is carefully distributed exactly where it is meant to go and therefore there is no or little light wasted by illuminating the night sky. This is a considerable plus especially if the local community has a Darksky Initiative (refer Appendix 3).

- Natural light spectre – Colour Rendering Index

  LED street lamps with colour temperature 3.500-4.200 kelvins are rendering more natural light than the yellow of sodium lamps or green of fluorescent streetlights. Colour rendering index (CRI) is high (80-90) and displays the natural colours of illuminated objects.

- Free of harmful substances with a lower environmental impact when disposed of.

  LED luminaires contain no harmful substances, like mercury, lead or other hazardous chemical and gases. Spent LED lamps can be disposed of without any special handling since they are recyclable and environmentally friendly. Other light technology often has hazardous materials such as lead and mercury requiring special handling and waste management procedures which have both economic and environmental costs.

Smart lighting networks

In addition to the benefits of adaptive dimming there is thinking among city administrators and research organisations that a move to LED lighting is just the beginning – the digital era of street lighting offers many opportunities for cities to maximise the capability of their street lighting network.

One observer, Professor Michael Siminovich[11] from the University of California, recently claimed

> "*Street lights with control systems offer dynamic dimming during long periods of inactivity, a feature with tremendous potential to save energy, mitigate waste, reduce light pollution, and increase public safety. In spite of all these advantages, there is no nationwide control standard established to date, and LED street lights are being installed* en masse *without this important feature. These fixtures are likely to be in use for as long as 20 years, so the fixed-wattage, un-retrofittable fixtures sold today represent a significant loss in long-term savings opportunity."*

It is foreseeable that smartphone applications could be used in synergy with the street lighting network to:

- Advise motorists of available parks via satellite navigation devices
- Advise of bus arrival times
- Perform traffic-count functions
- Allow for waste management planning
- Transmit remote metering information for area water meters
- Transmit wastewater/stormwater pump-station performance data.

It is important that this aspect of taking the city's street lighting network into the digital era recognises both the potential of the network and the risk of not being in a position to build on the capability of the network either through the correct selection of fittings now or the selection of lights that can be retro-fitted with additional capabilities at a later date.

Without considering the wider capability of the street lighting network there is real potential a straight replacement of existing technologies with a LED replacement could lock a territorial authority into a programme of reduced energy savings that make further enhancements to the network's capability financially unattractive.

LED lights in Wellington

Wellington City Council has been installing LED lights on a number of pathways over the past few years with good feedback received in the majority of cases. Where lights have proven to be too powerful they have been successfully substituted for less powerful options.

With the increased efficacy and directional capability we can now use LED lights to illuminate long and narrow stretches of pathway without running the risk of lighting up private property or houses.

[11] Siminovich, M., UC *Davis Professor calls for a state-wide "time out" on further public purchases of led street lights*, University of California, Davis,

A small number of streets were chosen in Tawa earlier this year for a trial of LED lights from different manufacturers. These streets, listed below, were chosen due to their proximity to each other, similar topography and design and limited effects from hills, trees and corners.

Until mentioned the majority of residents spoken to in Tawa have not noticed any difference in the lighting levels in the ‘trial’ streets – or in fact the lights had been changed.

Additional installations

In addition to the lights discussed above, street lights in Courtenay Place, Allen Street and Blair Street have been replaced with LED lights. This was undertaken largely to reduce the network load and lessen the probability of a network failure leaving the area unlit for an unacceptable period of time.

It also reduced the likelihood of Courtenay Place requiring a large trenching project that would have resulted in significant disruptions to retailers, the hospitality sector, residents and commuters. Overall the energy consumption for the area has been reduced by 66% (from 19 kilowatts to 6.5 kilowatts).

A lighting design is being completed for Cuba Mall – this will see the mall area lit to the same level as Courtenay Place, Allen Street and Blair Street - with the intention to reduce the number of poles, overall energy consumption and unwanted light pollution simultaneously.

This design, which will reduce energy consumption by 83%, will see the existing stock of 16 lights (at a total of 3800 watts) replaced with a combination of LED lights centrally suspended on a catenary system and 7 pole mounted lights (640 watts).

Roll-out options

One of the key considerations is the manner in which a project of this nature is implemented – at one end of the scale is a slow and steady roll-out, possibly within existing budgets and maintenance strategies and programmes over a period of 7–10 years (for example) and at the other end an accelerated or rapid rollout carried out as quickly as financially and physically feasible.

The immediate differences can be simply expressed – the longer the rollout the longer it takes to realise the advantages of LE technologies. This will be manifested in lower energy savings, continued maintenance and operational costs and reduced purchasing power. The shorter the rollout period the sooner the savings and benefits can be fully realised.

Reflecting a short, medium and long-term rollout scenario, the following tables illustrate the equation numerically and also the scenario where the reduction in energy averages just 60%. The 2013/14 maintenance costs are used as a guideline. It should be noted that the maintenance figures are assumed to remain constant in ratio to the percentage of old lights yet to be replaced.

		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Short (2 Years)	Installations	50%	100%	Ongoing reduced budgets							
	OPEX / CAPEX	50%	100%								
	Energy Savings	50%	100%								
Medium (5 Years)	Installations	20%	40%	60%	80%	100%	Ongoing reduced budgets				
	OPEX / CAPEX	20%	40%	60%	80%	100%					
	Energy Savings	20%	40%	60%	80%	100%					
Long (8 Years)	Installations	12.5%	25.0%	37.5%	50.0%	62.5%	75.0%	87.5%	100.0%	Ongoing reduced budgets	
	OPEX / CAPEX	12.5%	25.0%	37.5%	50.0%	62.5%	75.0%	87.5%	100.0%		
	Energy Savings	12.5%	25.0%	37.5%	50.0%	62.5%	75.0%	87.5%	100.0%		

