Strategic Road Lighting Opportunities for New Zealand

A report written for the New Zealand Transport Agency
Road Maintenance Task Force

By

Godfrey Bridger
Bridger Beavis & Associates Ltd

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1 Table of Contents

1 TABLE OF CONTENTS 2

2 EXECUTIVE SUMMARY 6

3 INTRODUCTION 10

4 SAFETY 13

4.1 INTRODUCTION - SAFER JOURNEYS 2010-2020 13
4.2 RELATIONSHIP BETWEEN STREET LIGHTING AND ACCIDENTS 13
4.3 THE NEED FOR A STREET LIGHTING STRATEGY 14
4.4 NZ ILLUMINATION LEVELS 15
4.5 LIGHT 15
4.6 HUMAN PERFORMANCE - DETECTION AND RESPONSE 19
4.7 HUMAN PREFERENCE & SECURITY 22
4.8 COLOUR CONCLUSIONS 23
4.9 REPORTED INJURIES OCCURRING DURING DARKNESS 24
4.10 THE IMPACT OF ROAD SURFACE REFLECTANCE ON LIGHTING 27
4.11 RECOMMENDATIONS 27

5 INCREASING VALUE FOR MONEY – NEW GENERATION TECHNOLOGIES 29

5.1 INTRODUCTION 29
5.2 NEW GENERATION TECHNOLOGY 31
5.3 LED ROAD LIGHTING IN NEW ZEALAND 45
5.4 LEADERSHIP OPPORTUNITY FOR NZTA 49
5.5 A STRATEGIC OPPORTUNITY 50
5.6 RECOMMENDATIONS 53

6 INCREASING VALUE FOR MONEY - PUBLIC PRIVATE PARTNERSHIPS (PPPS) 54

6.1 PUBLIC PRIVATE PARTNERSHIPS IN NZ 54
6.2 A PROCUREMENT MECHANISM NOT A FINANCING ONE 55
6.3 PPPS FOR ROAD LIGHTING 57
6.4 A HYPOTHETICAL FINANCIAL MODEL FOR HAMILTON CITY EXTRAPOLATED TO NZ 60
6.5 RECOMMENDATION 62

7 ECONOMIC DEVELOPMENT 63

7.1 INTRODUCTION 63
7.2 PARADIGM SHIFT IN ROAD LIGHTING 64
7.3 OPPORTUNITIES FOR INNOVATION AND ECONOMIC DEVELOPMENT 68
7.4 RECOMMENDATIONS 74

8 CHALLENGES AND OPPORTUNITIES FOR CHANGE 75

8.1 CENTRALISED PROCUREMENT AND ASSET MANAGEMENT 75
8.2 NZTA LEADERSHIP 75
8.3 FINANCIAL 76
8.4 NZ STANDARDS 76
8.5 DIGITAL LIGHTING SKILLS & TRAINING 77
8.6 ELECTRICITY SUPPLY 81
8.7 ROAD CONTROLLING AUTHORITIES (RCAS) 83
8.8 CONSULTANT ENGINEERING CONCERNS 83
8.9 RECOMMENDATIONS 85

9 CONCLUSIONS AND RECOMMENDATIONS 86

9.1 VALIDATE THE FIGURES AND CLAIMS MADE IN THIS REPORT 86
9.2 SUPPORT THE DRAFTING OF A ROAD LIGHTING STRATEGY WITH THE FOLLOWING GOALS (SECTION 4.11): 86

9.3 SUPPORT THE INTRODUCTION OF NEW GENERATION ROAD LIGHTING TECHNOLOGIES (SECTION 5.6): 87
9.4 SUPPORT THE USE OF PRIVATE CAPITAL TO UPGRADE ROAD LIGHTING (SECTION 6.5): 87
9.5 DRAFT AND IMPLEMENT AN INNOVATION STRATEGY (SECTION 7.4): 88
9.6 CHALLENGES TO OVERCOME (SECTION 8.9): 88
9.7 FURTHER RECOMMENDATIONS 89

10 BIBLIOGRAPHY 91

APPENDIX 1. NZTA ROAD MAINTENANCE TASK FORCE ANNOUNCEMENT 95

APPENDIX 2. ROAD MAINTENANCE TASK FORCE TERMS OF REFERENCE 96

APPENDIX 3. STRUCTURE OF GOVERNMENT TRANSPORT SECTOR 99

APPENDIX 4. LIST OF INFORMATION SOURCES 100

APPENDIX 5. AUTHOR CREDENTIALS 106

APPENDIX 6. TYPE OF ROAD USERS INJURED DURING DAYLIGHT AND DARKNESS (SOURCE: MINISTRY OF TRANSPORT) 108

APPENDIX 7. ACKNOWLEDGEMENTS TO PEOPLE CONSULTED FOR THIS REPORT 109

APPENDIX 8. LIGHTING TECHNOLOGIES (SOURCE: CLINTON FOUND'N. & US DOE) 111

APPENDIX 9. LOS ANGELES CASE STUDY (SOURCE: CLINTON FOUNDATION) 115

APPENDIX 10. ERNST & YOUNG PAPER ON NZ ROAD LIGHTING PPP 128

APPENDIX 11. NZTA AND LOCAL BODY COSTS FOR STREET LIGHTING AS AT 2007 130

APPENDIX 12. AA COMMENTS: STRATEGIC ROAD LIGHTING OPPORTUNITIES FOR NEW ZEALAND 131

APPENDIX 13. SUBMISSIONS TO COMMERCE COMMISSION ON EDB INFORMATION DISCLOSURE 133
10.1 NZTA E-MAIL 133
10.2 BRIDGER BEAVIS & ASSOCIATES SUBMISSION 134

APPENDIX 14. NZ LED TRIALS 141

APPENDIX 15. US DEPARTMENT OF ENERGY SOLID STATE LIGHTING R&D 142

APPENDIX 16. UK, SURREY STREET LIGHTING PFI CASE STUDY 143

APPENDIX 17. FURTHER PPP DISCUSSION...148

APPENDIX 18. 2012 LUMEN MAINTENANCE FACTORS FOR CREE LEDS 149

APPENDIX 19. LED PENETRATION IN NZ FOR ADVANCED LIGHTING TECHNOLOGIES NZ (CREE/BETALED) AND MODUS LIGHTING (PHILIPS) 150

Figure 1 The different response of the eye at different lighting levels. White line is daylight, black line night conditions (Source: website)...16

Figure 2 High Pressure Sodium (HPS) Lamps (Source: Philips) 17

Figure 3 Scotopic/Photopic Ratios for various light sources (Source: Lawrence Berkley National Laboratory) 18

Figure 4 S/P ratio comparison between typical HPS and LED lights (Source: MeXSI Inc[27]).......19

Figure 5 Correction factors to apply for different S/P ratios and background illumination levels (Source: Puolakka et al)...19

Figure 6 Driver Reaction Times to different colours and angles from central axis (Source: Rensselear Polytechnic Institute[32]) 20

Figure 7 Reaction Time measured against logarithmic value of Luminance (Source: Arizona Department of Transportation)....21
Figure 8 Reaction time for Orange HPS lights 9% longer than for while Metal Halide lights (Source: Rensselear Polytechnic[33]) 22
Figure 9 An explanation of British Standard BS5489-1:2003 relating to the colour of street lighting 23
Figure 10 Reported Injury Crashes During Darkness 2006–10 (Source: NZTA[47])....25
Figure 11 Hamilton City Council mapping of night time accidents and street lighting illumination levels (Source: Hamilton City Council[51]) 26
Figure 12 Diagram & photo of Light Emitting Diode (LED) (Source: CREE, DOE)....30
Figure 13 GE Road Tunnel LED installation Case Study with 4 year payback 32
Figure 14 GE LED Case study with less than a 4 year payback....33
Figure 15 Lumen Maintenance for most recent HPS lamp competing with Philips Cosmopolis (Source: GE 2012) 34
Figure 16 Lumen Depreciation and Operating life is significantly affected by ambient night time temperatures (Source: RUUD 2010) 35
Figure 17 Comparison between photometrics of HPS and LED lamps (Source: CREE 2010 Brochure)....36
Figure 18 Illustration of wide range of optic distribution patterns available for LED luminaires (Source: CREE 2010 Brochure) 37
Figure 19 Philips Starsense Central Management System brochure claims to save nearly 40% energy per year (Source: Modus Lighting) 39
Figure 20 Another excerpt of the same brochure showing other savings (Source: Modus Lighting)....40
Figure 21 New Philips City Touch Lighting Asset Management System (Source: Modus Lighting)....40
Figure 22 Philips CityTouch system integrates with third party products (Source: Modus Lighting)....41
Figure 23 Screenshot from CityTouch (Source: Modus Lighting)....41
Figure 24 Colour Temperature measured in degrees Kelvin 42
Figure 25 Circuit diagram for an HPS Luminaire showing Power Factor Compensating Capacitor (Source: GE)....44
Figure 26 Lumen Affordability since 2005 (Source: CREE, 2012)....47
Figure 27 Wellington City Council Street Lighting (Source: WCC[46])....48
Figure 28 A CMS diagram with Power Line controls signalling (Source: Echelon Inc)....51
Figure 29 Market Share and Performance of Street Lighting Technologies (Source: Clinton Foundation 2010) 52
Figure 30 LED lighting market rapid growth forecasted (Source: McKinsey & Company 2011)....52
Figure 31 Payment profile for traditional procurement (Source: Morrison & Co – modified from Deloitte Research 2006) 56

Figure 32 Payment profile for PPP procurement (Source: Morrison & Co -modified from Deloitte Research 2006) 56
Figure 33 Public Sector advantages of PPPs (Source: Morrison & Co) 57
Figure 34 Comparative experience in UK (Source: Morrison & Co, citing National Audit Office (UK) Report: "Performance of PFI Construction" October 2009) 58
Figure 35 PPP Road Lighting Experience in Europe (Source: HRL Morrison & Company) 60
Figure 36 British Road Lighting Private Financing Inititiatives (Source: PUK) 60
Figure 37 Comparison of Business as Usual, PPP and Internally Funded LED lighting replacement programme for Hamilton City (Source: Bridger Beavis & Associates Ltd) 61
Figure 38 The technical evidence of impending LED lighting revolution (Source: US DOE[116]) ..66
Figure 39 US Expenditure in Solid State Lighting R&D (Source: US DOE[116]) 67
Figure 40 Odyssey Energy Lux mapping (Source: Website) 68
Figure 41 Rei-Lux Non-destructive lighting pole testing (Source: Website) 69
Figure 42 Car Parking Technologies (Source: Website) 69
Figure 43 LATA Lighting Control Module (Source: Website) 70
Figure 44 11Ants Analytics (Source: Website) 71
Figure 45 Other potential uses of road lighting 72
Figure 46 "Intelli-street" Intelligent Lamp Poles 73
Figure 47 Example of photometrics for a LED Lamp (Source: GE) 78
Figure 48 Example of wide range of factors involved in LED luminaire selection (Source: GE) 79
Figure 49 Sample of Road Controlling Authorities showing widely varying Fixed and Variable Energy costs (Source: NZTA[45]) 82
Figure 50 US Lighting Consumption by Sector & Lamp Type (NB HID = HPS, LPS, MV & MH - see explanations below) 111
Figure 51 Comparison between yellow HPS Lighting and White LED Lighting 127
Figure 52 Fixed versus variable energy costs for road lighting in a sample of 20 NZ Councils in 2007 138
Figure 53 Widely varying maintenance and energy costs of road lighting across a sample of 20 Councils in 2007 138
Figure 54 Widely varying proportions of maintenance and energy costs for a sample of 20 Councils in 2007 139
Figure 55 Solar PV module prices 140
Figure 56 LED Package Pricing trends (Source: US DOE[84]) 142
Figure 57 Projections of White Light LED Efficacy (Source: US DOE[84]) 142

2 Executive Summary

1. This report was commissioned to identify opportunities for efficiencies in delivery of road lighting, "including innovative services, products and methods of procurement, and to encourage their consistent uptake through the country" as required by the Road Maintenance Task Force.
2. The report's conclusion is that New Zealand should upgrade its road lighting in order to:
   a) save lives and reduce the annual $1.2 billion cost of dark-time accidents through increased use of modern white street lighting;
   b) halve the annual $55 million operating and capital costs of lighting NZ roads;
   c) use private capital to fund the upgrade;
   d) provide these benefits as soon as possible to Canterbury where infrastructure requires re-building after the earthquakes, and
   e) provide significant economic growth opportunities in a global market where a LED lighting revolution is just starting and where commercial openings will exist for NZ to lead in niche high value services and manufacturing.
3. The report is organised around the three Government Transport priorities: safety, value for money and economic development.
4. ***Safety***
   From a safety perspective this report has uncovered a blindspot over the potential for improving NZ road lighting to reduce road accidents in the hours of darkness by between 30% and 65% - as both NZ and international research suggests is possible.
5. Of the 14,388 road accidents (including deaths) that cost an estimated $3.8 billion in 2010, 31.3% of them occurred in relative darkness which suggests a cost of about $1.2 billion per year. This alone justifies a separate road lighting strategy to reduce these numbers.
6. On an equivalent lighting power basis (measured in lumens) white light provides more illumination than does yellow light due to the eye's lower sensitivity to yellow light in night time conditions. This advantage can be magnified by the significantly reduced electrical energy input (Wattage) required by highly efficient white Light Emitting Diodes (LEDs).
7. It is estimated that 76% of New Zealand's road lighting is yellow – a characteristic of NZ's widespread adoption of High Pressure Sodium (HPS) lighting technology originally developed by General Electric (now called GE) in 1964.
8. As well as providing greater illumination per lumen, white light allows easier recognition of coloured objects (measured by Colour Rendering Indexes, CRI) than does yellow light. The higher the CRI, the greater the ability to detect colours. Yellow HPS lights typically have a CRI of 20 and white LEDs typically have a CRI of greater than 70.
9. The amenity values of a high CRI include:
   a) an enhanced sense of security (not only are coloured objects, including faces, easier to recognise, but also studies show that better street lighting reduces crime and the fear of crime),
   b) an enhanced sense of attractiveness of the lit area (which is important for tourism), and
   c) a likely improvement in traffic safety due to improved reaction times and peripheral vision (next paragraph).
10. Research has shown that white light sources improve driver peripheral vision and reduce driver brake reaction time by at least 9% at night. It is therefore likely, but not confirmed by this study, that replacing yellow lighting with white lighting could lead to reduced accident rates during twilight and darkness. This is an important question to research and it is recommended that the relevant Ministries facilitate such research, especially as LED lighting provides so many other benefits.

11. ***Technology revolution***
The new LEDs represent what international consultancy McKinsey & Company calls a revolution in lighting technology. This is because LEDs:
   a) can last more than three times longer than HPS lighting;
   b) use about 50% less energy;
   c) allow IT systems to control them to achieve additional energy savings of 20-40% by adapting lighting levels to usage;
   d) turn on instantly; and
   e) are not susceptible to vibration from wind or heavy traffic.

12. At a December 2011 UN Climate conference Philips, probably the largest lighting manufacturer in the world staked its reputation on an announcement that LED technology is mature enough for it to be used in <u>all</u> applications.

13. Many trials have been conducted both in New Zealand as well as internationally, but cities overseas have been converting to LEDs in earnest. In 2009 Los Angeles embarked on a replacement programme of 140,000 HPS lamps (equal to about 42% of NZ's total street lighting) and by July 2011 had replaced 54,000 HPS lamps with LEDs. Los Angeles reported exceeding most of their targets for savings and public acceptance (including 59% energy saving). Other cities doing the same include Boston in USA and Birmingham in UK.

14. No LED installations of equivalent scale exist in NZ, although installations of between 100 and 250 lamps exist, including the very impressive state-of-the-art Eden Park. Yet the payback time for replacing the entire New Zealand road lighting system with LEDs is no more than 9 years – and probably a lot less - under a simple, publicly-funded scenario when only energy and maintenance savings are considered. If all current road lighting luminaires were replaced at a speculatively estimated $231 million investment, a 50% saving on the estimated $55 million annual total road lighting costs (electricity, maintenance and replacement) would translate into an annual saving of $27 million. However, if new centralised control systems were also applied, the savings would be even greater. Note that the above economic savings do not include any benefits from decreased injuries or improved amenity values arising from significantly improved road lighting.

15. ***Innovative Procurement – Public Private Partnerships***
If Public Private Partnerships were utilised these savings would be shared, but without the need for the public sector to fund the capital expense. PPPs for road lighting have been established overseas, most commonly in the UK, where the private sector has moved quickly to take advantage of the certainty and reliability of the revenue stream for road lighting. In the UK there are 19 street lighting PPPs ranging in size from only £8.5 to £225 million.

16. The revolutionary performance advantages of LEDs, together with the revenue certainty of road lighting, make road lighting PPPs far more attractive than PPPs for roads, schools, bridges and other infrastructure where the business margins available are much smaller.

17. On the basis of modelling undertaken on the Hamilton City Council road lighting system, this study hypothesises that the profits available to a road-lighting PPP are more than enough to offset the transaction costs of setting up the PPP. This is in contrast to a position taken by the National Infrastructure Unit of Treasury that does not support PPPs for road lighting due to the perceived high transaction costs and small size of the potential projects.

18. The model used in this study used publicly available information from Hamilton City Council based on a 10,000 luminaire replacement programme. Incorporating a large number of conservative assumptions the payback using a PPP occurred in 13 years on electricity and maintenance savings <u>alone</u>.

19. On an even more speculative basis this was extrapolated to New Zealand-wide model of 330,000 luminaires. The 15 year accumulated savings using a PPP to take virtually all the risk was $345 million. The advantage of this model for NZ road lighting operations is that PPPs would pay for the $231 million capex required to upgrade new generation lighting

systems and the PPP operator would also be contractually bound to deliver lighting performance to pre-agreed levels. If the PPP operator failed to meet these performance standards, it would not get paid and further indemnities could be invoked.

20. Road lighting PPP advisers in NZ who have gained their experience in the mature UK PPP market include Ernst & Young, HRL Morrison & Co, and Kensington Swann. An initial overall view expressed by them is that infrastructure investment funds are available for road lighting PPPs.

21. McKinsey and Company predict that global LED lighting sales growth will be 35% *per year* compounding until 2016 when LED lighting will have reached a market share of 43% from the 7% it was in 2010. LED lighting is at the start of a major uptrend and it represents an opportunity for New Zealand to upgrade its fragmented road lighting infrastructure. Earthquake-damaged Christchurch is another opportunity to invest in the new technology at an early stage and leverage Christchurch's upgrade for NZ's overall benefit.

22. NZTA funds about 45-50% of all road lighting costs in New Zealand with 76 "Road Controlling Authorities" (City, District and Regional Councils) paying for the balance. These councils also operate the lighting and make most of the Capex and Opex decisions.

23. Recent decisions by NZTA to use HPS lighting for large projects are puzzling in the face of overseas experience and studies. For NZTA it appears that the high 8% discount factor used for investment decisions is a disincentive for long-term savings. This view is confirmed by an NZIER study commissioned by the Road Maintenance Task Force suggesting that such a rate is inappropriate. Further investigation is required since there are other factors at play.

24. As for Councils, their lack of any commitment to LED lighting is based on several factors including the unfounded belief that the technology has yet to be proven, lack of financial incentives (including inelastic electricity charges), inadequate road lighting standards, lack of capital, lack of leadership by NZTA, lack of understanding of the choice and comparative values of different LED technologies, and the expectation that prices for LED luminaires will drop rapidly leading to a misguided belief that it would pay to delay the introduction of LED road lighting.

25. With regards this last issue, the internationally-renowned Clinton Foundation has concluded that prices of LED road lighting would need to drop by at least 15% per year to make it economic to delay a changeover to LED. Even in the event of such continued price drops, all other benefits of LED lighting would be foregone during the delay period. The annual greenhouse gas benefits would be foregone, as would the safety benefits and the ability to leverage economic development opportunities to earn foreign exchange.

26. ***Leveraging NZ's Innovation Strategy:***
An early decision to change to LED road lighting would open up opportunities for commercial development that are sought under NZ's innovation strategy. The April 2011 "Powering Innovation" report to stimulate the High Value Manufacturing and Services sector identified that one of the challenges was to identify a niche where innovation could be turned into economic development. LED road lighting is precisely such a niche.

27. Several examples are identified in this study for innovation in the road lighting sector. The manufacture of LED semiconductor devices is *not* considered to be an opportunity for NZ since massive international investment has already taken place, but the surrounding hardware, software and systems required for optimising LED lighting operations represent new and rapidly evolving markets in which NZ could aim to take a niche leadership position. Potential examples are provided in section 7 of this report.

28. One of the most challenging aspects to commercialising innovation is finding a customer willing to purchase early phase products or services. NZTA, MSI and NZTE might share the risks to assist innovation in this new and burgeoning area. By doing so, these agencies could meet goals of safety, value for money, and economic development at the same time as making progress on four of the Government's six policy drivers.

29. Several areas of investigation are required to complete this study. They include a deeper understanding of how road lighting assets are managed now (and could be managed in the future), what they really cost, how electricity energy and distribution companies will adapt to the introduction of advanced metering, and other economic, social and environmental factors.

30. Advanced technologies such as LED offer white light that provide increased light clarity and perception of safety through improvements in colour temperature and rendering, but it's equally important to manage the transition to the introduction of these technologies to maximise these benefits for NZ. It would be undesirable if New Zealand was to become a haphazard patchwork of new white and old yellow lighting technologies with highly visible transitions between them. This is just as likely to have negative consequences for bothsafety and attractiveness, and would therefore carry potential dis-benefits for the valuable tourism sector.

31. This report recommends that NZTA:

a) invests further resources into validating this report's findings;

b) ***initiates a road lighting strategy*** to
i) reduce the 4,567 injuries (31.7% of total accidents) occurring in relative dark;
ii) save $27 million per annum by halving the annual $55 million road lighting cost through replacement of HPS lighting by advanced LED technology lighting;
iii) utilise private capital and performance incentives to avoid more debt on public balance sheets and reduce performance risk;
iv) rapidly upgrade road lighting infrastructure with advanced technologies in Christchurch; and
v) identify areas for innovation and economic development that advance the road lighting strategy *and* provide opportunities to leverage NZ innovation strategies for economic growth;

c) ***provides incentives to Councils to form innovative procurement practices such as PPPs***. (For example, consider foregoing NZTA's share of energy and operating savings from the new LED lighting for the first five or ten Councils that upgrade);

d) ***investigates other more far-reaching possibilities*** such as limiting the number of PPPs covering the whole of NZ to, say, three to five, and centralising road lighting strategy and policy functions including equipment procurement into a secretariat that is appropriately governed and funded;

e) addresses the electricity charging disincentives for investment in the beneficial new technologies.

3 Introduction

32. Please note that all references to Appendices, Paragraphs, Figures and Footnotes are hyperlinked in the MS Word and PDF electronic file of this document so a mouse click on most of them[1] will send the reader to the corresponding reference.

Terms of Reference

33. This report was commissioned by the NZ Transport Agency (NZTA) for its *Road Maintenance Task Force* on 23 December 2011 with a deadline of 24 January 2012. The authors were then invited to use the initial report to conduct further consultation and produce this final report to be published with the Road Maintenance Task Force findings.)

34. The establishment of the Task Force was announced by the Minister of Transport on 26 July 2011. (See Appendix 1) Its purpose "is to identify opportunities for efficiencies in delivery of operations, road maintenance and renewals, including innovative services, products and methods of procurement, and to encourage their consistent uptake through the country", and it is to publish its findings in March of 2012. (The full terms of reference for the Task Force are provided in Appendix 2)

35. The Government transport sector is extensive and governed by several organisations shown in Appendix 3. Overall governance is by the Minister of Transport (Hon Steven Joyce in the last Government, and Hon Gerry Brownlee in the Government elected November 2011).

36. The NZTA Road Maintenance Task Force is aligned with the Government's strategy for transport policy as outlined in *Connecting New Zealand*. Its high level goal is expressed as: "*The government is seeking an effective, efficient, safe, secure, accessible and resilient transport system that supports the growth of our country's economy, in order to deliver greater prosperity, security and opportunities for all New Zealanders*."[2]

37. This report addresses strategic opportunities for road lighting procurement that contribute towards the "*three key areas of focus for transport*"[2] as described below by the Minister of Transport to the Cabinet Economic Growth and Infrastructure Committee[3]:

    a) ***Economic growth and productivity***
    The government's overall goal for New Zealand is to grow the economy to deliver greater prosperity, security and opportunities. Transport's role in this is to move people and freight as safely and efficiently as possible. Better transport links and services can lower costs and enhance accessibility of businesses by expanding markets and improving access to supplier inputs and labour. Increased access and connectivity provides opportunities for enhanced trade, competition, and specialisation, which can lead to long-term productivity gains."

    b) ***Value-for-money***
    Improving performance and productivity across the public sector is a high priority for the government. To achieve this, we need to focus on lifting the performance of transport Crown entities and ensuring the regulatory transport framework is fit-for-purpose (and supports the delivery of the results we want). The individual components of the transport system also need to be efficient and effective. Achieving this requires a greater focus not only on what infrastructure and services are provided, but also on how activities and projects are delivered, how assets are managed and the extent to which costs are minimised over time."

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[1] When "hovering" the mouse over a reference, the cursor marker should change to a hand to indicate the reader can click on the reference to get "sent" there. Unfortunately the Table of Contents will not work this way due to an incompatibility between Microsoft and Adobe.

[2] Connecting New Zealand: a summary of the government's policy direction for transport, Minister of Transport, August 2011, Page 3.

[3] Connecting New Zealand – a summary for stakeholders of the Government's policy direction for transport, Cabinet Economic Growth and Infrastructure Committee, Hon Stephen Joyce, Minister of Transport, July 2011 (released by the Ministry of Transport to the internet under Official Information Act OIA)

c) ***Safety***
The government is committed to reducing the road toll and its impact on communities and families. A safer roading system will benefit businesses as well as individuals and their families. However, achieving significant improvements in the safety of the roading system will take time and ongoing commitment by central government, local government, and the community."

Report Themes

38. This report is organised around these three themes, but in reverse to the order identified in the Cabinet paper and transport policy direction paper[2,3], to reflect the potential impact of this paper's findings (ie Safety; Value for Money; and Economic Development)[4].

39. Both the scope and specific priority order was not originally envisioned for this paper as the emphasis of the Road Maintenance Task Force is "value for money". At first sight, the combination of new technologies (including for example LEDs[5] road lighting and Lighting Management Control Systems) and advanced procurement systems (including PPPs and PFIs)[6] appeared to contribute only to "value for money" goals.

40. As the study progressed it became evident that these new technologies, and their timely adoption, could also potentially make significant contributions to NZTA safety and economic development goals. However, the urgent timetable and traditional Christmas holiday period made these unexpected findings more challenging to research, consult on, and analyse.

Government Policy Drivers

41. The Government set out six policy drivers for meeting its economic objectives[7]. They are:
    a) Regulatory Reform.
    b) Investment in Infrastructure.
    c) Better, Smarter Public Services for Less.
    d) Education and Skills.
    e) Innovation and Business Assistance.
    f) A World-Class Tax System.

42. This report proposes actions that will lead to improvements in four of the above policy areas. It does not advance arguments on the first and last on the list: "regulatory reform" and "a World Class Tax System".

Timetable

43. The compressed timetable available for a first draft of this report commissioned on the day before Christmas Eve 2011 with a completion target of 24th January 2012 required significant compromise in all aspects of the report. Time available for appropriate research, consultation, analysis and synthesis of the report was sub-optimal. Improvement in all these areas will result from subsequent focus should the NZTA decide outlined strategic opportunities are worthwhile investigating further.

44. Following a decision by the NZTA in February 2012 to request the author to seek external feedback, Draft 2.1 was distributed to more than 100 people who requested the report for comment. Their names and affiliation are shown in Appendix 7***.*** This final Version 3 was completed in May 2012, incorporating the results of this consultation.

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4 Note however, that neither the Cabinet Paper, or the policy strategy paper *Connecting New Zealand* specifically identifies that the key areas are listed in order of priority.

5 Light Emitting Diodes

6 Public Private Partnerships (PPP) and Private Finance Investments (PFI) as they are called in the UK

7 Cross Agency Initiatives Process; Guide for Public Service Agencies, The Treasury, NZ Government, 1 September 2010, Page 10. (See ***http://www.treasury.govt.nz/publications/guidance/planning/caip***)

Excluded Analysis

45. Time constraints meant several issues were excluded from the report, including a detailed discussion of the technical characteristics of available advanced road lighting technologies and their application to the practical requirements of road engineering. Another important and vital area excluded from analysis, is whether the fixed and variable costs of electrical energy for road lighting are appropriate. This falls under the jurisdiction of the Commerce Commission and Appendix 13 shows the submissions made by NZTA and BBA in response to a call by the Commission for submissions on information disclosure.

46. The conclusions drawn and recommendations made in this report have been tested against experts in the field (Appendix 7).

Report Authors

47. Godfrey Bridger, principal of Bridger Beavis & Associates Ltd ("BBA"), was commissioned by Bernard Cuttance, NZTA's Principal Advisor, who reports to the Road Maintenance Task Force Project Manager, Lynley Hutton.

48. BBA is a two person independent consultancy that sub-contracts associates where required. BBA is owned and operated by Directors Godfrey Bridger and Crystal Beavis. Their credentials and experience are summarized in Appendix 5 and can also be seen at ***www.bba.org.nz***. There are no known conflicts of interest between BBA, its principals and NZTA or this report.

49. BBA sub-contracted Bryan King, principal of Lighting Management Consultants Ltd, to contribute to several aspects of this report. Bryan and Godfrey first met when studying for their Executive MBAs and have remained in professional contact when common activities have brought them together. King is also owner of Modus Lighting Ltd, the exclusive agent for Philips road lighting products in New Zealand. The knowledge and experience Bryan King has made available to BBA and NZTA is invaluable, and a summary of this experience is provided in Appendix 5. His ownership of Modus does not constitute a conflict of interest as he serves only as an advisor to BBA which is delivering a strategy advisory service, not an equipment supply contract.

50. For questions, contributions and comments on this document please contact Godfrey Bridger of Bridger Beavis & Associates Ltd, e-mail: godfrey@bba.org.nz, ph (07) 859 0059, mobile (021) 274 3437.

Acknowledgements, Consultation & Desk Research

51. Appendix 7 outlines the people and organisations consulted for this report. Many went to significant effort to provide written contributions and for this the authors are very grateful. The aforementioned Bryan King, BBA's subcontractor for this project, should also get special mention for his extraordinarily wide and deep knowledge of the subject, which made a very substantial contribution to the study. Given the tight deadline, research for this report was primarily internet based. The subject is deeply covered on the internet and accumulated documents quickly outstripped the time available to analyse them. Appendix 4 provides a list of all documents downloaded from the internet or provided by others, *but which have not yet been studied*, in contrast to those documents *which were analysed* and which are listed in the Bibliography in Section 10.

4 Safety

13.1 Introduction - *Safer Journeys 2010-2020*

52. In the Minister of Transport's Foreword to *Government's Safer Journeys - New Zealand's road safety strategy 2010–2020*[8] the Hon Steven Joyce provides an appropriate and concisely worded introduction. The *"… document is designed to guide New Zealand's efforts to improve road safety for the next 10 years. It sets out the direction and actions we will take to reduce the number of deaths and injuries on our roads*".

53. "*The need for this strategy is clear. Despite substantial progress over the last 30 years, New Zealand still lags behind many other countries in road safety. Every year, hundreds are killed on our roads and nearly 2,900 people are seriously injured. Approximately 13,000 New Zealanders suffer minor injuries as a result of road crashes. We also know that the level of road death and injury suffered by our young people is especially high".*

54. *"These numbers reflect lives lost and ruined in what are mostly preventable crashes, but they do not show the effect of these crashes on families, the wider community and the health system. Road crashes can also have an economic impact – the annual social cost of crashes is estimated to be $3.8 billion".*

55. *"As road user numbers grow, our current efforts will not be enough to further reduce the level and impact of road crashes. Safer Journeys represents a new approach to this problem".*

56. *"Its aim is that death and injury will in the future no longer be an inevitable part of our road system. To achieve this aim, the strategy outlines a Safe System approach with actions spread across the entire road system: roads and roadsides, speeds, vehicles and road use."*

57. As identified by the Minister above, New Zealand's safety record lags behind its international peers. On page 6 of the same document, it states *"Based on 2008 results, we have 8.6 deaths per 100,000 population. This compares with 6.9 deaths per 100,000 population for Australia. Our fatality rate is double that of the safest nations shown (United Kingdom, Sweden and the Netherlands)*"

58. This section suggests that a new approach to street lighting could help to reduce this high social cost. It references a number of scientific publications to support this hypothesis.

13.2 Relationship between street lighting and accidents

59. The Ministry of Transport publishes comprehensive crash statistics collected by NZ Police. In those statistics (understood to represent a country database more complete than most) for the year ended December 2010 46.6% (174) of all deaths and 31.3% (4,393) of all injuries occurred in times of darkness. The Crash Analysis Statistics (CAS) database identifies whether the roads where the accident occurred were illuminated but not to which of the 10 different illumination levels acceptable in the Australian and New Zealand standard that covers street lighting - AS/NZS 1158.

60. New Zealand research[9] on 217 sites indicates that accident rates were reduced overall by 33% when lighting was installed. A 38% reduction occurred for "*crashes involving multi-vehicle collisions*" where lighting was installed and a 41% reduction in accidents where lighting was installed at intersections. As the NZTA study concludes "*The results above are in general agreement with that found in international literature*."

61. An American study by Elvik[10] concludes "… *that the best current estimates of the safety effects of public lighting are, in rounded values, a 65% reduction in night time fatal accidents,*

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[8] *Safer Journeys, New Zealand's Road Safety Strategy 2010-2020*, Ministry of Transport, 2010

[9] *Road lighting Improvements*, NZTA (Land Transport Safety Authority), December 1997 (Authorship undisclosed). Conclusions

[10] Elvik R. *A meta-analysis of evaluations of public lighting as accident countermeasure*. Transportation Research Record 1995; 1485:112–23. (can be purchased at ***http://worldcat.org/isbn/0309061229***)

a 30% reduction in night time injury accidents, and a 15% reduction in night time property-damage-only accidents"

62. There appear to be many international studies that support these substantial benefits. However, even if the research indicated that the advantages of road lighting were *half* of what the scientific community is claiming, there would still be a substantive case for improving road lighting wherever accidents in darkness are occurring. As the AA suggests "*Literature has been around for decades supporting lighting's potential to significantly reduce road crashes in darkness*" … "*With about a third of NZ crashes occurring in darkness, this means reducing the road toll by 10-20% pa, using a relatively low cost, or even negative cost, treatment. It would be a pity to focus on cost savings at the expense of maximising the road safety potential*."[11]

13.3 The need for a Street Lighting Strategy

63. Given this well-established relationship between road injury and deaths and lack of road illumination, it is puzzling that no programme exists to specifically reduce the relatively high darkness accident rate through a targeted road illumination strategy.

64. *Safer Journeys* identifies 4 major categories of strategy – *Safe Roads and Road Sides; Safe Speeds; Safe Vehicles*; and *Safe Road Use*. However, no reference is made to any aspect of improving road illumination's impact on reducing accidents – in fact neither of the key words "lighting" or "illumination" are mentioned anywhere in what is otherwise a very impressive 44 page strategy.

65. There is strong recognition of the negative effects of road injury and deaths on the social, health and economic wellbeing of New Zealand. However it appears that there is as yet no recognition in official documents[12,13,14] that new street lighting strategies could play a significant role in reducing accidents.

66. Of the estimated annual $3.8 billion cost of accidents, about $1.2 billion (31.7%)[15] every year is caused by accidents in periods of darkness. This alone would appear to justify a separate street lighting strategy, but other sections in this report strongly make the same case for different reasons[16].

67. A street lighting strategy would be aimed at minimising accidents, crime and other negative social impacts while at the same time minimising expenditure and environmental impacts and maximising other positive utility factors such as security and attractiveness to tourism. It would need to consider benefit/cost assessment of several issues including street light colour, road reflectance, light design and placement, energy efficiency, innovative procurement and several other aspects many of which are covered in this study.

68. When asked for comment The Automobile Association of NZ (AA) responded "… *the AA strongly supports the report's focus on lighting's potential role in safety as the key priority*." AA's full comments are provided in Appendix 12 where they observe "*Rather than investing in a piecemeal way based on crash locations, lighting treatments must first be in a* ***strategy that integrates with the State highway classification system and local road hierarchy.*** *Lighting design is a key* **perceptual cue** [their emphasis] *to road users as to what speed or*

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[11] Jayne Gale, Principal Adviser, Motoring Policy, NZ Automobile Association, 30 March 2012. Full text of comments are in *Error! Reference source not found.*.

[12] *Statement of Intent 2011-2014*, Ministry of Transport, 2011

[13] *Safer Journeys, New Zealand's Road Safety Strategy 2010-2020*, Ministry of Transport, 2010 indicates that all road accidents cost NZ $3.8 billion per year and the Ministry's Motor Vehicle Crashes in New Zealand 2010 publication identifies that

[14] *Connecting New Zealand, A summary of the government's policy direction for transport*, Minister of Transport, Page 7.

[15] *Motor Vehicle Crashes in New Zealand*, Ministry of Transport, figures for the year ending 31st December 2010, calculated from figures on Table 8, Page 29.

[16] For example, in Australia they put together a strategy solely for energy efficiency purposes – see *Draft Street Lighting Strategy*, Equipment Energy Efficiency Program, July 2011. ***http://www.energyrating.gov.au/wp-content/uploads/Energy_Rating_Documents/Library/Lighting/Street_Lighting/Draft-streetlight-Strategy.pdf***

hazard level environment they are in. It is important that we develop a consistent strategy for the lighting design to fit into the rest of the roading design (lane widths, markings etc) to create a subconscious response to the cue ie "self explaining" driver behaviours and speeds. We also support the warning about a "patchwork" transition between yellow and white light, and the need to roll this out in a logically consistent way."

13.4 NZ Illumination Levels

69. Industry practitioners suggest that insufficient illumination levels exist because "*a very high percentage of currently installed lighting in New Zealand is not compliant with the required standards*"[17] as laid out in AS/NZS1158.

70. Furthermore, AS/NZS1158 specifies much lower light levels than occurs elsewhere in the world. Practitioners suggest the levels are about half the levels encountered in UK, Europe and the USA.

71. AS/NZS1158 specifies two classes of use – Category P that applies to road lighting where pedestrians are the focus and thus require lower light levels of typically white light, and Category V where higher levels of road light levels is directed at vehicle safety and typically yellow or "gold" colour. Within each class there are four sub-categories (for NZ) that correspond to levels of illumination specified for appropriate levels of usage, subcategory 1 being the highest illumination level and 4 being the least.

72. As with all benefits, increasing safety and illumination comes at a cost. However, there appears to be no research that specifically investigates the trade-off between benefits and costs of road illumination in New Zealand despite the fact that traffic accidents during the hours of twilight or darkness are estimated to cost us $1.2 billion every year. Further investigation of this would appear to be worthwhile.

