# Street Lighting Procurement

## Recommendations

That the Board:

i. Approves stage 1 of an accelerated street lighting renewals of 40,000 70w High Pressure Sodium (HPS) replacing them with Light Emitting Diode luminaires (LED) over a period of 5 years and installation of a Tele-Management System (TMS) at a total additional capital cost of $22m.

ii. Delegates authority to the Chief Executive to approve the Procurement Plan for new street light maintenance and renewals contracts to replace the existing nine legacy contracts. The total estimated contract value over the term (4 years + 1 year + 1 year) excluding the proposed additional capital cost for stage 1 is $82.4m.

iii. Notes that the stage 1 programme will be funded from AT's reduced current capital envelope or from a separate operating offset funding agreement with NZTA.

iv. Notes anticipated net savings in energy and maintenance arising from stage 1 of the LED replacement programme of $36m over 20 years.

v. Notes that the technology for conversion of the remaining 64,000 higher powered luminaires isn't yet sufficiently mature to make accelerated conversion commercially viable, but it is anticipated that it may be in approximately 3 years.

## Executive summary

Auckland Transport (AT) is responsible for approximately 108,000 street lights and amenity lights. Approximately 44,000 are 70w HPS lights on 'P' category roads (pedestrian predominant) with the remaining 64,000 higher wattage HPS lights on 'V' category roads (vehicle predominant).

LED technology for the 70w HPS luminaires is now sufficiently mature that an accelerated renewals programme across the network is commercially viable. This is not yet the case for higher powered luminaires. Over the next 3 years the cost of these higher power luminaires is expected to decrease and the efficiency increased to make it commercially attractive to replace these remaining 64,000 luminaires.

Replacement is therefore proposed in two stages, with 70w HPS luminaires replaced in stage one and the balance assessed for replacement in a subsequent programme (stage two). Stage one additional capital costs are $22m over 5 years (at approximately 20% p.a.); this will supplement the current $14m p.a. street lighting renewals and maintenance budget. This accelerated programme will result in energy and maintenance savings giving an 8 year pay back and total cost of ownership savings exceeding $36m over a 20 year period. The future implementation of stage two is anticipated to produce further savings when the technology is sufficiently mature and costs have decreased.

# Strategic context

Energy Resilience and Low Carbon Action Plan

The proposed replacement of existing HPS street lights with energy efficient LED street lights supports Auckland Council's objective of reducing energy use and carbon emissions by 40% by 2040. The Energy Resilience and Low Carbon Action Plan is structured around five areas of transformation including the way we use and generate energy. The initiatives identified in the section "Managing energy demand" include "Establishing a plan to deploy modern energy efficient technology for street lighting to improve energy efficient outcomes".

Operational Costs

The proposed replacement programme will also contribute to the Board's sustainable funding theme by reducing long term operating costs. The energy and maintenance savings over the 20 year life will be $36m.

Above Ground Assets

With an increasing number of power and telecommunications services being undergrounded, AT is a significant owner of assets that remain above ground in the road corridor. These assets provide a platform for a range of functions including street/pedestrian/feature lighting, banners, CCTV, wireless telecommunications technology, traffic signals, signage, pedestrian signals, etc. Strategically, streetlights are an asset which are likely to have increasing future value to AT and others.

# Background

AT spends $28m p.a. to operate and maintain our 108,000 street lights; this budget is 50% subsidised by NZTA. Energy costs account for approximately $14m p.a. of the total with the balance being maintenance and renewals. The underlying load growth on the street light network is circa 2.5% per annum due mainly to new subdivisions. The resulting increase in electricity and maintenances costs is over $500k p.a.

There are currently nine legacy street light maintenance and renewals contracts across the region. All are past their end dates and must be retendered in some form. It is considered that the existing contracts are expensive due to the increasing cost adjustment index applied to scheduled contract rates. While we expect better rates in the new contracts there have been significant increases in the number of street lights on the network in recent years which will offset some of the savings expected from more competitive rates.

Over recent years LED technology has matured such that it has been trialled and introduced in a number of cities worldwide to provide more energy efficient street and amenity lighting.