		Current	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
Short (2 Years)	Purchase		5,850,000	5,850,000							
	OPEX / CAPEX	985,000	492,500	246,250	200,000						
	Energy	2,365,000	1,743,012	1,120,754	1,120,754						
Totals		3,350,000	8,085,512	7,217,004	1,320,754						
Variance over Year One			4,735,512	3,867,004	- 2,029,246						
Medium (5 Years)	Purchase		2,340,000	2,340,000	2,340,000	2,340,000	2,340,000				
	OPEX / CAPEX	985,000	788,000	630,400	504,320	403,456	322,765	200,000			
	Energy	2,365,000	2,116,367	1,867,464	1,618,561	1,369,658	1,120,754	1,120,754			
Totals		3,350,000	2,904,367	2,497,864	2,122,881	1,773,114	1,443,519	1,320,754			
Variance over Year One			- 445,633	- 852,136	- 1,227,119	- 1,576,886	- 1,906,481	- 2,029,246			
Long (8 Years)	Purchase		1,462,500	1,462,500	1,462,500	1,462,500	1,462,500	1,462,500	1,462,500	1,462,500	
	OPEX / CAPEX	985,000	861,875	754,141	659,873	577,389	505,215	442,063	386,805	338,455	200,000
	Energy	2,365,000	2,209,706	2,054,141	1,898,577	1,743,012	1,587,448	1,431,883	1,276,319	1,120,754	1,120,754
Totals		3,350,000	3,071,581	2,808,282	2,558,450	2,320,401	2,092,663	1,873,947	1,663,124	1,459,209	1,320,754
Variance over Year One			- 278,419	- 541,718	- 791,550	- 1,029,599	- 1,257,337	- 1,476,053	- 1,686,876	- 1,890,791	- 2,029,246

Table 6 - rollout scenario based on a 60% energy saving and 2013/14 maintenance costs

Finance options

A range of finance options are being made available to municipalities considering large capital investments in energy and cost saving initiatives. This reflects what is happening globally as municipal authorities look to replace ageing infrastructure.

Some of the options range from the traditional funding through rates to traditional lending against capital, lease arrangements with manufacturers, power companies, investment funds and service providers, public-private partnerships and ‘green loans’ with performance-based contracts.

The wider implications, advantages and risks associated with any funding option need to be carefully balanced against the overall objective of providing a safe, efficient and effective lighting service to residents, pedestrians, cyclists and motorists.

An advantage of initiatives of this nature is the ability to repay financing through the savings achieved through reduced energy consumption and maintenance – the greater the energy reduction, the greater the savings and therefore the shorter the payback period. This also means it is a shorter period of time before the Council benefits from the reduced costs of providing street lighting services.

The three options appearing to impact the least on ratepayers are the public-private partnership (or variants), a performance-based lease arrangement or a lending package based on achievable savings (green lending).

With each of these options the Council is not required to fund the capital expense of the new technologies itself. Although new to this country in terms of funding options exercised by councils there are several examples of each approach being exercised overseas that can be explored further to enable comparisons of their respective strengths, weaknesses and suitability to Wellington's street lighting.

The following summary of some of the options available to the Council for the procurement of street lighting equipment and infrastructure construction services[12] is intended to be 'option-neutral' It should be noted however there are other aspects to be considered including the value attached to branding Wellington as a 'Smart'- or 'Eco'- City. As described previously there are specific risks attached to replacing luminaires only without providing for future developments.

This cost calculation is part of what is now being described as 'total value of ownership' versus the traditional 'total cost of ownership'.

Where the notion of TCO takes into account all costs linked to new infrastructure: from the initial investment (capex) to the operating costs (opex) such as maintenance, re-lamping, energy, disposal and so forth, TVO takes a different approach.

Within a smart city context, infrastructure can become a dynamic platform enabling continuous innovation. Accordingly TVO enables a holistic approach encompassing the less tangible values gained by a city's brand, strategic goals or community identity alongside the more traditional 'costs' of operation.

Developing infrastructure with a TVO-based approach includes:

1. Linking the project to the city's vision in terms of liveability, economic growth, and sustainability.
2. Defining the connected public lighting infrastructure as a 'network of networks' and a platform for service innovation.
3. Working actively with stakeholders (councils, retailers, hospitality, emergency services, cellular operators, ISPs, and citizens to create meaningful use cases.
4. Investing operational cost savings (not only from lighting) in the platform to enable new functionalities.
5. Measuring the total value generated year-over-year in terms of savings and revenues, jobs created, and liveability improvements.

All of these aspects reinforce the Council's goals of Wellington being a smart-, eco, connected, and liveable destination for residents, businesses and educational organisations.

Traditional competitive price (CP) specification and tender

The traditional benchmark approach to procurement has been widely used over the years and has served local government reasonably well. It is possibly more suitable to environments or applications where there has been 'evolution' rather than a technological change (such as the impact of LED lights on street lighting).

[12] The summary of finance options has been researched and provided by consulting firm Strategic Lighting Partnerships (Hamilton).

This approach will only consider the upfront financial cost and the contract will traditionally be awarded to the tenderer that provides the lowest conforming cost – the full lifetime cost of ownership and its impact on environmental and social factors is not fully quantified.

Another key disadvantage is its reliance on the designer's interpretation of requirements which usually follows traditional low-risk practices. Offering improvements arising from innovation are rarely considered worth the risks as there is no reward for innovation, whereas there are many penalties for failure.

The two variations on this model for street lighting are described below.

Product supply-and-install competitive price (CP) contract

With the product supply-and-install model a specialist design consultant – for example an electrical engineer or lighting designer - is commissioned to design lighting to meet the expected standards within a framework of AS/NZS 1158 and the Council's requirements. The design consultant will develop a designed solution and will specify the luminaire type(s) and selected brand in detail as well as installation and construction methods to be employed.

These design requirements are then expanded by a quantity surveyor into a schedule of quantities and will be combined with construction contract requirements by a project manager. This supply-and-install contract package is then usually tendered to the market for bids from contractors who will seek luminaire pricing from suppliers, sometimes with electrical wholesalers as intermediaries in the lighting supply chain.

This method was adopted by Tauranga City Council for its Capital Streetlight Upgrading 2010/2011 project.