73. A lack of focus on the relationship between road lighting and traffic accidents is not just a New Zealand phenomenon. As in all areas of scientific and technological development, there appears to be a lag between scientific knowledge of the interplay between illumination and visual acuity, the availability of new lighting technologies, and a developed understanding of how this knowledge and these new technologies could be brought together in practical applications in the marketplace for the benefit of the wider population. Nevertheless there is enough development beginning to occur in other international jurisdictions to indicate that New Zealand should begin to focus on this area as well to ensure it takes advantage of new technologies that offer both cost and carbon-efficiencies as well as social benefits.

13.5 Light

74. Unlike most other measurements of a physical quantity, light is a measure that relates to the biological response of the human eye. Thus for example mass, distance, and electrical current are measured by the physical units of kilogram, metre and Ampere, all of which are objectively measured irrespective of the human observer. Light on the other hand is measured in relation to the human eye's response[18].

75. The science of visible light is therefore complicated by the biology of the eye. Different photoreceptors on the retina, known as rods and cones, work in different ways to govern our night time and day time vision. Understanding of the science is advancing at the same time as rapid commercial progress is being made in lighting technology. The latest developments as a result of this interaction appear to have left New Zealand road lighting practice behind[19].

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[17] One of the contributors in *Error! Reference source not found.*

[18] The physics of light therefore distinguishes between "radiant flux" or power which is the measure independent of a human eye's response, and "Luminous flux" or power which has been adjusted by the eye's response.

[19] A controversial statement explained by sections 4, 5 and 8.

76. Most people are aware that the eye's response changes according to the colour or the wavelength of the light being observed. During daylight hours, yellow-green light is much more visible by the human eye than red or purple light of identical intensity.

77. However, in low lighting levels such as those encountered at night on a road with street lighting, the eye's response is very different. As Figure 1 shows, the eye is most sensitive to green/yellow in daylight conditions (the 100% point on the white line corresponding to a wavelength 555 nano metres[20]), but in low light conditions the eye's sensitivity to that same colour drops to only 40%, and so we find it much more difficult to see green/yellow light at night. At night the black line shows that the eye is most sensitive (the 100% point) to blue/green light of wavelength 507 nm.

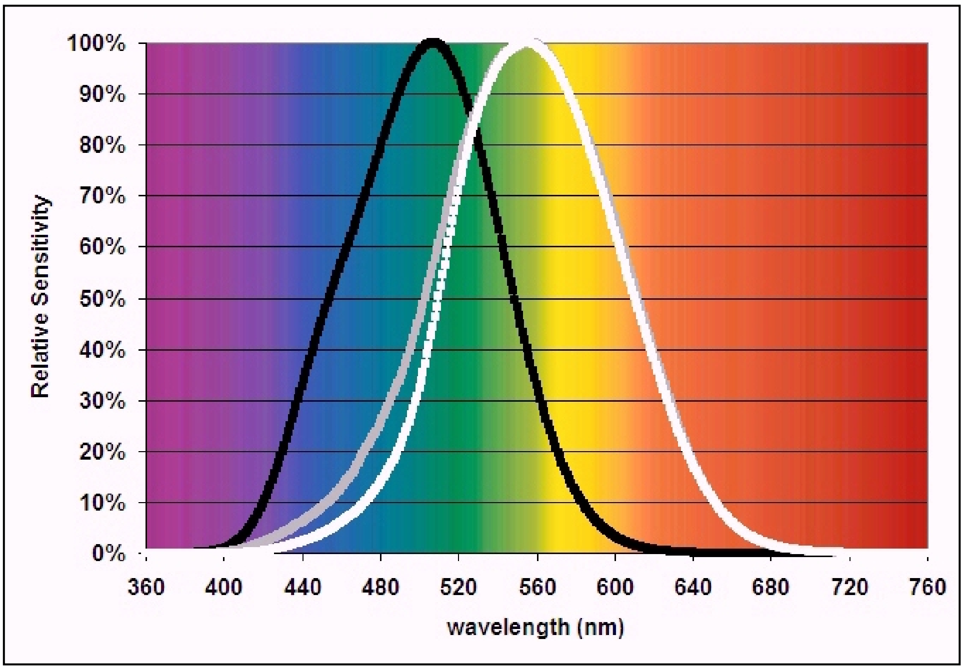

Figure 1 The different response of the eye at different lighting levels. White line is daylight, black line night conditions (Source: website[21])

78. Lighting levels in between these two extremes of daylight and darkness are referred to as the "mesopic" region. This term is used widely in the scientific and technical literature and explains the dangers of the twilight period during which neither the cones nor rods are operating at their highest efficiency.

79. The total amount of visible[22] light emitted by a source is measured in the SI Unit of "lumen" with a symbol of "lm"[23]. This is the measure used to describe the amount of light modern lamps provide.

80. When describing illumination levels one considers the amount of visible light falling on a surface, and the SI unit of "Lux" (symbol lx) is used. Thus 1 lux is equal to 1 lumen per square metre. This measure is used by lighting designers with instruments that measure light levels at specific distances away from the light source.

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20 A nano metre (nm) is a billionth of a metre or a millionth of a milli metre (mm).

21 ***www.resodance.com/ali/pho_sens.html***. The white line represents the "Standard Observer" or "the" photopic sensitivity function (also called vlambda or ybar2) comes from the CIE and dates to 1931. This data represents the sensitivity of the 2 degree visual field associated with foveal vision. The grey line represents the "Supplementary Observer" sensitivity function which corresponds to the 10 degree visual field that is described as para-foveal and was published by the CIE in 1964.

22 "Visible light" is the very small proportion of the electromagnetic spectrum which is visible to the human eye.

23 One lumen is equal to one "candela", symbol "cd", spread over the section of a sphere corresponding to a "steradian" – a "solid" angle describing a specific cone proportion of that sphere.

81. The main types of road lighting in New Zealand are the efficient 1970s technology yellow High Pressure Sodium (HPS) lights commonly seen in more than three quarters of the country and shown in Figure 2 and in the photograph in Figure 51**,** Appendix 9 in which light output is compared to LED lighting. Other old and inefficient technologies existing in New Zealand include orange Low Pressure Sodium (LPS) lamps, and white Mercury Vapour (MV) lamps. There are also small representative amounts of the other white light technologies – LED, Metal Halide (MH) and Ceramic Metal Halide (CMH), and Fluorescent. 0 provides further description of these technologies. Note that with the exception of LED and Fluorescent lighting, all the other technologies mentioned above are a subset of High Intensity Discharge or HID lamps which is a term used to describe lamps that emit light from an arc produced by ionised gases.

Road lighting design

82. The eye's response in low light conditions (referred to as Scotopic response) is different to its response in bright light conditions (Photopic response), and this has only been partially factored-in to NZ and Australian lighting Standards AS/NZS 1158.

83. The international organisation responsible for lighting outside of USA is the CIE, an acronym for the French word Commission International de L'Eclairage or International Commission on Illumination. A CIE Technical Committee[24] was formed to address the issues described above and published its guidelines in 2010[25].

Figure 2 High Pressure Sodium (HPS) Lamps (Source: Philips[26])

84. The different sensitivities of the eye at night time illumination levels are addressed by using the Scotopic/Photopic ratio or "S/P". Thus each lamp type will have an S/P ratio which indicates its suitability for night time street lighting. The higher the ratio the better. Figure 3 illustrates the S/P ratio for different coloured lamps.

85. Figure 4 shows an illustrative but typical 100W HPS light with an S/P ratio of 0.64 and a 88W LED light with an S/P ratio of 1.68. As the author of the web article points out[27], "*The*

[24] TC 1-58 'Visual Performance in the Mesopic Range'

[25] Recommended System for Mesopic Photometry Based on Visual Performance, CIE 191:2010. See ***www.cie.co.at/Publications/index.php?i_ca_id=788*** & *CIE Supplementary System of Photometry*, CIE 200:2011.

[26] Philips Ceramalux® High Pressure Sodium Lamps specification brochure.

Photopic lumen output of both sources, 100W HPS and 88 input W LED, is equal. The ***Scotopic*** *lumen output advantage of the LED is 11,179 to 4,226 Scotopic lumens for the 100 W HPS*[28]." Thus at low lighting levels the eye detects significantly more light for the LED lamp than it does for the yellow HPS lamp.

86. The CIE chairperson responsible for the review of mesopic lighting guidelines[29] observed "*Mesopic lighting applications include road and street lighting, outdoor area lighting and other night-time traffic environments. So far, there has been no internationally accepted system of mesopic photometry. This means that suitable methods to evaluate the visual effectiveness of lighting products and installations in the mesopic region have not been available."* … "*Finally, in 2010 we will have a mesopic photometric system to accompany the photopic V(λ), which has served since 1924*."

87. A recognised New Zealand authority on road lighting, Mike Jacket, recently commented[30] "*In 2005 light from HPS and LPS was "derated" in category P4 and P5 lighting specifically because of S/P ratio* (described below*). In 2008 following a request from NZ this derating was extended to include all of category P. More widespread changes involving both P and V lighting are now needed to align with the new CIE mesopic scale. AS/NZS1158 has not met for some time presumably this will be on the agenda when it does*".

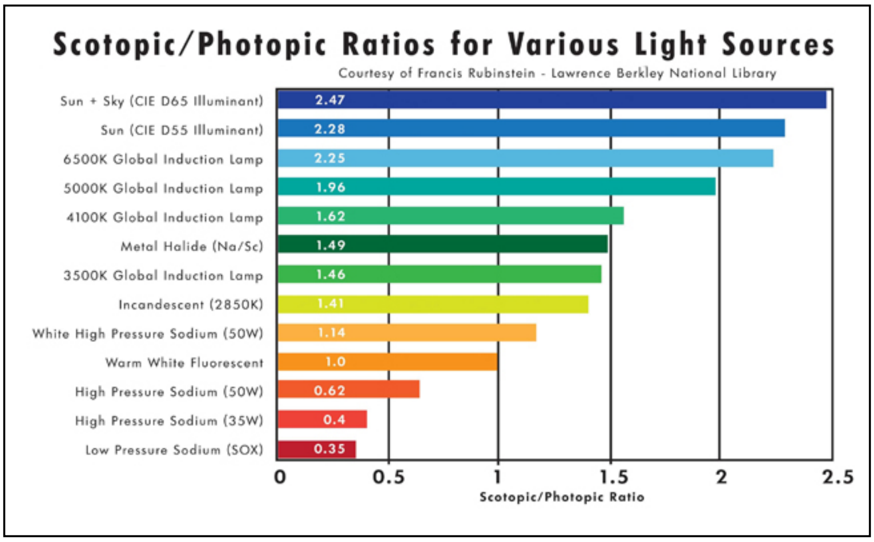

Figure 3 Scotopic/Photopic Ratios for various light sources (Source: Lawrence Berkley National Laboratory)

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27 Salvador Behar, Partner, MeXSI Inc, Architectural & Energy Efficiency Practice, New York (***http://www.mexsi.com/about.html***) diagrams and article at ***http://mexsi.wordpress.com/2009/04/***.

28 Lumen totals are calculated from the area under each of the graphs. Scientifically this is referred to as integrating lumens/nm for all wavelengths across each of the scotopic and photopic spectral response curves.

29 CIE News No. 92, July 2010, Prof. Liisa Halonen, Chairman CIE TC 1-58, Professor in the Lighting Unit of Aalto University in Finland.

30 Jacket, M., e-mail correspondence 3 May 2012.

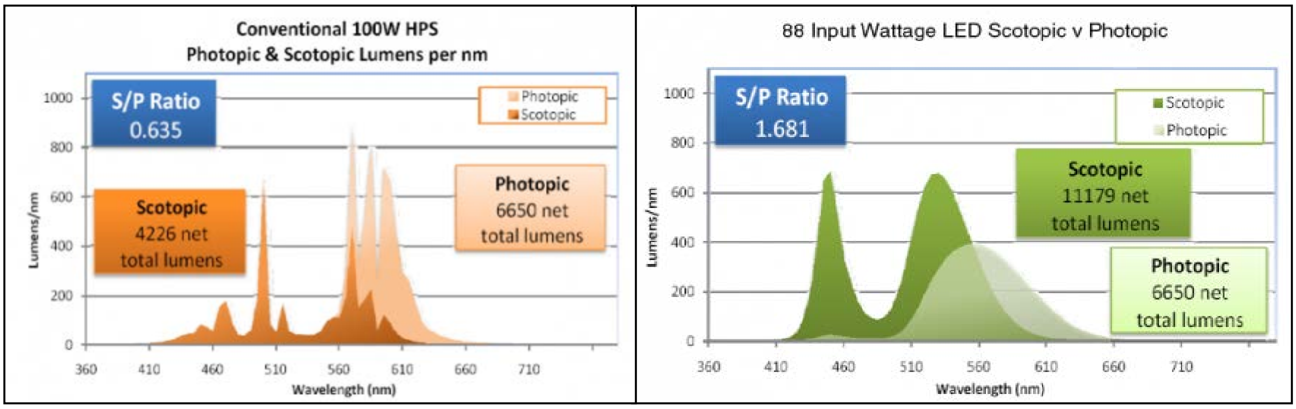

Figure 4 S/P ratio comparison between typical HPS and LED lights (Source: MeXSI Inc[27])

Table 1. Differences between mesopic and photopic luminances (%) calculated with the recommended mesopic system for a range of light source S/P-ratios.

		Photopic luminance cd·m^{-2}									
	S/P	0,01	0,03	0,1	0,3	0,5	1	1,5	2	3	5
LPS ~	0,25	-75 %	-52 %	-29 %	-18 %	-14 %	-9 %	-6 %	-5 %	-2 %	0 %
	0,45	-55 %	-34 %	-21 %	-13 %	-10 %	-6 %	-4 %	-3 %	-2 %	0 %
HPS ~	0,65	-31 %	-20 %	-13 %	-8 %	-6 %	-4 %	-3 %	-2 %	-1 %	0 %
	0,85	-12 %	-8 %	-5 %	-3 %	-3 %	-2 %	-1 %	-1 %	0 %	0 %
	1,05	4 %	3 %	2 %	1 %	1 %	1 %	0 %	0 %	0 %	0 %
MH warm white ~	1,25	18 %	13 %	8 %	5 %	4 %	3 %	2 %	1 %	1 %	0 %
	1,45	32 %	22 %	15 %	9 %	7 %	5 %	3 %	3 %	1 %	0 %
	1,65	45 %	32 %	21 %	13 %	10 %	7 %	5 %	4 %	2 %	0 %
	1,85	57 %	40 %	27 %	17 %	13 %	9 %	6 %	5 %	3 %	0 %
LED cool white ~	2,05	69 %	49 %	32 %	21 %	16 %	11 %	8 %	6 %	3 %	0 %
	2,25	80 %	57 %	38 %	24 %	19 %	12 %	9 %	7 %	4 %	0 %
MH daylight ~	2,45	91 %	65 %	43 %	28 %	22 %	14 %	10 %	8 %	4 %	0 %
	2,65	101 %	73 %	49 %	31 %	24 %	16 %	12 %	9 %	5 %	0 %

Figure 5 Correction factors to apply for different S/P ratios and background illumination levels (Source: Puolakka et al[31])

88. LED white light sources are significantly better for road lighting than HPS light sources – when compared by either output lumen for output lumen, or by input Watt for input Watt.

89. This is scientifically demonstrated by CIE's correction factors shown in Figure 5 where Photopic luminance (the light output measured on the daylight sensitivity of the eye and quoted by manufacturers) is corrected either downward or upwards according to the colour of the light and the background illumination level. At very low lighting levels (0.01 cd/m^2) a white Metal Halide (MH) light is 132% (101% - - 31%) more visible to the eye than HPS but at bright lighting levels (5cd/m^2) there is no difference.

13.6 Human Performance - Detection and Response

90. Whereas Section 4.5 is about what a human eye observes, Section 4.6 is about how the human driver *reacts* to what he/she observes.

91. Many studies have been conducted to verify that cool white LED lighting improves peripheral (scientific literature calls it "off-axis") vision LED vehicle headlights are especially well-researched. One of those studies is identified in the footnote below[32] and the bibliography

[31] *CIE new system for mesopic photometry*, Puolakka M., Halonen L. Proc of CIE Lighting Quality and Energy-Efficiency, CIE x035:2010, p. 457-462, presented at the CIE 2010 "Lighting Quality and Energy Efficiency conference.

[32] *Spectral Effects of Forward Lighting*, Van Derlofske, J., Bullough, J.D., Watkinson, J., Lighting Research Centre, Rensselear Polytechnic Institute, April 2005.

from whence Figure 6 is taken which shows slower driver reaction times in "warm" colour conditions than in "cool" (blue end of the spectrum) colour conditions, particularly at peripheral target angles.

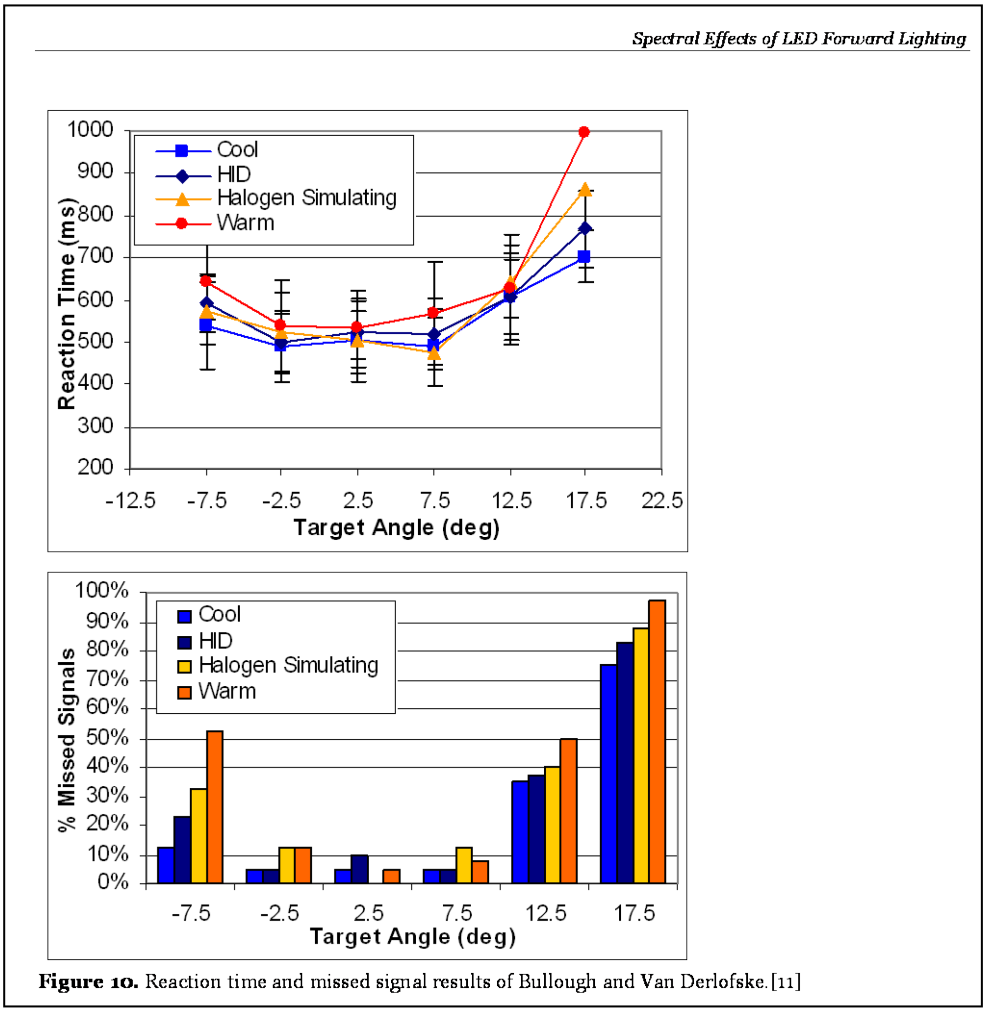

Figure 6 Driver Reaction Times to different colours and angles from central axis (Source: Rensselear Polytechnic Institute[32])

92. Another study by Rensselear Polytechnic Institute's Lighting Research Centre confirms this same characteristic for road lighting. Its finding on reaction times is illustrated below by the presentation slide[33] on night time visibility shown in Figure 8 which suggests that human reaction times are 9% longer under High Pressure Sodium lighting, than under blue/white Metal Halide (MH) lighting. The full scientific paper to which Figure 8 refers was accepted for publication in 2008[34] and conducted significantly before this time when LED road lighting was not widely available nor cost effective. Nevertheless it is relevant because the research outcomes relate to the colour of lighting, not the way the light is generated (ie MH vs LED).

93. A greater difference in reaction times was reported in another earlier study[35] shown in Figure 7 clearly demonstrating a significant improvement in driver reaction times in white lighting under the ambient light levels encountered during night time driving (less than 1.5 cd/m^2).

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33 Rensselaer Polytechnic Institute, Troy, NY 12180 USA http://www.lrc.rpi.edu/programs/transportation/pdf/LRCTransportationOverview.pdf

34 *Several views of metal halide and high pressure sodium lighting for outdoor applications* Rea, M. S., J. D. Bullough and Y. Akashi (2009). Lighting Research and Technology. p. 41(4): 297-320.

35 "*Visual Performance as a Function of Spectral Power Distribution of Light Sources at Luminances Used for General Outdoor Lighting*." Lewis, Alan, Journal of the Illuminating Engineering Society, Winter 1999, Vol. 28, No. 1. P. 37-42. Illuminating Engineering Society of North America, New York

94. In another report commissioned by Transport for London and funded by several others[36], Transport Research Laboratories suggests that "*The MOVE*[37] *project has confirmed a relative benefit of "white" light for off-axis (or peripheral) vision), which increases as the lighting level falls*."

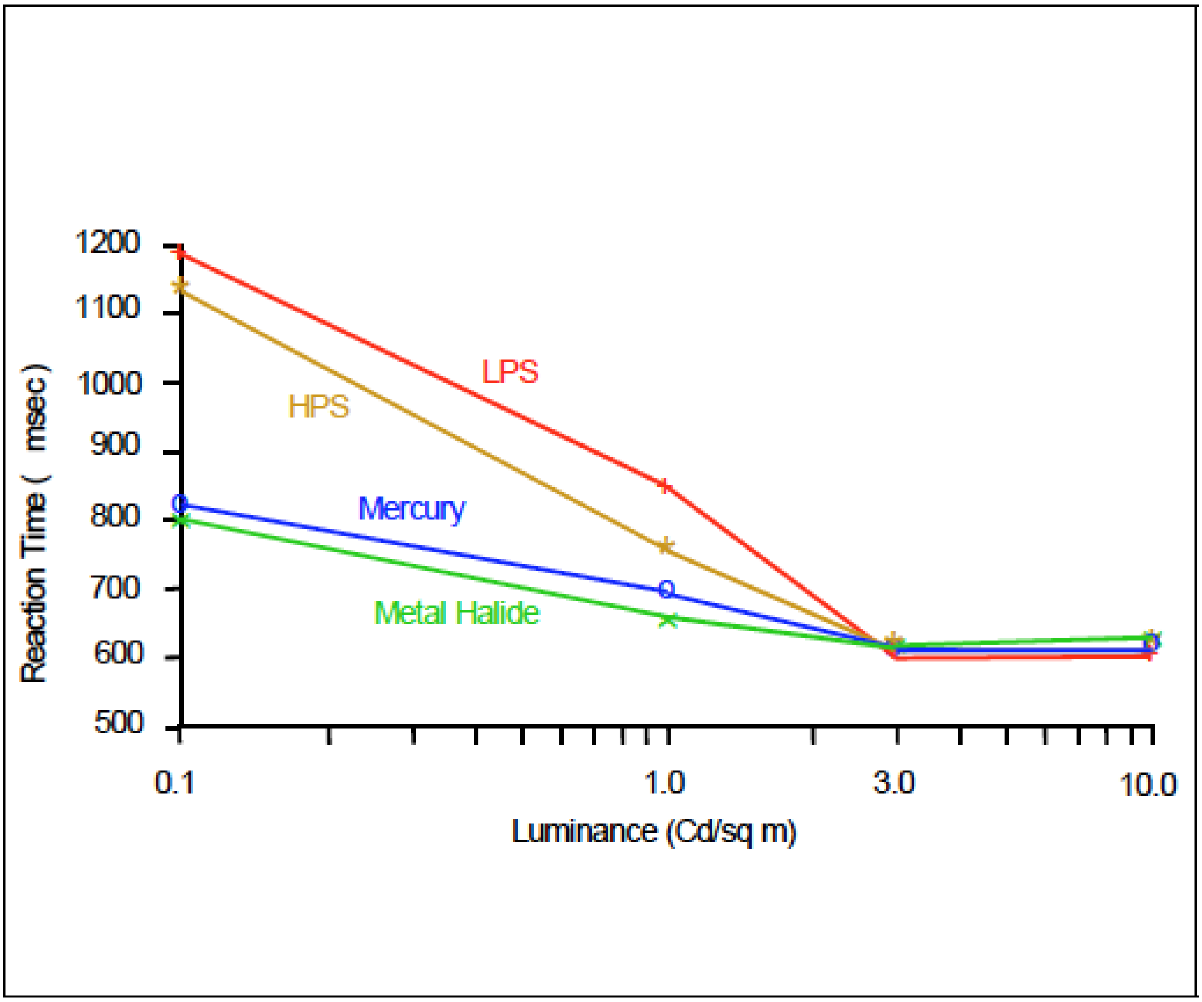

Figure 7 Reaction Time measured against logarithmic value of Luminance (Source: Arizona Department of Transportation[38])

36 *Review of the class and quality of street lighting* By Crabb, G.I., Beaumont, R., and Webster, D., Transport Research Laboratory Ltd, commissioned by Transport for London, published in January 2009.

37 MOVE stands for Mesopic Optimisation of Visual Efficiency, a project funded by the European Commission.

38 Roadway Lighting: An Investigation and Evaluation of Three Different Light Sources, Final Report 522, Arizona Department of Transportation, May 2003. See web link provided by M. Jackett: ***http://www.azdot.gov/TPD/ATRC/publications/project_reports/PDF/AZ522.pdf***

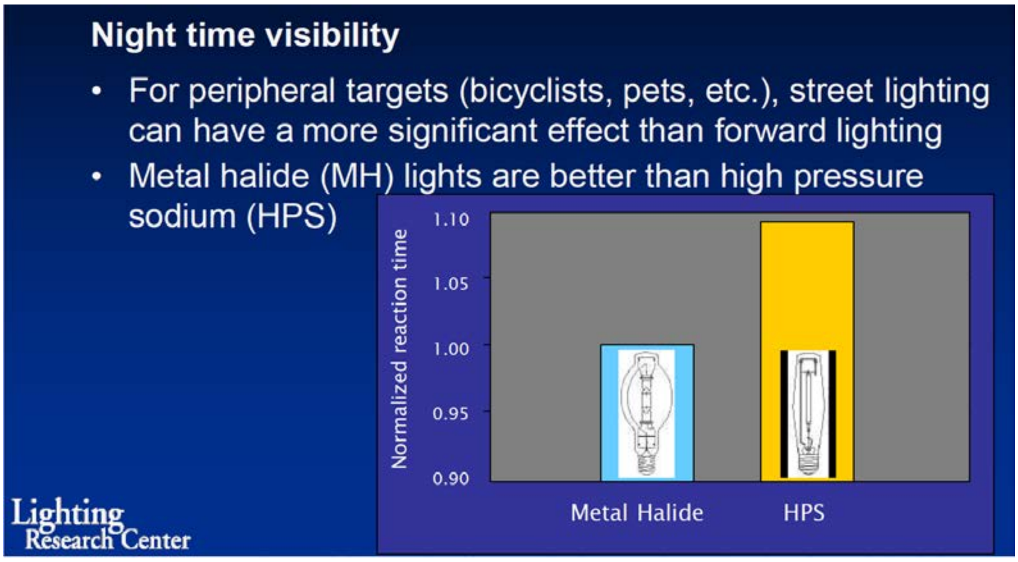

Figure 8 Reaction time for Orange HPS lights 9% longer than for while Metal Halide lights (Source: Rensselear Polytechnic[33])

95. It appears that enough credible international research exists for this study to conclude that white road lighting – on an *output* lumen for lumen comparison – is safer. White lighting provides better peripheral vision and driver reaction times than yellow or orange lighting. which is the predominant colour used in New Zealand road lighting. On an *input* electrical Watt for Watt comparison, the difference in favour of LED white lighting is even greater, but in economic terms alone.

13.7 Human Preference & Security

96. The conclusion that white lighting is safer fits closely with the intuitive preference that people have for white lighting over yellow lighting at night. Anyone who has the opportunity to compare an environment illuminated by each colour will establish this for themselves. It is harder to distinguish colour and detail under yellow lighting than under white lighting, and this makes yellow lighting much less "attractive" at night.

97. Noting this intuitive observation, the scientific community has researched this preference and not surprisingly confirmed it from several perspectives. Roads in residential areas ("Category P" in Australia and NZ) use lighting for vehicle and pedestrian security purposes so the relationship between crime and lighting levels is one of some consequence.

98. A relevant characteristic of security lighting is its intensity, measured in Lux, and the support it provides the eye to distinguish colours, measured by the Colour Rendering Index or CRI. The ability to clearly identify a potential threat and testify for evidential purposes is seen to be an objective measure of crime deterrence. Yellow HPS lighting has a CRI of about 20 whereas "white" lighting has CRIs of greater than 60. In order to avoid a discussion of the research, one can simply identify the standards which reflect that research[39].

99. As shown in Figure 9**,** in Britain the use of white light (CRIs greater than 60) allows 30% lower levels of illumination to be used.

[39] This can be done for the crime and security issue but unfortunately not for reaction time and mesopic lighting issues covered in sections ***4.4*** and ***4.6*** where the standards are still catching up.

A UK example of EN:13201

Crime Rate	R_a value	Minimum Maintained horizontal illuminance (Lux)		
		Low Traffic Flow	Normal Traffic Flow	High Traffic Flow
Low	$R_a < 60$	5	7.5	10
	$R_a > 60$	3	5	7.5
Medium	$R_a < 60$	7.5	10	15
	$R_a > 60$	5	7.5	10
High	$R_a < 60$	10	15	15
	$R_a > 60$	7.5	10	10

The British standard BS5489-1:2003 states that the illuminance level can be **reduced by -30%** in subsidiary roads when light sources with a colour rendering index of over 60 (CRI>60) are used.

Figure 9 An explanation of British Standard BS5489-1:2003 relating to the colour of street lighting

100. The abstract of a study published in 2011[40] highlights the changes that are taking place but have not yet reached New Zealand: "*Road lighting practice in Europe is currently under change, the changes being induced by the European Union Ecodesign regulations, the rapid development of LEDs and the new CIE system of mesopic photometry. …"*

101. Another scientific study by Philips published in 2010[41] suggests "*Public lighting improves visibility and provides orientation. It also contributes to the perception of comfort and safety of people outside after dark. At present, high pressure sodium lamps are widely used in street lighting. This is in part due to their high efficacy and relatively long lifetime (16 000 hours). Their use, however, comes at the expense of good colour rendering. Recently developed ceramic metal halide lamps provide many of the advantages of HPS in addition to white light and better rendering of colours. In this paper, results of research conducted in three European countries on the effect of lamp spectrum on face recognition and the perception of safety and comfort outdoors are presented*."

102. While this study was performed by Philips, which had an interest in promoting its Ceramic Metal Halide technology, it references 14 other independent scientific articles and clearly met the required scientific standard of the Journal of Lighting Research and Technology.

13.8 Colour Conclusions

103. These important changes in approach to road lighting design are being recognised world-wide and the scientists who are experts in this area have been publishing extensively. One of those scientists is Professor Steve Fotios from the University of Sheffield's School of Architecture Lighting Research Group who has published prolifically on road lighting research and recently published a paper "*Proposed UK guidance for lighting in residential roads*" in the journal Lighting Research and Technology in 2012[42].

104. In e-mail correspondence for this study[43] Professor Fotios made the following observation: "*It has recently been established that for the low light levels typical of road lighting, light sources*

[40] *Road lighting in change: User advice for designers*, Viikari, M., Puolakka, M., Halonen, L., and Rantakallio, A., Lighting Research and Technology 2011; Volume 0: Pages 1–15 (Volume 0 probably refers to the fact that this has been published electronically but not yet printed)

[41] *Field surveys of the effect of lamp spectrum on the perception of safety and comfort at night*, Knight, C., Lighting Research and Technology 2010; Vol 42: Pages 313–329.

[42] *Proposed UK guidance for lighting in residential roads*, Fotios, S., Goodman, T., Lighting Research & Technology, 2012 Vol 44: Pages 69-83.

[43] E-mail from S Fotios, Professor of Lighting and Visual Perception, University of Sheffield to G Bridger dated 30 April 2012 11:49:25 AM NZST. His profile can be seen at ***http://www.shef.ac.uk/architecture/people/fotios_s***

with higher S/P ratio (higher optical radiation in the short-wavelength region of the visible spectrum) improve the probability of detection in peripheral vision, and reduces reaction time to detect peripheral targets. Such light sources tend to appear whiter than the strongly orange coloured sodium sources commonly used for road lighting, and have thus become popularly known as white light. For drivers, this improvement in peripheral detection may lead to a reduction in accidents, or alternatively it may allow a reduced amount of light (luminance) to be used, thus saving energy, but maintaining the same level of visual benefit. Lighting of higher S/P ratio is also of benefit to pedestrians, but the critical visual tasks for pedestrians also demand a high colour rendering index (a measure of the appearance of objects and surfaces under different sources of light)".

105. He continued "*Fundamental aims of road lighting are to reduce traffic accidents on main roads and to reduce crime against people and property, and fear of crime, on residential roads. Lighting of higher S/P ratio appears to enhance the visual tasks associated with these aims. However the causes of accidents, crime and fear of crime are based on many factors in addition to lighting, otherwise there would be no accidents or crime in daylight. Long-term trial installations are required in order to measure the impact of changes in lighting.*"

106. New Zealand probably has a higher proportion of internationally defined two-way "urban" roads than most other countries due to its relatively small population and low density. Comparatively we have fewer "unidirectional" motorways and highways. Motorways have fewer threats from the side. Thus the above conclusions by Professor Fotios probably apply to a significantly higher proportion of roads in NZ than are found in other countries[44]. This appears to be particularly relevant to public policy as yellow HPS lighting is estimated by Merrifield[45] to be about 76% of New Zealand road lighting. The proportion could be significantly greater as, for example, in Wellington it is 93%[46] as shown in Figure 27.

107. The key conclusion appears to be that wherever traffic requires peripheral vision, white light should be used to reduce night-time accidents. For a given required level of illumination, white light should be used to reduce accidents except where traffic is "unidirectional" such as on motorways or arterial roads without side roads. Research to test this conclusion in New Zealand would be extremely useful.

13.9 Reported Injuries occurring during darkness

108. New Zealand has a sophisticated database of accident statistics called the Crash Analysis System or CAS. Between 2006 and 2010, 57,551 crashes occurred on New Zealand roads and 18,437 of them (32%)[47] were during the time when road lighting is normally switched on. The location type, the existence of street lighting, and whether the lighting was on or off, are factors graphed in Figure 10 below.

109. Figure 10 captures the lighting conditions in which night-time injury crashes occur, and that have between $3 and $5 billion dollars worth of negative economic impact (based on current Government estimates[48]).

110. Accordingly, the following three avenues of investigation would appear worthwhile for a street lighting strategy:

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44 Clearly a matter for investigation.

45 Merrifield, A.L.R, *Review of Street Lighting*, Land Transport New Zealand, November 2007. 76% was the proportion of a review sample of 20 Territorial Authorities in 2007.

46 Thessman, M., Project Manager – Street Lighting, Wellington City Council, e-mail 30/4/2012.

47 Provided by Fergus Tate, National Traffic and Safety Manager, Highways and Network Operations Group, NZTA, 17 April 2012.

48 In 2011 the Minister estimated that road accidents cost the country $3.8 billion per year. Four years (2006-2010) comes to $15.2 billion times 32% dark time accidents is 4.86 billion not accounting for inflation or or reduction in accident rates.

g) Why was the existing street lighting off for the 1,240 crash injuries that occurred during darkness? (The red-brown shaded parts of the graph) How could this situation be reduced?;

h) Where street lighting existed and was on, could improvements be made to reduce the 10,794 accidents that occurred as shown by the green shaded parts of the graph? For example, were the illumination levels high enough? Would white lighting reduce accidents? (In Australia, which has a lower overall accident rate than New Zealand, 47% of all street lighting is white[16], whereas in NZ only 21% is white[49]). Is the design and location of the lighting optimum?

i) Should the (more costly) option of installing street lighting be investigated in those areas where the 6,403 crash injuries occurred but no street lighting exists (the blue areas in the graph)?

111. Note that the benefits from reducing injuries discussed above and shown in Figure 10 are the responsibility of NZTA and central Government. Unfortunately most of the decisions on the road lighting assets that relate to these injuries are made by Road Controlling Authorities (RCA) not NZTA (with the exception of State Highways). RCAs are driven to save ratepayer funds and do not have as strong driver to reduce economic impacts due to injuries and deaths as do central Government and NZTA. This misalignment of governance drivers provides another reason for centralising street lighting governance.

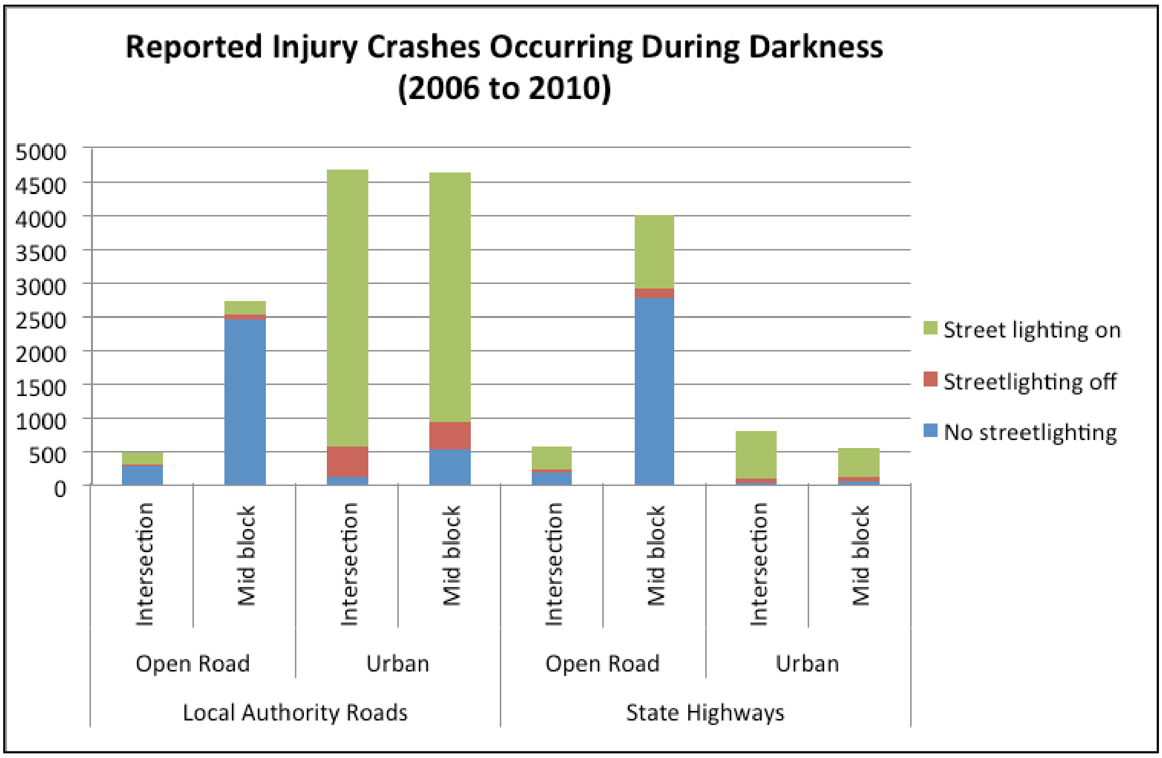

Figure 10 Reported Injury Crashes During Darkness 2006–10 (Source: NZTA[47])

112. Ideally a Road Illumination Strategy will establish how many kilometres of roading fall into each category of illumination (P4 being the lowest and V1 being the highest). As Jackett and Frith[50] identify "*there is an established international relationship (eg Scott 1980) between the level of lighting and the night time crash frequency. Higher light levels produce fewer night time crashes.* Current research *by* Jackett and Frith for NZTA may soon establish this relationship specifically for New Zealand.