LED technology has a number of benefits over the older HPS technology:

- A 50% reduction in energy use and corresponding energy costs.
- Reduced maintenance due to more reliable luminaires and longer lamp life. Note: Current HPS lamps are changed every 7 years whereas the design life of an LED is 20 years with an expected life of up to 25 years.
- The LED's have a white light which is internationally recognised as providing a safer environment for pedestrians and vehicles at lower electricity use.

- Less light spill and road surface glare (see Los Angeles examples at Attachment 5)

Combining the replacement programme with the installation of a TMS on each retrofit luminaire provides further benefits:

- Allows central control of each light on the network; studies estimate that a further energy saving up to 15% can be achieved through better control of light levels on the network through a central management system.
- The system will manage lights on and off, control light levels at times of low traffic and pedestrian use to more appropriate levels.
- The system will also accurately record actual energy use at each light point and report daily for lights that have not switched on or lights that remain on after sunrise (day burners). This allows real time control and monitoring of the network.
- The system negates the need for night patrols of the network and provides an enhanced customer service as lights out, lights on, will be evident immediately. This has potential to reduce the 750 street light related calls per month to AT's call centre.

Attachment 1 provides a graph to illustrate the relative street lighting budget forecast for the existing network (do nothing) and the true cost of LED replacement including a TMS. A graph is also provided to illustrate the forecast whole of life savings over 20 years.

# Issues and options

Economic options analysis

Unlike the replacement of a HPS lamp, conversion to LED lamps requires the replacement of the luminaire. Typically HPS lamps have a life of around 7 years, and a luminaire life of around 20 years. In considering the rate at which to convert it is important to assess and balance the incremental capital cost for any one year, against the resulting whole of life cost savings, payback period, and time to complete.

In order to determine that balance five cases were assessed:

Case 1 – Replacing all 40,000 luminaires in one year
Case 2 – Replacing 50% in one year; and the remaining on attrition
Case 3 – Replacing 33% in one year; and the remaining on attrition
Case 4 – Replacing 10% in one year; and the remaining on attrition
Case 5 – Replacing 20% per year, i.e. a 5 year phase-in

The analysis (summary shown in Attachment 3, and detailed model shown in Attachment 4) concluded that Case 5 required relatively low incremental annual costs without overly compromising savings, payback, or time to complete.

Procurement model and contract form

It is proposed to replace the existing HPS street lights with energy efficient LED street lights and to install a TMS to achieve an estimated 65% reduction in energy use. Evaluation of the potential procurement approaches was undertaken by PwC against a number of objectives / criteria. The evaluation also reviewed overseas experience with alternative and PPP models. The models, described in further detail in Attachment 2, were ranked in the following order of preference against the qualitative evaluation criteria:

| Rank | Model | Assessment |
|---|---|---|
| 1 | Design, Construct, Maintain (DCM) | DCM allows the combination of maintenance and replacement to be optimised by the contractor, with AT retaining the benefits associated with AT owning the asset. The replacement programme is however subject to annual budgeting reviews and which may introduce uncertainty into the investment timeline. |
| 2 | Design then Construct (DC) with separate maintenance contracts (status quo) | As per DCM, but without the potential benefits of optimising the maintenance and replacement programme works. |
| 3 | Public-Private Partnership (PPP) [Design, Build, Finance, Operate] | PPP is ranked low in the analysis largely because the increased level (and related cost) of effort and specification, combined with the higher cost of private finance, often means that PPPs only provide value for money in projects approaching $100m or greater in size. |
| 4 | Privatisation | Privatisation is ranked lowest here as it requires some level of regulation to ensure lighting performance over the long term and to address various other issues related to lack of competition. It also relinquishes control of an asset with potential future importance. |

PwC concluded that DCM is the preferred procurement approach. Key aspects of the proposed contract under this model are:

- Four contract areas are proposed. In addition to recognising some differences in the configuration of the electrical supply either side of the Harbour Bridge / Whau boundary, it also serves to align with the Road Corridor Maintenance boundaries. Evaluation will be configured in such a way as to preserve competition by limiting the number of contract areas that any one supplier can win.
- Contract duration of 4 years (plus a 1+1 year RoR) to align with the conclusion of the 70w replacement programme and the likely maturity of higher wattage LEDs identified for stage two. This will allow AT to tender the larger stage two programme in conjunction with NZTA (see 'Collaboration with other Agencies' below) if it is deemed appropriate at the time.
- AT specifies the LED luminaire to be used during each of the contract years, and negotiates the price for these directly with the supplier. This ensures that bulk pricing discounts are achieved despite the installation contract being split. Annual price negotiation preserves competition while allowing AT to take advantage of further advances in technology and/or price reduction.
- Contracted installation and maintenance costs.