Advantages

- A traditional model, well understood and which has worked reasonably well during times of little change in technology or performance expectation.
- A simple process as the project is tendered and usually concludes with a singular 'lowest cost conforming' bid for the provision of both goods and contracting services.
- Cohesion is usually good. Application and installation detail issues can often be resolved without recourse to the original design consultant.
- Procurement costs are low as it is a straightforward process requiring no extended performance calculations or verification.

Disadvantages

- Focus is on detailed inputs to the project rather than on the results actually delivered. Such detailed management of inputs can stifle or preclude innovation and may hinder the potential advantages of a wider scope of commercial competition.

- A ‘consultant as gatekeeper’ approach to product selection can lead to a restrictive narrowing of the offerings under consideration and could be a barrier to more innovative and better-value results.
- The selection of a luminaire of one brand with an ‘or equivalent’ option can dilute consultant intentions and/or cede authority to the construction contractor to negotiate and decide the price/quality trade-off, which may not be in the best long-term interests of the council client. This approach can also lead to the supplier gaining manufacturer price concessions that may not be transferred in full through to the Council.
- The meaning of ‘product equivalence’ and the evaluation can be complicated and should be undertaken by the original consultant (this should be factored into the fee structure and not be left to the contractor to control at its sole discretion, as is often the case).
- Sometimes a seemingly level and competitive consultant-compiled luminaire specification can actually be written around the combination of technical attributes of one particular brand or model of luminaire. This product specification skew can be difficult to recognise and requires a wide knowledge of competing product attributes to detect. This practice can serve to reduce competition with the potential to increase costs to the Council.
- High levels of product selection and design conservatism are incentivised in a climate where risk aversion is paramount. This excessive conservatism may lead to solutions that perform below the otherwise available best-value level. With this model there is no incentive to explore innovative and potentially higher-performing options as the project KPIs are not aligned with the consultant time investment and potential for consultant self-borne risk.
- There is a fundamental disconnect between capex decisions and opex results. The focus on lowest initial cost can disguise higher operating and maintenance costs over life. Such ‘siloed’ decision-making does not usually generate the best overall long-term value for the Council.
- The use of electrical wholesalers in the supply chain adds margins and offers value to the contractor in the form of product sourcing and financing services. These benefits do not necessarily flow through to the client and usually have the effect of increasing prices to the Council.
- Some luminaire suppliers and some wholesalers offer brand loyalty bonuses to their customers in the form of financial rebates or travel incentive programmes. Such schemes are attractive to contractors as an effective margin enhancer but these schemes incur additional and hidden supply chain costs and may unduly influence brand choices.
- Usually there very short (1-3 year) warranty periods for this type of contract.

Product supply-only competitive price (CP) contract

As an alternative to the above, a lighting consultant could develop a luminaire product specification and this will be combined with supply-only contractual conditions by a project manager and be offered to the market for tender bids from luminaire supplier/importers. After procurement by the Council, the luminaires will then be installed by the Council's contractor.[13]

Advantages

- This is a traditional model that is well understood by relevant parties and which has worked reasonably well during times of little change in technology or performance expectations.
- The process is simple as the project manager tenders and selects a 'lowest cost conforming' tender bid for the product supply.
- A straightforward process with low procurement costs requiring no extended performance calculations or verification.

Disadvantages

- The contract focus is on the detailed technical input aspects of the luminaire rather than on the results it may actually deliver. Such detailed management of inputs can stifle innovation and may hinder the potential advantage of a wider base of commercial competition.
- The 'consultant as gatekeeper' approach that stipulates required product technical attributes can preclude other valid options and lead to an inappropriate narrowing of the offerings under consideration and could be a barrier to more innovative and better-value results.
- Sometimes a seemingly level and competitive consultant luminaire specification can actually be written around the combination of technical attributes of one particular brand or model of luminaire. This product specification skew is difficult to recognise and requires a wide knowledge of competing product attributes to detect. This practice can serve to reduce competition with the potential to increase costs to the Council.
- High levels of conservatism in product requirements are incentivised in a climate where risk aversion is paramount. This undue conservatism may lead to solutions that perform below the otherwise available best value level. With this model there is no incentive to explore innovative and potentially higher performing options as the project KPIs are not aligned with the consultant time investment and potential self-borne risk.
- Focus on lowest initial cost can disguise higher operating and maintenance costs over life. May not generate the best long-term value for the Council.
- A contractor supplying labour-only installation services may not have an adequate incentive for appropriate pre-installation care and handling of client-supplied goods. Installation contractors usually have a strong preference to be part of the supply chain for the supply of goods as this is often more profitable for them and contractor friction can occur if this opportunity is precluded.
- Usually short (1-3 year) warranty periods for this type of contract.

[13] A recent local example of a product supply-only contract is Napier City Council - Contract 741 - Supply of Street Lighting Luminaires - April 2012

Innovation focussed procurement contracts

Contracting externally for a complete street lighting service is a new concept for New Zealand but is extensively used in Europe. It offers potential performance gains and cost savings from advanced lighting technologies without the need for a council to have the finance, resources or expertise in-house. There is a variety of contracting approaches, the most common being energy performance contracts (EPCs) or public-private partnerships (PPPs).

Street lighting infrastructure is a long-lived asset and therefore lends itself to long-term outsourcing arrangements, typically over 15-25 years. Outsourced contracts generally involve designing, building, financing, operating and maintaining a large street lighting project of many thousands of lights. The initial one to five-year stage of such contracts is called the core investment period (CIP) during which the old lights of the existing network are removed on an accelerated basis and replaced with advanced lighting. The advantages for a council are the fully-encompassing nature of the arrangement with a financed and risk-managed contract usually with guaranteed savings and/or continuous improvement provisions.

Performance contract - non-financed

This model is an output-based turnkey performance contract that stipulates the required results but does not specify the required product engineering attributes at the micro level. This is a systems-based contract specification for the installation and maintenance of an installed road lighting network that states a wide range of quantitative and qualitative attributes required and the KPIs that measure and verify those attributes.

The principal KPIs are usually focused on the main areas of energy savings and the resultant carbon emissions savings, lighting quality and service levels, lighting failure response and waste and environmental practices.