49 Merrifield, A.L.R, *Review of Street Lighting*, Land Transport New Zealand, November 2007, as extrapolated from a sample of 20 Road Controlling Authorities, page 36.

50 Jackett, M., W, in written contributions for earlier drafts of this report, January 2012.

113. Hamilton City Council has begun to relate accidents to the illumination levels measured by Odyssey Energy's Lux Mapping service[51]. If this research establishes a relationship between lighting illumination levels and frequency (or severity) of accidents, it will be of international significance. More importantly, it could help guide increased road lighting efficacy, increased energy efficiency and reduced accidents and injuries. This new Lux Mapping technology is examined in more detail in Section 7.3 *Opportunities for innovation and economic development.*

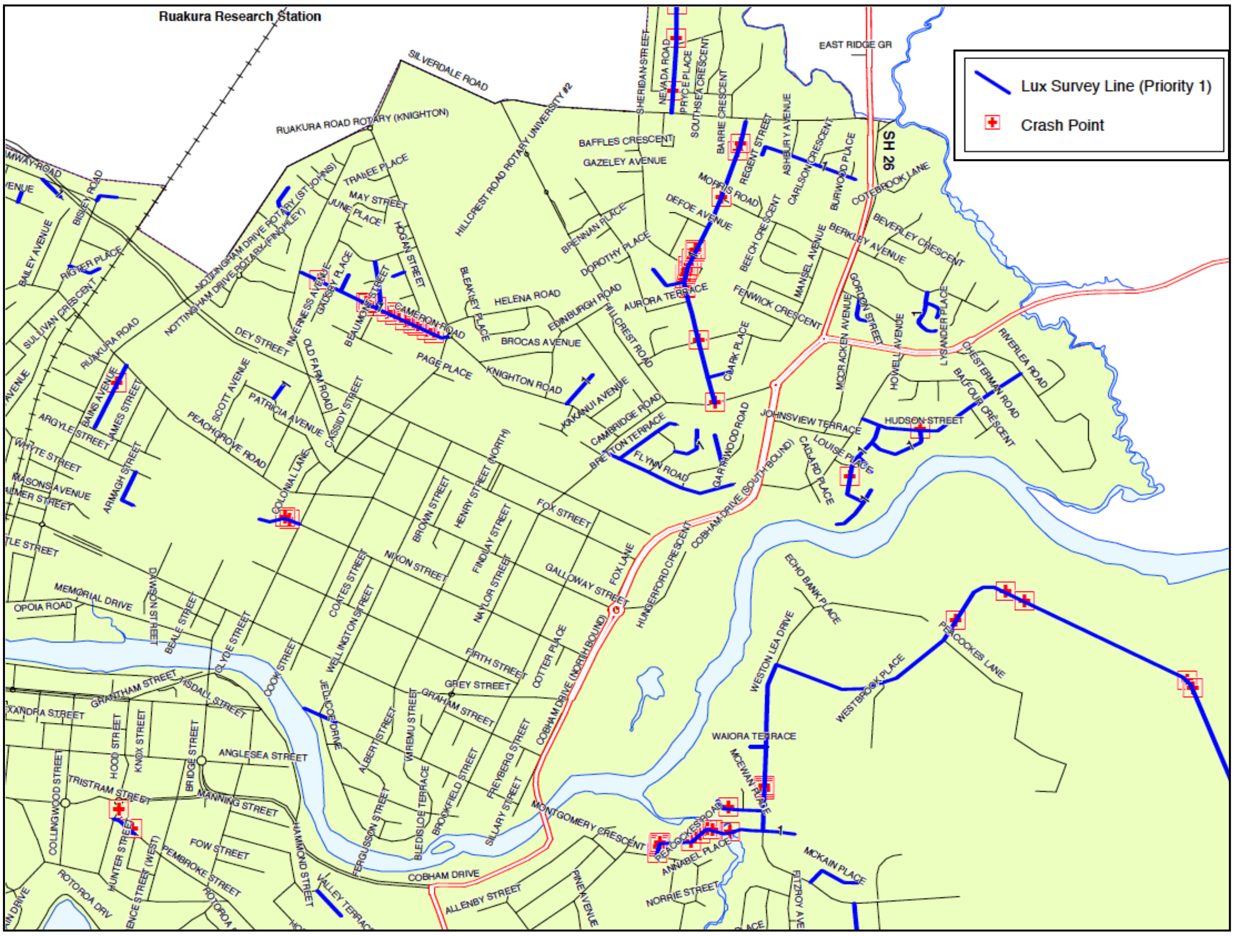

Figure 11 Hamilton City Council mapping of night time accidents and street lighting illumination levels (Source: Hamilton City Council[51])

114. It would also be interesting to relate crime statistics in New Zealand to street lighting. NZTA should be considering crime as a transport objective is to encourage use of public transport, walking and cycling. These are all vulnerable users at night. Thus researching the relationship between lighting, criminal activity and perceptions of security, is an area that would benefit from a "whole of Government" integration between the Police, Ministry of Transport and NZTA.

Comparison between Australia and New Zealand injury statistics

115. In Australia the proportion of white lighting is 47%, made up of Mercury Vapour (43%), Metal Halide and Fluorescent technologies[16] (4%). As previously mentioned, in NZ only 21% of road lighting is estimated to be white. According to a report by the Australian Government[52] in 2006-07, Australia's injury rate from land transport was 157 people per 100,000 population. In the same year, New Zealand's was more than twice this rate at 367 injuries

[51] E-mail from Phil Consedine, City Transportation Unit Manager, Hamilton City Council, 29/3/2012.

[52] "*Serious injury due to land transport accidents, Australia, 2006–07*" Australian Institute of Health & Welfare, December 2009.

per 100,000 population[15]. A valid question to be investigated is whether there is a relationship between white or yellow road lighting and road injury statistics in New Zealand.

13.10 The Impact of Road Surface Reflectance on Lighting

116. Another important component of road illumination is the reflectance of the road surface, a factor which is normally accounted for in lighting design for main (not residential) roads. Research conducted in New Zealand by Opus International Consultants for NZTA in 2009[53] concludes "*The average value found for [reflectance parameter] Qo (0.050) is 44% lower than the value currently used in design. This difference is substantial and suggests that our roads are being lit to a rather lower level of average brightness than had previously been anticipated.*"

117. The authors observe "*Road lighting for safety in New Zealand is based on the Australian and New Zealand standards AS/NZS 1158.1.1:2005 and AS/NZS 1158.2:2005. These standards provide instructions to lighting engineers for designing lighting installations, using tables of pavement reflectance provided by the international body on lighting, Commission Internationale de l'Eclairage (CIE). The tables can be adjusted for local use if the reflection parameters Qo and S1 are known. The New Zealand tables are based on local measurements made by Nicholas and Stevens in 1982*"

118. Jackett and Frith continue: "*Efficient use of resources requires a detailed knowledge of the reflection properties of the road surface so that the specified road surface luminance is achieved with the minimum amount of light*".

119. In the Executive Summary[53] they also observe … "*using the misaligned r-tables currently specified doesn't just mean that our pavements*[54] *are less well-lit than previously thought – it also means that motorists are subjected to higher levels of glare than was intended. New Zealand glare levels are already high compared to CIE recommendations, and the increasing age of the driving population draws attention to the need to reduce the effects of glare in road lighting installations. Older drivers suffer greater impairment from glare than younger drivers*."

120. Clearly the conclusions of the NZTA Opus report are that the AS/NZS 1158 Standard for road lighting is not being applied properly to New Zealand conditions – for ***all*** established lighting technologies, let alone new ones – and that our road lighting could therefore be universally substandard. Substandard road lighting and higher accident statistics in New Zealand compared with Australia may not be mere coincidence.

13.11 Recommendations

121. **That** the Ministry of Transport (MoT) and the NZ Transport Agency (NZTA) establish a targeted programme with strategies to reduce road transport injuries during the hours of darkness (which in 2010 were 4,567 or 31.7% of total accidents[15]) and improve other amenity values such as security, and tourism values. This programme should closely integrate and seek synergies with the issues identified above and opportunities identified in the next two sections to ***improve value for money*** (***Sections 88 and 6***) and increase ***economic development*** (***Section 7***) through street lighting.

122. **That** Opus's recommendations in the NZTA report on road reflectivity[53] be implemented with one alteration:

    f) "[to] *form the basis of a first-principles, safe-system approach review of the processes used in road-safety lighting design in New Zealand. This should review r-tables, luminance levels, uniformity levels, glare levels and direct on-site measurement of lighting parameters, as the technology to do this becomes more accessible*."

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53 Jackett, M. and Frith, W., *Measurement of the reflection properties of road surfaces to improve the safety and sustainability of road lighting*, Opus International Consultants, Lower Hutt, NZ, NZ Transport Agency research report 383, 2009

54 The term "pavement" refers to road surfaces, not footpaths.

g) "*In parallel, an investigation should be made into the relationship between night-time crashes and key technical parameters of road lighting in New Zealand*",

h) "*Ongoing monitoring of road surface reflection properties (including the economics of using pavement brighteners) should be carried out, based on methods developed in this project*."

i) Replace the word "crashes" in b) above by "injury accidents" to include all class of accidents including pedestrians.

123. **That** a Research and Development strategy for road lighting be coordinated across the Ministry of Science and Innovation (MSI), the Ministry of Transport (MoT), NZTA, the Ministry of Economic Development (MED), the Health Research Council (HRC) and the Tertiary Education Commission (TEC) to provide a whole-of-Government approach to:

a) Facilitate the above recommendations; and

b) Discover whether NZ innovations can result in a decrease in road accidents during the hours of darkness. This recommendation is strongly supported by observations made in subsequent sections on ***value for money*** and ***economic development;***

5 Increasing Value for Money – New Generation Technologies

13.1 Introduction

Road Maintenance Task Force 2011

124. In its press release of 26th July 2011 shown in *Error! Reference source not found.* the Government announced the establishment of a Road Maintenance Task Force "*to drive value for money and seek opportunities to reduce costs for roading authorities around the country. Transport Minister Steven Joyce says the taskforce has been set up alongside the new Government Policy Statement on Land Transport Funding to encourage initiatives in the road maintenance and renewals area that save money without sacrificing quality*"

125. The Road Maintenance Task Force terms of reference (Appendix 2) states that "Funding from the National Land Transport Programme is allocated for the operation, maintenance and renewal of both local roads and state highways. The levels of funding for these activities are set with the aim of ensuring the asset condition is maintained to achieve target levels of service, while at the same time providing funding pressure to realise efficiency gains."

126. "*Anecdotal evidence suggests there are opportunities to create greater efficiencies, for example by fostering an environment that supports using innovative products, alternative methods of procurement, sharing best practice and standardising contract documentation*."

127. A focus on road lighting is one such opportunity, in fact validating the above paragraph. Road lighting appears to provide valuable un-tapped opportunities to meet <u>all</u> the Task Force objectives outlined in Appendix 2.

128. This study was initiated because there are two strategic trends occurring worldwide which appear to have significant 'value for money' consequences for NZ road lighting. The first is the development of LED lighting technologies (and associated controls) is being described as a revolution in lighting technology for reasons of energy efficiency, reduced maintenance, flexibility and safety. The second trend is that the public sector in New Zealand (and worldwide) is keen to engage with the private sector more deeply to strengthen public good outcomes (and of course value for money).

The Economic Opportunity

129. NZTA figures (shown in Appendix 11) establish that in 2006/07 NZTA together with Territorial Authorities (TAs) spent $45.3 million on "Carriageway Lighting". This includes both maintenance and electricity costs. The figures do not separate electricity from maintenance costs although New Zealand Local Government Street Lighting Technology supplement[55] suggests in 2008 that electricity cost local bodies $18 million per year which appears plausible[56]. Note also that "maintenance" includes several separate identifiable activities: lamp replacement, luminaire cleaning and replacement (a luminaire is the physical and electrical structure that holds the lamp), and fixing or replacing the poles on which the luminaire is mounted.

130. Because this carriageway lighting cost data has not been collected since 2007, an annual inflation figure of 4% per year has been applied to the 2007 data to approximate what the costs are today. These are also shown in Appendix 11 and the total is forecast to be $55 million in 2011/12.

131. New generation road lighting technologies provide opportunities to make substantial savings on annual operations costs at the same time as improving performance. The Clinton Foundation's 2010 Whitepaper *Improving Performance while Reducing Costs and*

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55 *New Zealand Local Government Street Lighting Technology Supplement*, Page 19

56 However, the same figure appears in a June 2011 Powerpoint presentation by Synovate on the Effectiveness of Street Lighting Programme commissioned by EECA, but suggests that this is the cost of electricity to New Zealand so further investigation is necessary.

Greenhouse Gas Emissions[57] suggests that 50% savings are possible and quote two programmes of LED retrofit, one in Anchorage, Alaska where 4,650 LED street lights were installed in 2008 and energy savings were observed of 45% to 58% over High Pressure Sodium lamps.

132. The second programme was in Los Angeles where 140,000 HPS street lights (equivalent to about 42% of New Zealand's total street lighting, if NZ estimates are correct[55]) were being replaced starting in 2009. In July 2011 the Clinton Foundation undertook a 2nd report focussed on the Los Angeles LED retrofit[58] (see Appendix 9) saying it is ***"the largest LED street lighting retrofit ever undertaken globally***" to date and it is rich with information and hard data.

133. In the Clinton Foundation's Los Angeles report the authors say "*As of July 2011, the city has installed 51,035 LED street lights, achieving energy savings of 59 percent, reducing CO2e*[59] *emissions by 12,560 metric tons annually, and cutting utility costs by $1.9 million annually. Feedback from the community, including residents, politicians, and law enforcement officials, has also been positive. This new data strengthens the business case for the project and provides a roadmap for other cities to develop similar projects around the world."*

Technology Sea Change

134. The first lighting technology to be developed was the incandescent lamp invented by Edison in 1870. The two subsequent technologies were fluorescent lamps in the 1920s, high intensity discharge lamps in the 30s (including High Pressure Sodium lamps in the 60s). The most recent technology is Light Emitting Diodes or LEDs. Figure 12 shows magnified diagram of what a typical LED light looks like and a very simplified view of how its made.

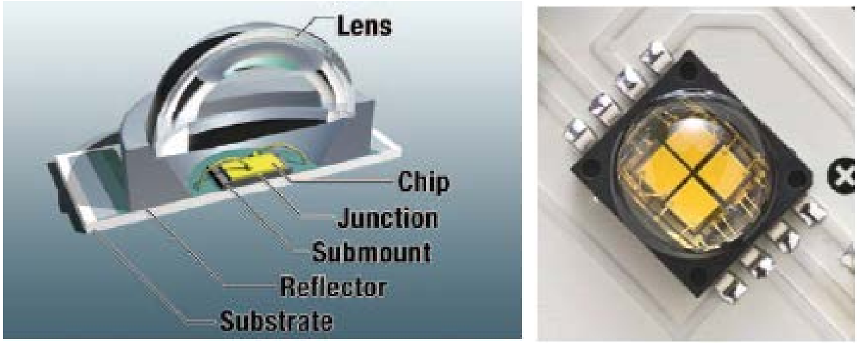

Figure 12 Diagram & photo of Light Emitting Diode (LED) (Source: CREE, DOE)

135. LEDs were invented by NASA in 1962 as low power sources of light for control panel status indication. More recently they have been developed for high power applications in vehicle lighting and road lighting. The physics on which LEDs are based is fundamentally very different to the three lighting generations before it. 0 is a plain(ish) english description of the relevant street lighting technologies extracted from the Clinton Foundation's 2010 White Paper[27].

136. (Note that in this report - a strategy document not an engineering one - "LED" and "LED technologies" are loosely used to describe new generation technologies that have LED-like characteristics and applications - see 0).

137. Among the variety of benefits available from LED lighting, is the ability to integrate closely with computers to illumination levels (the industry calls this "dimmable") to match usage, reduced maintenance through improved longevity, reduce lighting pollution due to its physical characteristics, instant illumination when power is applied, reduced toxic material pollution at

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57 *Street Lighting Retrofit Projects: Improving Performance while Reducing Costs and Greenhouse Gas Emissions*, Clinton Climate Initiative, Clinton Foundation, June 2010.

58 *City of Los Angeles: LED Street Lighting Case Study*, C40 Cities Climate Leadership Group, Clinton Climate Initiative, Clinton Foundation, July 2011

59 CO2e is Carbon Dioxide equivalent

end-of-life, reduced energy usage and a lower carbon footprint[60]. As the international management consultancy McKinsey & Company said in 2011 about LED technologies[61] "*This totally different technology for emitting light is upending the role of the replacement business and transforming the landscape of the lighting industry value chain entirely* …"

13.2 New Generation Technology

138. LED street lighting provides the following potential benefits quoted from the Clinton Foundation's paper[62]:

a) *Energy savings with potential for 50 percent savings over high-pressure sodium;*

b) *Long fixture[63] life with fixtures rated at greater than 50,000 hours operation until end-of-life, defined as less than 70 percent of original lumen output;*

c) *Instant on/off;*

d) *Ability to integrate dynamic controls;*

e) *Directional light emission that allows, with the proper optics, highly efficient fixtures;*

f) *Improved color rendition, often over 70 CRI;*

g) *Potential for enhanced visibility due to its broader spectral distribution (white light).*

139. These seven advantages are substantial and each warrant further discussion. Note that the sample of commercial products provided below are predominantly sourced from Philips, GE and BetaLED/CREE due to lack of time available to research other examples from the other world leading companies like Schreder and Sylvania etc. It is important that readers of this paper understand that its purpose is not about choosing a particular product.

Energy Savings

140. The first observation that LED street lighting saves 50% of energy when compared to HPS lights is likely to be conservative. After installing 51,035 luminaires Los Angeles City is saving 59%. Savings quoted by other studies are significantly higher than this especially when including the other benefits of longer life, lower maintenance and dynamic controls.

141. For example, in a press release at a recent UN Climate Change Conference South Africa, Philips challenged the conference by claiming that[64]. "*A full switch to the latest energy-efficient LED lighting combined with smart control and management systems could provide very significant energy savings of up to 80% in many applications*." and "*that a tipping point has been reached in the development of LED lighting that can now be used for general high-quality lighting in almost all applications*"

142. Similar claims are made elsewhere in many places on the internet by firms as large and credible as Philips. Commercial marketing material by the multinational LED manufacturers supports this and Figure 13 is a case study for tunnel lighting provided by GE for its LED luminaires claiming a 4 year payback and significant numerical information to compare against New Zealand figures.

143. Another less quantifiable source of energy saving from LED technologies is the reduced need to over-light roads to compensate for the light reduction or "depreciation" that occurs in HPS lamps over time. Current practice is to replace HID lamps when they reach 70% of their luminous output. To lengthen the time before replacement, street lighting is designed to be

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[60] Though of course NZ's electricity carbon footprint is smaller than most with its average 70% renewable generation content

[61] *Lighting the Way: Perspectives on the global lighting market*, McKinsey & Company, July 2011, Page 18.

[62] *Street Lighting Retrofit Projects: Improving Performance while Reducing Costs and Greenhouse Gas Emissions*, Clinton Climate Initiative, Clinton Foundation, June 2010, Page 9

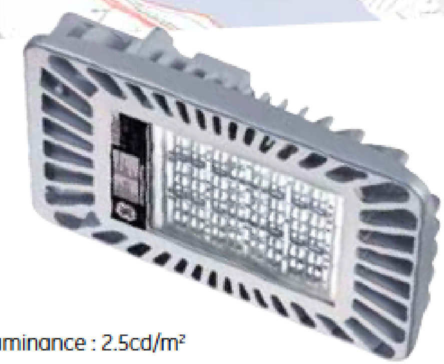
[63] A "fixture" is US terminology for a "luminaire"

[64] Harry Verhaar, Senior Director for energy and climate change at Philips Lighting, UN Climate Change Conference in Durban, South Africa, 5 December 2011. http://ledsmagazine.com/press/33737

over illuminated at the start – thus wasting energy but lengthening the time before its replacement.

144. Because LED lumen depreciation is at a significantly lower rate than it is for HID lamps, it takes a much longer time (between a factor of 1.5 and 3 times) for the 70% lumen output to be reached for LEDs and therefore there is less need to overlight LEDs at the start. In fact the situation is better than this. Because LED lighting can also be dimmed by more than HID lamps, and become more efficient as they are dimmed (in contrast to HID lamps which can only be dimmed by up to 75% and then become much less efficient) LED street lighting can start dimmed and gradually be less dimmed over time to compensate for lumen depreciation.

145. The net effect of all of this is less wasted energy, lower light pollution, less maintenance cost, more constant lighting, and longer luminaire life.



Case study: urban tunnel

Lighting parameters

- 60km/h speed
- Length 1000m
- Follow European standard requirements (CIE 88 2004)
- Required luminance : 2.5cd/m²
- Required Uo: 0.4
- Required Ul: 0.6

	System consumption [W]	Lane	Width [m]	Fixture Spacing [m]	Height [m]	Luminance [cd/m²]	UL	%Ti	Eav (lx)	Uo	S [m²]	Lux/ [W/m²]
Tunnel LED symmetric	95	2	8	7.5	5.5	2.96	0.87	11.83	43.33	0.67	60	27.37
PFE-400/SYM HPS150	170					4.19	0.9	4.86	80.79	0.78	60	28.35

Measuring the savings

System life comparison			
Light source	HPS	T5	Tunnel LED
Lumen / watt	110	86	100
Lamp life [h]	28,500	36,000	50,000
Relamping hours	20,000	36,000	0
LPD (W/m²)			
Site wattage [W]	17,100	16,823	12,667
Energy cost @ €0.11/kWh	16,447	16,210	12,205
Lifetime site energy cost [€]	207,252	203,899	153,520
Maintenance			
Maintenance cost/luminaire/year [€]	70	50	15
Annual site maintenance cost [€]	7000	16666	2000
Total site maintenance cost	88,045	209,631	25,155
Lifetime calculation			
Lifetime maintenance cost [€]	88,045	209,631	25,155
Lifetime energy cost [€]	207,252	230,899	153,520
Total cost of ownership [€]	295,298	413,531	178,676

LED photometry means:

- Fewer lumens to meet the requirements
- Improved uniformity on the road and reduced hot spots on the walls
- Reduced site wattage
- Payback in less than 4 years

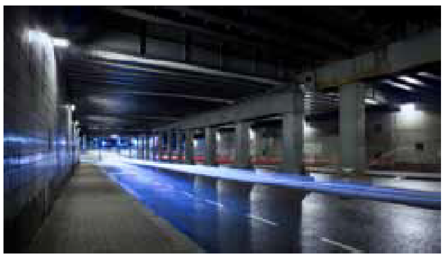


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Figure 13 GE Road Tunnel LED installation Case Study with 4 year payback

Long life & low maintenance

146. LED road lighting luminaires are on the market with specifications of 70,000 to 100,000 hours life[65] (16 years @ 12hrs/day), compared to High Pressure Sodium lamps which are considered to have a maximum life of 24,000 hours (5.5 years @ 12hrs/day) and higher specification one achieve 40,000 hrs (9 years)[26]. The cost of replacing a single lamp in New Zealand ranges from $3,000 on busy motorways where expensive traffic management is required, down to perhaps $400 in a quiet town[66].

147. Naturally, the number of lamps being replaced at a time has a large bearing on the unit cost or lamp replacement. With ever increasing costs of traffic management and OSH[67] related costs, the saving in maintenance frequency equates to a very substantial amount in any maintenance budget.

148. Increased lamp longevity is a substantial benefit but current NZTA selection guidelines appear to heavily weight the procurement decision on up front costs rather than life cycle cost of ownership. This should be further investigated as NZTA's own procurement manual requires consideration of lifetime costs[68].

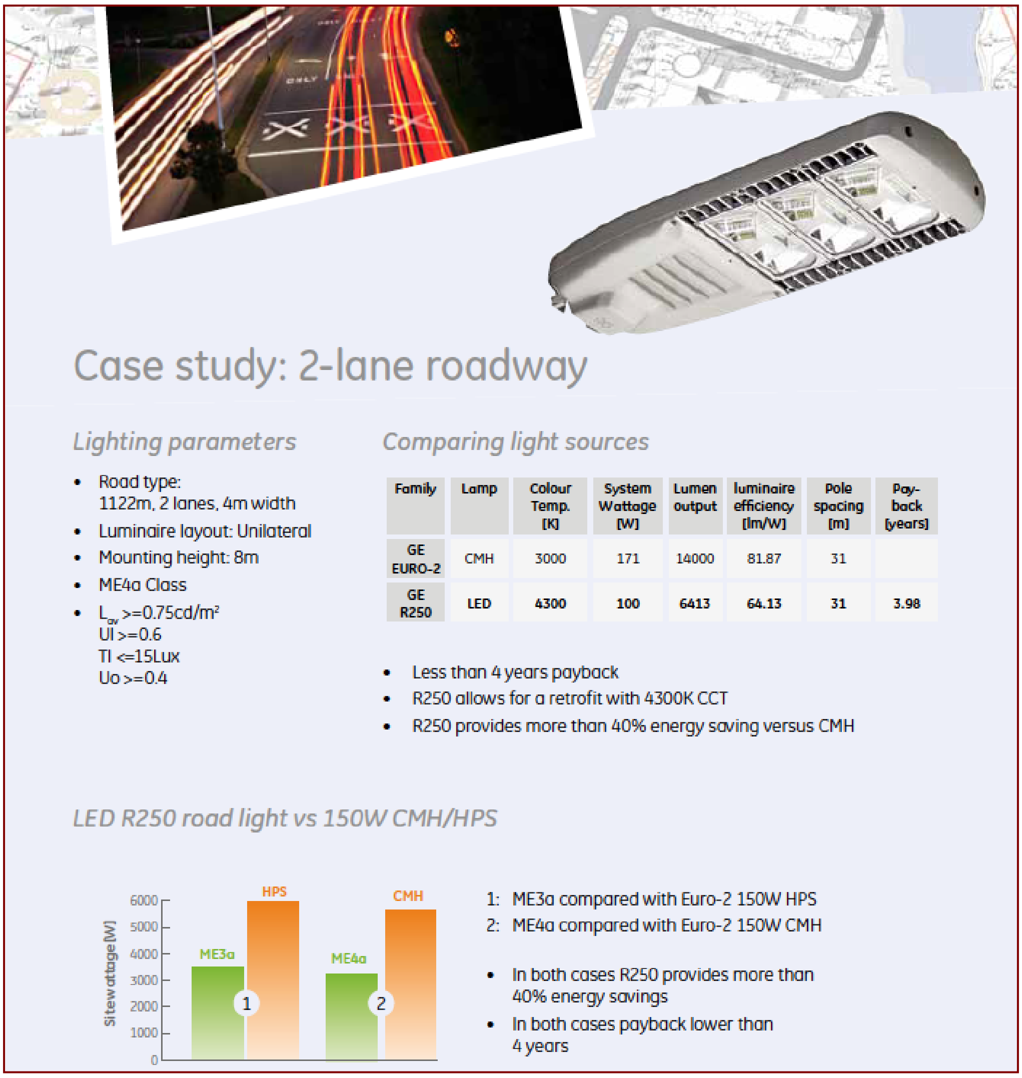

Figure 14 GE LED Case study with less than a 4 year payback

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65 Philips Roadstar Series see http://www.lumec.com/products/luminaires/serie_roadstar.html?A

66 Provided by one of the people consulted in *Error! Reference source not found.*

67 Occupational Safety and Health

68 *Procurement Manual for activities funded through the National Land Transport Programme*, NZTA 2009

149. Both Figure 13 and Figure 14 from GE (formerly known as General Electric) marketing material provide useful examples of the economic returns available from the use of the LED road lighting on roads and tunnels although some economic externality costs are not included. For example, including the avoided cost of toxic Mercury environmental damage and/or the cost of greenhouse gas avoidance would improve the payback shown.

150. Another important technical characteristic of all lighting is the reduction of light output (in lumens) that lamps undergo as they get older. This effect has been studied in great detail and is well understood for the older HID technologies (HPS. LPS, MV) that have been around for several decades. The industry calls it “lumen depreciation” or “Lumen Maintenance” (the reciprocal of depreciation). Figure 15 shows an example of lumen depreciation over time for GE’s latest HPS lamp product, CMH Streetwise which has a lifetime of 22,000 hours at the 70% lumen output level (called LM70 by the industry). This is understood to be the “state-of-art” for HPS lamps.

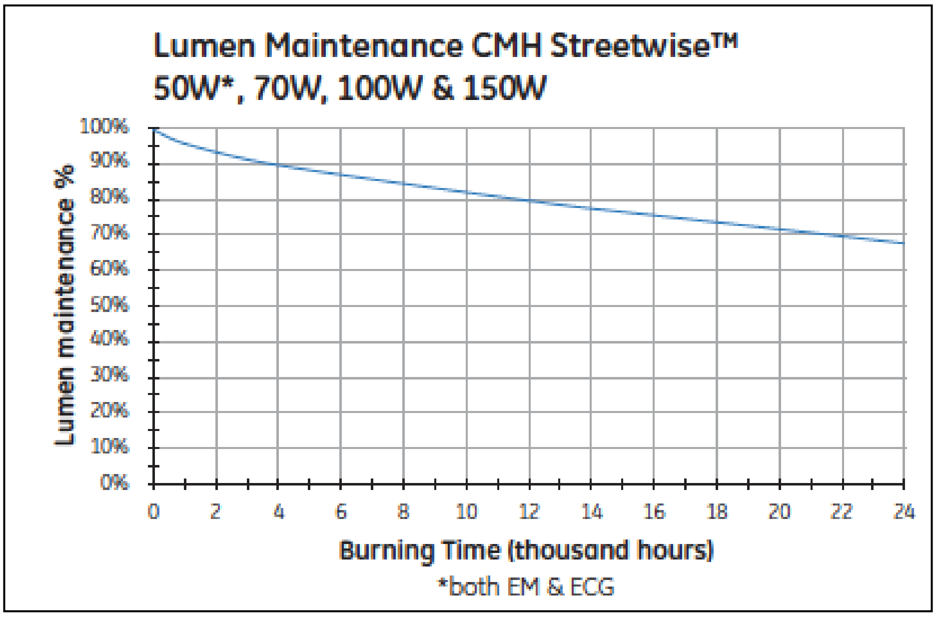


Figure 15 Lumen Maintenance for most recent HPS lamp competing with Philips Cosmopolis (Source: GE 2012[69])

151. LEDs are a relatively new technology that hasn’t been around for much longer than half the lifetimes being predicted. However, credible manufacturers confidently predict this lumen depreciation by robust scientific laboratory tests which are certified by independent organisations. This poses a credibility barrier to traditional public service engineers who have not been exposed to the sophistication of semiconductor electronics and treat such predictions with understandable suspicion. The situation is of course exacerbated by the wide availability of Chinese LED manufacturers of widely ranging credibility. This is another compelling reason to choose credible multinational suppliers.

152. Figure 16 shows an equivalent LED Lumen depreciation (or lumen maintenance) graph published by RUUD in 2010 (before they were purchased by CREE). Because LEDs are very sensitive to ambient temperature, the lumen maintenance needs to be provided for different temperatures. Figure 16 shows that at average ambient night time temperature of 35 °C (somewhere in the tropics) the BetaLED 350mA[70] product is expected to last for 90,000 hrs at the 70% level. In cooler climates this it is expected to last much longer.

[69] E-mail Craig Palmer, National Business Manager, GE Home & Business Solutions – Lighting, 3 April 2012.

[70] The drive current measured in milli Amps (one thousandth of an Amp) relates to the amount of current the LED was designed/selected to accommodate and because the voltage is held constant, is the main indicator of power at the LED semiconductor level.

153. Note however, as mentioned above that these were forecasts made in 2010 and more recent figures for CREE are provided in Appendix 18 where the information is provided in a different format and was published early 2012. At 25 °C a 350ma drive lamp has an output of 82% of its initial lumen output at 100,000 hrs.

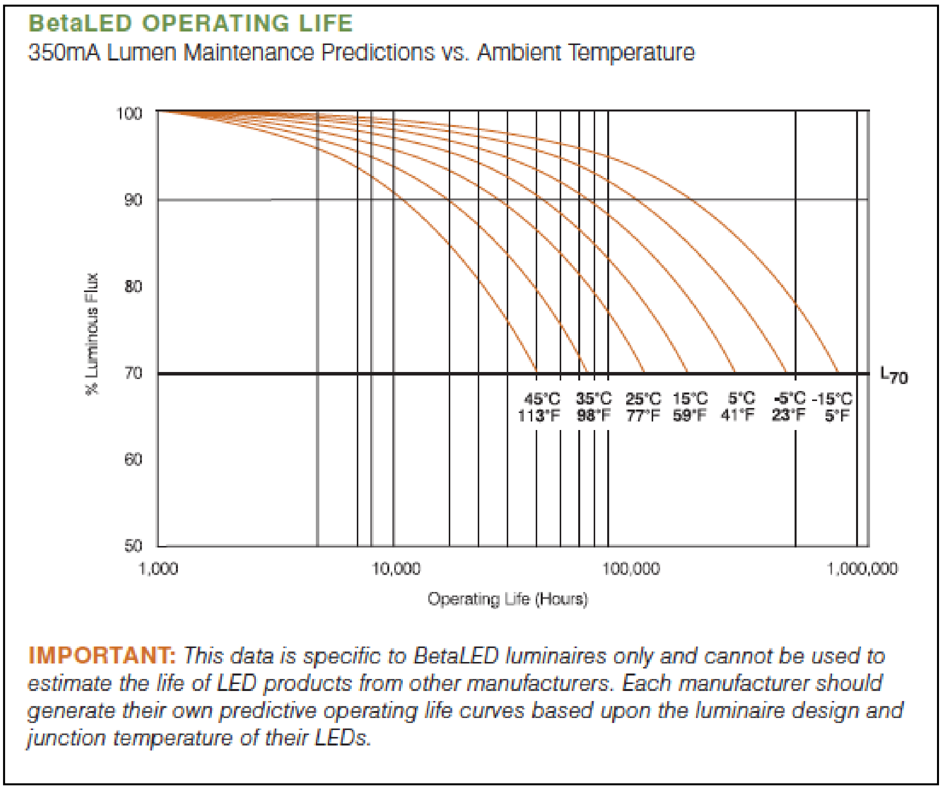


Figure 16 Lumen Depreciation and Operating life is significantly affected by ambient night time temperatures (Source: RUUD 2010)

Directional light emission

154. The LED can be designed to optically shape and control the resultant light with far greater precision and flexibility than the older technologies. Incandescent, fluorescent and HID[71] sources usually require an external reflector to collect and direct light to where its required. The extra mechanical components for this require trade-offs.

155. In contrast, LEDs allow luminaire designers to greatly improve the applicability of the luminaire to control light spill, waste light and the resultant light pollution. Some of these aspects are illustrated by US LED manufacturer CREE in both Figure 17 and Figure 18.

[71] High Intensity Discharge (HID) lamps are all those that use an electric arc to generate light and include High and Low Pressure Sodium and Mercury Vapour

LED ADVANTAGE #2

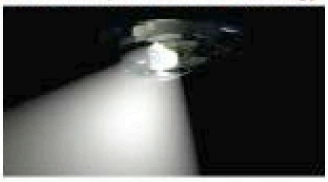
Optical Control

Most light sources, when utilized in luminaires, produce uncontrolled light – resulting in "hot spots" and other discontinuities in the illumination. The elimination of uncontrolled light results in incredible uniformity.

BetaLED luminaires are designed with patented NanoOptic® product technology, which controls the photometric distribution of the LED luminaire. NanoOptic product technology uses precision, injection molded acrylic plastic covers over the LED package. BetaLED luminaires closely match the light distribution achieved with traditional reflectors and with the other light sources in use today. The increased uniformity allows the lighting designer to specify lower average light levels in a layout while maintaining or improving the minimums. **The result: Increased energy savings and a better quality of lighting design.**

Without NanoOptic Product Technology

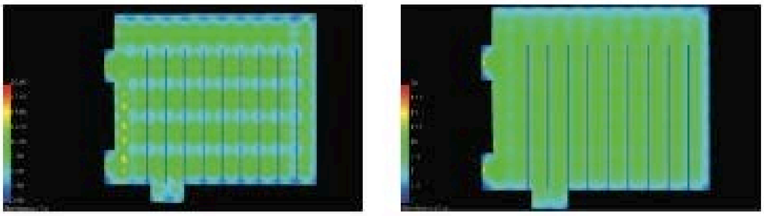
With NanoOptic Product Technology



A computer rendering of the NanoOptic™ altering the original packaged LED's photometric distribution.

APPLICATION COMPARISON

A computer rendering comparing the uniformity of lighting in a parking garage application using metal halide and LED lighting systems.