This is a significant contract; it is anticipated the procurement and contract negotiation process will take until April 2015 to conclude. In the interim it is intended to commence the replacement and convert approximately 4,000 luminaires by obtaining competitive quotes from existing maintenance suppliers.

Collaboration with other Agencies

A number of councils are at similar points in their establishment of an LED replacement programme. Most notably New Plymouth District Council has recently approved a programme to replace all 8000 luminaires. A number of councils have expressed interest in collaborating with AT in the annual negotiation of LED luminaires; these agencies already use AT's approved list of luminaires when specifying approved fittings. Subject to timing of approvals AT intends to work closely with these other agencies in order to maximise commercial leverage.

The luminaires on NZTA's state highway network however are generally higher power, like those 64,000 of AT's identified for a stage two programme, i.e. their replacement will likely be more commercially viable in around 3 years' time. We are, however, working with NZTA on our stage one programme.

## Funding

This proposal occurs at a time when we are facing significant reductions in our capital programme. Operating expenditure will also be constrained. Analysis shows that it has a pure financial Benefit Cost Ratio of 2.06 (see Attachment 5). Given this project has a positive future cash flow, and given the small annual investment (less than 1% of AT's annual capital plan) it is recommended that this proposal proceed. We are also speaking to NZTA about the potential that they provide funding and receive repayments from the annual operating subsidy.

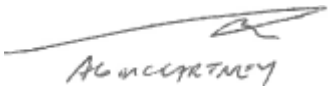
## Next steps

1) Finalise EOI and RFP and issue to market;
2) Obtain NZTA approval for the contracts and accelerated renewal programme.

## Attachments

| Number | Description |
|---|---|
| 1 | Comparison of total cost (energy, maintenance, renewals) for proposed retrofit and status quo |
| 2 | Description of assessed procurement models |
| 3 | Summary of economic options analysis |
| 4 | Detailed economic options analysis for Case 5 |
| 5 | BCR for Case 1 and 5 |
| 6 | Before and after lighting upgrades in Los Angeles |

# Document ownership

| | | |
|---|---|---|
| **Recommended by** | David Dick<br>**Team Leader Street Lights** |  |
| | Chris Morgan<br>**Group Manager Strategic Development** |  |
| | Tony McCartney<br>**Group Manager Road Corridor** |  |
| | Richard Morris<br>**Chief Financial Officer** |  |
| | Greg Edmonds<br>**Chief Operations Officer** |  |
| **Approved for submission** | David Warburton<br>**Chief Executive** |  |

**Attachment 1 – Comparison of total cost (energy, maintenance, renewals) for proposed retrofit and status quo**

## Attachment 2 – Description of assessed procurement models

1. **Design, Construct, Maintain (DCM)** – Under this model AT develops and controls the specification, manages any environmental approvals and land issues, but subcontracts the design, installation, and integration with any civil works. AT retains responsibility for collection of any development contributions and any revenue from non-lighting use (e.g. cell towers, advertising banners, etc.). The contractor is responsible for operation, maintenance, and renewal during the contract period but ultimately hands this back to AT when the contract concludes.

2. **Design then Construct (DC) with separate maintenance contracts** (status quo) - Under this model AT develops and controls the specification, manages any environmental approvals and land issues, subcontracts the installation and integration with any civil works. AT takes the risk of the subcontractor not being able to 'construct' (install) to design or the design not meeting the performance requirements. As with the DCM model AT retains responsibility for collection of any development contributions and any revenue from non-lighting use (e.g. cell towers, advertising banners, etc.). A separate contractor is responsible for the on-going operation, maintenance and renewal during the contract period and ultimately hands this back to AT when the contract concludes.

3. **PPP (Design, Build, Finance, Operate)** – unlike traditional models the PPP model is a long term, whole of life approach to infrastructure development. Risk allocation is determined up front including maintaining the infrastructure and providing the services to a pre agreed condition for the duration of the concession. The level of detail and specification required is substantial, and specifications are expressed in output terms. Under this model AT develops and controls the specification, manages any environmental approvals and land issues. The PPP is responsible for design, installation, integration with any civil works, operation, maintenance, asset renewal, and ultimately handing back the asset in pre-agreed condition.