The turnkey project approach requires the formation of an alliance group contracting company called an SPV (special purpose vehicle) to 'design, supply, install, commission, operate and maintain' the street lighting system for a stipulated contractual term. Financing is not part of this model and asset ownership resides with the Council.

The design risks, product performance risks and the operational risks are all assigned to the private contractor which indemnifies the client council against untoward occurrences. There are usually penalties levied upon the contractor should it fail to deliver the required performance.

The City of Sydney recently used this option in its project to retrofit the city's public domain lights.

Advantages

- The complete turnkey project responsibility is with the contractor.
- Result-focused KPIs are the contract focus for contractor rewards or penalties.
- Whole-of-life cost is the focus not just first-cost selection.
- Technology-neutral performance is what matters, not favourite technologies.

- Brand-neutral performance is what matters, not favourite brands.
- Open RFP procurement requirements encourage and incentivise innovation and stretch targets and do not unreasonably restrict options.
- Performance comparisons are quantitative. They allow objective ranking of offers and rationalise complex features and ‘let the numbers do the talking’.
- Supplier underwrites technology and operational risk.
- Extended and long-term warranties are the norm.

Disadvantages

- The procurement process is less well understood and project-management training is usually required.
- For the Council, procurement contracts are more complex and require more time to initially develop and to set up. More time and effort is required to evaluate responses.
- For the contractor, procurement contracts are more complex and require more time to develop and respond. Bid costs are higher.

Performance contract - financed

There is a range of descriptors for various nuances of financed performance contracting models such as public private partnerships, private finance initiatives, shared savings schemes, energy performance contracts etc. These are all variations on a common theme so for the sake of simplicity these will be referred to in this report as public private partnerships (PPPs).

The PPP model is an output-based turnkey performance contract that stipulates the required results but does not specify the required product engineering attributes at the micro level. A PPP is a systems-based contract for the procurement, financing, operation and maintenance of an installed street lighting network over the longer term (typically 15 to 25 years). The contract documents state a wide range of quantitative and qualitative attributes required and state the metrics that measure and verify those attributes.

The principal KPIs are usually focused on the main areas of energy savings and the resultant carbon emissions savings, lighting quality and service levels, lighting failure response and waste and environmental practices. Sometimes social and/or cultural development programs and targets are required.

The PPP turnkey project approach requires the formation of an alliance group contracting company (called a special purpose vehicle or SPV) to ‘design, supply, install, commission, finance, operate and maintain’ the street lighting system for a stipulated long-term contract period. Capital and operational financing is part of this model so asset ownership is with the contracting SPV with the council as client. Energy supply is also usually included.

At the start of the contract there is a period (say 3-5 years) of intensive asset renewal activity (called the core investment period or CIP) to quickly remove obsolete infrastructure and replace with new and more efficient equipment. Payments to the contractor are made on a regular (monthly) basis with contractual provisions for various inflationary adjustments to cater for longer-term contract viability.

At the end of the contractual term the network asset is usually vested to the client council at zero cost.

Risks associated with design, product performance, financing and operations risks are assigned to the private contractor which indemnifies the client council against such exposure. There are usually penalties levied upon the contractor for failing to deliver the required quantitative performance results.

There are also provisions for the contractor to drive further gains through innovation and to update and improve the system performance at stipulated regular intervals over the life of the contract with additional savings being shared by the client and contractor on a pre-agreed proportional basis.

Advantages and disadvantages

The same advantages and disadvantages exist as with non-financed performance contracts but the financing element is introduced. This makes the procurement process and management process more involved, but acts as a project enabler when internal council finances cannot deliver the required capital funding.

This type of contract could be termed a PFI or PPP or an EPC and as such requires quite a complex contractual and management model. To counter this there are model templates available for road lighting applications (UK Treasury's *Local Partnerships* initiative) as well as more NZ-specific guidance from Treasury.

Risk

As with any project of this size there are inherent risks. A risk matrix should be applied to the specific risks identified in the selection, procurement and installation of LED lighting technologies, control systems and operations/maintenance programmes.

While a detailed risk identification and analysis exercise will be completed as part of any continuation of this exercise the key areas of risk identified thus far are listed below along with the likelihood, impact (L/I) and possible mitigation[14]. They are ranked from high to low.

Risk 1: Electricity supply network charges (high/high)

Mitigation: The risk that network companies (and power companies) will seek to recover lost revenue (from reduced consumption) through variations to pricing structures is real. Ongoing communications with supplier, regulators and the Commerce Commission in this area will seek to reduce the risk/impact.

Wellington Electricity (as network provider to the city's electricity retailers) has indicated its response to a reduction in consumption will be to adjust the fixed/variable ratio accordingly to maintain the existing return on their investment.

[14] The summary of risks has been researched and provided by consulting firm Strategic Lighting Partnerships (Hamilton).

Wellington City Council's recourse in this area is to work with regulatory authorities to ensure that the legislative requirements in relation to promoting energy efficiency are adhered to.

Risk 2: Technical specification too detailed/not detailed enough (medium/high)

Mitigation: Specification knowledge can be sourced from overseas experiences, the US Department of Energy and locally via Opus Consulting, Connetics, Auckland Transport and Christchurch City Council.

Risk 3: Sub-optimal procurement (medium/high)

Mitigation: Along with guidance from Council finance staff and procurement personnel, staff from central government, Treasury and Westpac Bank are able to offer inputs to minimise risk to the Council. There is also the ability to access information from overseas projects and procurement procedures used to implement similar projects.

Risk 4: Equipment pricing exceeds assumption (low/medium)

Mitigation: Discussions with local authorities, suppliers and consultants lead us to believe this risk is relatively low and only likely to impact on any implementation if there are excessive delays in procurement.