150W MH Solution		LED Solution		Notes
AVG	7.77 fc	AVG	7.59 fc	Same Level of Illumination
MAX	19.1 fc	MAX	11.6 fc	39% Lower MAX with LED
MIN	1.9 fc	MIN	2.3 fc	21% Higher MIN with LED
MAX/MIN	10:1	MAX/MIN	5:1	Much Improved Uniformity
LLF	0.75 (@ 6,000 Hrs.)	LLF	0.95 (@ 50,000 Hrs.)	Superior Lumen Maintenance for LED
Power	185 Watts	Power	128 Watts	31% Energy Savings for LED

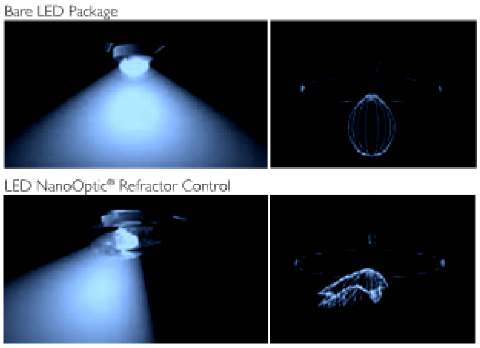
Figure 17 Comparison between photometrics of HPS and LED lamps (Source: CREE 2010 Brochure)

NanoOptic® Technology

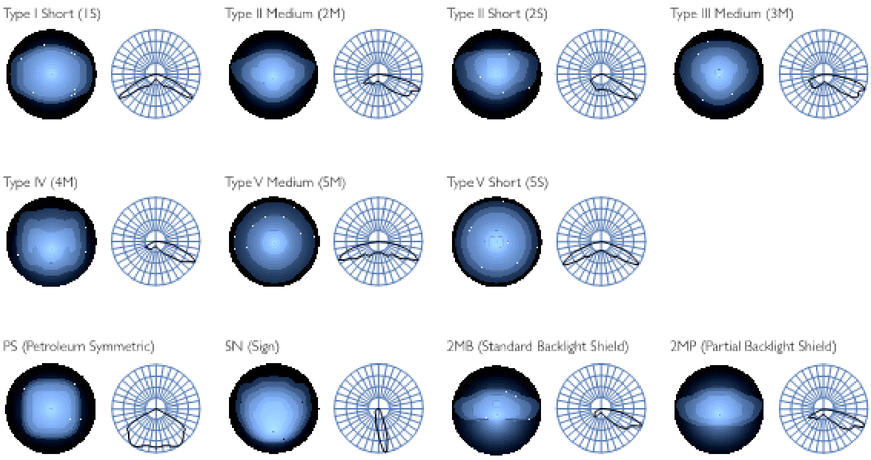
8 | 9

Over 20 Optic Choices for the Flexibility You Need

Traditional luminaire technologies offered limited choices when it came to optical selections. BetaLED changed that with patented NanoOptic® product technology; highly efficient optics available in more than 20 distributions. BetaLED's wide range of NanoOptics provide new possibilities for highly optimized target illumination performance and the flexibility you need to achieve the specific illumination requirements for each unique application.

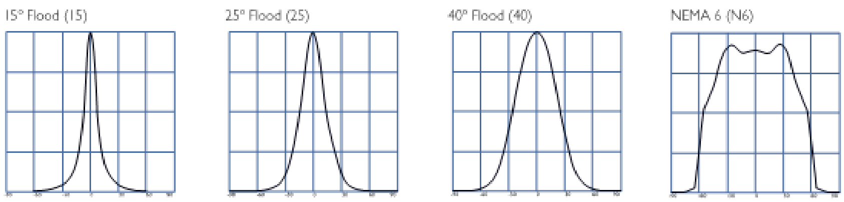


Examples of NanoOptic distributions are depicted below.



The NanoOptic refractor system provides superior light control with:

- More lumens delivered in the target area
- Improved uniformity ratios
- Controlled high angle brightness
- Over 20 optical distribution patterns to choose from



A graphic representation illustrates the LED optical fine tuning range that BetaLED luminaires can provide. The gray area represents Type II Short optic coverage. The Short optic can be utilized to comply with more stringent light spill and high angle brightness specifications or codes by incorporating a lower main beam. The extended blue area indicates the Type II Medium optic coverage. The Medium optic incorporates a slightly higher main beam to allow wider, more economical pole spacing.

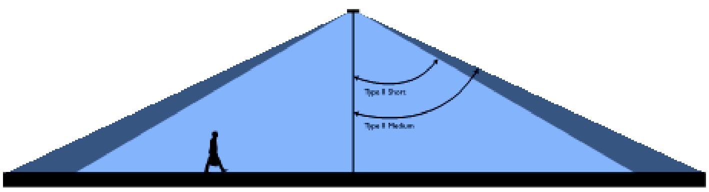


Figure 18 Illustration of wide range of optic distribution patterns available for LED luminaires (Source: CREE 2010 Brochure)

Instant on/off

156. In contrast to HPS lamps which can take 5 -15 minutes to stabilise luminant output[72], LEDs activate and light up instantly, achieving full brightness in microseconds. LEDs are very suited for use in applications that are subject to frequent on-off cycling, unlike fluorescent lamps that fail more quickly when cycled frequently, or HPS lamps that require a long cool-off time before restarting. Thus LED's are very well suited for applications requiring and/or accommodating variable light levels or time based control (thus saving energy and minimising light pollution).

Ability to integrate with dynamic controls

157. The instant-on feature is a characteristic of the fact that LEDs are semiconductor diodes which have had a place in electronics and computers for several decades to let current flow in one direction, but **L**ight **E**mitting **D**iodes also emit light. They are therefore ideally suited to being managed by Central Management Systems (CMS) which are IT systems that allow designers and operators to optimise road lighting parameters to the priorities set by its owners, and the conditions encountered in the roading system.
158. This is probably the reason LED and the IT systems used to control them, are now referred to as "digital lighting". The benefits available from closely integrating computers and communications (ICT[73]) with road lighting are potentially enormous. The changes taking place in this area will lead to substantial benefits for communities world wide as well as open up many opportunities for innovation and economic development.
159. As one of, if not the world leader in lighting, Philips are aggressively investing in systems that not only control the lights (CMS), but also manage their maintenance and treat them as an important class of assets to manage and govern from top to bottom. No doubt the other multinational lighting companies have recognised this strategic opportunity as well but this study draws on ICT material provided by Philips.
160. Figure 19 shows an excerpt from a Philips brochure promoting a Central Management System and the hardware required. Philips claim that their system can save up to 40% energy by dynamically controlling lighting to suit the client and the conditions. These savings are of course on top of the LED efficiency savings identified above (and could also be made with other non-LED technologies that were CMS friendly).
161. Figure 20 shows another excerpt from the same brochure which shows other maintenance savings that the CMS can make. The use of CMS systems enables accurate and localised switching on/off to dusk/dawn with link to local astronomical clock, as well as dimming, which extends the life of the bulb or LEDs through reduced daily hours of usage. Information from CMS changes maintenance from a reactionary process to a predicative process, reducing spot maintenance or lights not working due to unknown end of life
162. More recent promotion material in Figure 21 shows Philips CityTouch software suite of programs to integrate all road lighting functions together. Figure 22 shows the ability to integrate their system with other manufacturer's CMS and control hardware and Figure 23 provides an example screenshot of their system showing light location and asset details.
163. Figure 28 shows an excerpt from another CMS provider that illustrates some of the inter-relationships between CMS user (the street light operator), the street lights themselves and the end-user.
164. If (when) information relating illumination levels with accidents shown in Figure 11 (Hamilton City Council use of Odyssey Energy's Lux Mapping tool) is imported into asset management systems such as CityTouch, the system will be transformed into from asset management tool

[72] Practitioners suggest that HPS takes 2 minutes to reach 90% of it luminous output, but compared to microseconds this is a long time.

[73] Information and Communications Technology

into one that will improve community amenity by saving lives and injury. As identified in ***Section 7*** this could be an opportunity for NZ economic development.

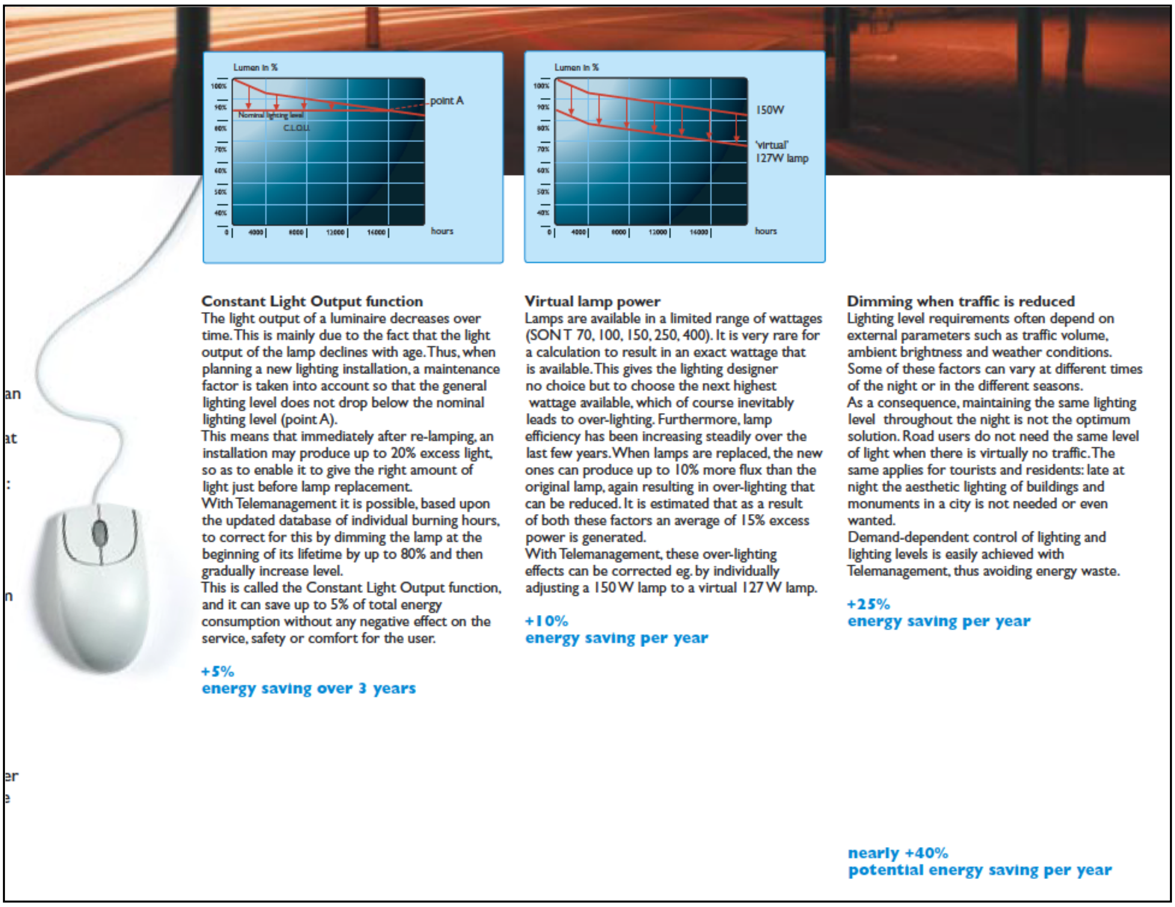
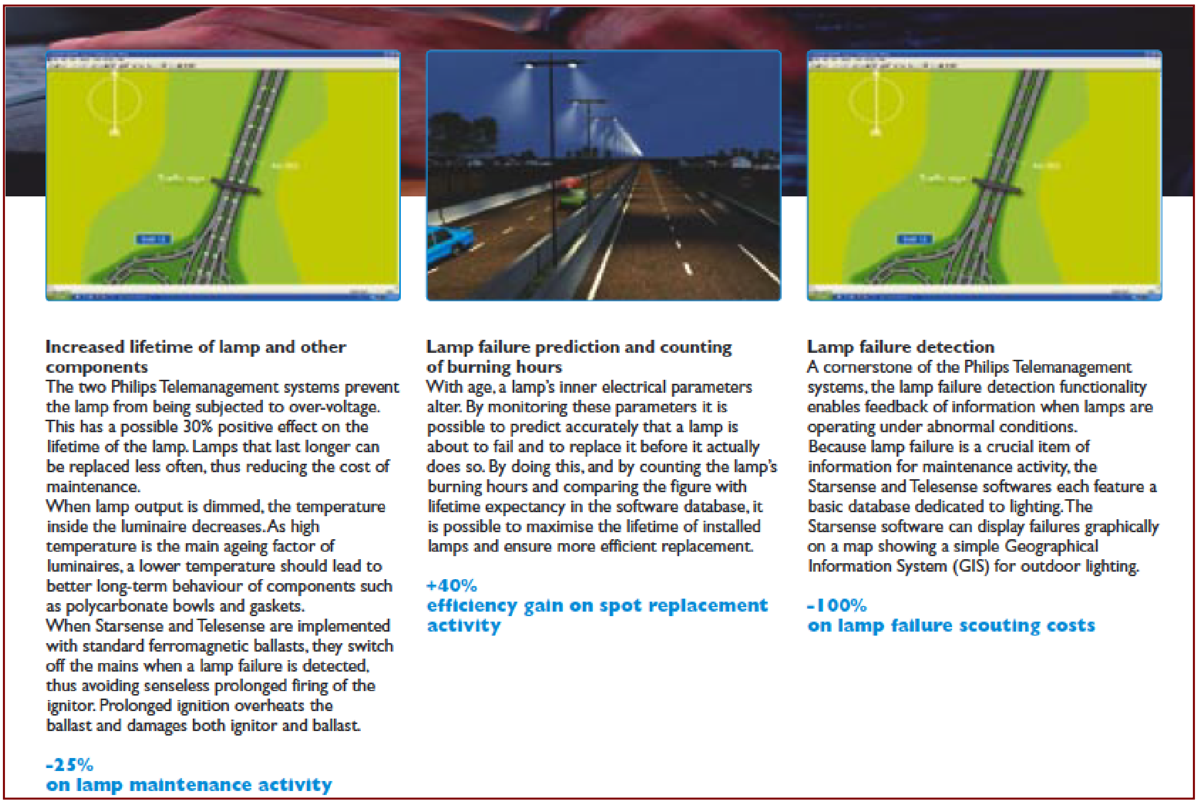


Figure 19 Philips Starsense Central Management System brochure claims to save nearly 40% energy per year (Source: Modus Lighting)



Increased lifetime of lamp and other components
The two Philips Telemanagement systems prevent the lamp from being subjected to over-voltage. This has a possible 30% positive effect on the lifetime of the lamp. Lamps that last longer can be replaced less often, thus reducing the cost of maintenance.
When lamp output is dimmed, the temperature inside the luminaire decreases. As high temperature is the main ageing factor of luminaires, a lower temperature should lead to better long-term behaviour of components such as polycarbonate bowls and gaskets.
When Starsense and Telesense are implemented with standard ferromagnetic ballasts, they switch off the mains when a lamp failure is detected, thus avoiding senseless prolonged firing of the ignitor. Prolonged ignition overheats the ballast and damages both ignitor and ballast.

-25%
on lamp maintenance activity

Lamp failure prediction and counting of burning hours
With age, a lamp's inner electrical parameters alter. By monitoring these parameters it is possible to predict accurately that a lamp is about to fail and to replace it before it actually does so. By doing this, and by counting the lamp's burning hours and comparing the figure with lifetime expectancy in the software database, it is possible to maximise the lifetime of installed lamps and ensure more efficient replacement.

+40%
efficiency gain on spot replacement activity

Lamp failure detection
A cornerstone of the Philips Telemanagement systems, the lamp failure detection functionality enables feedback of information when lamps are operating under abnormal conditions.
Because lamp failure is a crucial item of information for maintenance activity, the Starsense and Telesense softwares each feature a basic database dedicated to lighting. The Starsense software can display failures graphically on a map showing a simple Geographical Information System (GIS) for outdoor lighting.

-100%
on lamp failure scouting costs

Figure 20 Another excerpt of the same brochure showing other savings (Source: Modus Lighting)

Figure 21 New Philips City Touch Lighting Asset Management System (Source: Modus Lighting)

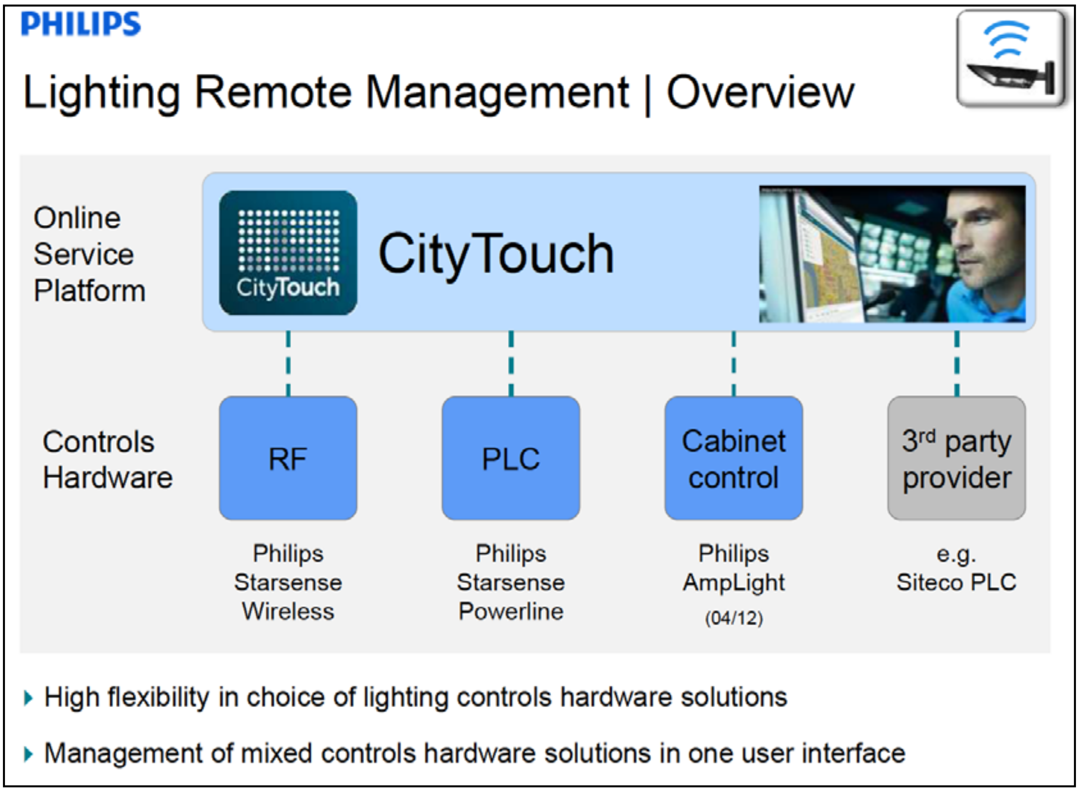


Figure 22 Philips CityTouch system integrates with third party products (Source: Modus Lighting)

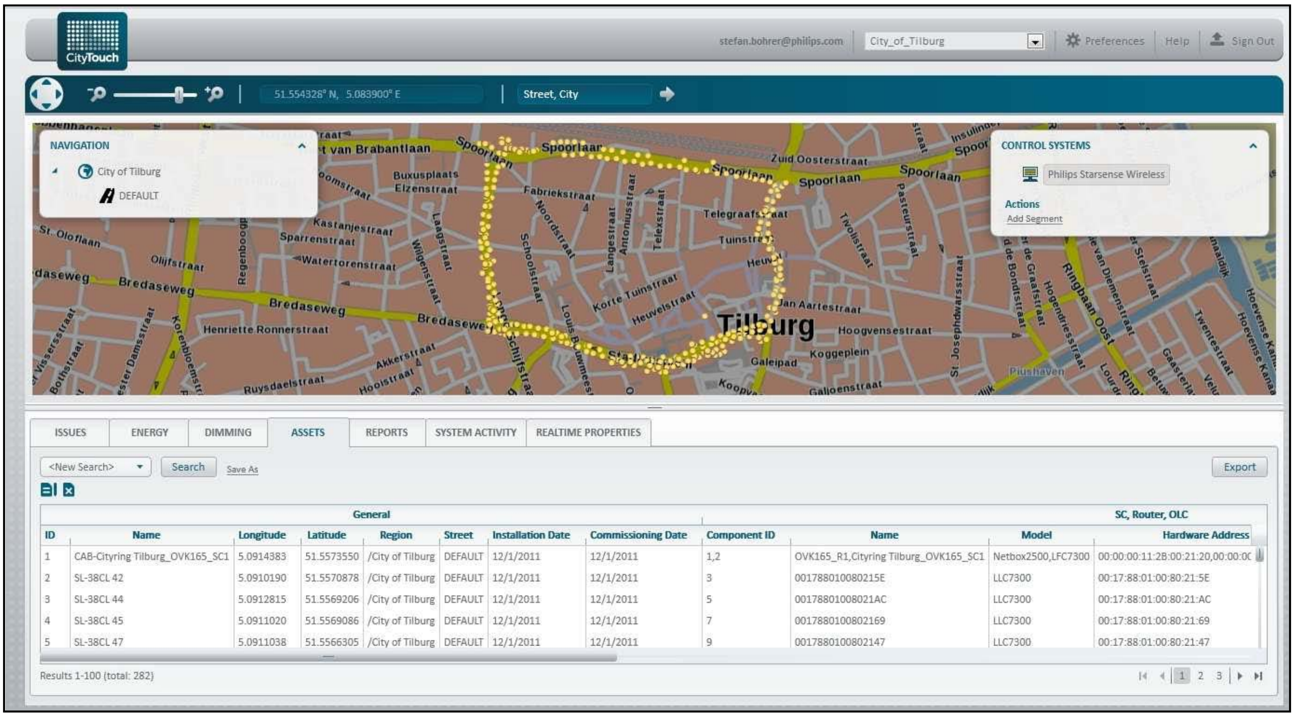


Figure 23 Screenshot from CityTouch (Source: Modus Lighting)

Improved colour rendition

165. In the context of this report Colour Rendition is the ability of a lamp to illuminate objects in a way that their colours appear similar to when illuminated by light sources such as daylight or

the incandescent lamp. ***Colour Rendition Index (CRI)*** is a number calculated from measurements to CIE standards that attempts to objectively quantify that comparison. The subject is fraught with scientific and commercial debate as it appears to prejudice LED lighting. Nevertheless, in general the higher the CRI, the better. For example, an incandescent lamp or daylight will have a CRI of 100 whereas High Pressure Sodium has a CRI of approximately 20 and white LED lights have CRI's that are greater than 60.

166. In contrast but very much linked to colour rendition, is the colour "temperature" of light which is measured in kelvins - also the measure of temperature relative to absolute zero. Lord Kelvin[74] observed that when a "black body" of carbon burned, the colour related to the temperature of the incandescent material burning. A common household incandescent light bulb with its burning tungsten filament emits mostly heat (only 10% of its energy is light) and is therefore very close to an ideal "black body". Hence its colour temperature of between 2,700K and 3,300K indicates the real temperature of the filament[75]. Similarly a match flame has a colour temperature of 1,700K and that of a candle flame is 1,859K[76].

167. In contrast, a compact fluorescent bulb which uses fluorescence, has a colour temperature of 3,000K but operates at a temperature somewhere between 300K and 350K because it is not incandescent (ie it doesn't burn). Colour temperatures of commonly observed phenomena are illustrated in Figure 24.

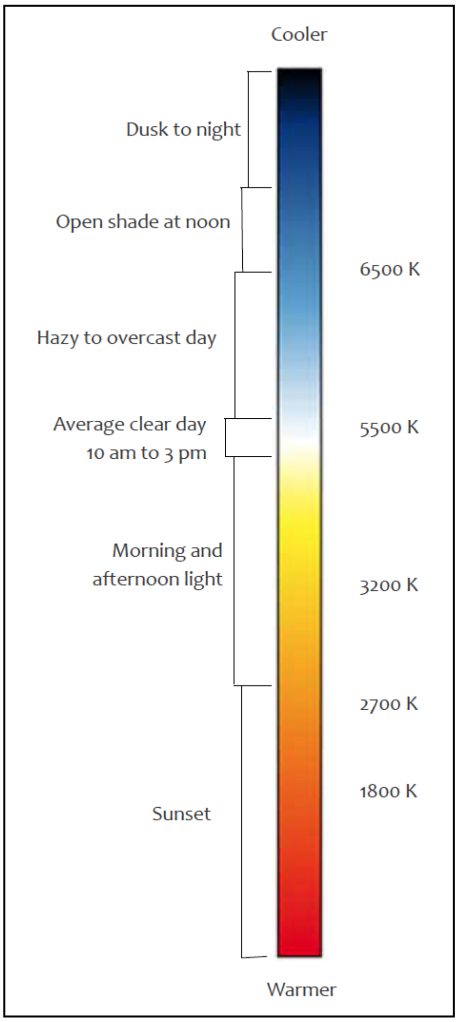


Figure 24 Colour Temperature measured in degrees Kelvin

74 As the measure is named after a person, the symbol for the unit of colour temperature is a capital K.
75 Subtract 273 to give degrees Celcius
76 Wikipedia, see ***http://en.wikipedia.org/wiki/Colour_temperature***

Improved peripheral visibility and reaction times due to white light at low illumination

168. The science of this has been covered in Sections 4.5 - 4.8 but current industry practice is structured to not acknowledge the advantages of white street lighting for three reasons:

a) The substantial change from white to yellow lighting took place a long time ago due to the (then) large economic advantage that High Pressure Sodium lights had over the white Mercury Vapour lams. Thus the highly visible yellow lighting may be considered to be a positive Key Performance Indicator (KPI) since at least 76% of NZ is illuminated with yellow HPS light which is a highly visible KPI;

b) The eye's decreased sensitivity to yellow lighting at low (mesopic and scotopic) illumination levels is now well known but still not fully recognised in Standards. This "modern" knowledge is only crudely applied in AS/NZS 1158 to lighting roads for pedestrian purposes by "derating" to 0.75 of the quoted value of HPS lighting[77] that signals a lighting engineer to simply increase the wattage of HPS lighting only in P3 and P4 category roads by 1.33. CIE guidelines suggest a more sophisticated application depending on the SP ratio outlined in Figure 5 which covers ***all*** categories of road lighting from 0.01 cd/m2 where the "derating" factor difference between HPS and LED cool white is 100% through to V1 category roads (1.5cd/m2) where the difference between the two is 12%. Thus there is a significant lag between NZ and Europe in the understanding and application of white lighting;

c) Current road lighting design leans heavily on the AS/NZS 1158 standard which divides road lighting into four categories (for NZ) for lower level pedestrian lighting (P1 to P4) and four higher level lighting for vehicles (V1 to V4)[78]. The Standard has no objective for Category P road lighting to reduce vehicle traffic accident and injury prevention. This leads to the apparent belief that white lighting is only useful for pedestrian areas, and then mainly because it "looks good".

169. To quote from AS/NZS 1158.3.1.1:2005 Section 2.2 which covers Category P lighting *"The major purposes of the lighting covered in this Standard are to assist pedestrians to orientate themselves and detect potential hazards and to discourage fear of crime"* … "*The lighting may also be used to enhance the prestige and amenity of the location but should be designed to minimize any obtrusive effects*." … "*The lighting, with certain exceptions, is not meant to provide drivers with adequate visibility if motor vehicle traffic is present at the location; for this the vehicle headlights are used. The exceptions are where there is interactive pedestrian and vehicular activity present in designated areas, eg transport interchanges, car parks."*

170. In fact as suggested in sections 4.6 and 4.7, scientific evidence suggests that white lighting at mesopic and scotopic levels of lighting (from 1.5 cd/m^2 down to 0.1 cd/m^2) provides significant benefits to reaction times and peripheral visibility. While this study has not sighted research that relates accident and injuries to lighting colour, it would seem to be highly likely that such a relationship existed.

171. Given that the cost of such benefits are the capital investment which has paybacks ranging from 6 to 9 years[79] (excluding the economic value of safety benefits) plus a number of other offsetting benefits from white LED lighting, it would seem justified to include the benefit of increased reaction time and peripheral visibility as well.

Resistance to vibration and shock damage

172. LEDs, being solid state components, are difficult to damage with external shock and are inherently more vibration resistant than HID light sources. This is an important advantage as

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[77] AS/NZS 1158.3.1.2005 section 2.6

[78] The Standard has an extra category of lighting in each of P and V for Australia, ie P1 to P5 and V1 to V5.

[79] Discussed in Section 6.

High Intensity Discharge (HID) lamps (lams that use electric arcs[80]) are vulnerable to vibration caused by wind and traffic.

Gradual failure

173. LEDs mostly fail via light diminishing over time, rather than by abrupt failure. This provides extra safety for any area illuminated by LEDs. Even if the LEDs diminish over time, the LEDs are unlikely to fail completely.

No Toxic Mercury

174. LEDs do not contain toxic Mercury, unlike all other road lighting technologies, and thus pose less of an environmental risk after disposal.

High Power Factor

175. LED lighting has a better Power Factor than HPS or most other lighting technologies that use transformers or inductors. In order to correct for the lower Power Factor, HID and Fluorescent luminaires incorporate compensating capacitors. These capacitors fail, often without any visible sign (in contrast to lamp failure) so field operatives either don't bother, or save costs by not checking them.
176. The "Power Factor" is important because when it is equal to one, the electricity delivered is the same as that produced. When it is much lower than one (eg HPS lights with failed compensating capacitor) significantly more electrical current is required to be supplied to the luminaire than is actually used. Alternatively one can describe the effect of "low power factor" is that caused by devices having "inductive" loads (for any light that uses a ballast inductor) and thus requiring electric cables larger to carry "useless" current.
177. The consequence is that "low power factor" loads cost the electricity companies more to supply, than those with high power factor, such as LED lighting. Some practitioners have suggested that faulty components in the luminaries[81] result in Power factors of 0.5 which means that 50% more electricity is being generated than is being used. LED lighting needs no additional failure prone compensating capacitors.

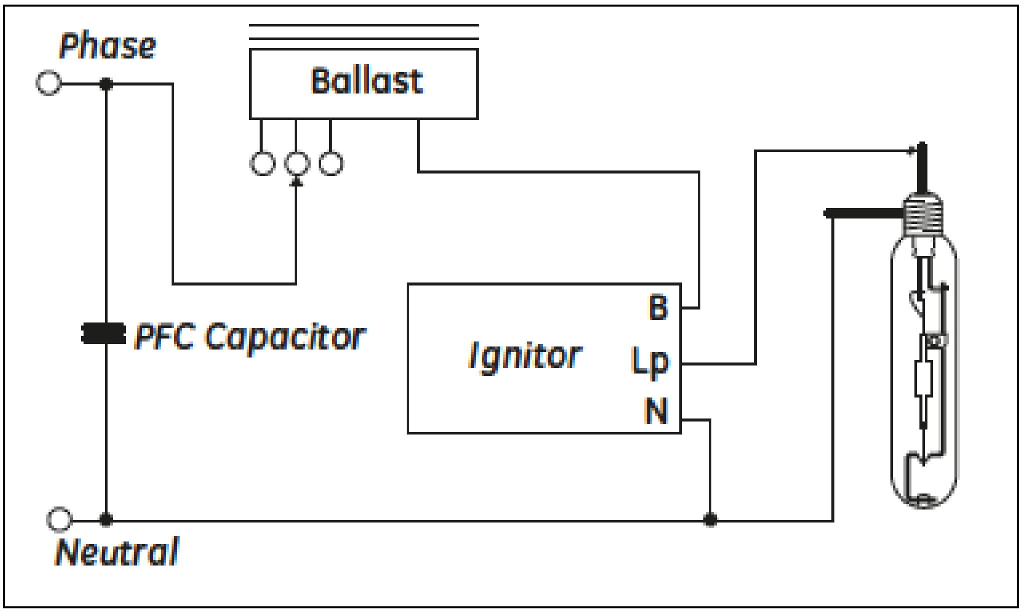

Figure 25 Circuit diagram for an HPS Luminaire showing Power Factor Compensating Capacitor (Source: GE)

80 HID lamps generate light from an electric arc that is formed across ionized gasses.
81 HID lamps are inductive loads so therefore require compensating capacitors which can fail.

13.3 LED Road Lighting in New Zealand

178. Despite these significant advantages, other than the Eden Park lighting conversion done for the Rugby World Cup in 2011, no substantive LED road lighting installations exist in New Zealand at present of any comparable international scale. Although Eden Park does not reflect the scale of international LED installations in volume of luminaires, it certainly does in terms of representing a state-of-art package which ranges from LED luminaire through to a complete computerised lighting management system. Opus, the consultants who designed the installation, stand out as one consultancy firmly in support of the integration of LED and CMS technology.

179. Two of the biggest LED distributors in New Zealand offered to provide their records of the LED luminaires installed in New Zealand and this list is shown in Appendix 19 and the total of all outside LED luminaires is estimated to be about 3,000. This includes car parks, petrol stations, pedestrian walkways and other non-roading infrastructure. It is also estimated that twenty one "trials" are understood to have taken place or been underway[82] by Road Controlling Authorities including NZTA shown in Appendix 14.

180. One of those trials has been installed for NZTA at Drury with 130 LED of 221W to comply with Category V3 of the road lighting standard AS/NZS1158 (when the LED's are at full power). Further details of this trial are provided in Appendix 19. Practitioners suggest that no trial or installations have more than 300 luminaires which therefore compares poorly with international progress.

181. The approach of the NZTA, many of the smaller 'Road Controlling Authorities' (City, District and Regional Authorities) and some consultants can be summed up by the belief that the technology is too early in its lifecycle and thus too risky to implement and in any case a delay of two or three years will bring significant price reductions.

182. But the Clinton Foundation suggests that waiting for price reductions is not economically rational: "*The economics of this decision will depend on each municipality, but analysis suggests that prices would need to fall nearly 15 percent annually for municipalities to recover the energy and maintenance savings lost by delay. Municipalities cannot recover the additional greenhouse gas emissions from a one-year delay, even if fixture efficiency improves by up to 15 percent during that time*."

183. This is corroborated by Figure 26 which shows progress of a major manufacturer, CREE, in reducing the cost of LED lights for the illumination provided (measured in lumens, the SI Unit[83] of luminous power). From the graph it can be seen that from 2012 onwards the decrease in cost per lumen is expected to be relatively small compared to the past 5 years, but still improving (ie decreasing) significantly every year.

184. This observation is also confirmed by the America's Department of Energy (DOE) Solid State Lighting Programme[84] across <u>all</u> US manufacturers. However, because DOE plots the data on a logarithmic scale of $/lumen (to show all historic data and predict the future which spans an enormous range), the graph is linear and provides an initial impression that price is dropping continuously in a straight line. In fact the opposite is true and the DOE graph shown in Appendix 15 confirms the same exponential price drop shown in Figure 26 below. This scientific way of portraying data could be confusing the market. The benefit of waiting for further price reductions is rapidly diminishing.

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[82] Sourced from the discussions with John Birks, General Manager of evolve and Mark Kirkham of Advanced Lighting Technologies (distributor for BetaLED) as identified in *Error! Reference source not found.*. The 21 trials are identified in Appendix 14.

[83] SI Units are the International System of Units

[84] *Solid State Lighting Research & Development: Multi-Year Program Plan*, US Department of Energy, Energy Efficiency & Renewable Energy, Lighting Research and Development Building Technologies Program, April 2012, Figure 3.5, Page 45.

185. On the same subject, in the March 2012 edition of the LEDs Magazine the editor reports on a February conference where a consultant from Strategies Unlimited, Vrinda Bhandarkar, suggests[85] that " *… (her) projections rely on less aggressive estimation of price decline relative to that the DOE had presented. The DOE has used a relative cost index of 100 to represent the cost of an LED lamp or luminaire in 2010. By 2015 the DOE projects a reduction of 80% to a relative index of 80. Bhandarkar expects a more moderate 13-15% decline each year, and that would equate to an index in the range of 38 to 43 by 2015*." Bhandarkar's forecast is therefore just at the point where the Clinton Foundation suggests it becomes economically irrational to wait.

186. Note however, that these pricing debates only consider the offsetting benefits of energy savings, whereas there are several other significant benefits available which are not factored into the pricing discussion. Thus, given the significant time taken to implement any change, it is this study's view that delays in replacing old technologies with the new should not be encouraged.

187. Several NZ practitioners have made the point that road lighting illumination levels are much lower than overseas. Reasons given are because our AS/NZS 1158 standard specifies lower levels than overseas and because many roads are not compliant with this lower illumination Standard. To this could be added the incorrect reflectance parameters being used as outlined by Jackett and Frith[53]. Thus the potential to save energy from Standards compliant LED lighting will be significantly less than experienced internationally because lighting levels will need to be increased.

188. However the issue is more complex than this as there are several other offsetting factors. These include:

   a) the eye's scotopic and mesopic response to white lighting and the lack of current use of S/P ratios to determine illumination levels across <u>all</u> road categories (where currently a crude 75% factor is applied only to P4 and P5 roads);

   b) the energy saving measures of time-of-night dimming and controls;

   c) the use of best practice design, asset management and maintenance practices, and

   d) the lack of NZ research that relates injury accidents to lighting illumination levels and colour.

189. Taking only some of the above factors out of context with the others (such as just the non-compliant lighting levels), will simply distort the energy savings possible.

[85] *LED lighting market to grow while LED component market goes flat*, LEDs Magazine, March 2012, Page 25.

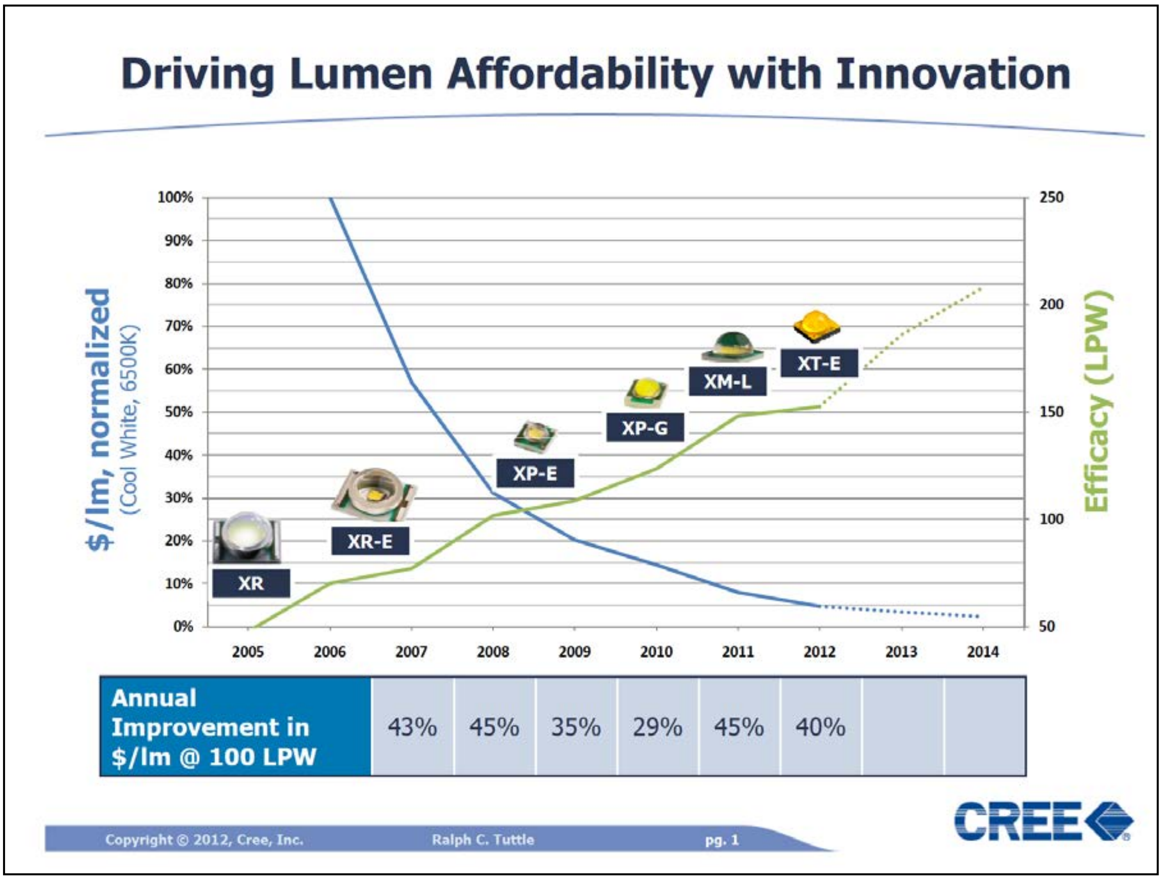

Figure 26 Lumen Affordability since 2005 (Source: CREE, 2012[86])

Other risks

190. Nevertheless, the genuine concerns on risks faced by introducing new technologies too early are very real, but these issues are being scrutinised internationally and becoming ever more transparent. The Clinton Foundation's report identifies the conflict between lack of LED uptake despite its high performance in its Table 3 shown below in Figure 29. It continues with the acknowledgement that:

191. "*… the use of LEDs for the aforementioned applications is still relatively new – early adopters must therefore take precautions to ensure that they select quality products. With some manufacturers making unrealistic claims about product quality and performance, the precautions must be even more deliberate."*

192. However as the Clinton Foundation itself suggests "*These pitfalls can all be avoided through responsible project planning and specifications*."