4. **Privatisation** – Under this model AT would still maintain the responsibility for specifying the outputs that it was willing to pay for, and would likely retain the risk of land issues. A mechanism would need to be developed to deal with development contributions and any revenue flows for non-lighting use.

## Attachment 3 – Summary of economic options analysis

The following analysis is taken from a report commissioned by AT and prepared by Opus. When considering options to implement street light energy and maintenance savings the report recommended that AT adopt a LED 5 year phase-in option – Case 5 in the table below.

Opus noted that *progressive implementation allows the adoption of new iterations of the white light technology as these are developed and released across the phase in period, …together with a reduced initial capital investment*. In addition it noted, *phased acquisition would enable Auckland Transport to take advantage of likely reductions in acquisition cost as the technology matures still further and manufacturers production runs increase. Progressive implementation also recognises that available installation resources dictate timeframes*.

| LED Implementation | | | | | |
|---|---|---|---|---|---|
| | **Year One replacement** | **Year One Capital Cost ($M)** | **Whole of Life Savings ($M)** | **Payback Period** | **Time to Complete** |
| **Case 1** | 100% | 21.7 | 39.6 | 7 years | 1 year |
| **Case 2** | 50%, followed by replacement of remaining on expiry | 10.9 | 31.2 | 9 years | 11 years |
| **Case 3** | 33%, and as above | 7.2 | 28.7 | 7 years | 14 years |
| **Case 4** | 10%, and as above | 2.2 | 23 | 4 years | 19 years |
| **Case 5** | 5yr phase-in (20% p.a.) | 4.4 | 36.4 | 8 years | 5 years |

Source: *Auckland Transport – Street Light Energy Strategy – Detailed Report 1-42570.00 17022012*

The model has been peer reviewed by Cranleigh Merchant Bankers who concluded that *the construction and financial integrity of the financial model is sound and the approach taken in modelling the impact of replacing 40,000 HPS lights with lower energy usage LED lights and introducing a CMS is appropriate.*

## Attachment 4 – Detailed economic options analysis for Case 5

The following spread sheet shows the detailed economic model for Case 5 ("Scenario 9" – a 5 year replacement programme at 20% p.a.) compared with Case 1 ("Scenario 1" – 100% replacement in Year 1).

**AUCKLAND TRANSPORT LED RETROFIT SPREADSHEET**
Whole of Life Savings & NPV Evaluation of Existing 70W HPS Instalation vs. Proposed LED 5-Year Replacement Programme with Tele Management System

| | |
|---|---|
| Author: | Molly Dogra |
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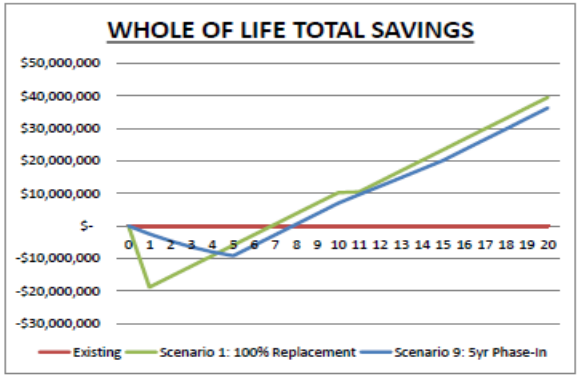
| Client: | Auckland Transport |
| Contact: | David Dick |
| Version: | 5.1 |
| Sheet: | 1 of 1 |
| Released: | 3/09/2014 |

NOTES:
1. Refer to Opus report for Auckland Transport for derivation of assumptions and initial values:
   - "*Street Lighting Energy Strategy - Detailed Report*", March 2012
2. Refer to Opus reports for Auckland Transport for methodology:
   - "*Street Lighting Energy Strategy - High Level Discussion Paper*", Feb 2012
   - "*Street Lighting Energy Strategy - Detailed Report*", March 2012
3. Refer all questions regarding this spreadsheet to Molly Dogra, Electrical Engineer, Opus Auckland