Risk 5: Opportunity cost (low/low)

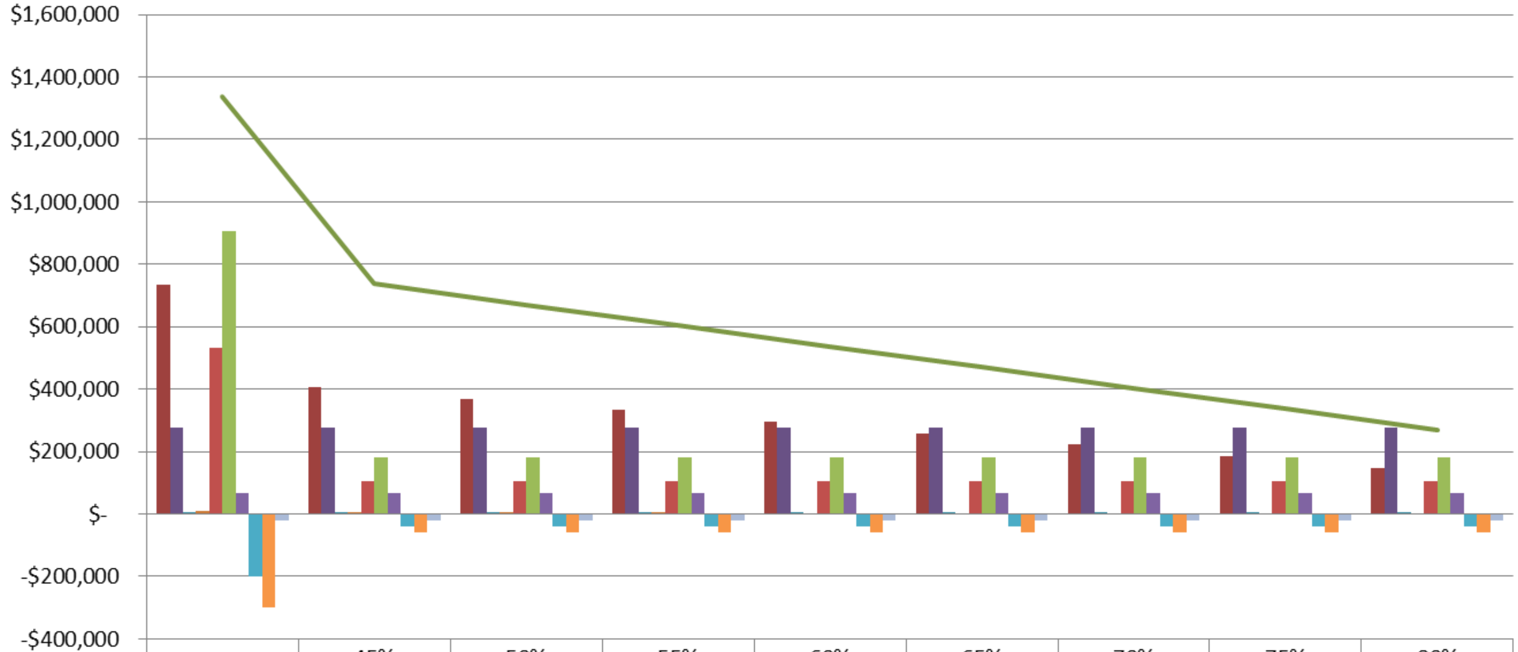
Mitigation: Decisive actions in response to any directions received by the Council will enable prompt action and lessen the impact of lost opportunities.

Appendix One – Cost Savings tables

Following are tables and graphs providing estimated savings across the complete street lighting activity. The table below indicates the costs assigned to each component with visual representation following. The third graph shows the effect of a 75% savings in energy alone based on 2014/15 contract prices.