193. But there are more important risk mitigation measures available. When innovations and technologies of any type have been developed with hundreds of millions of dollars investment, manufacturers' that have made these big investments are willing to provide encompassing performance warranties to get uptake – as long as the purchase is of sufficient magnitude.

194. Thus the large multinational LED lamp and luminaire manufacturers such as Philips, GE, CREE/BetaLed, Schreder, Sylvania and provide manufacturers performance warranties[87], and the larger of them are in a solid position to deliver on those warranties if required.

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[86] *LED Technology For General Lighting Applications*, Ralph Tuttle, Applications Engineering Manager, Presentation to the Illuminating Engineering Society of NZ, 26th March 2012.

[87] If the luminaire is being purchased from a large reputable luminaire manufacturer they will typically offer appropriate warranties.

Furthermore, larger orders will always obtain more encompassing warranties – as well as pricing advantages – than smaller orders. And there is always the possibility of separately underwritten performance insurance. Thus in this study's view, the risk of long term deficient performance is relatively easily managed.

Leading Councils

195. New Zealand's largest Council, Auckland City, has a team that is putting together a proposal for its Council to invest in an upgrade of about 40,000 lamps to new generation technologies, and its likely that only LED luminaires will meet the requirements. Auckland City's advisers are Opus who have done significant advanced lighting work for the city including the Eden Park LED conversion[88] which was completed for the World Cup games in November 2011. Thus Auckland City appears to be the most progressed along this route.

196. Christchurch and Hamilton are the other major cities who have invested substantial effort into getting ready for a significant road lighting upgrade. Each also have consultants who are experts in this area.

197. In Hamilton, Odyssey Energy have long been experts and advocates of modern energy efficient lighting and have developed their own proprietary "Lux Mapping" system to survey the illumination performance of the road lighting network. Hamilton City Council is using this data to relate it to nightime accident (Figure 11) but is not properly resourced to do this world-leading work.

198. Christchurch City Council owns Connetics, an engineering consultancy who together with Council engineering staff represent a pool of well recognised expertise receptive to the new technologies.

199. Wellington City Council (WCC) also appears to be preparing itself for the future by analysing the state of its street lighting assets. Like most if not all Councils WCC use the RAMM (Road Assessment and Maintenance Management) data base for daily maintenance, condition grading, renewal programming and payment for electricity usage.

200. WCC export data from RAMM and present it in EECA's Right Light Street Light Efficacy format[89]. This has been used to programme the upgrade from Mercury Vapour lamps and the less efficient HPS Elliptical lamps to the more efficient "SON-T" model of the HPS lamp. For example Figure 27 shows that of WCC's approximately 17,000 lights, 93% are High Pressure Sodium luminaries.

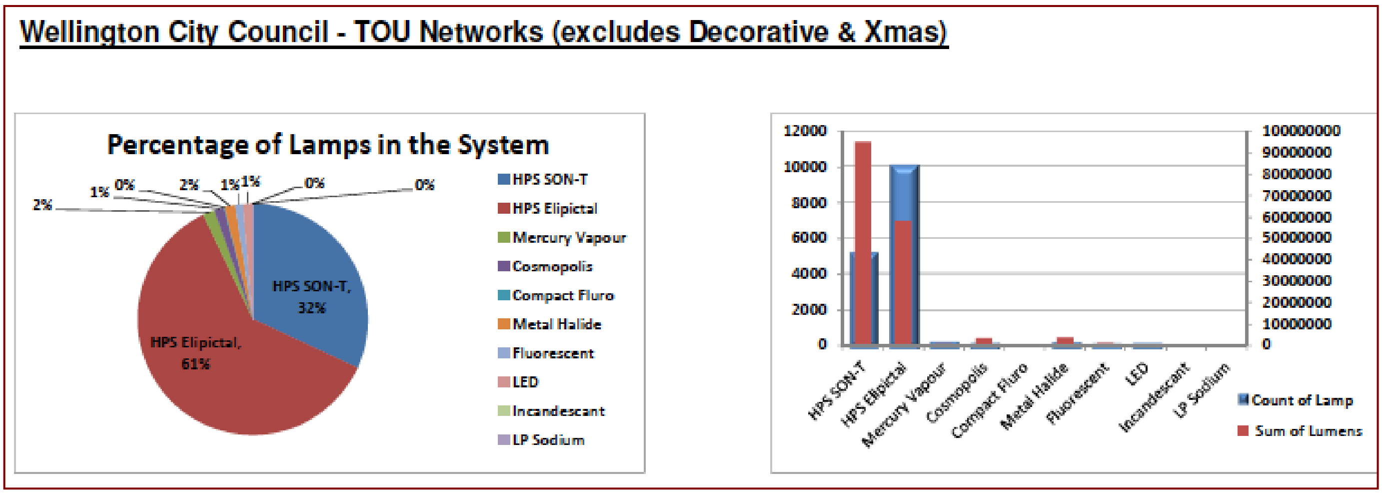

Figure 27 Wellington City Council Street Lighting (Source: WCC[46])

[88] *Intelligent Street Lighting – Eden Park Surrounds Auckland*, Collins, A., Senior Lighting Consultant, Opus International Consultants, Auckland Office, NZ

[89] According to the Energy Efficiency & Conservation Authority *RightLight Efficient Road Lighting Resource* - an Efficacy calculator to provide an overview of the efficacy of the network and identify areas that can be targeted for improved energy efficiency done for a series of street lighting workshops around the country.

13.4 Leadership Opportunity for NZTA

201. Despite the encouraging technical and procurement advances together with increasing pressure to save energy, reduce pollution, and to do more with less financial and other resources, progress in New Zealand has been slow. In this study's view it is because road lighting in New Zealand - like many places in the world - could largely be described as highly fragmented, technically over conservative, and lacking in leadership.

202. The revolution in road lighting technology has taken its already overburdened customer/stakeholders - Road Controlling Authorities including NZTA - by surprise.

203. Historically, the technical and management capabilities required for road lighting have not been demanding. The new LED technology - with its substantial benefits - requires a significant increase in capability resourcing especially during the initial change. This increase in technical capability is the single largest disadvantage of LED street lighting. This type of challenge is not unique and comes with virtually all progress.

Road lighting not perceived as a priority

204. NZ's geographic isolation has had a negative impact on the ability of road lighting engineers, asset managers and their general managers to visit and experience some of the step-change advances made elsewhere in the world. This has left many practitioners with the impression that NZ road lighting practice is in a better relative position than is actually the case.

205. While NZ compares well with Australia who still have 43% of their lights using the very old and inefficient (but white) Mercury Vapour[16], NZ is behind Europe, USA and Asia where a even quick Internet searches indicates strong moves to convert road and public lighting to the new technologies.

206. NZ Councils have budgets under great pressure from ratepayers and with 76 Road Controlling Authorities it's unreasonable to expect them all to fund trips overseas, or even to allocate sufficient resources to a small part of their already complex and demanding portfolio of responsibilities. However, this means that New Zealand road lighting practitioners urgently require more efficient and effective ways to learn from international best practice.

207. Until these issues are addressed, "value for money" is unlikely to be achieved in a sector estimated to cost NZ $55 million per year, have an impact on accidents in darkness costing the economy $1.2 billion per year and potentially have significant positive economic development opportunities for NZ (discussed in Section 7).

208. Paragraph 88 and section 6 together with Section 7 attempt to outline a significant opportunity for New Zealand to leverage improvements in road lighting safety and value for money into significant economic development.

209. An important issue to address is the need to educate the NZ road lighting organisations (Road Controlling Authorities and the NZTA) to manage these innovation risks through good commercial business and technological practices. New Zealand's road lighting culture – like that in most places of the world – is one that is not accustomed to deal with innovation.

210. Similarly, when new technologies are introduced to mass markets, prices reduce rapidly and this acts to delay adoption. This is addressed by assessing the benefits of moving early versus the benefits of delay. As quoted above, the Clinton Foundation suggests that delays are not worth the price reductions. Given that any transformation like this takes time, delay to benefit from price reductions is not rational when the benefits of change re so great.

211. Despite the international evidence of significant benefits covered above, it appears that substantial NZTA projects have recently made the decision to continue with the HPS yellow lighting rather than convert to the new technologies. One outstanding example is the Waterview Tunnel where 4,800 lamps are distributed over two tunnels 2.4 km long. As these lamps will be on for 24hrs per day the economic imperative from saving energy and maintenance costs alone should made a decision to use the latest technologies easy. The fact that this has not occurred justifies close scrutiny of the decision-making process.

13.5 A Strategic Opportunity

212. These technology risks appear to be worth managing in return for the full inventory of benefits to NZ *in addition* to the 50% energy and unspecified but significant maintenance benefits already outlined above[58]. The additional benefits include:

a) White light which is more appreciated by tourists, travellers, pedestrians and residents, and has potentially significant safety benefits;

b) close and easy integration with control systems that should be considered as an integral part of LED street lighting to maximise the benefits and allow dynamic "balancing" between safety and security needs with electrical energy costs and environmental "bads" (eg carbon footprint). For example Central Management Systems (CMS) allow dynamic altering of lighting both geographically (different lighting in different places) and temporally (different lighting at different times);

c) Reduced light "spill" or light "pollution" to areas not requiring – or impaired by light (eg an observatory or residential housing);

d) The absence of toxic Mercury (unlike any other road lighting technology);

e) There are also particular benefits accruing to New Zealand if a decision is taken to adopt LED technologies now:

- Providing an opportunity to upskill the NZ street lighting sector in advance of a massive increase in LED lighting use worldwide. When the City of Los Angeles chose to launch its replacement of 149,000 street lights with LED lighting[57] in 2009 it "determined that LED technology represented a new paradigm in lighting that reflected its ambitions as a global leader on climate change." In 2011 McKinsey & Company predicted that the market penetration of LEDs will be 35% per year between 2010 to 2016[90] as shown in Figure 30.
- New Zealand has a limited window of opportunity to use its purchasing power, its significant technical capabilities, innovation and high value manufacturing strategies[91] to leverage substantial niche market economic development opportunities (covered in Section 7);
- An early decision to move to LED would also provide the latest technologies an opportunity to urgently deliver LED road lighting to earthquake damaged Christchurch to avoid use of old technologies that lock in deficiencies for decades to come. With the right targeted support and leadership Christchurch is a major opportunity to leverage off a new national road lighting strategy.

213. Localised business cases have shown that new residential/commercial developments (where the cost is born by developers) and retrofits involving replacing road lighting poles (local government/NZTA cost) are the most cost effective immediate opportunity to significantly upgrade road lighting within current funding while the longer-term mass upgrade funding is developed.

214. The NZTA could actively promote installation of more efficient road lighting technologies (luminaries, control & dimming systems) that they partially fund (45-50%) in preparation for large scale change once funding opportunities such as PPP have been established.

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[90] *Lighting the Way: Perspectives on the global lighting market*, McKinsey & Company, July 2011, Page 20. Predicts 2010 figures in 2011 due to the lag in statistics.

[91] Professor John Raine (Chair), Professor Mina Teicher, Philip O'Reilly, *Powering Innovation: Improving access to and uptake of R&D in the high value manufacturing and services sector*, Ministry of Science and Innovation, April 2011.

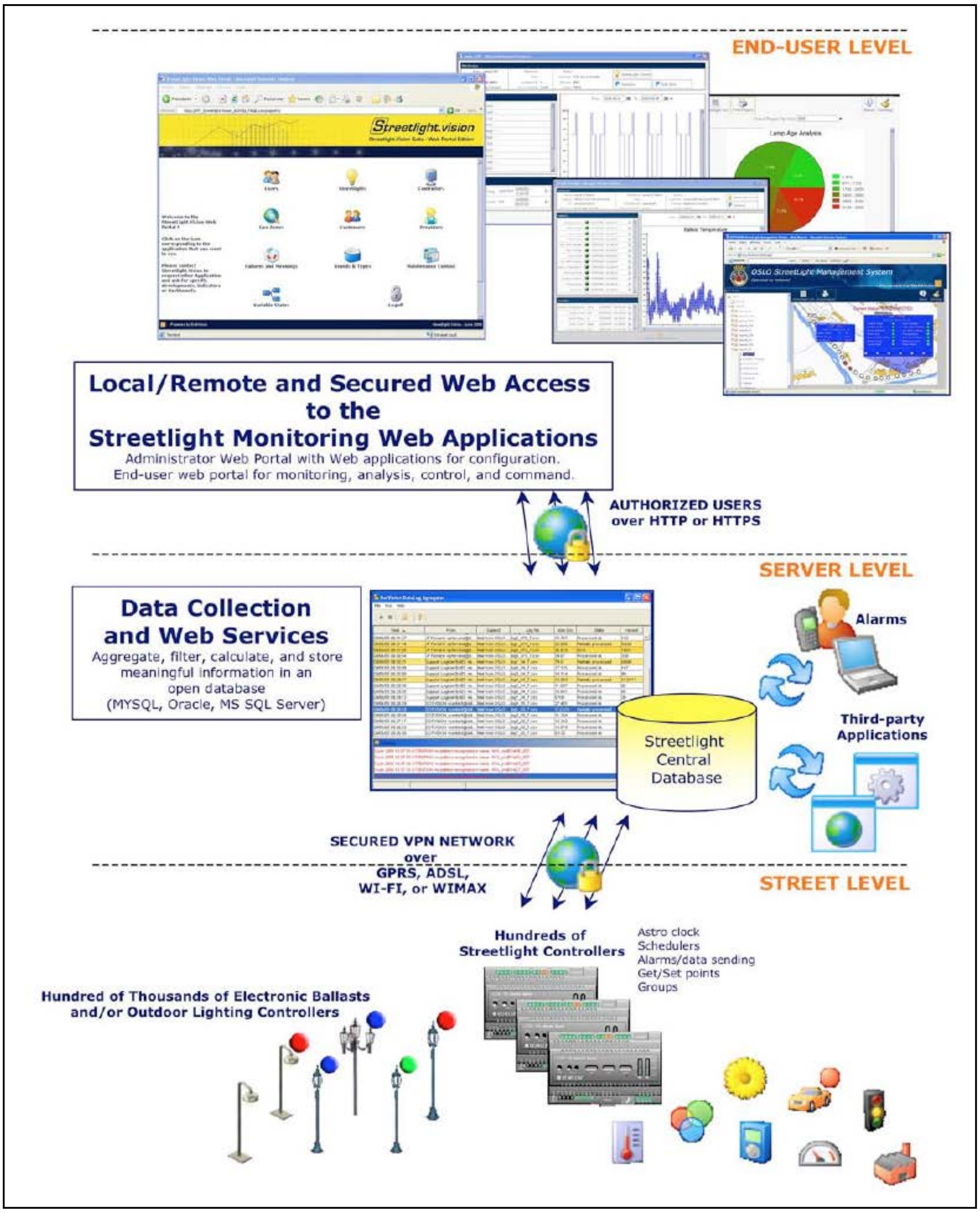

Figure 28 A CMS diagram with Power Line controls signalling (Source: Echelon Inc)

	% Market Share		Performance Profile				
	United States[xix]	Europe (EU-25)[xx]	Typical Lamp Efficacy (lm/w)	Typical Fixture Efficiency	Typical Net Efficacy (lm/w)	Currently Dimmable with CMS[1]	Net Efficacy Improvement
High-pressure Sodium	59%	47%	70 - 150	45%	32 - 68	Yes	No
Low-pressure Sodium	10%	9%	68 - 177	25%	17 - 44	No	No
Mercury Vapor	20%	32%	34 - 58	30%	10 - 17	No	No
Metal Halide[2]	5%	3%	61 - 85	35 - 40%	21 - 34	Yes	No
Compact Fluorescent	2%	8%	50 - 70	60%	30 - 42	Yes	No
Incandescent	4%	0%	10 - 17	60%	6 - 10	Yes	No
LED	0%	0%	50 -100	60 - 90%	30 - 90	Yes	Yes, rapid
Induction	0%	0%	60 - 80	60 - 80%	36 - 64	Yes	Yes, limited
HE Ceramic Metal Halide[3]	0%	0%	95 -120	60 - 80%	57 - 96	Yes	Yes, limited

Data for high-pressure sodium, low-pressure sodium, mercury vapor and MH Performance from Eurelectric 2004,[xxi] Fluorescent and incandescent data from US DOE and Efficiency Vermont.[xxii]

[1] Dimmable ballasts or drivers are required for dimming functionality.

[2] "Metal Halide" excludes CosmoPolis system, which merits treatment separate from other metal halide products.

[3] "HE (High-Efficacy) Ceramic Metal Halide" refers to new, highly efficient ceramic metal halide CosmoPolis system.

Figure 29 Market Share and Performance of Street Lighting Technologies (Source: Clinton Foundation 2010)

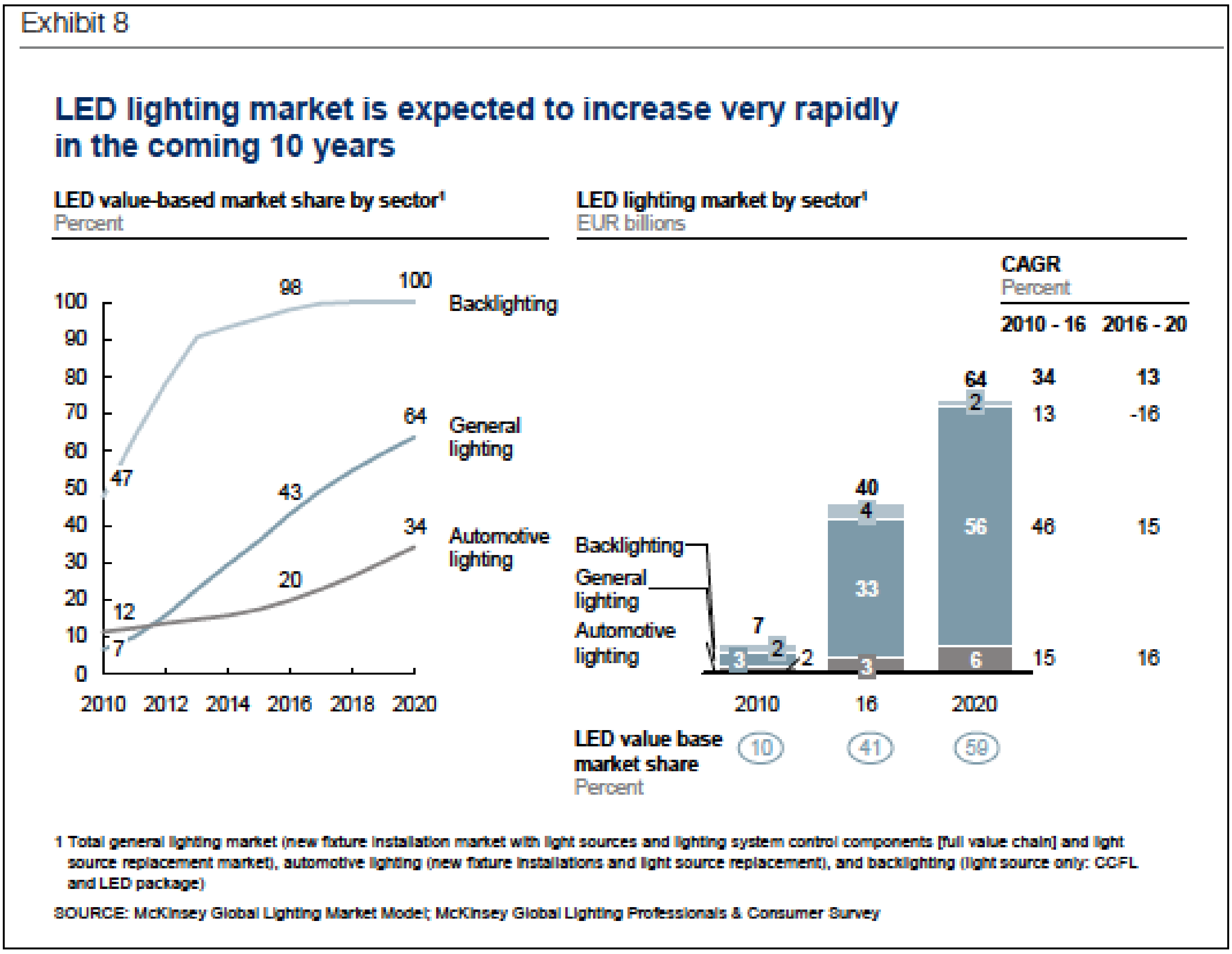

Figure 30 LED lighting market rapid growth forecasted (Source: McKinsey & Company 2011)

13.6 Recommendations

215. **That** the Ministry of Transport (MoT), the NZ Transport Agency (NZTA), the Ministry of Economic Development (MED, including its energy division), Canterbury Earthquake Recovery Agency (CERA), and NZ Treasury investigate the establishment of a targeted programme of road illumination to:

a) improve the accuracy of the estimated benefits identified in this report including the ones identified below through further information and gathering of NZ and international advice;

b) significantly reduce the number of road accidents that occur during darkness[92] through the use of modern white road lighting;

c) potentially halve the $55 million costs of road lighting in NZ by the use of a programme to introduce advanced road lighting technologies including Central Management Systems across the country;

d) introduce advanced road lighting technologies to Christchurch as quickly as possible for its rebuilding program and leverage the experience gained to the rest of NZ;

e) leverage off the above programmes to strategically position New Zealand to benefit from the rapid global uptake of the "revolutionary" LED technology predicted by highly credible sources (including US Department of Energy, McKinsey & Co);

f) investigate in detail why current large road NZTA lighting projects have not chosen to use the advanced technologies to determine whether future installations should specify them. Particular examples are the Waterview tunnel and the Eastern Link.

g) mitigate against the risks of new technologies through implementing well established commercial techniques and contract terms to move risk to suppliers;

h) mitigate against the risks of cultural resistance to change from the public sector and its conservative private sector advisers through a strong education and communications programme;

i) provide incentives to Road Controlling Authorities to convert to modern road lighting by allowing them to keep more of the operating savings made than NZTA would normally allow through its 45-55% of funding formula;

216. **That** where NZTA fully funds road lighting:

a) lead by example by providing consultants and suppliers requirements to utilise the newer beneficial technologies that meet international standards;

b) Increase NZTA subsidisation for renewal or new installation projects with lower whole of life cost and conversely lower subsidisation of 'business as usual' technology for the next 5 years, while a longer-term plan is being developed.

[92] *Motor Vehicle Crashes in New Zealand*, Ministry of Transport, figures for the year ending 31st December 2010, Table 8, Page 29.

6 Increasing Value for Money - Public Private Partnerships (PPPs)

Introduction

217. It is generally understood that one of the benefits of PPPs is that they provide large sums of capital to build expensive infrastructure like bridges and motorways for the public sector in exchange for a regular income spread over 20 to 30 years. Thus the Council or Government Agency does not need to pay the up front construction costs of the infrastructure being considered for a PPP.

218. What is less well understood is that this repayment for the capital and the service provided is dependent on the service being delivered to specified performance levels. Thus the private sector partner providing the up front capital, risks their ability to repay any borrowed capital (usually the overwhelming majority of the capital cost) if they do not deliver the service to the public to the standards they promised. It is as if a bank house mortgage only had to be paid every month as long as electricity, water, telephone and refuse collection services were satisfactory, there were no leaks in the roof or windows and all plumbing, electrical cabling, and lighting worked properly – each month.

219. Naturally in order for the extra services to be provided, the "bank" in the fictitious example above would need to charge more than the cost of the mortgage (the financing cost) to cover the service provision plus a margin for risks and profit (out of which the shareholders get their return).

13.1 Public Private Partnerships in NZ

220. As Deloitte says in its 2006 paper[93], "*PPPs are used around the world to build new and upgrade existing public facilities such as schools, hospitals, roads, waste and water treatment plants and prisons, among other things. In addition to these global sea changes in lighting technology, the public sector has increasingly engaged with the private sector*".

221. "*Compared with traditional procurement models, the private sector assumes a greater role in the planning, financing, design, construction, operation, and maintenance of public facilities. Risk associated with the project is transferred to the party best positioned to manage it*".

222. The NZ Government "*intends to use public private partnerships (PPPs) where they represent value for money to taxpayers*"[94]. More recently the latest 2011 version of the National Infrastructure Plan[95] states "*The government has agreed that for all new capital projects greater than $25 million an alternative procurement method such as a Public Private Partnership (PPP) must be considered*."

223. PPPs have been widely used for large capital projects for buildings, bridges, motorways, and in Europe, for road lighting. What makes a road lighting PPP today to appear more compelling than for other PPP applications is the extensive range of benefits that the new LED technologies provide to all three participants: the public partner; the private partner; and most importantly the travelling public.

224. As a paper by Ernst & Young provided in Appendix 10 suggests: "*Historic under-investment in street lighting stock in New Zealand, resulting in aging and deteriorating assets, and predicted population growth in urban areas also underlines the growing need for investment in this area."*

225. This report hypothesizes - based on initial financial modelling for Hamilton city - that this increased attractiveness of the PPP model for road lighting is likely to make it economically and socially attractive to use PPPs for smaller transactions than the $25 million threshold currently set by Government, perhaps down to capital projects of $10 million.

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[93] *Closing the Infrastructure Gap; The role of public private partnerships*, Deloitte Research, a part of Deloitte Services LP, 2006. Page 5

[94] *National Infrastructure Plan 2010*, NZ Treasury, March 2010, Page 67

[95] *National Infrastructure Plan 2011*, NZ Treasury, July 2011, Page 47

226. The confluence of the revolutionary LED technologies and their benefits together with New Zealand's stock of mature technology road lights and the PPP procurement model provides a powerful opportunity for New Zealand to improve its road lighting more quickly than would otherwise have been possible.

227. Leveraging off the experience of others is important and the United Kingdom is considered to be the most advanced country in its use of PPPs (where a specific PPP type is called PFIs or Private Finance Initiatives) as a result of a strong Government initiative launched about twenty years ago by the UK Treasury[96]. In a recent publication[97] by UK's Treasury it appears to suggest that more than 650 PPP projects have been undertaken since PPPs became a procurement policy tool.

228. Consequently, UK has also been the most advanced in its use of PPPs in road lighting and New Zealand is fortunate to have legal, finance and investment professionals that have operated specifically in road lighting PPPs in the UK. Their names and affiliations are provided in Appendix 7 as they have been consulted, along with others also identified, for this report.

229. One of these advisers[98] has made the point that a major contributor to the uptake and success of road lighting PPPs in the UK is that there is a significant UK Government fund set aside only for PPPs, which PPPs can bid for. If Government wanted to encourage use of PPP models, setting aside part of their subsidy into such a pot would be the most effective way to do it.

13.2 A procurement mechanism not a financing one

230. The additional responsibility on the private partner for availability of services and the consequent risk of the private partner not being able to pay for substantial capital borrowed if those services aren't up to standard, is one of the key benefits to the public sector. That is why PPPs are a "procurement" tool, NOT a "financing" mechanism.

231. This is an important distinction because the public sector always has its own reliable ability to raise substantial funds through rates (in the case of councils), tax (in the case of Government) or petrol levies (in the case of NZTA). This provides the public sector with an ability to borrow funds at low rates because the market assesses the risk of lending money to the public sector as very low – because the risk of not receiving rating/taxing/levies is very low. Appendix 17 discusses and provides more of the financial details relating to PPP debt and equity and the rates used for the financial model discussed below.

232. PPPs are a good mechanism to consider[99] because they contrast well with traditional methods which have the following characteristics and illustrated in Figure 31:

a) Capital costs paid by public sector
b) The design risks sits with the public sector;
c) Procurement is subject to delay and cost over run;
d) But financing costs are very low;
e) Operating costs are paid for by public sector and subject to over run;
f) Maintenance costs are subject to over run;
g) Long term performance of asset is a public sector risk
h) Maintenance is often neglected due to budget constraints and the public sector owns the assets

[96] Speech by The Commercial Secretary to the Treasury, Lord Sassoon at the PPP Forum annual dinner, 3 November 2010, United Kingdom. See http://www.hm-treasury.gov.uk/speech_comsec_031110.htm
[97] *Public Private Partnerships - Technical Update 2010*, HM Treasury, United Kingdom, Page 10.
[98] Duncan Halliwell of Kensington Swann.
[99] Sourced from a Powerpoint presentation by Proctor S, *PIP Fund Informal Discussion: Street lighting*, Morrison & Co, May 2011, slide 5

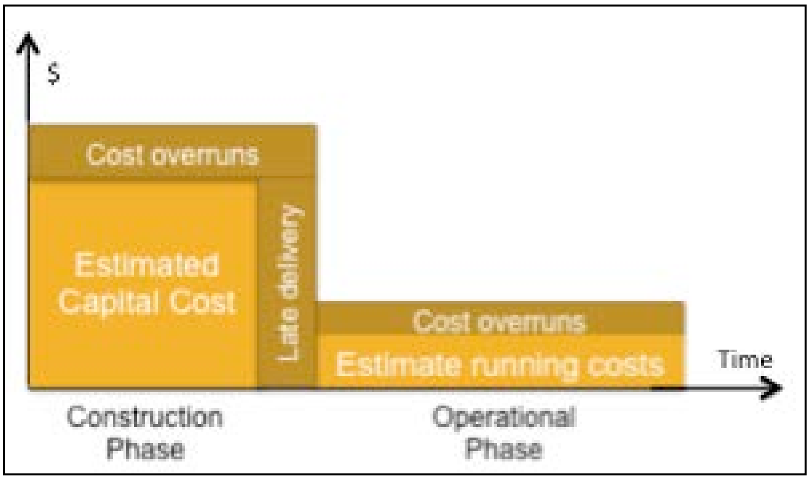

Figure 31 Payment profile for traditional procurement (Source: Morrison & Co – modified from Deloitte Research 2006)

233. In contrast, PPPs have the following[99] characteristics illustrated in Figure 32:

a) Capital costs are paid by the private sector and cost over run is private sector risk;

b) Payment is due only once an asset is operating to the required standard;

c) Operating costs are paid for by the private sector and cost over runs are born by them too;

d) Long term performance of asset is a private sector risk;

e) No payment is due if assets fail;

f) Public sector ownership rights are preserved, the private sector has "license" for typically 25 years, assets revert to public sector with no payment at concession end with pre-agreed levels of maintenance at hand back.

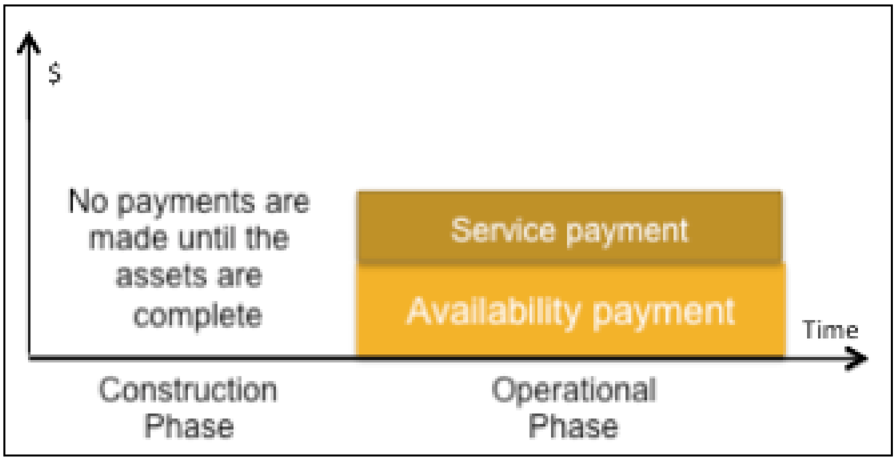

Figure 32 Payment profile for PPP procurement (Source: Morrison & Co - modified from Deloitte Research 2006)

234. PPPs are a mature vehicle and audits of their performance have indicated that they perform better than traditional mechanisms – as shown in Figure 33 and Figure 34. In Australia on average 15% of non PPP projects over-ran their budgets compared to an average of 1% of their PPP counterparts, and on timing, on average 24% of the non-PPP projects were behind schedule whereas on average the PPP projects ran 3% ahead of schedule.

13.3 PPPs for road lighting

235. PPPs appear specifically attractive for NZ road lighting for the following reasons:

a) Unlike other more common but less predictable PPP sources of revenue, lighting is not subject to demand fluctuation. PPPs for tolled motorways, bridges or community theatre complexes are reliant on predicted, and thus uncertain patronage. In contrast, night follows day as long as the earth continues to rotate.

b) They are a proven mechanism used in 25 instances in Europe, with a further 20 in the pipeline as of mid 2011. These figures are sourced from Morrison & Co[100] and shown in Figure 35. Note that the number of lamps covered by these PPPs is almost twice the total number of 330,000 street lights in New Zealand as published by Local Government NZ[101] in 2008.

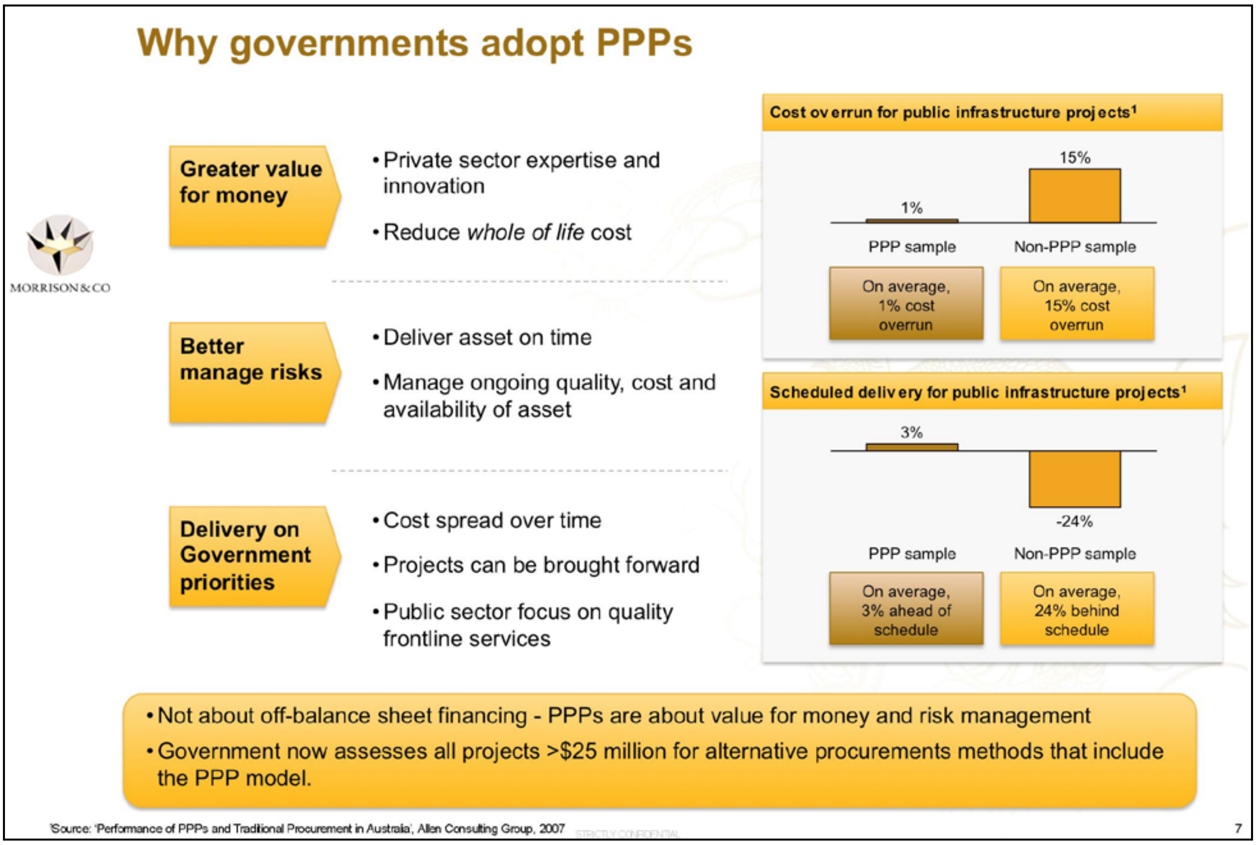

Figure 33 Public Sector advantages of PPPs (Source: Morrison & Co)

c) There is proven availability for PPP funding in NZ. Both the school and hospital PPP produced three fully funded bids. Furthermore HRL Morrison & Co manage the Public Infrastructure Partners (PIP) Fund which has $178 million available for infrastructure projects and is sufficient to leverage a total of $1.2 billion worth of assets. The fund is currently underinvested, but even if it weren't, there are several other potential investment funds including the Government Superannuation Fund, Maori Iwi investors, and Electricity Network Companies and their owning Trusts.

d) The substantial operating cost savings available through PPP investment in new generation lighting technologies like LED allow these substantial savings to offset the relatively high initial set-up transaction costs of putting the PPP together. Thus the size of the PPP might be able to be reduced to less than the Government's guidance

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[100] Proctor S, *PIP Fund Informal Discussion: Street lighting*, Morrison & Co, May 2011

[101] *New Zealand Local Government Street Lighting Technology Supplement*, Page 11. See http://www.localgovernmentmag.co.nz/Portals/3/LG-Lighting%20Sup.pdf

threshold of a $25 million project. However, this would not be a factor if the recommendations of this report are followed, as NZTA could facilitate say three or four PPPs to cover the whole country, instead of 76 Councils each organising their own.