**Assumptions**

| | | |
|---|---|---|
| Number of luminaires for replacement for purposes of this study | | 40,000 |
| Cost of 70W HPS luminaire c/w photocell (like for like in small BAU quatities)[1] | $ | 535 |
| Cost of new LED c/w with Nema socket (in bulk quantities)[2] | $ | 417 |
| Cost of installation of luminaire (HPS/ LED)[3] | $ | 75 |
| Cost of 70W HPS luminaire replacement (like for like in small BAU quantities)[4] | $ | 610 |
| Cost of 70W HPS luminaire replacement with new LED (in bulk quantities)[5] | $ | 492 |
| Annual cost of night patrols across all regions | $ | 99,012 |
| Cost to visit & relamp HPS luminaire + clean (like for like in small BAU quantities) | $ | 150 |
| Cost to visit & clean LED luminaire (in bulk quantities) | $ | 75 |
| Power per 70W HPS luminaire (W) | | 78 |
| Power per LED luminaire (Ruud LEDway Type2M 525mA 4300k 20count) (W) | | 37 |
| Hours burnt/year | | 4,000 |
| Number of 70W HPS lamps replaced/year | | 5,000 |
| Lifetime of 70W HPS lamp (hrs) | | 32,000 |
| Percentage of 70W luminaires on P3 roads (not P4) | | 50% |
| LED Dimming Savings | | 17.5% |
| Total cost of TMS | $ | 2,000,000 |
| Cost of running TMS/annum | $ | 100,000 |
| Discount rate | | 6% |
| Teminal value | $ | - |
| Cost of power to Auckland Transport ($/kWhr) | | 0.17 |
| Existing # 70W HPS luminaires replaced/year | | 2,100 |
| Percentage of HID maintenance required while retrofit occurs | | 20% |




**Whole of Life Total Savings**

| Year | Existing | Scenario 1: 100% Replacement | Scenario 9: 5yr Phase-In |
|---|---|---|---|
| 0 | $ - | 0 | $0 |
| 1 | $ - | -18,872,730 | -$2,491,338 |
| 2 | $ - | -15,639,458 | -$4,656,824 |
| 3 | $ - | -12,406,186 | -$6,496,458 |
| 4 | $ - | -9,172,914 | -$8,010,239 |
| 5 | $ - | -5,939,642 | -$9,198,167 |
| 6 | $ - | -2,706,370 | -$5,964,895 |
| 7 | $ - | 526,902 | -$2,731,623 |
| 8 | $ - | 3,760,174 | $501,649 |
| 9 | $ - | 6,993,446 | $3,734,921 |
| 10 | $ - | 10,226,718 | $6,968,193 |
| 11 | $ - | 10,459,990 | $9,601,465 |
| 12 | $ - | 13,693,262 | $12,234,737 |
| 13 | $ - | 16,926,534 | $14,868,009 |
| 14 | $ - | 20,159,806 | $17,501,281 |
| 15 | $ - | 23,393,078 | $20,134,553 |
| 16 | $ - | 26,626,350 | $23,367,825 |
| 17 | $ - | 29,859,622 | $26,601,097 |
| 18 | $ - | 33,092,894 | $29,834,369 |
| 19 | $ - | 36,326,166 | $33,067,641 |
| 20 | $ - | 39,559,438 | $36,300,913 |

| | PV | NPV |
|---|---|---|
| Existing = | $48,765,655 | |
| Scenario 1 = | $34,115,361 | $14,650,293 |
| Scenario 9 = | $34,620,226 | $14,145,429 |

| | |
|---|---|
| TMS on (Y/N)? | y |

**Capital Costs for LED**

| | |
|---|---|
| Scenario 9 = | $21,680,000 |

**Average Energy Savings per year over 20 Years period**

| | |
|---|---|
| Scenario 9 = | $1,082,934 |

**Average Maintenance Savings per year over 20 Years period ***

| | |
|---|---|
| Scenario 9 = | $1,881,000 |

**Luminaire & lamp replacement and luminaire glass cleaning visits*

[4] *Cost provided by Betacom for Ambar2 CG luminaire, 70W HPS lamp & Photocell .*
[2] *Luminaire Cost provided by ADLT for CREE LEDway 20LED ($377) for 5000 units or more. Assumed $40 for NEMA socket installation based on estimates received from Techlight.*
[3] *Contractor's installation cost from Transfield.*
[4] *Total Costs of HPS luminaire and installation (1+3)*
[5] *Total Costs of LED luminaire and installation (2+3)*

OPUS

**Attachment 5 – BCR for Case 1 and 5**

# AT LED Retrofit Spreadsheet Summary

## Background:

Opus Consulting carried out the original financial analysis and using their spreadsheets an analysis has been carried out to determine the BCRs of proposed solutions.