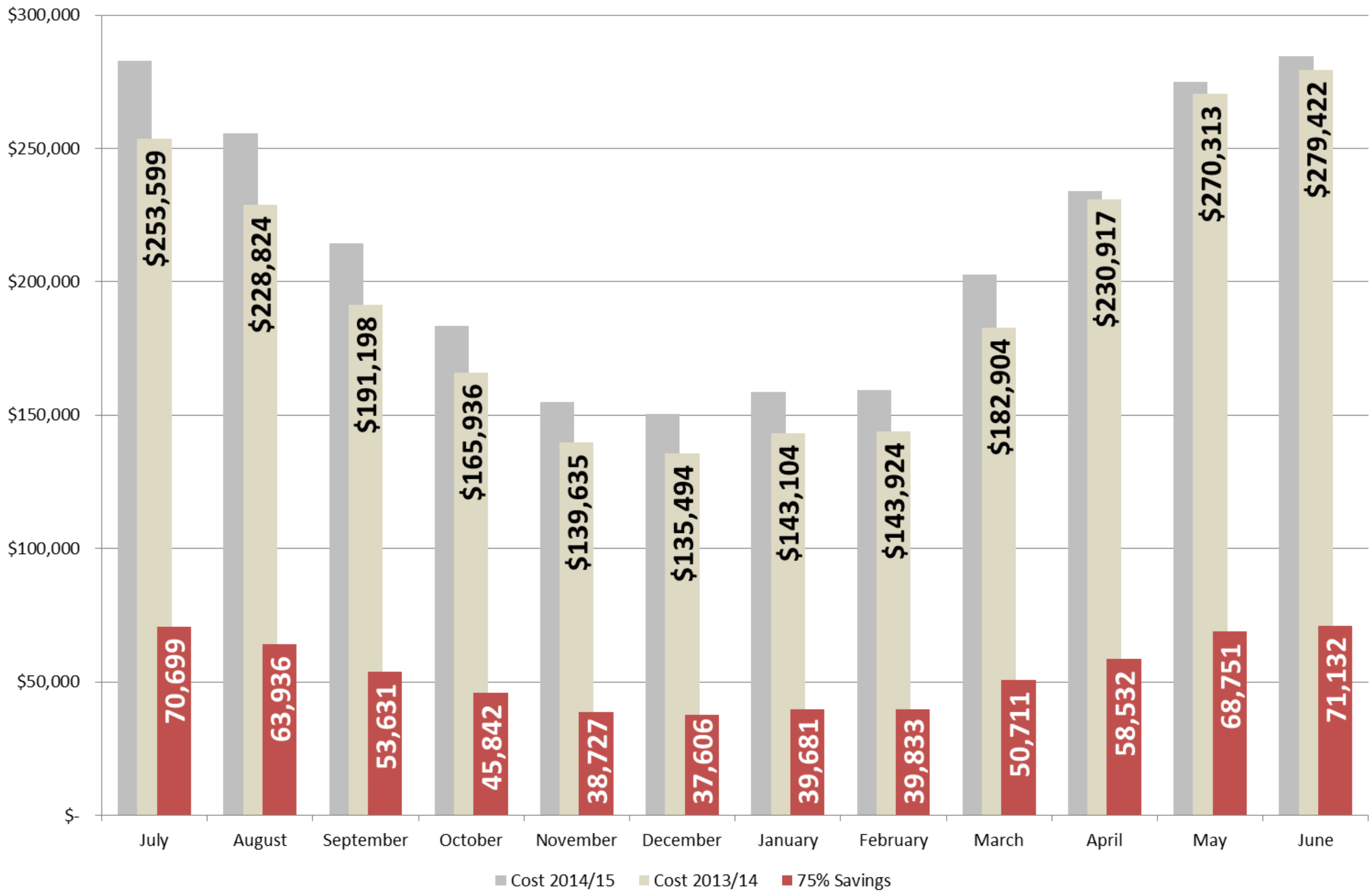
	Energy Costs	Line Charges		Administration Charges	Electricity Authority Levies	2013/2014 Totals	OPEX	CAPEX		NZTA Subsidies			Overall Lighting Costs	Potential savings
		Variable	Fixed					Renewals	Upgrades	OPEX	Renewals	Upgrades		
Direct lighting costs	735,657	1,335,901	277,782	6,551	9,380	2,365,270	531,000	904,455	68,077	- 198,594	- 298,470	- 22,465	3,349,273	
45% reduction in load	405,979	737,262	277,761	6,551	5,177	1,432,730	106,200	180,891	68,077	- 39,719	- 59,694	- 22,465	1,666,019	1,683,253
50% reduction in load	369,207	670,598	277,806	6,551	4,708	1,328,870	106,200	180,891	68,077	- 39,719	- 59,694	- 22,465	1,562,160	1,787,113
55% reduction in load	332,442	603,739	277,768	6,551	4,239	1,224,739	106,200	180,891	68,077	- 39,719	- 59,694	- 22,465	1,458,029	1,891,244
60% reduction in load	295,674	536,977	277,782	6,551	3,770	1,120,754	106,200	180,891	68,077	- 39,719	- 59,694	- 22,465	1,354,044	1,995,228
65% reduction in load	258,906	470,215	277,782	6,551	3,301	1,016,755	106,200	180,891	68,077	- 39,719	- 59,694	- 22,465	1,250,045	2,099,227
70% reduction in load	222,138	403,454	277,782	6,551	2,830	912,755	106,200	180,891	68,077	- 39,719	- 59,694	- 22,465	1,146,045	2,203,228
75% reduction in load	185,369	336,692	277,782	6,551	2,359	808,754	106,200	180,891	68,077	- 39,719	- 59,694	- 22,465	1,042,044	2,307,229
80% reduction in load	147,365	267,787	277,782	6,551	1,875	701,360	106,200	180,891	68,077	- 39,719	- 59,694	- 22,465	934,650	2,414,623

Table 7 - street lighting components based on different levels of energy savings



	Direct lighting costs	45% reduction in load	50% reduction in load	55% reduction in load	60% reduction in load	65% reduction in load	70% reduction in load	75% reduction in load	80% reduction in load
Energy Costs	$735,657	$405,979	$369,207	$332,442	$295,674	$258,906	$222,138	$185,369	$147,365
Line Charges Fixed	$277,782	$277,761	$277,806	$277,768	$277,782	$277,782	$277,782	$277,782	$277,782
Administration Charges	$6,551	$6,551	$6,551	$6,551	$6,551	$6,551	$6,551	$6,551	$6,551
Electricity Authority Levies	$9,380	$5,177	$4,708	$4,239	$3,770	$3,301	$2,830	$2,359	$1,875
OPEX	$531,000	$106,200	$106,200	$106,200	$106,200	$106,200	$106,200	$106,200	$106,200
CAPEX Renewals	$904,455	$180,891	$180,891	$180,891	$180,891	$180,891	$180,891	$180,891	$180,891
CAPEX Upgrades	$68,077	$68,077	$68,077	$68,077	$68,077	$68,077	$68,077	$68,077	$68,077
NZTA Subsidies OPEX	-$198,594	-$39,719	-$39,719	-$39,719	-$39,719	-$39,719	-$39,719	-$39,719	-$39,719
NZTA Subsidies Renewals	-$298,470	-$59,694	-$59,694	-$59,694	-$59,694	-$59,694	-$59,694	-$59,694	-$59,694
NZTA Subsidies Upgrades	-$22,465	-$22,465	-$22,465	-$22,465	-$22,465	-$22,465	-$22,465	-$22,465	-$22,465
Line Charges Variable	$1,335,901	$737,262	$670,598	$603,739	$536,977	$470,215	$403,454	$336,692	$267,787

Graph 2 - street lighting components based on different levels of energy savings



Graph 3 - energy cost comparison with a 75% reduction compared to 2014/15 contract tariffs

Appendix Two – Payback tables

Assumed price (average)			Simple payback						
Luminaire	CMS	Subtotal	50%	55%	60%	65%	70%	75%	80%
$ 350	$ 200	$ 9,900,000	5.5	5.2	5.0	4.7			
$ 400	$ 200	$ 10,800,000	6.0	5.7	5.4	5.1			
$ 450	$ 200	$ 11,700,000	6.5	6.2	5.9	5.6	Not achievable		
$ 500	$ 200	$ 12,600,000	7.1	6.7	6.3	6.0			
$ 550	$ 200	$ 13,500,000	7.6	7.1	6.8	6.4			
$ 600	$ 200	$ 14,400,000	8.1	7.6	7.2	6.9			