MORRISON & CO

No clear data set for traditional procurement but:

- **UK National Audit Office***:
  - *"non-PFI public sector construction projects are delivering to timetable in around two thirds of cases and to price in around half."*
- **Audit Scotland ***
  - *"Audit Scotland reported 41 per cent of major capital projects delivered to the contracted timetable and 58 per cent to contracted price"*

PPP data for the UK 2009 NAO report	
Delivered on time	69%
Delivered on budget (removing client changes)	90%
Delivered on budget (including client changes)	65%

Figure 34 Comparative experience in UK (Source: Morrison & Co, citing National Audit Office (UK) Report: "Performance of PFI Construction" October 2009)

e) At the end of the 15 - 30 year PPP period, the road lighting infrastructure is handed over in a fully functional and well maintained state so that the public sector receives full ownership of a quality asset. Obviously this needs to be built into the economics for the private partner.

f) Another advantage of PPPs is the fact that they are 'outcome' driven. For example, in a pure street lighting PPP in an urban area the private sector is simply given a light level to maintain. How it does it (column height, lantern etc) is for them to design. This eliminates the design cost and risk from the public sector's perspective. However, this will undoubtedly meet with cultural resistance where provision of road lighting is a hands-on engineering function.

236. Despite these advantages there are practical disadvantages as well. Public sentiment is currently being portrayed in the media as anti privatisation as a result of the Government's asset sale programme and PPPs will be perceived as similarly unpopular[102].

237. In fact, PPPs have effectively been in existence in New Zealand for more than 14 years though they were not called that then. The NZ Air Force has operated a PPP for its 13 CT-4E Airtrainer Pilot Training aircraft which it took delivery in 1998. Other aircraft are also owned by a PPP for the Air Force. At the time the PPP concept was deemed to be controversial for the defence forces and was kept very low profile[103]. At the time the structure used was not described as a "PPP" but that's what it was.

238. PPPs are not privatization, at the most they are "temporary privatization" where the risks are temporarily transferred to the innovative private sector and ownership of the assets are returned to the public sector after 15 to 25 years in a guaranteed state of quality;

239. However, as Treasury observes "*We note that the proposal in your report is of a scale that is smaller than we would consider for a New Zealand PPP, where the minimum whole of life cost for consideration is $25m, and in practice the lower limit is closer to $100m. Smaller*

[102] Government is progressing its "mixed ownership" programme where up to 49% of four energy companies and Air NZ will be sold to the public. Significant political resistance is being expressed despite the fact that Government was elected in 2011 on the clear understanding that this was what it was going to do.

[103] Peter de Luca, Partner, Tompkins Wake, meeting on 1/3/2012

projects do not have sufficient scale to make the complicated contracting processes worthwhile given the difference between public and private sector rates of borrowing in NZ. In addition, the contracting process is likely to be more complicated for a project that involves a number of TLAs." "*In summary, we encourage thinking along the lines of moving from traditional design and construct contracts into performance-based contracting, but would not see this as viable candidate for PPP*."[104]

240. Nevertheless, this perception that street lighting projects are too small for a PPP needs investigation for the following reasons:

a) the United Kingdom has 19 such projects identified below in Figure 36 where there are two smaller than £13 million and professional services cost less in NZ than UK;

b) experience gained and imported into NZ from the UK can be used to reduce cost – including the use of existing experienced advisers[105];

c) amalgamating disparate Road Controlling functions for street lighting would provide significant other benefits identified in this report in addition to reducing the relatively high transaction cost. Amalgamation of all street lighting into three or four PPPs for the whole of NZ could provide significant procurement, (price, support, warranty), maintenance, and innovation benefits;

d) as identified in the next section 6.4 the profits available to both private and public partners are substantial and thus available to offset the significant set-up transaction costs;

241. Rationalising road lighting PPPs into three or four to cover the whole country would allow significant flexibility. Two different approaches might be followed: "Joint procurement" where a project is amalgamated for its duration, and "procuring jointly" is where a project is procured as a lump and then split apart at financial close into separate contracts. The latter would allow geographically separate entities (e.g. Far North and Invercargill) to procure together.

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104 Brian Hallinan, Team Leader - National Infrastructure Unit (NIU), Treasury, e-mail on 24/04/2012, at 5:28 PM.

105 Morrison & Co, Steve Proctor, Ernst & Young, Ben King & Libby Proctor, Kensington Swan, Duncan Halliwel

Experience From European Cities[2]

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Projects by Number	France	Germany	Italy	UK	Grand Total
Financial Close	3	1	1	20	**25**
Preferred Proponent	3	-	-		**3**
Pre-Launch		-	-	2	**2**
Transaction Launch	4	-	-	4	**8**
	10	**1**	**1**	**33**	**45**

Total lamps in schemes[3]	France	Germany	Italy	UK	Grand Total
Financial Close	8,000	20,000	?	605,684	633,684
Preferred Proponent	8,340	-	-	-	8,340
	16,340	**20,000**	**?**	**605,684**	**642,024**

[2]Source: As reported in trade press
[3]Not all PPP projects publish assets adopted and/or refreshed

Figure 35 PPP Road Lighting Experience in Europe (Source: HRL Morrison & Company)

Project	Category	Sector	Region	Capital Value £'m
Brent - Street Lighting	PFI	Street Lighting	Brent	8.5
Islington - Street Lighting	PFI	Street Lighting	Islington	12.17
Manchester - Street Lighting	PFI	Street Lighting	Greater Manchester	35.2
Newcastle & North Tyneside - Street Lighting	PFI	Street Lighting	Tyne & Wear	44.4
Staffordshire - Street Lighting	PFI	Street Lighting	Staffordshire	31.1
Stoke - Street Lighting	PFI	Street Lighting	Stoke on Trent	22.6
Sunderland - Street Lighting	PFI	Street Lighting	Tyne & Wear	27.35
Wakefield - Street Lighting	PFI	Street Lighting	West Yorkshire	19.5
Walsall - Street Lighting	PFI	Street Lighting	West Midlands	18.6
London Borough of Ealing - Street Lighting Project	PFI	Street Lighting	Ealing	34.3
South Tyneside Borough Council - Streetlighting Project	PFI	Street Lighting	Tyne & Wear	35.1
Redcar and Cleveland Borough Council - Streetlighting Project	PFI	Street Lighting	Redcar & Cleveland	20.3
Lambeth - Street Lighting Project	PFI	Street Lighting	Lambeth	17.22
Dorset Streetlighting Installations, Illuminated Traffic Signs and Bollards PFI	PFI	Street Lighting	Dorset	29.3
Norfolk County Council - Street Lighting PFI Project	PFI	Street Lighting	Norfolk	37.6
Derby City Council - Street Lighting Installations & Illuminated Traffic Signs PFI	PFI	Street Lighting	Derby	38.4
Leeds Street Lighting PFI Project	PFI	Street Lighting	West Yorkshire	104.9
London Borough of Barnet - PFI Street Lighting Improvements	PFI	Street Lighting	Barnet	28
London Borough of Enfield - PFI Street Lighting Improvements	PFI	Street Lighting	Enfield	24
South Coast Councils - Street Lighting & Illuminated Signs Maintenance Contract.	PFI	Street Lighting	Hampshire	225
TOTAL				**813.54**

Figure 36 British Road Lighting Private Financing Inititiatives (Source: PUK[106])

13.4 A hypothetical financial model for Hamilton City extrapolated to NZ

242. Using the figures mentioned in this section together with data from Hamilton City Council's public documents a financial model has been put together for a 10,000 luminaire and control systems replacement programme with LED lighting (NOT column replacement and earthworks) over a two year installation period and a PPP that lasts for 15 years.

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[106] Partnerships UK http://www.partnershipsuk.org.uk/puk-projects-database-search.aspx

243. Figure 37 is the resultant graph that shows significant savings to Hamilton City Council and NZTA even after factoring PPP capitalised set-up costs of about 10% of the capital cost of lighting. The financial model requires further work but is indicative of a PPP mechanism that can be made to work across New Zealand. The model suggests that by year 15 more than $10 million has been cumulatively saved (split equally between NZTA and Hamilton City) while both organisations, the travelling and walking public and New Zealand receive all the benefits described above (Safety, Advanced technologies and value for money through PPPs).

244. Note that Figure 37 shows an inset of the 'Partnership Premium' which is the turquoise coloured area between the PPP green line and the debt financed blue line. This represents the cost of the additional advantages of PPPs described above. The model predicts a cumulative cost for these benefits of under $4 million by year 15. From out of this sum the PPP entity pays for the risks that turn out badly or gets its profits.

245. Appendix 16 provides a comprehensive case study of the largest road lighting PFI in the United Kingdom in Surrey. Naturally the case study does not reveal the profitability of the venture, but for a US$200 million investment for 89,000 streetlights, poles and fully automated control system the PFI saves Surrey US$500,000 per year. Thus for an investment almost 30 times larger than Hamilton it only saves Surrey County Council 5 times more than the BBA model predicts Hamilton City Council would save. Its very difficult to make comparisons like this as there are so many unknown factors, but in BBA's view the Surrey case study probably indicates that the private partner, Skanska, are likely to be earning a very healthy return on their investment.

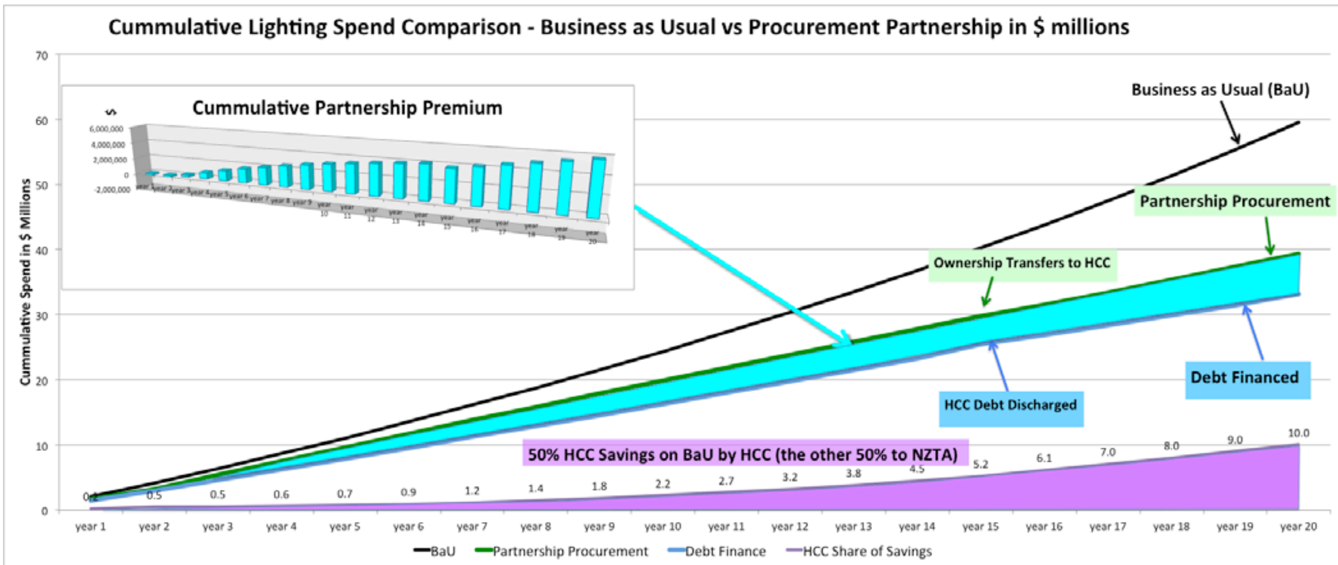

Figure 37 Comparison of Business as Usual, PPP and Internally Funded LED lighting replacement programme for Hamilton City (Source: Bridger Beavis & Associates Ltd)

246. *If* the $7 million capital investment for 10,000 lamps estimated for Hamilton applied nationally this would require a nationwide investment of $231 million and represent a 13 year payback or a healthy 7.7% Return on Investment. As these figures are highly speculative it wasn't worth adjusting them for the time value of money by applying discount factors.

247. If these figures are approximately correct they are remarkable because they represent a reasonable return on infrastructure investment without accounting for any increase in value due to the increase in functionality or amenity of the investment - such as modern white lighting attractive to tourists, reduction in light and environmental pollution, ability to fine tune illumination to the activities, nor for any decrease in the cost of accidents it saves. For example, if the investment led to reduced darkness accidents by 10% that would correspond to an economic saving of a further $160 million per year, or $2.4 *billion* over the 15 years.

And this is before further potential gains from the non-quantified factors identified in Section 5.5 or the economic development benefits discussed in the next section have been factored in.

13.5 Recommendation

248. **That** the Ministry of Transport (MoT), the NZ Transport Agency (NZTA), the Ministry of Economic Development (including its energy division), Canterbury Earthquake Recovery Agency (CERA), and NZ Treasury investigate the establishment of a targeted programme of road illumination to:

a) gather an up-to-date fully representational sample of road lighting asset management data to improve the accuracy of the economic benefits and confirm or otherwise the speculative economic estimates above;

b) obtain reliable advice on the applicability of UK road lighting PPPs to New Zealand and subsequently determine what modifications are necessary in New Zealand to make PPPs for road lighting here viable;

c) conduct a communication programme including workshops to familiarise the 76 RCAs with PPPs and their advantages;

d) utilise private capital through PPPs or variants thereof to capture the benefits identified in this section above;

e) investigate the possibility of amalgamating the road lighting interests of road controlling authorities to minimise the number of privately funded procurement contracts required, with a possible objective to limit them to four across NZ.

7 Economic Development

13.1 Introduction

249. In 2007 the Street Lighting Theme Audit[107] for NZTA's predecessor by Merrifield clearly identified road lighting did "*not contribute towards "Assisting economic development*"". This was based on the valid observation that road lighting contributed to safety, security and comfort rather than directly to economic development. The issue is moot because if roading is considered to directly contribute to economic development through the transport of vehicles and their loads, then one could argue that road lighting supported that same activity outside the hours of daylight.

250. Nevertheless, this paper proposes a different approach. It suggests that by launching a strongly supported new road illumination strategy that includes the use of new generation road lighting technologies and PPPs, significant niche economic development export opportunities will be created and exploited by New Zealand enterprises.

New services and product opportunities stimulated by international achievements

251. At the most modest end of the scale, NZ expertise could be contracted to countries overseas to provide new services. At the more ambitious end of the scale we could manufacture and export niche products and software that supported LED road lighting systems to add to luminaires manufactured by the majors. Other opportunities would provide additional software modules existing control systems, or make new ones.

252. Opportunities arising from the revolution in LED street lighting is analogous to economic opportunities from other major technological achievements such as Microsoft Windows, or the Apple iPhone. These new systems and products spawn many opportunities for economic growth and LED lighting will do the same. Further possibilities are discussed below and examples of existing innovative companies are identified in section 7.3.

Canterbury earthquake rebuild opportunity

253. The opportunity to leverage the replacement of old road lighting infrastructure in earthquake damaged Christchurch with new generation lighting and practices is particularly valuable. The risks are manageable as there are many well established international advanced street lighting programmes (some of which are mentioned previously) that have been operating for several years. It is also understood[108] that reputable multi national manufacturers are willing to provide long term guarantees if the orders are large enough.

Leverage Synergy from Government Strategies

254. The current Government has restated previous Government's commitment to economic development through innovation. For example, current and previous Governments have strongly supported the innovative creative film sector through initiatives led by the Ministry of Economic Development.

255. Launching an advanced road lighting strategy is another opportunity for the Government to leverage its strategies for Transport, Canterbury Earthquake Recovery (CERA), Ministry of Science and Innovation (MSI), Infrastructure (Treasury), Economic Development (MED) and even Tertiary Education (covered in section 8.5).

256. In its strong support for innovation, current and previous Governments have provided funding support which has recently been re-enforced in the 2012 budget built upon a "Powering Innovation" Task Force finding[109] that "*Rapid development of the high value manufacturing*

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107 Merrifield, A.L.R, *Review of Street Lighting*, Land Transport New Zealand, November 2007.

108 From discussions with two local distributors of multinational manufacturers

109 Raine, Professor J., Teicher, Professor M., O'Reilly, P., *Powering Innovation: Improving access to and uptake of R&D in the high value manufacturing and services sector*, Ministry of Science and Innovation, April 2011, Executive Summary Page 1.

and services sector (HVMSS) has the potential to generate a step change in the economic growth and social wellbeing of New Zealand".

257. That same report identifies an urgent need "*to overcome … the lack of identified niche areas on which the HVMSS (High Value Manufacturing and Services Sector) should focus*."[110] A road lighting strategy based on "digital" LED lighting and the ICT infrastructure it requires provides an ideal opportunity for Government to introduce innovation into infrastructure.

258. A key Government goal is to connect and integrate its wide functions to provide a "whole of Government" focus on solving economic, social, health, and education, problems and grow the economy. In the innovation based economy that Government aspires to, leveraging highly funded programmes and services - such as road transport - to provide the customer base for innovative providers is an attractive opportunity.

259. While a careful balance has to be struck in the large road infrastructure sector between conservative tried and tested procedures and techniques to ones that are innovative, a concerted effort needs to be made to request, direct and incentivise the NZ road lighting sector to be more innovative. By doing so, safety, value for money, and economic development goals are met as well making progress on four of the Government's six policy drivers (see paragraph 41). Examples of how this might be achieved are outlined in section 7.3***.***

Economic wealth from innovation

260. One of the most difficult barriers for innovative companies to hurdle is to convince the first customer to buy their products. Government currently risks almost $833 million dollars on R&D every year with what many commentators believe insufficient economic or entrepreneurial success. In section 7.3 a few examples are shown of innovative products and services which NZTA could lead in their use[111].

261. For example, New Zealand was – and perhaps still is - a world leader in the automated mapping of road illumination in 2004. Unless NZTA and more road controlling authorities take up this innovative service as part of a NZ street lighting strategy (see paragraph 279) this innovation is likely to be overtaken by future international competition. It would be a pity if this and NZ's other innovations relevant to this sector could not be leveraged into economic wealth creation. With the right policy settings in the road lighting sector – a new economic engine might be spawned.

262. Just as New Zealand seized the opportunities that creative film and super yacht making presented, it should seize the opportunity that digital lighting represents.

13.2 Paradigm Shift in road lighting

263. McKinsey and Co say in their report[112] *"The penetration of LED technology just described is driving a far-reaching change to the industry's structure." …* ***Upstream industry is experiencing a radical shift, with LED expected to capture a huge share of general lighting.*** [their emphasis] *LED production methods are very different from those used for traditional lamps, where electrical filaments or plasma with bulky glass covers are used. This is leading to the emergence of an entirely new industry and the upheaval of traditional industry structures"*

264. The 'general lighting' market (ie everything that is not 'automotive' or 'backlighting' for TV and computer screens) is the "*mainstream of the lighting market*". As shown in Figure 30, McKinsey reports that *"LED's market share was still low in 2010, at 7 percent."* But *"LED lighting is expected to grow at a rate of around 35 percent p.a. from 2010 - 16, leading to a*

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[110] *Powering Innovation: Improving access to and uptake of R&D in the high value manufacturing and services sector*, Ministry of Science and Innovation, April 2011, Page 48

[111] Examples are from the pre-existing knowledge of the authors. An inventory of NZ projects/companies that have synergies with the future of digital street lighting would be a worthwhile exercise for MED and MSI.

[112] *Lighting the Way: Perspectives on the global lighting market*, McKinsey & Company, July 2011, Page 22

market share of approximately 40 percent by 2016, with revenues of some EUR 40 billion. After that, the growth is predicted to slow down to less than 15 percent p.a. from 2016 - 20, resulting in an LED market share of around 60 percent in 2020"

265. These are massive changes and figures like these are not often seen in any markets. A paradigm shift is on the way predicted by McKinsey & Company, the US Department of Energy (DOE), and widely confirmed by both internet research and on-the-ground discussions with people in the industry.

266. US DOE also suggests that there is a "*Lighting Revolution*" and "*.. a window of opportunity to establish the United States as a global leader in solid-state lighting technology, retaining intellectual property rights, high-tech value added jobs, and economic growth for the nation*."[113]

267. In the same document the DOE suggests that " *LEDs are an obvious area where we can achieve energy savings and we can also achieve economic benefits—job creation*."[114]. While New Zealand is never likely to manufacture LEDs, our engineering capabilities could also play a role in the downstream value chain that similarly provided economic benefits. But it has only just started and New Zealand could catch the wave if actions were taken soon.

268. Figure 38 shows a fascinating diagram from the US DOE which compares progress of luminous efficacy (light output per electrical watt input) of the various technologies over the last sixty years and forecast for the next ten years. The almost vertical purple and black lines on the right hand side of the graph corresponding to LED lighting progress[115]. With dramatic improvements like this, the introduction of LED Solid State Lighting will probably be very rapid. Note that "OLED" refers to "Organic" LEDs which are a subset of LEDs based on carbon, and thus known as "organic". They are expected to be less costly than current LED technology, but they are several years away from being commercially available.

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113 *Solid State Lighting – Brilliant Solutions for America's Energy Future*, US Department of Energy, Energy Efficiency & Renewable Energy, January 2012.

114 U.S. Senator Jeff Bingaman (D-NM), Chair, Senate Committee on Energy and Natural Resources, as reported in footnote reference 113.

115 Elsewhere in the document (page 39, 40) it reports that LED luminous efficacy has already reached 100 lumens/Watt so the purple dotted line should be a solid line at 2012.

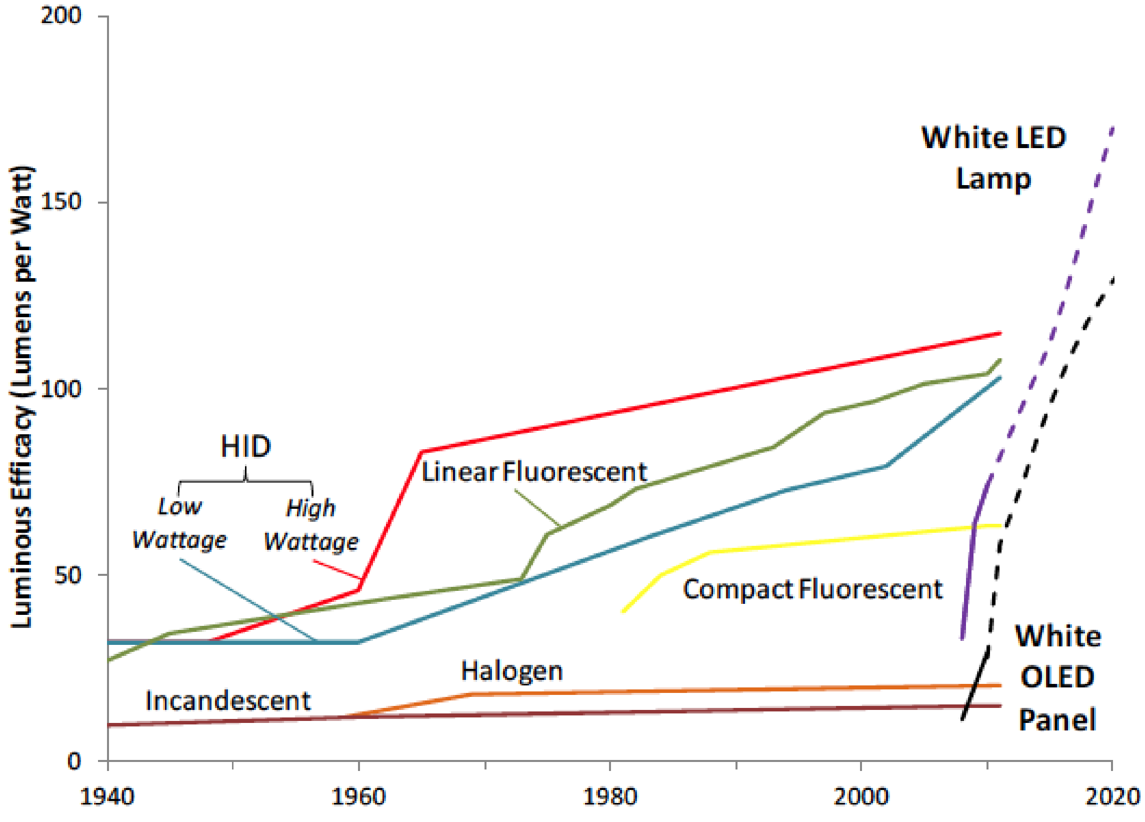

Figure 3.3: Historical and Predicted Efficacy of Light Sources[31]
Source: Navigant Consulting, Inc - Updated Lumileds chart with data from product catalogues and press releases
Note: Efficacies for HID, fluorescent, and LED sources include driver or ballast losses.

Figure 38 The technical evidence of impending LED lighting revolution (Source: US DOE[116])

Solid State Lighting Research

269. Research has been conducted widely by multinational companies world-wide in the area of Solid State Lighting (SSL) where “solid state” indicates the use of semiconductor physics which has underpinned the computer and electronics revolution of the last 20 years. LED lighting is the only commercial example of SSL technology so currently it is synonymous with “SSL”.

270. United States has recognised the strategic importance of SSL and has invested large sums of money to facilitate the country’s leadership in this area. Figure 39 shows how the US spent US$110 million last year on R&D completely focused on LED lighting. USA now has an R&D and commercialisation infrastructure that carefully plans how to achieve strategic and tactical goals[116] to deliver real economic wealth to their nation. This is published on their large and comprehensive website at ***http://www1.eere.energy.gov/buildings/ssl/information_resources.html***.

[116] *Solid-State Lighting Research and Development: Multi-Year Program Plan*, Lighting Research and Development Building Technologies Program, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy. April 2012.

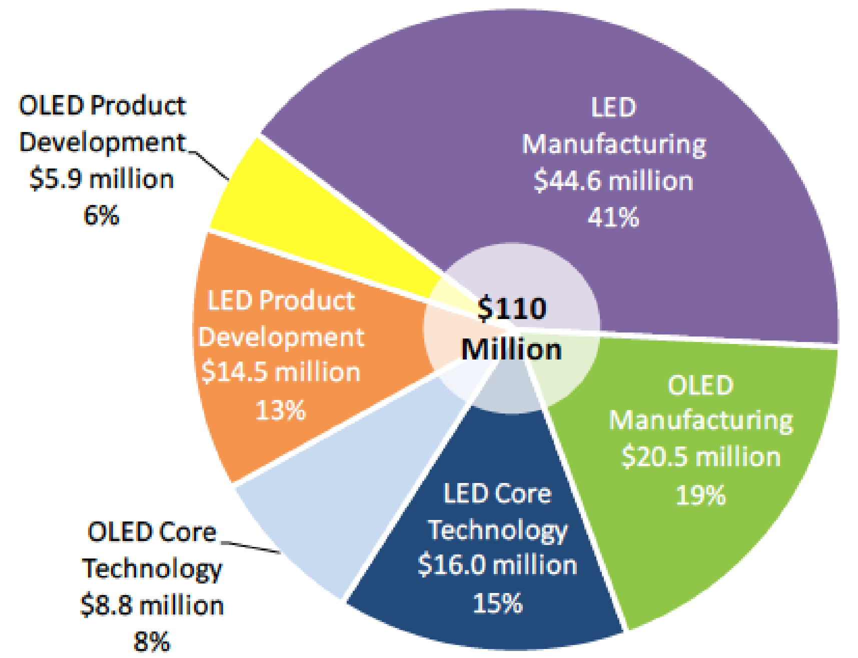

Figure 4.4: DOE SSL Total Portfolio Summary, March 2012

Figure 39 US Expenditure in Solid State Lighting R&D (Source: US DOE[116])

271. USA has recognised the importance of the impending SSL/LED revolution across all lighting sectors. This provides an opportunity for NZ to come up with its own R&D plan that leverages off USA's transparent strategy and focuses on niche opportunities in the narrow sub-sector of street lighting.

Powering Innovation – April 2011 MSI Report

272. In April 2011 MSI published *Powering Innovation*[109] which observed that New Zealand must *"… focus on niche advanced technologies where it can compete internationally. Science and innovation is dependent on government investment. To optimally support uptake of R&D in the HVMSS[117], it is critical that:*
(i) Advanced technology industry sectors are identified for prioritised investment.
(ii) The limited financial resources in this [High Value Manufacturing and Services] sector are spent as efficiently and effectively as possible and, in principle, that the prevalent use of matching funding by industry should continue to be used to help drive value from government interventions."

273. The advanced road lighting technology segment is precisely such a niche sector. NZ can provide products and services in almost all areas probably with exception of the luminaire itself where international investment has been huge. NZ engineering research and development expertise is well positioned to contribute to design and delivery of new system integration services, new goods and services such columns/poles, electronics, software control systems, other supporting tools and products, and other products and services that haven't yet been envisaged.

274. There will be opportunities for companies that perform system engineering design solutions for various applications and contracting to the Crown, local authorities and other businesses. There are potentials for local design, build, supply, install, maintain businesses within NZ.

275. Recognising that LEDs are imported stock other possibilities for export business should exist around system design expertise rather than LED components. Companies doing good

[117] HVMSS = High Value Manufacturing and Services Sector

system design work could conceivably position themselves in international contracting for systems supply.

13.3 Opportunities for innovation and economic development

276. With the impending digital lighting revolution the road lighting sector is likely to be rich with opportunities, and there are at least seven NZ entrepreneurial enterprises that are attempting to make an impact in this or an associated area. This is a large subject for investigation whether or not Government chooses to accept the recommendation of launching a new road lighting initiative.

277. The Ministries of Science and Innovation (MSI), Economic Development (MED) and Education should be made aware of the paradigm shifting opportunities available. Because Innovation policy is split between MSI and the Tertiary Education Commission (TEC, the organisation responsible for Universities and technical institutes), the TEC should be advised as well.

278. Known areas of innovation where allied road lighting economic development opportunities exist might include those identified below:

279. **Street Light Lux Mapping**
Odyssey Energy Ltd was founded by Roger Loveless who together with colleagues David Raven and Zoran Draca made a deep commitment to developing technology to survey street lighting illumination levels through the originally named HISLAT system, now called Lux Mapping. This is a unique service used by a few City Councils and allows performance monitoring of road lighting – an ideal service for any contract that uses performance as its foundation (including PPPs). The service appeared to be ahead of its time in 2004, when virtually all Road Controlling Authorities simply contracted out lamp replacement based on age and public complaints. Maintenance is currently managed by prediction - based on many often erroneous technical, historical and social factors, rather than actual current performance. The Odyssey performance measurement system efficiently measures light output and has been significantly upgraded by Raven and Draca after Loveless's retirement as shown in Figure 40. Hardware and software provide a map of the luminant output of street lighting taken from a moving vehicle. This could be a iconic example of a new generation lighting technology applied in NZ provides niche global opportunities - see website[118]

Figure 40 Odyssey Energy Lux mapping (Source: Website)

[118] *http://www.odyssey.co.nz/services.php?id=anytime4908294936a39*.

280. **Non-destructive street lighting pole testing**
"*Rei-Lux has patented an intelligent, three dimensional testing technique which is able to expose defects from below ground to the top of the column. It can reveal foundation weaknesses and uncover issues with connections to light fixtures and outreaches/brackets.*" See ***http://rei-lux.co.nz/index.php***.

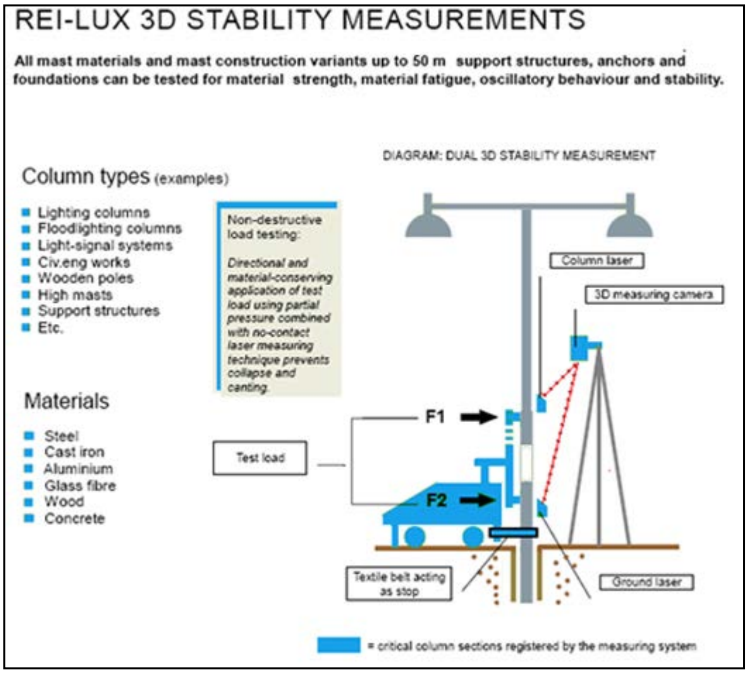

Figure 41 Rei-Lux Non-destructive lighting pole testing (Source: Website)

281. **Waikato University Power Electronics - Increasing electrical efficiency by up to 40%**
University of Waikato Scientists are patenting a system that allows electronic devices using DC current (as do LED lights) to use up to 40% less current. The electronic innovation achieves this remarkable result by a technique they call "SCALDO" which increasing the efficiency of the conversion of DC voltages within electronics wherever it is used. The SCALDO system promises to improve the efficiency of all electronics allowing devices to be made smaller or use less power or both. The benefits of this appear to be very useful in digital street lighting.

282. **Car Parking Technologies Ltd**
The award winning company based in Cambridge (but recently listed in Australia) has developed world beating hardware and software wireless parking technologies that could be either integrated into digital lighting systems to provide more ambitious solutions for the transport sector. The company is already involved in LED lighting overseas.

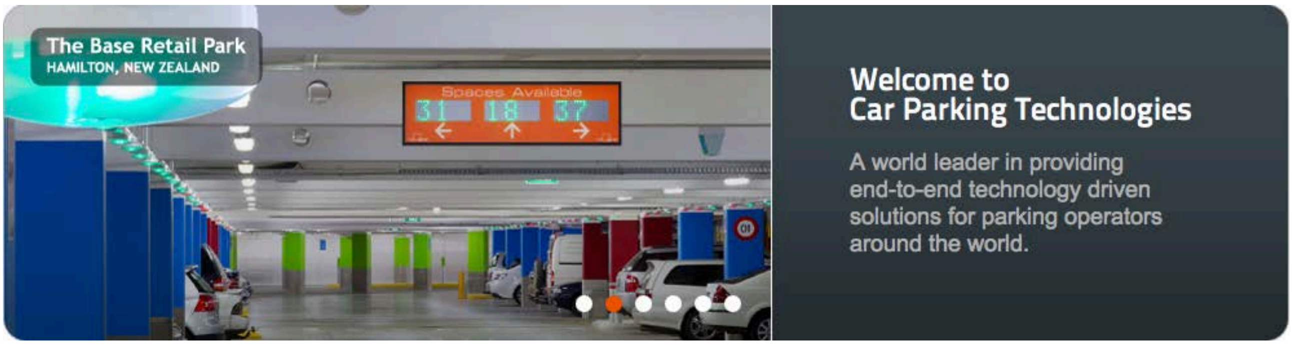

Figure 42 Car Parking Technologies (Source: Website)

283. **LATA Lighting Controls**
A small start-up company (JF2 see ***http://www.jf2.co.nz/***) has developed a CAN-bus based system to control commercial and residential lighting loads with the functionality of top end

lighting and power control systems but at a cost that probably adds only about 10% to the front-end capex of standard residential and commercial buildings, but pays back the difference in copper saving and increased energy efficiency while providing substantial functionality. LATA is a "*distributed control system that reduces the amount of mains cable required to wire the lighting system in most buildings, while providing features and benefits that are often technically difficult, or impossible to set-up*."

Figure 43 LATA Lighting Control Module (Source: Website)

284. **Solar Photo Voltaic (PV) Systems**
Currently virtually all road lighting is powered by electricity supplied by the grid. Prices of Solar PV are reducing and it is a matter of time before a proportion of the cables supplying power to lighting become 'stranded assets'. In New Zealand there are at least two separate enterprises, Manufacturing Systems Ltd and Solenza (which is not targeted at street lighting) which have received Government innovation funding. If a road lighting initiative and strategy was launched, at least MSL could become involved[119], as there are large niche opportunities for Solar PV in street lighting either as standalone items or as energy net-zero microgrids.

285. **Data Mining & prediction**
From their website "*11Ants Analytics is the leader in assisted predictive analytics. There is no other software on the planet that enables businesses to move as rapidly from a standing start to deploying advanced predictive analytics solutions*" This software might be useful to predict traffic movements and thus street lighting optimisation by linking it to the CMS and is available from ***http://www.11antsanalytics.com/default.aspx*** .

[119] Managing Director is Andrew Haynes.

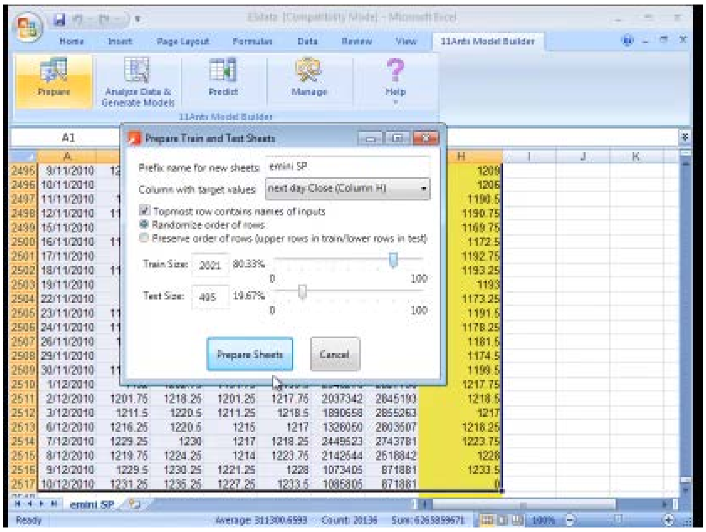

Figure 44 11Ants Analytics (Source: Website)

286. **Street Lighting Poles as licensable property**
As the world becomes more sophisticated and technology becomes further integrated and available to the public, street lighting poles will be seen as a very useful piece of property on which to build hi tech infrastructure. A road lighting strategy should anticipate this and provide for the licensing of the "real estate" offered by a pole to revenue generating service providers. Clearly a PPP operator who was innovative could exploit such "lighting column property services" and some of them might actually operate a service themselves. A possible example exists in Auckland City where modern bus shelters are built by the private sector for free in return for the use of the real estate to pursue revenue opportunities.

287. Examples of services that might generate revenue for potentially useful services to the public include:

   a) Cellphone, Bluetooth, and Zigbee transceiver stations (see Figure 45)
   b) LED Outdoor screens – Safety messaging and advertising
   c) Weather monitoring stations
   d) Air quality monitoring stations
   e) Audible safety alarms
   f) WiFi transceiver stations
   g) CCTV cameras
   h) LED luminaire optical data transmission
   i) Electric Vehicle charging stations

288. **Intelligent Lamp Poles**
In USA the ambitious Intelli-street concept has been promoted with a successful launch of 40 lamp poles of the type shown in Figure 46 concept and if it does take off, could have several niches for NZ companies to contribute, and perhaps used in a central business districts. NB Many councils in the US have an affinity with heritage look lighting equipment. This design style is portrayed in the below graphic, but is not an integral part of the technology concept. For more information visit ***http://intellistreets.com/***.