This was a high level desk-top analysis, and it is assumed readers already have some knowledge of the project.

## Introduction:

Currently AT lamp posts are fitted with HPS (high pressure sodium bulbs). These cost around $4.25m a year to maintain.

There are 2 proposed solutions to reduce this cost, both involve replacing the HPS bulbs with LED (light emitting diode) bulbs, in both a phased approach over 5 years, and a 100% replacement approach. Both strategies result in a significantly reduced cost of running AT's streetlights.

## Comparison of Options:

Over the 20 year time period the analysis is carried out over:

| | Existing | 5 Year Phasing | 100% Replacement |
|---|---|---|---|
| **Capital for LED's** | - | $21.7m spread over 5 years | $21.7m in year 0 |
| **Annual Energy Costs** | $2.12m | $0.92m | $0.92m |
| **Annual Luminaire Replacing** | $1.28m | - | - |
| **Lamp Replacement / Glass Cleaning** | $0.75m per year | $3.00m in year 11, spread over 5 years | $3.00m in year 11 |
| **Annual Licensing fees** | $0.1m | $0.1m | $0.1m |
| **Maintenance while retrofit occurs** | - | $1.28m spread over 5 years | $0.43m |

Both the 5 Year Phasing and 100% Replacement options have incremental opex savings of $3.04m per year (post capex spend).

| | | | |
|---|---|---|---|
| **Average annual opex** | $4.25m | $1.21m | $1.21m |

## Analysis Approach:

This analysis looks at options to reduce costs that AT is already committed to. AT has an obligation to run and maintain streetlights around Auckland. Changing to LED bulbs via 2 different scenarios represents an opportunity to significantly reduce these costs.

As a result the 20 year cash flows of each scenario are still "costs" in themselves, but to see the benefit of each scenario over the existing situation, these cash flows can be compared to the cash flows of the existing situation.

To calculate the BCR, where a scenario results in increased expenditure over the existing scenario, this is recorded as a cost. Where the scenario results in decreased expenditure compared to the existing scenario, this is recorded as a benefit.

In this analysis, the BCR for each scenario is measuring the **financial benefits only, as no non-financial benefits have been measured**. This analysis deals purely with proposed scenarios to reduce a cost AT is already committed to: welfare benefits are not applicable.

As a result the BCR's for these scenarios will not be directly comparable to the BCR's of existing projects in the LTP, which include both financial cash flows and non-financial monetized benefits (e.g. time savings)

## Summary:

**100% Replacement option:**

| **100% Replacement vs Do Nothing (Existing)** | | | |
|---|---|---|---|
| NPV additional Costs | NPV additional Benefits | Net additional NPV | BCR |
| -$20,452,830 | $33,116,154 | $12,663,324 | 1.62 |

Compared to the existing situation, the 100% Replacement option has:

- Significant upfront capital costs of $21.6m (NPV $20.45m) in year 0.
- Benefits of NPV $33.1m are realized from year 1 onwards.
- Net NPV of $12.66m

**5 Year Phasing option:**

| **5 Year Phasing vs Do Nothing (Existing)** | | | |
|---|---|---|---|
| NPV additional Costs | NPV additional Benefits | Net additional NPV | BCR |
| -$10,714,379 | $22,074,182 | $11,359,803 | 2.06 |

Compared to the existing situation, the 5 Year phasing option has:

- Increased capital costs of 21.6m spread over 5 years. These are offset by cost savings during this time starting at year 1, bringing the NPV of incremental costs to $10.71m.
- Benefits of NPV $22.07m are realized from year 5 onwards.
- Net NPV of $11.36m

- The BCR of 2.06 is better than the 100% Replacement option, largely because the phased in capital costs are discounted back to present value.

## Recommendation.

Assuming the assumptions in the analysis carried out by OPUS hold true, then the **5 Year Phasing** option is recommended.