Assumed price (average)									
Luminaire	CMS	Subtotal							
$ 350	$ 150	$ 9,000,000	5.0	4.8	4.5	4.3			
$ 400	$ 150	$ 9,900,000	5.5	5.2	5.0	4.7			
$ 450	$ 150	$ 10,800,000	6.0	5.7	5.4	5.1	Not achievable		
$ 500	$ 150	$ 11,700,000	6.5	6.2	5.9	5.6			
$ 550	$ 150	$ 12,600,000	7.1	6.7	6.3	6.0			
$ 600	$ 150	$ 13,500,000	7.6	7.1	6.8	6.4			

Assumed price (average)										
Luminaire	CMS	Tvilight	Subtotal							
$ 350	$ 200	$ 350.00	$ 15,150,000				7.2	6.9	6.6	6.3
$ 400	$ 200	$ 350.00	$ 16,050,000				7.6	7.3	7.0	6.6
$ 450	$ 200	$ 350.00	$ 16,950,000		Not applicable		8.1	7.7	7.3	7.0
$ 500	$ 200	$ 350.00	$ 17,850,000				8.5	8.1	7.7	7.4
$ 550	$ 200	$ 350.00	$ 18,750,000				8.9	8.5	8.1	7.8
$ 600	$ 200	$ 350.00	$ 19,650,000				9.4	8.9	8.5	8.1

Assumed price (average)										
Luminaire	CMS	Tvilight	Subtotal							
$ 350	$ 150	$ 350.00	$ 14,250,000				6.8	6.5	6.2	5.9
$ 400	$ 150	$ 350.00	$ 15,150,000				7.2	6.9	6.6	6.3
$ 450	$ 150	$ 350.00	$ 16,050,000		Not applicable		7.6	7.3	7.0	6.6
$ 500	$ 150	$ 350.00	$ 16,950,000				8.1	7.7	7.3	7.0
$ 550	$ 150	$ 350.00	$ 17,850,000				8.5	8.1	7.7	7.4
$ 600	$ 150	$ 350.00	$ 18,750,000				8.9	8.5	8.1	7.8

Appendix Three – Dark-sky initiative

The wonder of the night sky has been a constant since the dawn of civilization. It has inspired countless generations, poets, scientists and dreamers. Today this natural resource is threatened by the careless use of artificial light. The International Dark-Sky Association has been working to protect and preserve the night sky for future generations.

The International Dark-Sky Association (IDA) is an educational organisation that seeks to preserve the natural night skies worldwide. Light pollution is an increasing problem threatening astronomical facilities, ecologically-sensitive habitats, all wildlife, our energy use as well as our human heritage.

Light pollution – defined as 'excessive and inappropriate artificial light' has four components which are often combined and overlapping:

- Urban sky glow - the brightening of the night sky over inhabited areas.
- Light trespass - light falling where it is not intended, wanted, or needed.
- Glare - excessive brightness which causes visual discomfort. High levels of glare can decrease visibility.
- Clutter - bright, confusing, and excessive groupings of light sources, commonly found in over-lit urban areas. The proliferation of clutter contributes to urban sky glow, trespass, and glare.

The International Dark Sky Places programme was developed to recognise areas with natural night skies and communities that are committed to preserving them through action, outreach and education.

It is recommended the adoption of a 'Dark-Sky' policy be discussed with Carter Observatory in order to establish if marketing opportunities can be established for the city and/or region.

It should also be explored as an appendix to the Council's Public Space and Design Manual, District Plan and Code of Practice for Land Development.

Appendix Four – Photographs of LED installations

Los Angeles installations

The following three pictures are from Hoover Street in Los Angeles[15]

[15] Photos the City of Los Angeles Bureau of Street Lighting conversion sourced through www.gizmodo.com and www.lightpublic.com