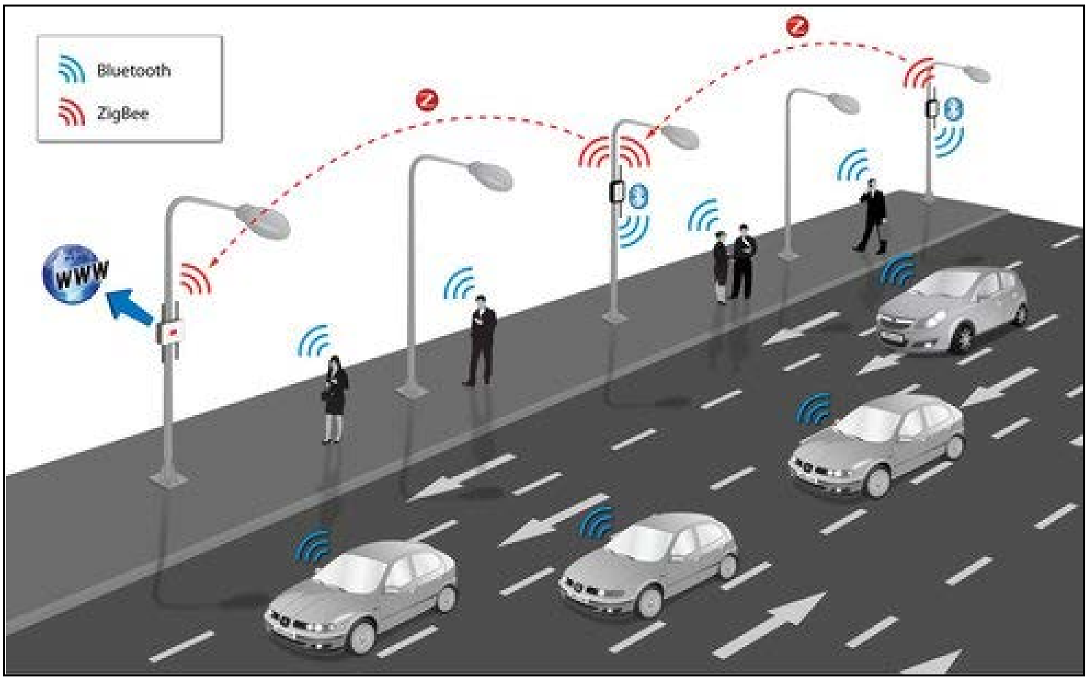

Figure 45 Other potential uses of road lighting

289. **Other areas for investigation**

As previously identified there are several areas where further applied R&D could result in valuable commercial products:

a) Adaptive Lighting – Conditions based real time light adjustment via CMS systems to adjust lighting levels in accordance with prevailing climatic and/or traffic flow conditions

b) "Light-bubble" control systems – for low traffic density roadways at off-peak timeslots, the light level may be programmed to a "normally dimmed" light level. The lighting system ramps up the light level when a vehicle or pedestrian arrives at a particular luminaire, and ramps it down after it has left. The cumulative effect of this is to generate a moving "light bubble" aura around the travelling road user/s who have the perception of a fully and permanently illuminated road.

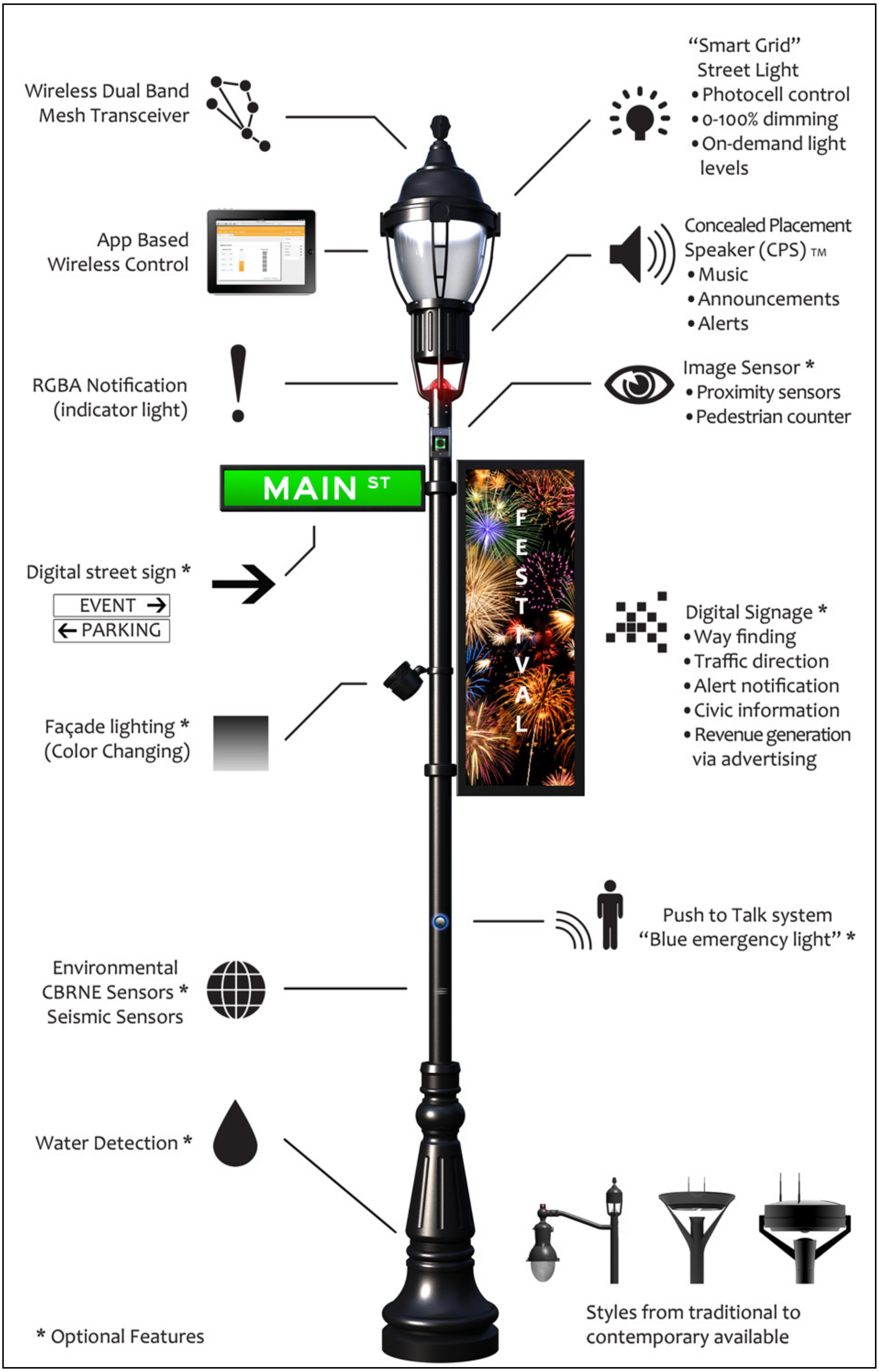

Figure 46 "Intelli-street" Intelligent Lamp Poles

13.4 Recommendations

290. **That** NZTA:

a) Launch a separate innovation strategy. The culture involved in promoting innovation to resolve problems, increase safety, enjoy economic growth or meet environmental challenges are fundamentally different from the culture required to operate an organisation that spends $1.95 billion[120] per year . BBA recommends that NZTA consider launching an innovation strategy that incorporates the observations and recommendations in this report for road lighting as below – but goes further than this to apply the same principles across the organisation.

b) Engage with NZTA staff to identify people, companies or organisations that have innovative products or services that would contribute to the previously recommended road lighting strategy, as well as provide those companies – and thus New Zealand - with economic growth opportunities.

c) Engage with the Ministries of Economic Development (MED), Science and Innovation (MSI), Education (MED), and the Tertiary Education Commission (TEC), Industrial Research (IRL), and Trade and Enterprise NZ (TRADENZ), to identify public and private organisations that could contribute towards NZTA's innovation strategy and provide economic development opportunities that would advance a road lighting strategy.

d) Review its Research and Development programme to incorporate the findings of this report. NZTA's research programme as published on the internet has a predominance of civil R&D. The terms of reference for the review should include matching concrete quantifiable outcomes to desired programs and their costs, much as MSI has begun to do. For example as identified in the recommended road lighting strategy – to facilitate the reduction of the 4,567 of injuries (31.7% of total) occurring in dark periods by xx and the budget to do this should be yy% of the total NZTA R%D budget or less.

e) Fund research to establish the relationship between land transport injuries and lighting levels and colour (during the hours of twilight and darkness);

f) Identify where most cost effective changes in the culture of NZTA should be made to increase its ability to innovate at the same time as deliver quality outcomes.

g) Together with the appropriate organisations identified in a) above, and the private sector, conduct "innovation workshops" to identify areas where NZTA and MoT objectives could be met through innovation – either in the public or private sector.

[120] NZTA Annual Report 2011

8 Challenges and opportunities for change

291. This section covers the challenges that need to be met in order to gain the identified benefits of advanced road lighting technologies through the use of private capital or performance-based procurement practices.

292. Revolutionary new generation lighting technologies have already been proven in the international market, and will inevitably be adopted in New Zealand at some point. There is a window of opportunity available to New Zealand now to take a considered approach to the timing and "methodologies" for adopting these new technologies.

13.1 Centralised procurement and asset management

293. The fragmentation caused by 76 Road Controlling Authorities (RCAs) acting independently could make it difficult to forge and implement a strategic direction in the interests of New Zealand. If NZ follows an ad-hoc path towards technology upgrades with 76 Road Controlling Authorities all moving at different speeds, uncoordinated LED procurement will result in significantly higher average costs – not just in procurement, but potentially also in technology implementation, and asset management.

294. Furthermore, this inefficient approach will be highly visible to everyone who travels at night as there will be an ugly patchwork of yellow and white lights across the country, each providing its own highly visible "illustration" of fragmentation.

295. Adoption of new road lighting technology would be optimally achieved through some form of cooperative action and decision-making, to
- harmonise technology choices,
- develop economies of scale for purchasing, and to
- coordinate implementation, management and maintenance functions.

296. Centralised procurement of the new technologies could provide significant up-front savings and facilitate comprehensive warranties to manage risk. .

297. NZTA already has strategic tools such as its Procurement Manual 2009, but few RCAs seem to execute NZTA's recommended procedures for procurement of road lighting – perhaps because road lighting is such a small part of each RCA's responsibilities that it may appear pointless to allocate resources to this area.

298. In the same way, Best Practice Asset Management (as described by the NAMS International Infrastructure Management Manual) does not appear to being practised universally either. Although some Councils use PAS 55, an asset management guide from the European Union.

299. Whatever the standard or guideline used, good asset management processes have a common logical standard framework:
1. Decide desired level of performance;
2. Measure what the performance level is;
3. Work out the deficiencies where actual performance falls short;
4. Programme improvements to correct those deficiencies;
5. Repeat as appropriate.

300. Such frameworks do not seem to be universally adopted by every RCA.

301. A centralised procurement and asset management function, governed to act in the interests of the RCAs as well as NZ, is likely to return dividends that far outweigh its cost.

13.2 NZTA Leadership

302. NZTA has an extensive and robust system to govern the process of project assessment, decisions and implementation. Clearly a study of this type requires a good understanding of that process to identify why the new advanced road lighting technologies have not been chosen for the latest roading projects, even though they appear to be good contenders.

303. Three recent examples of decisions that appear to be relevant to the question above are the 2.4km Waterview Tunnels project in Auckland, and the 7.5km Tauranga Eastern Link and Napier's tender for 1,000 luminaires.

304. The Waterview project is mentioned in section 5.5 paragraph 211 and requires significant further information before conclusions can be drawn.

305. On the other hand, the Tauranga Eastern Link project was the subject of a 28 page report by Beca Infrastructure Ltd, commissioned by NZTA[121], to - as the Opus consultant reports[122] - "*apparently discover whether LED lighting in conjunction with an adaptive lighting control system proposed by Opus International Consultants as part of the Tauranga Eastern Link Design Team, was a better purchase than HPS luminaire supplied by Sylvania as specified in the Principals Requirements (PRs) for the project*".

306. The terms of reference for the Beca report are not included in the report, but it is clear that Beca compared a single LED product with the Sylvania HPS luminaire. It did not set out to provide a wide-ranging comparison between LED lighting and HPS lighting.

307. Unfortunately, the Beca report has – probably unintentionally - sent out a wrong message to the New Zealand marketplace about LED road lighting. As a result perhaps of its limited brief, the Beca report's conclusions contradict almost all the international evidence gathered for this BBA report on *Strategic Road Lighting Opportunities for New Zealand.*

308. The Beca report appears to highlight a key observation made by suppliers to the road lighting industry (see Appendix 7) – that NZTA is asking the wrong questions and providing consultants with the wrong brief.

309. While it should be acknowledged that road lighting represents only a small component of New Zealand's overall roading budget, there is a clear and present opportunity for a technological leap in road lighting that would provide significant economic benefits and spin-off commercial opportunities, while also presenting the probability of significant improvements in road safety.

310. In order to take advantage of these opportunities there is an urgent need for NZTA to lead the development of a national strategy on road lighting.

13.3 Financial

311. The high discount rate of 8% for road maintenance is a disincentive for investments that may have long-term benefits. This was identified by the NZIER paper for the Road Maintenance Task Force[123].

13.4 NZ Standards

312. It is puzzling that a Public Good service (Standards Australia and NZ) should be wholly funded by the Private Sector. Standards are a critical part of our infrastructure. Yet they currently appear to be a barrier to progress in road lighting largely because of inadequate project funding and asymmetric stakeholder representation due to the requirement for self-funded volunteers on Standards review panels.

313. The road lighting standard AS/NZS 1158 is a prime example. It is variable in nature and appropriateness – from excellent and comprehensive in some places to narrow and restrictive of competition and innovation in others.

314. An example of its restrictive nature is in *Part 6: Luminaires*, where it requires specific designs and configurations - down to the specific size and type of screw - rather than stipulating levels of performance.

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[121] Williams, G., (Technical Director – Building Services Electrical), *Tauranga Eastern Link – Roadlighting Report*, Beca Infrastructure Ltd, 13 October 2011.

[122] Andy Collins, Team Leader Lighting Design, Opus International Consultants, 21 May 2012

[123] Chris Parker, *Road Maintenance Taskforce economics, Economic Issues Paper*, NZIER, Draft v1, 23 December 2011

315. AS/NZS 1158 has not kept up with the new advanced technologies, such as the use of Scotopic/Photopic ratio, reaction time and peripheral vision advantages of whiter light, and the road reflectance findings by Jackett and Frith of 2009[53] appear to fundamentally undermine the illumination standards it purports to set.

316. While AS/NZS 1158 sets standards for road lighting design, it gives almost no guidance as to an appropriate maintenance regime or regular test checks, to ensure continued delivery of the desired lighting performance. Road lighting can be compromised by factors ranging from tree growth to road surface changes, and this is not addressed by the Standard.

317. No matter what road lighting technology is used, a lack of effective measures to enforce best practice *asset management* is a significant barrier to maintaining a cost-effective road-lighting system that provides value for money.

318. It therefore appears as if AS/NZS 1158 should have a thorough review. This will be relatively expensive for the industry to fund but very important for both NZTA and New Zealand to have a modern standard that sets best-practice and allows for the introduction of cost-effective lighting technologies with knock-on benefits for economic development. Accordingly, we recommend that NZTA sponsor the full review.

13.5 Digital Lighting Skills & Training

319. As with any new technology, the introduction of new advanced road lighting technologies will need to be supported with industry training in new installation, design and management techniques. On first encounter, these new techniques may appear very complex and unfamiliar. There may be a slow initial uptake of the new technology until the industry is certain that a major investment in new skills training will be worthwhile. This section provides examples of the issues that need to be considered when converting to the new digital LED technologies.

Digital lighting assessment

320. The inherent “tuneability” of digital light sources means that there is vast opportunity to tune/select the luminaire output parameters to the exact requirements of any given job.

321. The most obvious lighting parameters of interest are light output, light distribution and colour temperature, all of which have a wide range of options on offer from any of the luminaires catalogued by the credible luminaire suppliers.

322. When sifting through the catalogued options of the major LED luminaire suppliers one often encounters many dozens of product permutations of light output, light distribution and colour temperature, all within a single luminaire product range. Behind these “headline” lighting parameter choices are also the “backroom” technical detail options such as colour rendering, spectral attributes, LED driver current etc, all factory tuneable/selectable to meet market/application requirements.

323. It requires diligence and perseverance to work through the variety of brands/models/options to find the most appropriate combination of attributes that will deliver an optimised lighting solution for any given project and client.

324. Finding the optimised “sweet-spot” is the name of the game. The challenge is to find the combination of luminaire attributes (output/distribution/life etc) that best meshes with the given site geometry (road width/column height/overhang etc) and achieves compliance for a given lighting design Standards (AS/NZS 1158) Category.

325. The LED luminaire that achieves this with minimised gross wattage and maximised column spacing potential (relative to competitors) is the best LED option ***from a lighting design perspective*** for that type and configuration of roadway.

Photometric data

326. Photometric data describes the output of a lamp at specific angles from the tested lamp-luminaire combination (the luminaire is made up of a lamp together with its physical and electronic components). A *Photometric File* assembles this photometric data in a given

format to be easily utilised by computer software. IES, CIBSE, EULUMDAT are examples of different file formats for managing photometric data.

327. All lighting fixture manufacturers publish photometric data gathered through an elaborate testing process for products they manufacture. This information (or "I-Tables"[124] as they are sometimes called) is generally available through the manufacturer or a sales representative, an example of which is shown in Figure 47.

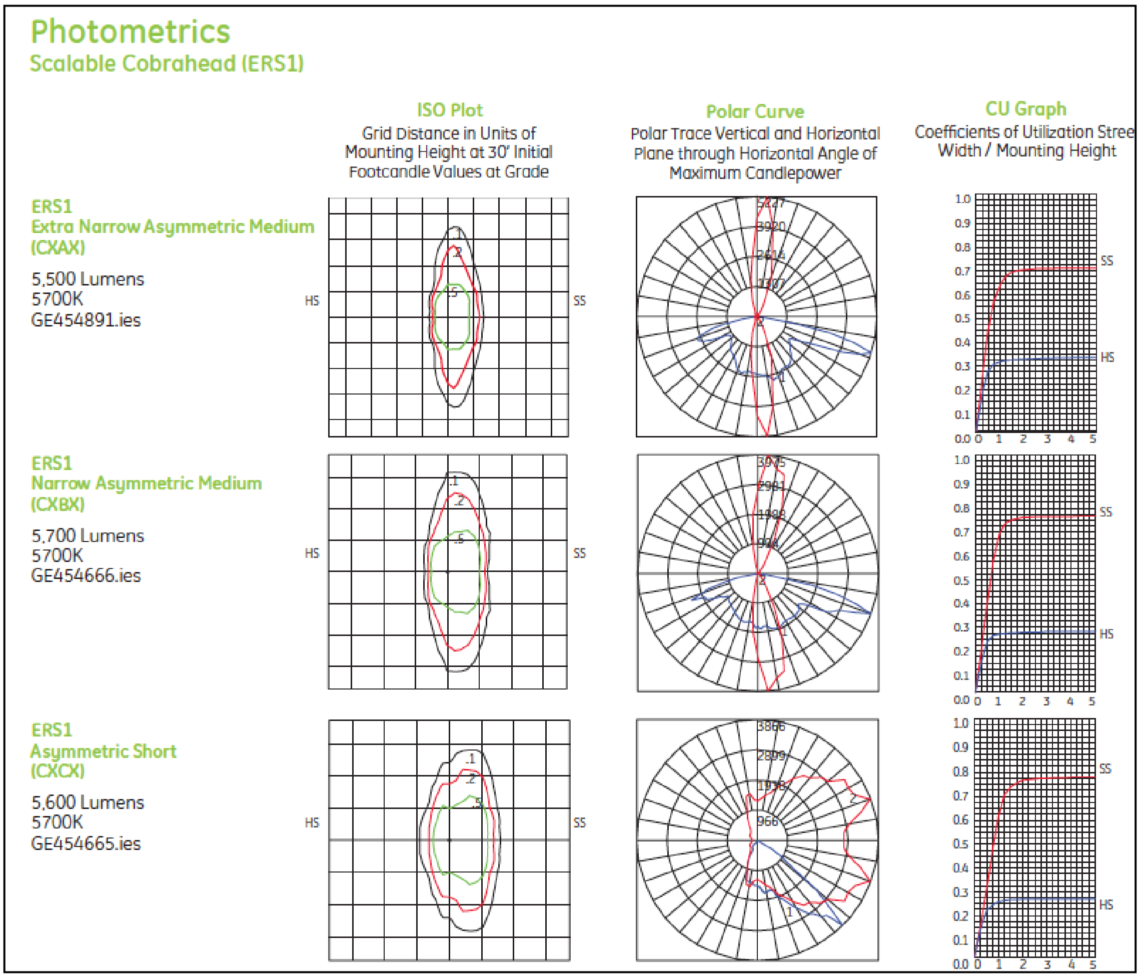

Figure 47 Example of photometrics for a LED Lamp (Source: GE)

328. Photometric data is essential for good design so that the lighting product is matched to requirements. The analogue lighting technologies of HPS, MH, CMH, LPS, MV[125] have photometric data that is generally simpler than LED lamps because the physics of LEDs allows a significantly greater number of variables to be changed – thus making it more customisable to a greater range of applications.

329. This adds complexity to design and selection but results in better outcomes if the investment in understanding and training has been made. Figure 48 provides a graphic demonstration of the complex choices involved.

330. Similarly photometric data provided by manufacturers must be reliable. As the industry is in a rapid development phase, there is a risk that the photometric data is not a precise and accurate representation of the performance of luminaires as delivered.

331. The quality/veracity of photometric data offered by NZ luminaire manufacturers and suppliers is highly variable, ranging from pristine and comprehensive to sketchy and uncertain.

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[124] The I standing for "Illumination"

[125] HPS = High Pressure Sodium, MH = Metal Halide, CMH = Ceramic Metal Halide, LPS = Low Pressure Sodium, MV = Mercury Vapour

Ordering Number Logic

Medium Cobrahead (ERMC)

E R M C _ _ - _ _ - _ _ - A - _ - _ _ _ _ - _

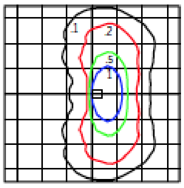
PROD. ID	VOLTAGE	OPTICAL CODE	LED COLOR TEMP	LENS TYPE	PE FUNCTION	COLOR	OPTIONS
E = Evolve **R** = Roadway **M** = Medium **C** = Cobrahead	**0** = 120 - 277 **H** = 347 - 480 **1** = 120* **2** = 208* **3** = 240* **4** = 277* **5** = 480* **D** = 347* *Specify single voltage only if fuse option is selected.		**43** = 4300K **60** = 6000K **65** = 6500K	**A** = Acrylic	**1** = None **2** = PE Rec. **4** = PE Rec. with Shorting Cap **5** = PE Rec. with Control PE control not available for 347-480V. Must be a discrete voltage.	**BLCK** = Black **GRAY** = Gray Contact factory for other colors	**D** = Dimmable (0-10 Volt Input)* **E** = Bubble Level **F** = Fusing **L** = Tool-Less Entry **S** = Shield **T** = Extra Surge Protection* **XXX** = Special Options *Contact factory for availability.

OPTICAL CODE	TYPE	TYPICAL INITIAL LUMENS 4300K	6000K	6500K	TYPICAL SYSTEM WATTAGE 120-277V	347-480V	POLE SPACING (2-4 LANES)	IES FILE NUMBER* 4300K	6000K	6500K
A1	Asymmetric Wide	5400	6000	N/A	95	100	4-6:1	454245	454237	N/A
A2	Asymmetric Wide	7800	8700	N/A	142	149	4-6:1	454246	454238	N/A
A3	Asymmetric Wide	8600	9600	N/A	157	165	4-6:1	454247	454239	N/A
A4	Asymmetric Short	4600	5100	N/A	80	84	2-4:1	454248	454240	N/A
A5	Asymmetric Short	6300	7000	N/A	115	121	2-4:1	454249	454241	N/A
A6	Asymmetric Short	7000	7800	N/A	127	133	2-4:1	454250	454242	N/A
A7	Asymmetric Wide	2800	3100	N/A	52	55	4-6:1	454251	454243	N/A
A8	Asymmetric Wide	3700	4100	N/A	65	68	4-6:1	454252	454244	N/A
B1	Asymmetric Short	5400	6000	N/A	95	100	2-4:1	454583	454577	N/A
B4	Asymmetric Wide	4600	5100	N/A	80	84	4-6:1	454584	454578	N/A
B5	Asymmetric Wide	6300	7000	N/A	115	121	4-6:1	454585	454579	N/A
B6	Asymmetric Wide	7000	7800	N/A	127	133	4-6:1	454586	454580	N/A
B7	Asymmetric Short	2800	3100	N/A	52	55	2-4:1	454587	454581	N/A
B8	Asymmetric Short	3700	4100	N/A	65	68	2-4:1	454588	454582	N/A
C1	Asymmetric Wide	6300	N/A	7000	95	100	4-6:1	454594	N/A	454589
C3	Asymmetric Wide	10200	N/A	11300	157	165	4-6:1	454595	N/A	454590
C5	Asymmetric Short	7300	N/A	8100	115	121	2-4:1	454596	N/A	454591
C6	Asymmetric Short	8300	N/A	9200	127	133	2-4:1	454597	N/A	454592
C7	Asymmetric Wide	3200	N/A	3600	52	55	4-6:1	454598	N/A	454593

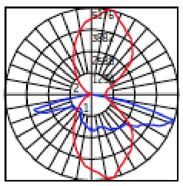
*Shielded options available. Contact factory for IES files.

Photometrics

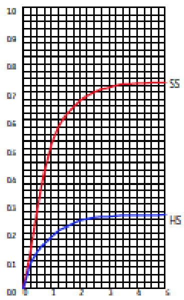
ERMC - Asymmetric Wide (A3)
9,600 Lumens, 6000K (GE454239.ies)



Grid Distance in Units of Mounting Height at 30' Initial Footcandle Values at Grade

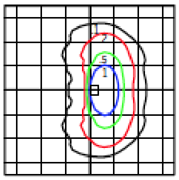


Polar Trace Vertical and Horizontal Plane through Horizontal Angle of Maximum Candlepower

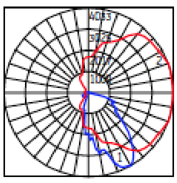


Coefficients of Utilization Street Width / Mounting Height

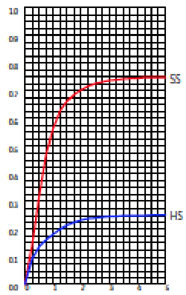
ERMC - Asymmetric Short (A6)
7,800 Lumens, 6000K (GE454242.ies)



Grid Distance in Units of Mounting Height at 30' Initial Footcandle Values at Grade



Polar Trace Vertical and Horizontal Plane through Horizontal Angle of Maximum Candlepower



Coefficients of Utilization Street Width / Mounting Height

Figure 48 Example of wide range of factors involved in LED luminaire selection (Source: GE)

332. Reported problems include:

a) Data files not in accordance with IESNA LM79 guidelines.

b) Data files not from, or verified by, a recognised photometric laboratory.

c) No auditable linkage between the data files and the exact luminaire on offer.

d) Differing LED driver current between data files and luminaire on offer.

e) Scaling up of lumen output with increase in LED driver current (scaling down is OK)

f) Incorrect colour temperature match of data to luminaire on offer.

g) Incorrect match of LED chip version number in data files to that of luminaire on offer.

333. Design and procurement documentation needs to be compiled very carefully with precise and specific technical data requests to potential suppliers. Firm rejection provisions should apply for those that do not comply.

Life Cycle Assessment

334. A Life Cycle Assessment (LCA) of the operation of the roadway in question over the life of the project (20-30yrs) is required in order to determine the Best Value (BV) solution. In this case BV is likely to mean lowest life cycle cost (Capex+Opex NPV), lowest total life cycle energy consumption, lowest life cycle carbon and environmental impacts.

335. Such assessments need to compare- on an “apples with apples” basis – say the top few LED options with Business As Usual (BAU) options (ie HPS or Metal Halide) in order to determine a “winner” that delivers best value for that project.

336. Currently some scenarios are “no-brainers” and some are “no-go”. Delivering improved value depends on the skilled alignment of right application, right technology, right lighting design, right management and operations.

Industry progress

337. This is a very fast moving industry. The economics of equipment capital costs are similar to those for IT/electronic equipment. Once volumes build and critical mass is achieved the unit costs will drop further.

338. In the last year the installed capital cost/unit of CMS control systems (as opposed to the LED Luminaires) from some suppliers has halved. The capital cost premium of discrete step-dim controls (over the cost of regular non-controllable LED drivers) has now dropped to zero.

339. The combination of major subsidies in the US (ARRA) and strict regulation in the EU/UK (EU EcoDesign Directive) is driving the production volume economics of LEDs, and it is likely that volume buyers from other territories (such as NZ) are also likely to benefit.

340. Being able to manage the risks arising from all these changes will provide significant benefits to NZ and RCAs. The challenge is to overcome the understandable momentum to stay with the status quo.

Adoption and Installation

341. Additional precision is required for both designers and installers. With HPS technology a metre or degree out of alignment was hardly noticeable. Alignment of highly-directional LED technology can make a big difference in what is delivered on the road. - enough to turn a success into a failure.

342. Digital lighting (LED luminaires control devices and control systems) is a whole new game that involves not just new equipment, but also new design techniques, new procurement and contractual approaches, new asset management approaches and perhaps new financing approaches.

343. Everyone is on a learning curve. If New Zealand can use its significant resource of designers, engineers, technicians, operations people, maintenance and management staff to travel up this learning curve, this will return dividends in economic development opportunities elsewhere.

344. The digital lighting opportunity is one that has the potential to deliver improved value now (in certain applications) and increasingly in the future. But it requires new approaches and skills to turn potential into reality. The new regime offers a “surgeon’s scalpel” capable of finely

honed application and execution, but it requires more specialized, higher-level skills in ***all*** areas.

345. Just as cars, computers, and mobile phones have come to offer higher Benefit Cost Ratios, but now require more specialised skills to select, operate and maintain, the same is the case for the new generation of digital lighting. It is not an area for generalists or a "No.8" wire approach.

346. The multi-disciplinary nature of new technology road lighting crosses the comfort boundaries of almost every individual practitioner. Optimal solutions and added value rely on the application of consultative, networking and inter-personal skills. Practises being used elsewhere in the NZTA contracting arena (eg an interactive flexible alliance approach to contract variations) need to be applied in the road lighting sector.

347. There is a need for more knowledge and information dissemination of street lighting technologies. EECA has done this well (eg Rightlight) but needs to be allocated more resources to improve upon this;

13.6 Electricity Supply

348. Road lighting is made up of the following elements starting from the end of the chain:
   a) Lamp;
   b) Luminaire (or "fixture" in the USA) which drives and controls the lamp;
   c) Pole and connectors;
   d) Network cable;
   e) Control switchgear including meters if any. From this point "onwards" road lighting becomes an inseparable part of the electricity network infrastructure (transformers, high voltage network, the transmission grid and generators).

349. Road lighting infrastructure suffers from several challenges including:
   a) disparate ownership of different parts of the infrastructure identified above;
   b) decision-making relating to operation, maintenance, replacement and construction of lighting assets is spread between the 76 Road Controlling Authorities for the majority of roads and NZTA for motorways and most of the State Highways;
   c) the cables and electrical hardware up to the pole (but sometimes including that and the luminare as well) are owned by the 28 network distribution companies or Electricity Distribution Businesses (EDB) as they are known in that sector;
   d) un-metered loads - thus electricity use is calculated from the specifications of the lamps and usual hours of operation which the electricity industry calls "profiling" rather than the actual electricity used;
   e) a large variety of tariffs - electrical energy is mainly generated by six big generators - Genesis, Meridian, Mighty River Power/Mercury Energy, Contact Energy, Trust Power and Todd Energy who also retail the electricity along with 9 other smaller retailers[126] - each having their own ways of charging for the energy ranging from a fully fixed charge to a fully variable demand charge (where the load is metered);

350. The challenges posed by the combination of the above factors is formidable but the most important change that needs to be made is the removal of fixed electricity costs otherwise increased efficiency from the new generation lighting technologies will not be rewarded. Naturally this also requires that road lighting is metered. Figure 49 shows the widely ranging proportions of fixed energy costs with four of the 12 showing 100% fixed energy costs.

351. New lighting Centralised Management Systems (such as those covered in Section 5.2) are able to monitor energy usage but these new systems need to be approved by the energy

[126] ***Bay of Plenty Electricity***, ***Empower***, ***Energy Direct***, ***Energy Online***, ***Just Energy***, ***King Country Energy***, ***Nova Energy***, ***Powershop*** and ***Tiny Mighty***.

retailers for revenue gathering purposes as a “revenue meter”. These systems clearly meet international requirements so it should be a relatively low hurdle to overcome.

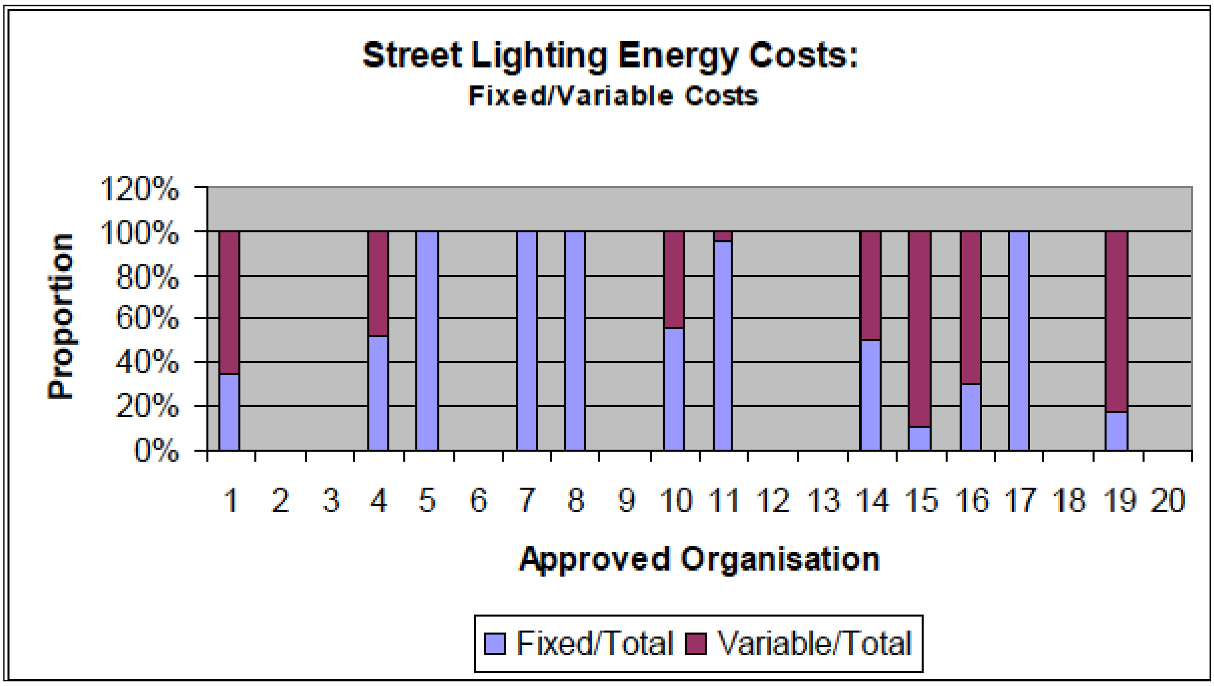


Figure 49 Sample of Road Controlling Authorities showing widely varying Fixed and Variable Energy costs (Source: NZTA[45])

352. As Powerco[127], an Electricity Distribution Business said “Powerco would be happy for councils/ NZTA to invest in metering streetlights. We suspect the costs of doing this are likely to outweigh the benefits – it is a decision for the owner of the streetlights to make, rather than Powerco.” This approach is very likely to be representative of all 28 EDBs.

353. EDBs invest in their networks to meet peak demands. Because street lighting is a night load which corresponds to the lowest levels of demand, EDB’s are not motivated by business drivers to invest in road lighting assets.

354. On the contrary, verbal feedback from one network owner suggested that the EDB was not receiving an adequate return on the street lighting network it owned. Its difficult to assess with confidence how representative this might be, but from experience in this sector one of the authors of this study believes that street lighting is of so little significance to EDBs that modest losses would be written off against the benefits of good relations with the local bodies. Good relations are important as both EDBs and Local Bodies are motivated to serve the interests of their communities.

Call for submissions by Commerce Commission

355. BBA made a submission to the Commerce Commission shown in Appendix 13. The submission was made to reflect the concerns that fixed energy pricing was not in NZ’s interests. Furthermore despite substantial focus on EDB asset management disclosures, there was no information available on EDB road lighting assets to facilitate the issues identified in this study. With the justifiable lack of EDB incentive to invest effort in further disclosures of road lighting information, the Commerce Commission is the only avenue open to provide the driver required.

356. Powerco’s response to BBA’s submission is quoted below and is likely to be very representative of most EDB’s: “The cost benefit justification: Powerco already discloses hundreds of pages of information each year on its electricity network to the Commerce Commission. This includes an asset management plan, pricing methodology, tariff

[127] Charlotte Littlewood, Regulatory Manager, Powerco, 13 April 2012.

information, financial information and technical statistics. It is expensive to collect, audit and publish information – a cost that ultimately falls on consumers. Each requirement must pass a cost benefit test. We do not think your request passes this test for the reasons below."

357. "High cost of collecting information: Powerco inherited gaps in streetlight information and have had problems obtaining information from councils and NZTA. There also seems to be poor historical records of ownership in some areas, and instances of unauthorised work being carried out on our network. Therefore there will be a high cost to obtain this information to the Commerce Commission standard (if some data can be found at all)."

358. "Low benefit of obtaining information: Only a small amount of the electricity cost of streetlights is the distributor cost. The retailer packages the distributor cost and determines the final variable/ fixed split. Therefore there is more benefit in collecting and understanding retailer changes on streetlights. (And we note that councils are able to switch electricity retailers if they want a lower cost or different fixed/ variable split.)"

359. "Economic justification: EDBs costs to supply streetlights are largely fixed, so it is not unreasonable to have a large proportion of the distributor cost recovered as a fixed cost. Retailers control the most variable part of electricity costs (the cost of the energy), so it is more likely that retailers would recover costs by a variable charge."

360. These observations are highly relevant – with one exception. As Powerco itself admits in the introduction to their feedback "*We have only reviewed section 8.6 (Electricity Supply).*" Thus in fact no assessment was made of the benefits discussed in the other 7 sections of the report.

361. This study suggests that in contrast to Powerco's position, the benefits to New Zealand night and twilight drivers do in fact justify the extra cost of gathering the information.