This option requires half the additional upfront cost of the 100% Replacement option, and returns a NPV of $11.36m in cost savings over the 20 year period of analysis.

This represents an opportunity to significantly reduce a cost that AT is already committed to, freeing up financial resources for other projects.

**Additional Factors:**

Outside of the scope of this analysis, there is likely a strong case to be made to secure funding from NZTA to assist with the upfront capital costs of the preferred option.

There may also be an opportunity to generate carbon credits with the environmental benefits that LED lights have over HPS lights.

Both of these potential benefits can be investigated at a later date.

**LTP Prioritisation**

Projects in the LTP have been prioritised against 3 criteria: Strategic fit, Effectiveness and Efficiency (BCR). We understand that in the LTP prioritisation this project did not receive a rating score for the first two criteria. It was decided that applying the criteria to a non-transport project was too difficult.

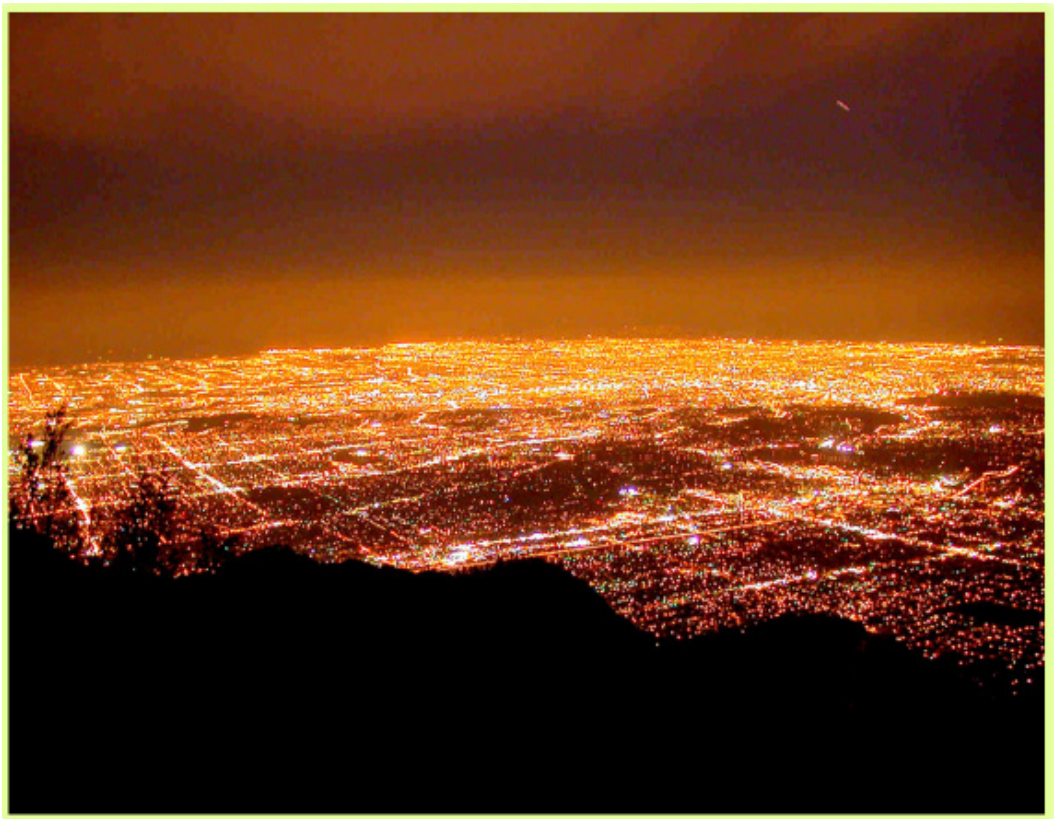
Prioritisation of projects that are weighted heavily toward financial cash flows vs more traditional financial + economic cash flow orientated projects is something that needs to be further investigated.

## Attachment 6 – Before and after lighting upgrades in Los Angeles

Sepulveda Tunnel under LAX – 400W HPS Light Pipe, before LED retrofit

Sepulveda Tunnel under LAX – 572 LED Fixtures; 64% energy saving; 300cd/m2, after LED retrofit

Los Angeles Basin – View from Mount Wilson, before LED retrofit project 2008



Los Angeles Basin – View from Mount Wilson, after LED retrofit project 2012