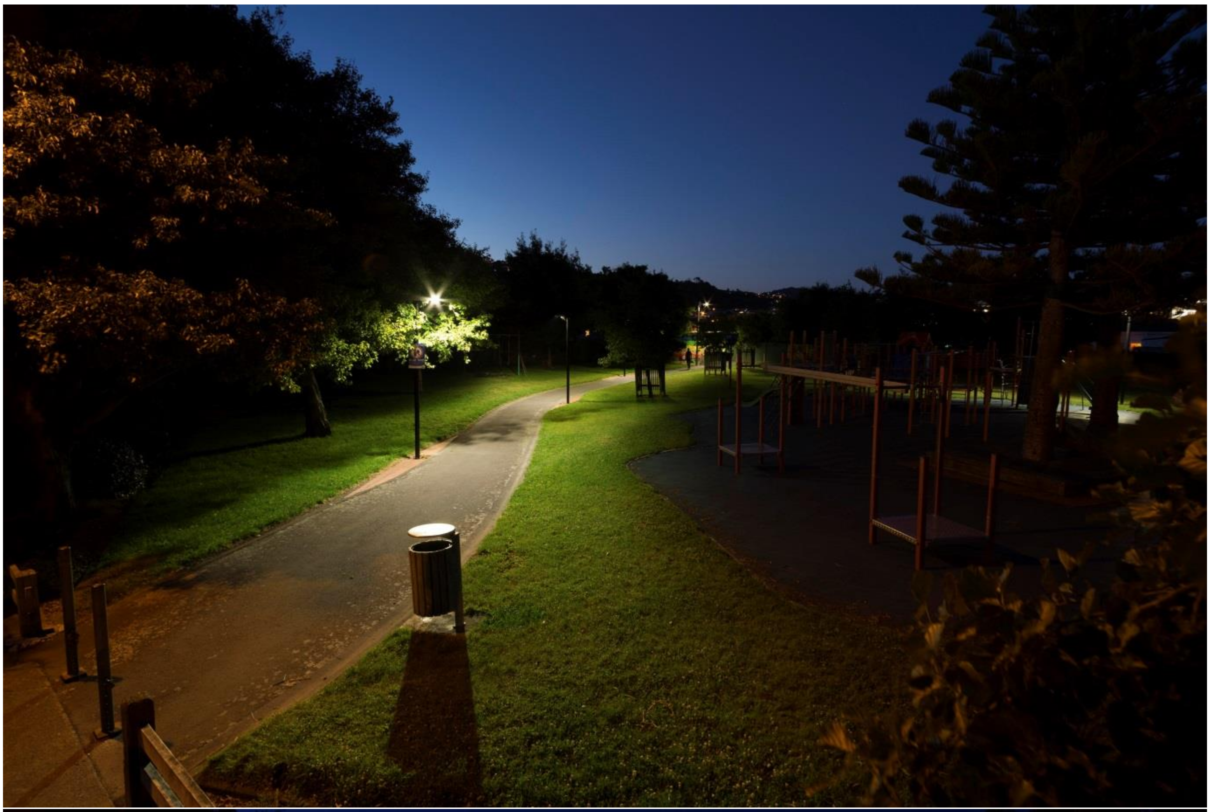
Wellington Installations

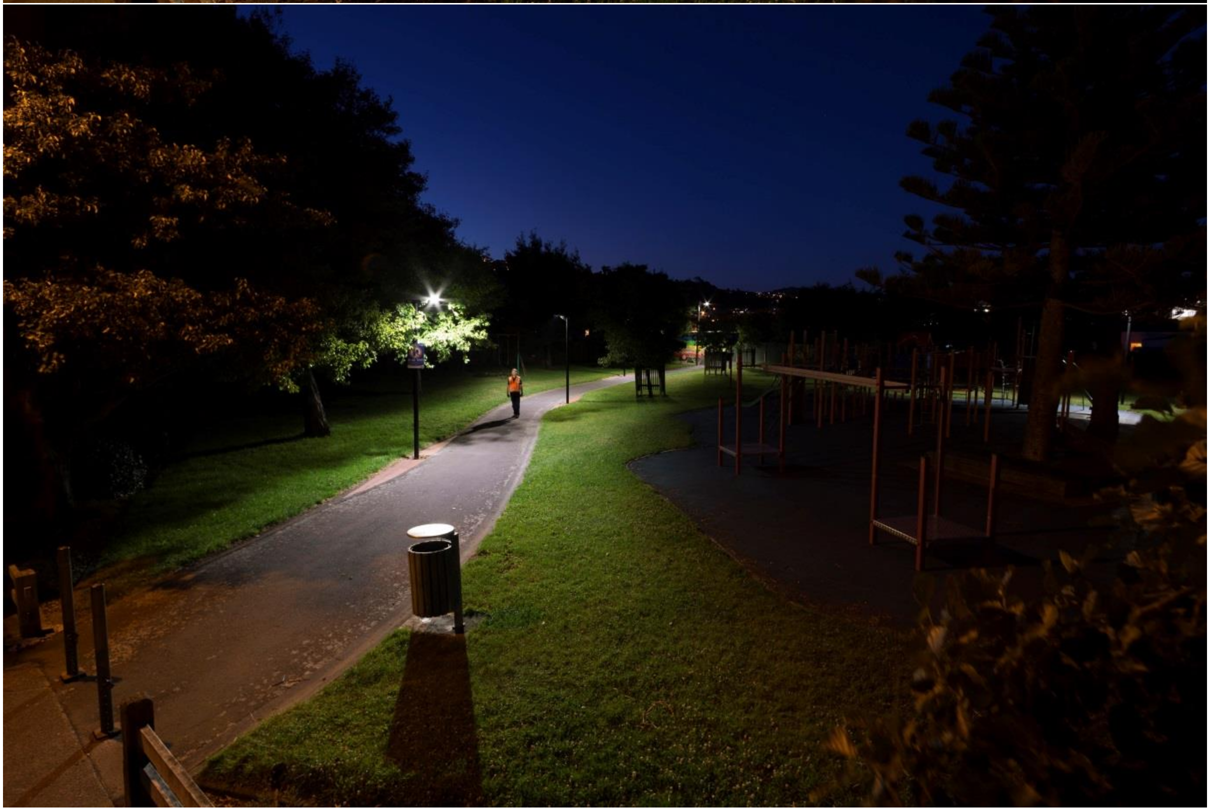
The two photographs above show Findlay Terrace in the Wellington suburb of Tawa before and after a conversion from 70w high pressure sodium lamps to Betacom's 27w GL500 LED luminaire. This luminaire utilises a LED unit retrofitted to a luminaire body common to the New Zealand market and is visually similar to the luminaire it replaced. This achieved a reduction in energy consumption of 61%.

The following four photos show Mariri Road in the Wellington suburb of Kelburn before and after a conversion from 70w high pressure sodium lamps to the award winning[16] NXT-S LED luminaire from Canadian manufacturer LED Roadway Limited. This conversion saw 9 high pressure sodium

luminaires being replaced with (10) 14 watt NXT-S units and a light covering an intersection at 18 watts. This achieves a reduction in power consumption for the street of over 75%.

[16] http://www.ledroadwaylighting.com/press-releases/nxt-s-ngl-award.html





The conversion shown above is to illustrate the colour rendition and cut-off characteristics of the LED luminaire – this conversion is on the access-way running through Carrara Park in Newtown between Regent Street and Daniell Street.

Appendix Five – selected reference materials and sources

Publications

AS/NZ 1158 "Lighting for roads and public spaces"

Boosma, C., and Steg, L., *The effect of information and values on acceptability of reduced street lighting*, Journal of Environmental Psychology, 2013, http://dx.doi.org/10.1016/j.jenvp.2013.11.004

Bridger, G., and King, B., *Strategic Issues for a business case for WCC LED street lighting upgrade*, Strategic Lighting Partners, Hamilton, New Zealand, July 2014 (unpublished)

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www.eco3.org	*Guidelines: Energy efficient street lighting*
www.ledroadway.com	
www.leotek.com	*A municipal guide for converting to LED street lighting*
www.lighting.philips.com	
www.procurement.govt.nz	*Mastering procurement: A structured approach to strategic procurement*
www.silverspringnet.com	
www.telematics.wireless.com	
www.theclimategroup.org	
www.tvilight.com	No need to wait: Accelerating adoption of LED street lighting
	Lighting the clean revolution: The rise of LEDS and what it means for cities
	Global outdoor LED trials: Analysis for lighting managers