13.7 Road Controlling Authorities (RCAs)

362. Feedback from an RCA suggests[128] that "Council road lighting engineers are continuously confronted with many propositions of new technologies of varying quality. They can be slow to trial or plan significant uptake the technologies, as they are uncertain of how to examine new technologies on a similar basis (eg HPS and LED) or are uncertain how to proceed differently from business as usual. In many cases, the cost of mass installation is outside the council 10-year renewals budget."

363. "Of particular concern is the issue of having enough road lighting designers to redesign the layout of aged road lighting infrastructure to meet current lighting standards. The industry has indicated a shortage of skilled designers to cope with potential mass upgrades."

364. "Current industry participants may also have a dis-benefit in encouraging NZTA and councils to upgrade road lighting infrastructure in mass, as it will reduce their current business based on long-term road lighting redesign or replacing blown light bulbs. Identifying opportunities to supporting industry participants to develop new business solutions will be critical to assist the road lighting industry adapt to the future."

365. The concerns identified above are fundamental and valid. This study suggests that NZTA works with RCAs and enlist EECA and other industry experts to embark on a strategy to lift the sector's skill and understanding. The issue of the industry ending up with lower levels of business is of course true, but like any change there will be initially a significant increase and then in the medium term a definite need for the lower skilled people to retrain and find other work.

13.8 Consultant Engineering Concerns

366. A consulting engineer contributor suggested that some less reputable "lighting suppliers are prone to making outlandish claims that cannot be supported by scientific evidence, or "twist" the evidence in a way that sometimes hides the truth." "Evidence of this is the claims of

[128] Michelle Dawson, Energy Manager, Auckland Council.

some manufacturers that their LED's will last over 100,000 hours, but omitting to mention that the useable light output is miniscule or has not been tested for this length of time. This has gradually reduced over time to the point where manufacturers have stated their useable light output is commonly an average of 50,000 hours. Other claims are in the areas of energy saving, where manufacturers mention light output (lumen) per watt, but omit to add the electronic control gear into the equation."

367. LED lighting technology is still changing very quickly. "When consultants carry out their design, their brief is typically to provide a system that will last for some 25+ years. This assumes that the lights will be available and replaceable for this period of time. Due to the speed of technology change, it is not always possible to replace a LED luminaire with an identical model even 6 months after it was installed. This is problematic for the asset owner who then needs to continue large stocks, or find suitable replacements (eg in the event a car hits a pole)."

368. "There is a huge reluctance within local councils to increase the base of standard luminaires – we are already getting significant pressure to standardize on a few selected models without adding the complication of LED "equivalents" into the mix of luminaires that need to be held in stock."

369. "The NZTA in particular is now commonly (standard in Auckland) specifying twin-arc HPS lamps, with an average lifespan of some 55,000 hours for 250W motorway lighting, and 40,000 for the smaller wattages - 50/70/150W typically used in Council road lighting. The reactor based control gear used is less efficient than the electronic control gear used with the newer technology, though this tends to last for 30 – 40 years, whereas electronic control gear is rated for between 50,000 and 100,000 hours (depending on the specification of the control gear). It is important to consider all parts of the luminaire when examining lifetime claims by manufacturers, not just the lamp. Typically, the luminaire housing for an HPS based luminaire will last for 50 years+, with replacements for lamp and control gear, whereas an LED replacement can sometimes (depending on the luminaire) require replacement of the entire luminaire – at the corresponding high cost, although (including traffic management etc) this can be a small proportion of the entire cost of replacement."

370. These are real and valid concerns that need to be addressed. However, on the whole this study forms the view that most of the above issues have been addressed internationally and the following observations are relevant:

a) Referring to paragraph 366 only aggressive new start-up (desperate?) lighting suppliers are likely to make "outlandish claims". If well established firms make "extravagant" claims its probably either because they are accompanied by assumptions that have been overlooked, or because they have been mis-represented by under-skilled local distributor or because the claims are actually correct and the consultant needs to upskill. Established multinational firms have massive investments in the "old" technologies and are very unlikely to risk their hard fought reputation on outlandish claims for new technologies in order to shorten the economic life of their large established investments. The solution to this problem would appear to be improving the understanding and knowledge of everyone in the industry and this is perhaps a role for EECA;

b) The concern over longevity of luminaire or lamp design (paragraph 367) is one that should be relatively easily managed by good commercial practice. Again, reputable suppliers with reputations at risk will be willing to provide appropriate guarantees on this count – as long as the purchase order is of an economic size. If RCA and consultants insist on continuous trialling of the technology for small quantities, then of course the supplier is unlikely to guarantee model longevity. Its impossible to enjoy the fruits of innovative progress without commitment and having some "skin in the game".

c) The argument for standardisation (368) has great merit. New Zealand is not economically strong enough to have a wide range of unnecessary product options. This contributes to a strong argument that greater rationalisation, amalgamation and centralisation should occur for street lighting procurement.

d) The consultant suggests in paragraph 369 that modern HPS 250W lighting appears to be better than LED product offerings. Certainly this appears to be the case on the figures provided. However no financial data was included and the point of this report is that such product offerings should be carefully compared against the new LED technologies that will inevitably replace the old. So the key question is when is it best to convert and should there be a planned strategy to do this given the contents of this study?

As a different commentator suggested *"In a few short years we will be experiencing LED based lighting everywhere much like we now use MP3 players, digital photography and the Internet. Currently we are planning new substantial infrastructure projects that specify lighting based on fifty year old technology (High Pressure Sodium). Continuing to invest in this technology is surely a complete waste of money."*

Another different consultant made the following observation after attenting the largest lighting trade fare in the world: *"It was extremely difficult to find any Luminaire Suppliers promoting HID Luminaires. From there I went to Lyon, France to the Philips Lighting Research and Development Centre. Basically from what they told me there is no more development in HID Lighting Technology after 2013. It is LED all the way."*

13.9 Recommendations

371. That NZTA:

a) Together with MED (who already has several programs to aggregate purchasing) set up a centralised road lighting procurement group for New Zealand to leverage best value advanced road lighting technologies and optimum risk management to improve value for money;

b) Sponsor a study to identify a very short list of advanced technologies to confirm or otherwise that they should replace HPS luminaires as soon as possible (especially for Christchurch);

c) Conduct a review of NZTA procurement practices to discover if they can be streamlined for, and customised to, multidisciplinary advanced technology road lighting;

d) Establish an advanced road lighting training unit with assistance of EECA, Ministry of Education and Tertiary Institutions, probably most likely the Institutes of Technology and Polytechnics (ITPs);

e) Commission a study to identify the impediments for electricity efficiency in road lighting and recommendations on how best to remove them;

f) Reduce the 20 – 30 year project hurdle rate for road lighting investment from 8% to something closer to international best practice so that medium to long term savings are not foregone;

g) Sponsor a full review of AS/NZS 1158 Lighting for roads and public places;

h) Work with tertiary institutions to grow the number of road lighting designers and engineers to meet near future demand.

i) Encourage addition of future road lighting technologies and whole of life cost evaluation to graduates road lighting skill base.

j) Include supporting industry participants in discussions to assist them identify future business services.

k) Encourage the Commerce Commission to request road lighting asset management information from the Electricity Distribution Businesses;

l) Form a working group to investigate the potential to negotiate a bulk purchase of road lighting electricity from the retailers that was economically efficient for NZTA and the road controlling authorities.

9 Conclusions and Recommendations

372. As a result of this relatively rapid desk research exercise, together with two rounds of consultation involving more than 120 people, there appears to be a strong case to suggest that Government should take a leadership position through the NZTA to:

13.1 Validate the figures and claims made in this report

373. Further consultation/investigation with a larger cross section of experts is a priority. People to be consulted include:

a) More staff from within NZTA relating to the Task Force, the way capital projects are managed, and how projects are monitored and performance measured, and access to the data bases mentioned in this report (eg RAMM)

b) Street lighting engineers and consultants especially those responsible for previous relevant reports (eg Merrifield, Frith, etc)

c) Relevant staff from MoT, EECA, Treasury, NZTE, MED, MSI, CERA, Local Government NZ (LGNZ) IPENZ, and possibly SANZ.

d) Road Controlling Authorities (RCAs) that have already trialled new generation lighting technologies, plus one or two (larger ones) that haven't to ensure a good reason not to proceed hasn't been missed.

e) Those involved in budgeting and financial modelling for NZTA and RCAs

13.2 Support the drafting of a road lighting strategy with the following goals (Section 4.11):

374. Reduce the 4,567 injuries (31.7% of total accidents) in darkness and improve other amenity values such as perception of security against criminal threats, prosperity for tourists etc;

375. That Opus's recommendations in the NZTA report on road reflectivity[53] be implemented with one alteration, ie to:

a) "*form the basis of a first-principles, safe-system approach review of the processes used in road-safety lighting design in New Zealand. This should review r-tables, luminance levels, uniformity levels, glare levels and direct on-site measurement of lighting parameters, as the technology to do this becomes more accessible*."

b) "*In parallel, an investigation should be made into the relationship between night-time* ***crashes*** [see d below] *and key technical parameters of road lighting in New Zealand*", and

c) "*Ongoing monitoring of road surface reflection properties (including the economics of using pavement brighteners) should be carried out, based on methods developed in this project*."

d) Replace the word "crashes" in b) above by "injuries" to include all class of accidents including pedestrians.

376. Coordinate a Research and Development strategy for road lighting across the Ministry of Science and Innovation (MSI), the Ministry of Transport (MoT), NZTA, the Ministry of Economic Development (MED), the Health Research Council (HRC) and the Tertiary Education Commission (TEC) to provide a whole-of-Government approach to:

a) Facilitate the above recommendations; and

b) Discover whether NZ innovations can result in a decrease in road accidents during the hours of darkness.

13.3 Support the introduction of new generation road lighting technologies (Section 5.6):

377. NZTA coordinate the Ministry of Transport (MoT), the Ministry of Economic Development (MED, including its energy division), Canterbury Earthquake Recovery Agency (CERA), and NZ Treasury investigate the establishment of a targeted programme of road illumination to:

a) improve the accuracy of the estimated benefits identified in this report including the ones identified below through further information and gathering of NZ and international advice;

b) significantly reduce the number of road accidents that occur during darkness[129] through the use of modern white road lighting;

c) potentially halve the $55 million costs of road lighting in NZ by the use of a programme to introduce advanced road lighting technologies including Central Management Systems across the country;

d) introduce advanced road lighting technologies to Christchurch as quickly as possible for its rebuilding program and leverage the experience gained to the rest of NZ;

e) leverage off the above programmes to strategically position New Zealand to benefit from the rapid global uptake of the “revolutionary” LED technology predicted by highly credible sources (including US Department of Energy, McKinsey & Co);

f) investigate in detail why current large road NZTA lighting projects have not chosen to use the advanced technologies to determine whether future installations should specify them. Particular examples are the Waterview tunnel and the Eastern Link.

g) mitigate against the risks of new technologies through implementing well established commercial techniques and contract terms to move risk to suppliers;

h) mitigate against the risks of cultural resistance to change from the public sector and its conservative private sector advisers through a strong education and communications programme;

i) provide incentives to Road Controlling Authorities to convert to modern road lighting by allowing them to keep more of the operating savings made than NZTA would normally allow through its 45-55% of funding formula;

378. Where NZTA fully funds road lighting:

a) lead by example by providing consultants and suppliers requirements to utilise the newer beneficial technologies that meet international standards;

b) Increase NZTA subsidisation for renewal or new installation projects with lower whole of life cost and conversely lower subsidisation of ‘business as usual’ technology for the next 5 years, while a longer-term plan is being developed.

13.4 Support the use of private capital to upgrade road lighting (Section 6.5):

379. NZTA coordinate the Ministry of Transport (MoT), the Ministry of Economic Development (including its energy division), Canterbury Earthquake Recovery Agency (CERA), and NZ Treasury investigate the establishment of a targeted programme of road illumination to:

a) gather an up-to-date fully representational sample of road lighting asset management data to improve the accuracy of the economic benefits and confirm or otherwise the speculative economic estimates above;

b) obtain reliable advice on the applicability of UK road lighting PPPs to New Zealand and subsequently determine what modifications are necessary in New Zealand to make PPPs for road lighting here viable;

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[129] *Motor Vehicle Crashes in New Zealand*, Ministry of Transport, figures for the year ending 31st December 2010, Table 8, Page 29.

c) conduct a communication programme including workshops to familiarise the 76 RCAs with PPPs and their advantages;

d) utilise private capital through PPPs or variants thereof to capture the benefits identified in this section above;

e) investigate the possibility of amalgamating the road lighting interests of road controlling authorities to minimise the number of privately funded procurement contracts required, with a possible objective to limit them to four across NZ.

13.5 Draft and implement an innovation strategy (Section 7.4):

380. We recommend that NZTA should:

a) Launch a separate innovation strategy. The culture involved in promoting innovation to resolve problems, increase safety, enjoy economic growth or meet environmental challenges are fundamentally different from the culture required to operate an organisation that spends $1.95 billion[130] per year . BBA recommends that NZTA consider launching an innovation strategy that incorporates the observations and recommendations in this report for road lighting as below – but goes further than this to apply the same principles across the organisation.

b) Engage with NZTA staff to identify people, companies or organisations that have innovative products or services that would contribute to the previously recommended road lighting strategy, as well as provide those companies – and thus New Zealand - with economic growth opportunities.

c) Engage with the Ministries of Economic Development (MED), Science and Innovation (MSI), Education (MED), and the Tertiary Education Commission (TEC), Industrial Research (IRL), and Trade and Enterprise NZ (TRADENZ), to identify public and private organisations that could contribute towards NZTA's innovation strategy and provide economic development opportunities that would advance a road lighting strategy.

d) Review its Research and Development programme to incorporate the findings of this report. NZTA's research programme as published on the internet has a predominance of civil R&D. The terms of reference for the review should include matching concrete quantifiable outcomes to desired programs and their costs, much as MSI has begun to do. For example as identified in the recommended road lighting strategy – to facilitate the reduction of the 4,567 of injuries (31.7% of total) occurring in dark periods by xx and the budget to do this should be yy% of the total NZTA R%D budget or less.

e) Fund research to establish the relationship between land transport injuries and lighting levels and colour (during the hours of twilight and darkness);

f) Identify where most cost effective changes in the culture of NZTA should be made to increase its ability to innovate at the same time as deliver quality outcomes.

g) Together with the appropriate organisations identified in a) above, and the private sector, conduct "innovation workshops" to identify areas where NZTA and MoT objectives could be met through innovation – either in the public or private sector.

13.6 Challenges to overcome (Section 8.9):

381. We recommend that NZTA undertake the following actions**:**

a) Together with MED (who already has several programs to aggregate purchasing) set up a centralised road lighting procurement group for New Zealand to leverage best value advanced road lighting technologies and optimum risk management to improve value for money;

[130] NZTA Annual Report 2011

b) Sponsor a study to identify a very short list of advanced technologies to confirm or otherwise that they should replace HPS luminaires as soon as possible (especially for Christchurch);

c) Conduct a review of NZTA procurement practices to discover if they can be streamlined for, and customised to, multidisciplinary advanced technology road lighting;

d) Establish an advanced road lighting training unit with assistance of EECA, Ministry of Education and Tertiary Institutions, probably most likely the Institutes of Technology and Polytechnics (ITPs);

e) Commission a study to identify the impediments for electricity efficiency in road lighting and recommendations on how best to remove them;

f) Reduce the 20 – 30 year project hurdle rate for road lighting investment from 8% to something closer to international best practice so that medium to long term savings are not foregone;

g) Sponsor a full review of AS/NZS 1158 Lighting for roads and public places;

h) Work with tertiary institutions to grow the number of road lighting designers and engineers to meet near future demand.

i) Encourage addition of future road lighting technologies and whole of life cost evaluation to graduates road lighting skill base.

j) Include supporting industry participants in discussions to assist them identify future business services.

k) Encourage the Commerce Commission to request road lighting asset management information from the Electricity Distribution Businesses;

l) Form a working group to investigate the potential to negotiate a bulk purchase of road lighting electricity from the retailers that was economically efficient for NZTA and the road controlling authorities.

13.7 Further recommendations

382. We recommend that NZTA should consider the following:

a) (Like the UK) Establish **incentives for RCA's** to enter into PPPs to meet the road lighting strategy goals (Section 9.2 above)

b) Provide **financial incentives** to road lighting PPPs – such as i) fixed favourable terms long term loans; ii) increased share of operating savings (rather than the ~50% NZTA proportion) either for all PPPs or for the first few "off the block" to encourage rapid implementation and/or iii) other incentives to increase the efficacy of delivery of road lighting to improve safety, value for money and economic development.

c) Road lighting should have a **centre of excellence**, a champion and leadership. Like Los Angeles' Bureau of Street Lighting[131], NZ must vigorously pursue centralised transparent purchasing which requires several other things such as standards mentioned above. New Zealand is too small to have 76 different democratic organisations managing the introduction of highly beneficial, but complex technology;

d) Under the championship of the centralised secretariat/centre of excellence **a limited number of PPPs** should be allowed - perhaps ideally each having a minimum of 50,000 lights. The centralised function would require appropriate resourcing, management and governance structures in place with required legal, financial and other advisory services also centralised to save money;

e) All PPPs should be required to have centralised **management systems that share** all information with the centre of excellence and was available (promoted) to innovators and business developers alike – as well as of course NZTA, MoT etc.

[131] Which has oversight of about 42% of the number of road lights in New Zealand.

f) **Achievements of any type must be communicated** widely to stakeholders, and where appropriate, to overseas entities so that NZ becomes accepted as a centre of excellence in its niche areas;

g) Mitigate against the risks of new technologies through implementing well **established commercial techniques** and contract terms to lay-off risk to suppliers who will have large contracts to make it worth wile for them to do;

h) **Mitigate against the risks of cultural resistance** to change from the public sector and its conservative private sector advisers through a strong education and communications programme.

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1158.1.2:2010 Vehicular Traffic (Category V) lighting – Guide to design, installation, operation and maintenance,
1158.2: Computer procedures for the calculation of light technical parameters for Category V and Category P lighting;
1158.3.1:2005 Pedestrian area (Category PP lighting – Performance and design requirements;
1158.4 Lighting at Pedestrian crossings;
11158.5:2007 Tunnels and underpasses,
1158.6:2010 Luminaires;

Appendices

Appendix 1. NZTA Road Maintenance Task Force Announcement

1/12/12 beehive.govt.nz - Roading sector taskforce announced

beehive.govt.nz
The official website of the New Zealand Government

Steven Joyce **26 JULY, 2011**

Roading sector taskforce announced

The government has established a Road Maintenance Task Force to drive value for money and seek opportunities to reduce costs for roading authorities around the country. Transport Minister Steven Joyce says the taskforce has been set up alongside the new Government Policy Statement on Land Transport Funding to encourage initiatives in the road maintenance and renewals area that save money without sacrificing quality.

Mr Joyce says the push for value for money over the last two to three years has so far delivered variable results around the country.

"Some local councils and the NZ Transport Agency have been able to achieve very significant gains and savings, but others have been less successful.

"The Contractors Federation has told me that they believe significant savings are able to be gained through taking a more efficient approach.

"The task force will identify opportunities for efficiencies in road maintenance and renewals. It will also identify innovative products and best practice methods of procurement, and encourage their uptake through the country.

"It's important to know that the large amounts spent on roading each year will not only be invested sensibly, but that we are seeking to increase the return on every dollar spent.

The task force will be made up of individuals from local government, industry, and the NZ Transport Agency (NZTA), and will be convened by the NZTA.

Mr Joyce says he expects that the task force will be fully established by August, that it will complete its investigations and share its findings by April 2012.

Initial Task Force Members

Jim Harland (Convenor)
Regional Director, Southern Region, NZ Transport Agency

David Adamson
Chief Executive, Southland District Council

David Fraser
Group Manager: Asset Management, Hastings District Council

Murray Noone
Manager Road Corridor Maintenance and Renewals, Auckland Transport

Geoff Swainson
Manager Development and Infrastructure, Local Government NZ

Cos Bruyn
Chair, Roading NZ

Jeremy Sole
Chief Executive, NZ Contractors' Federation

Tony Porter
Member, Transportation Group, Assoc of Consulting Engineers NZ

Mark Kinvig
State Highways Manager, Napier, Highways & Network Operations, NZ Transport Agency

Appendix 2. Road Maintenance Task Force Terms of Reference

NZ TRANSPORT AGENCY
WAKA KOTAHI

ROAD MAINTENANCE TASK FORCE

Terms of reference

Purpose

The purpose of this Task Force is to identify opportunities for efficiencies in delivery of operations, road maintenance and renewals, including innovative services, products and methods of procurement, and to encourage their consistent uptake through the country.

Background

Funding from the National Land Transport Programme is allocated for the operation, maintenance and renewal of both local roads and state highways. The levels of funding for these activities are set with the aim of ensuring the asset condition is maintained to achieve target levels of service, while at the same time providing funding pressure to realise efficiency gains. Anecdotal evidence suggests there are opportunities to create greater efficiencies, for example by fostering an environment that supports using innovative products, alternative methods of procurement, sharing best practice and standardising contract documentation.

Task Force objectives

The Task Force objectives are to:

1) understand the cost drivers of maintenance and renewal activity and their relative importance
2) identify opportunities to improve both efficiency and effectiveness in the planning and delivery of operations, maintenance and renewals, that achieve least whole-of-life cost for the network and enhance community well-being
3) identify innovative services, products and methods of procurement to achieve value for money and a safe network
4) identify examples of best practice standards and guidelines, including standardised and harmonised contract documentation, that could be implemented
5) better understand the cost implications of risk transfer associated with planning and delivery of operations, maintenance and renewals and identify examples of good practice in risk identification, management and allocation to deliver better value for money across the Industry
6) promulgate the uptake of the Task Force findings
7) consider the benefits of continuing the Task Force approach, with the aim of fostering best practice and collaboration in the sector.

NZ TRANSPORT AGENCY
WAKA KOTAHI

Task Force Membership

The Task Force Governance Group will comprise representatives from the following organisations:

- NZ Transport Agency
- Local government representatives from the rural, provincial and urban sectors
- Local Government NZ
- NZ Contractor's Federation
- Roading New Zealand
- Association of Consulting Engineers NZ

Timeframes

The Task Force work will be undertaken in three stages:

Stage 1 (July - August 2011)
Establish scope and plan.

Stage 2 (March 2012)
Undertake investigation/research.
Develop and publish findings.

Stage 3 (April 2012)
Promulgate findings of the Task Force.

Roles and responsibilities

Convenor (NZ Transport Agency)
- To organise and chair the meetings of the Task Force Governance Group
- To draft and circulate minutes of the Task Force.

Members
- To attend and actively participate in the meetings of the Task Force.

In order to facilitate the work of the Task Force, the Task Force Convenor will chair the Governance Group. Technical working groups will be established which will provide the Task Force with analysis and advice. The Task Force Convenor will also form a small Secretariat that will provide logistical support to both the Task Force and the Working Group.

NZ TRANSPORT AGENCY
WAKA KOTAHI

Resources

Each organisation will make a commitment to ensure Task Force members are given the responsibility and time to fully commit to the group. Participating members will be expected to meet any costs arising. The NZ Transport Agency will meet the costs of attending meetings of the Task Force and technical working group members, such as the additional cost of travel.

The administrative costs for establishing and supporting the Task Force will be met by the NZ Transport Agency.

Communication

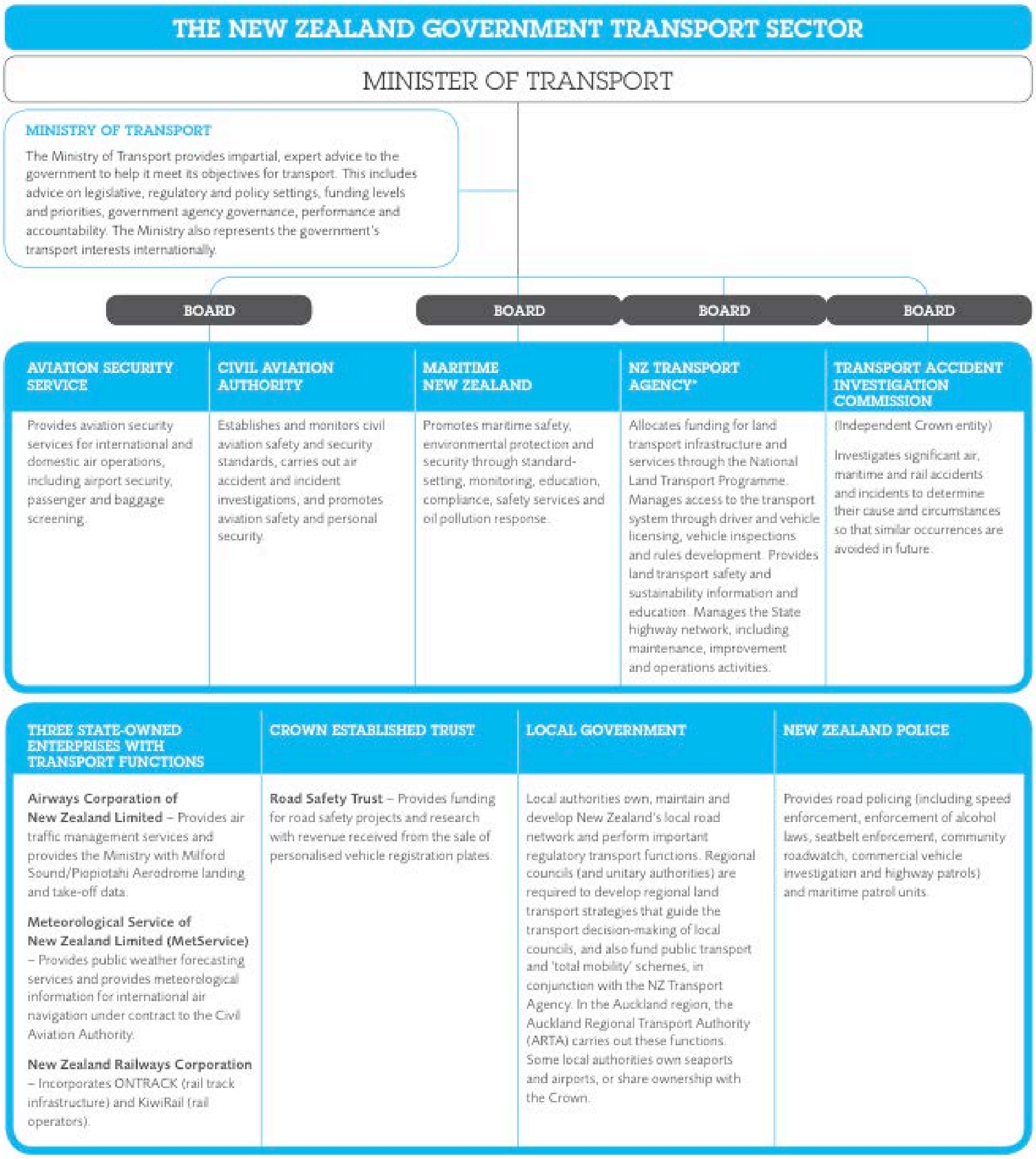
For Task Force communication, the Convenor will be the first point of contact.

Expectations

The Task Force findings may encourage better practices and inform decision making to ensure value for money. The NZ Transport Agency will present the findings of the Task Force to the Minister of Transport.

Appendix 3. Structure of Government Transport Sector

The New Zealand government transport sector includes the Minister of Transport, the Ministry of Transport, five Crown agencies, three state-owned enterprises and one Crown established trust. These agencies and their functions are explained in the table below.



* Land Transport New Zealand and Transit New Zealand merged to become the New Zealand Transport Agency (NZ Transport Agency) on 1 August 2008.

Appendix 4. List of Information Sources

Author(s)	Article	Book Title/Publication/Website	Publisher	Date
		Ministerial List as at 14 December 2011		2011
EECA, NZTA, LGNZ, et al		RightLight.govt.nz/roadlighting	RightLight Programme, EECA	2011
Tuenge, Jason	MSSLC Model Specification for LED Roadway Luminaires	DOE Solid-State Lighting Webcast	Pacific Northwest National Laboratory	2011
		Summary of the 6th Road Lighting Review Panel Meeting on 8 November 2011	EECA, Wellington, NZ (& NZTA?)	2011
		Christchurch Rebuild: Funding Options discussion with Christchurch City Council	Ernst & Young, NZ	2011
Office of the Auditor-General		Managing the Implications of Public Private Partnerships	Office of the Auditor-General, Wellington, NZ	2011
Proctor, Libby & King, Ben	Shedding Light on PPPs		Ernst & Young, NZ	2011
	LEDs Winning Fans in Hamilton	NZ Local Government Magazine		2011
Commerce Commission		Compliance Review of Electricity Distribution Businesses' Asset Management Plans for the period beginning 1 April 2011	Commerce Commission, Wellington, NZ	2011
King, Bryan	Development of a Road and Urban Lighting Holistic Assessment Model	Professional Lighting Design Convention, Madrid	Lighting Management Consultants Ltd, Auckland, New Zealand	2011
King, Bryan	Development of a Road and Urban Lighting Holistic Assessment Model	Professional Lighting Design Convention, Madrid	Lighting Management Consultants Ltd, Auckland, NZ	2011
		The PLDA Statement on Sustainability	PLDA	2011
		NZ Transport Agency annual report and the National Land Transport Fund annual report for the year ended 30 June 2011	NZ Transport Agency	2011
		LED for liveable cities: Bringing the city to life with the power of light	Koninklijke Philips Electronics N.V.	2011
Jerry Sanders, J., Mayor	BRIGHTER, MORE EFFICIENT STREETLIGHTS YIELD MORE THAN $2 MILLION IN ANNUAL SAVINGS	Press release	The City of San Diego	2011
Bailey, C (Hubbell Lighting) & McClear, M (Cree, Inc.)	Outdoor LED Lighting	2011 IES Street & Area Lighting Conference, New Orleans	Illuminating Engineering Society	2011
		Major North Island and South Island transport network connections (maps)		2011
Stuchinsky, Laura	MSSLC Remote Monitoring and Adaptive Controls Specification - Draft	IES Street and Area Lighting Conference Paper	Department of Transportation, City of San Jose	2011
Smalley, Stevens & Rosinbum	US DOE Municipal Solid-State Lighting Consortium Update	IES Street and Area Lighting Conference Paper	US Department of Energy	2011
King, Bryan	"Smart Lighting Needs Smart Procurement"	Local Government Magazine		2011
Haydon, Gary	Austin Energy - Controls and Asset Management	IES Street and Area Lighting Conference Paper	Austin Energy, Texas	2011
Mitchell, Paul	This Spec Shall Remain Nameless	LD+A	www.ies.org	2011
		Public Lighting Management: Expression of Interest Invitation (Contract 1112021)	Sunshine Coast Regional Council	2011
Wembridge, Neil		2011 Asset Management Plan Reviews (Report for Commerce Commission on NZ EDB AMPs 2011-2021)	Parsons Brinckerhoff NZ Ltd	2011
Wikipedia	Diffusion of Innovations	http://en.wikipedia.org/wiki/Diffusion_of_innovations	Wikipedia	2011
Stuchinski, Rosinbum & Poplawski	MSSLC Specification for Remote Monitoring & Adaptive Lighting Control Systems—The Next Step in SSL	MSSLC Southwest Region Workshop Paper, San Jose, CA	City of San Jose, City of Portland and Pacific Northwest National Laboratory (PNNL)	2011
Tuenge, Jason	MSSL Consortium Draft Model Specification for LED Street & Roadway Luminaires	MSSLC Southwest Region Workshop Paper, San Jose, CA	Pacific Northwest National Laboratory	2011
Berndt, Emma	Cost benefit analysis tools: evaluating the impacts of street lighting retrofit projects	MSSLC Southwest Region Workshop Paper, San Jose, CA	Clinton Climate Initiative, Clinton Foundation	2011
Cook, Eddie	LED Street Lighting Trial	Infrastructure Services Report on Objectives and Methodology	Invercargill City Council	2011
		NZSIF CHAIRMAN'S ADDRESS TO ANNUAL SHAREHOLDERS MEETING		2011
Cuttance, B		Notes for Road Maintenance Task Force	NZ Transport Agency	2011
	Developing our energy potential	NZ Energy Strategy 2011-2021 & the NZ Energy Efficiency and Conservation Strategy 2011-2016	Ministry of Economic Development, NZ	2011
		New Zealand Social Infrastructure Fund ASM Investment Manager's Report	Morrison& Co, Wgtn	2011
		Driving LED outdoor applications: Xitanium High Efficiency LED drivers	Koninklijke Philips Electronics N.V.	2011
Office of the Minister of Transport		Cabinet Paper: CONNECTING NEW ZEALAND – A SUMMARY FOR STAKEHOLDERS OF THE GOVERNMENT'S POLICY DIRECTION FOR TRANSPORT		2011
Joyce, S., Minister of Transport	Roading sector taskforce announced	Ministerial Press Release	www.beehive.govt.nz/release/roading-sector-taskforce-announced	2011
		New Zealand Social Infrastructure Fund Annual Report to Shareholders (covering letter)	NZSIF Ltd	2011
	What a bright idea! New system of 'intelligent lights' that turn off when you walk past	Daily Mail, UK		2011
Baumgartner et al		Lighting the Way: Perpectives on the Global Lighting Market	McKinsey & Company Inc	2011
Baumgartner et al		Lighting the way: Perspectives on the global lighting market	McKinsey & Company Inc	2011
		Government Policy Statement on Land Transport Funding 2012/13-2021/22	MOT	2011
Roorda, M and Alkema, A.	Evaluation of the value of NZTA research programme reports to end users	NZ Transport Agency research report 450	NZ Transport Agency	2011
	LED street lights improve visibility at UK highway junction	LEDs Magazine	www.ledsmagazine.com	2011
		LumiMotion – minimizing waste of light without compromising on safety	Koninklijke Philips Electronics N.V.	2011
	Energy saving, reduced maintenance costs, increased lighting service and safety/security for your Outdoor Lighting networks	DESCRIPTION OF THE STREETLIGHT MONITORING SOLUTION FROM STREETLIGHT.VISION AND SELC (SLV33-537 - Version 3.3)	Streetlight.Vision	2011
The Integral Group		2012-15 Table 2 - Construction FARs for improvement activities (NZTA Planning & Investment Knowledge Base)	NZ Transport Agency	2011
The Integral Group		2012-15 Table 3 - FARs for delivering specified activities (NZTA Planning & Investment Knowledge Base)	NZ Transport Agency	2011
The Integral Group		2012-15 Table 4 - FARs for certain circumstances (NZTA Planning & Investment Knowledge Base)	NZ Transport Agency	2011
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Powell, Jeanette, Minister for Local Government	Coalition Budget commitment to greening Victoria street by street	Victorian Coalition Government's 2011-12 Victorian Budget media release		2011
Nebel, Barbara	LCA in New Zealand	Int J Life Cycle Assess (2011) 16:489–492		2011
Aulich, C., Gibbs, M., Gooding, A., McKinlay, P., Pillora, S., and Sansom, G.		Consolidation in Local Government: A Fresh Look (Vol 1 Report)	Australian Centre of Excellence for Local Government (ACELG), Local Government Association of South Australia (LGASA), and Local Government New Zealand (LGNZ)	2011
		PIP Fund Informal Discussion: Street Lighting	Morrison& Co, Wgtn	2011
	Harvard wins Queen's Award for street-lighting innovation	LEDs Magazine	PennWell Corporation	2011

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		Ministerial List as at 14 December 2011		2011
EECA, NZTA, LGNZ, et al		RightLight.govt.nz/roadlighting	RightLight Programme, EECA	2011
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		Beautifully efficient: Philips Roadstar Series with customizable LED light control			G - Bryan 17
		Philips Roadstar Series - Specification	Philips Roadway Lighting, Illinois		G - Bryan 17
		Potential Energy Savings for NZ Road & Street Lighting			G - Bryan 17
King, Bryan	Streetlight Energy Metering: Opportunities and Impediments		Modus Lighting, NZ		G - Bryan 18
		Submission to the Ministry of Transport in the matter of the Government Policy Statement on Land Transport Funding 2012/13 – 2021/22	Local Government NZ		LGNZ
		Safer Journeys: New Zealand's road safety strategy 2010–2020	MOT		MOT
		Expenditure on Infrastructure and Services Regional 2007 (98/99 - 06/07)			MOT Statistics
		National Land Transport Programme Expenditure on Infrastructure and services 2007 (98/99-06/07)			MOT Statistics
		Number of accidents by mode 1999-2010			MOT Statistics
		Number of accidents by local body 2000-2010			MOT Statistics
		Number of road accidents by region 2000-2010			MOT Statistics
		Regional length of sealed State Highway in kilometres 2005/06 - 2009/10			MOT Statistics
		Road VKT billions by vehicle type 2001-10			MOT Statistics
		Type of Road Users Killed and Injured in each speed limit area during daylight and darkness (Year ended 31 December 2010)			MOT Statistics
		2012–15 NLTP indicative funding allocations to activity classes	NZ Transport Agency		NZTA
		2012–15 NZTA Investment and Revenue Strategy	NZ Transport Agency		NZTA
		Carriageway lighting expenditure by region (TAs and NZTA) 2000/01-2006/07			NZTA - Bernie Cuttance
		Road Maintenance Task Force: Terms of Reference	NZ Transport Agency		NZTA - Bernie Cuttance
International Institute for Energy Conservation (IIEC)		Survey (form) of LED Street and Outdoor Lighting Standards and Projects in APEC Member Economies	APEC		NZTA - Mike Jackett
Mark Kinvig		Maintenance and Operations Review Sep 2011 - June 2013 (presentation)	NZ Transport Agency and Headway		NZTA - NZTA projects
Jackett & Frith		Reflection Properties of New Zealand Road Surfaces for Road Lighting Design	Jackett Consulting & Opus International Consultants, Central Laboratories		Opus
		Media release Q&A on PIP Fund	NZSIF Ltd		PPP - NZSIF
Loveless, Mr, Roger	Street Lighting: A Visible Sign of Commitment to Sustainable Electricity Use	BDEM-106 NZSSES Paper Rev 2	Odyssey Energy Limited, Hamilton		Roger Loveless

Appendix 5. Author credentials

Bridger Beavis
& Associates

Consultancy Profile

Bridger Beavis & Associates Ltd (BBA) is a strategic advisory, business development and marketing communications consultancy with a particular interest in the commercialisation of new sustainable technologies in fields including energy and agritechnology.

BBA's two principals are senior practitioners in their complementary fields with experience at senior management and governance levels in both the public and private sectors. The consultancy has considerable depth of experience in the energy and utilities sectors from electricity corporatisation in the 1990s to the recent roll-out of fibre optics and investigation of newer technologies including solar and wind power. BBA can draw on a broad range of specialist expertise through its subcontracting network if required.

Godfrey Bridger ME (Elect), MBA (Exec)

Godfrey is a business development and commercialisation specialist, and is a member of MSI's On Demand Review Panel. He is a former CEO of the Government's Energy Efficiency and Conservation Authority (EECA), served for a term on the board of Mercury Energy, was an elected member of Auckland Regional Services Trust and also served as a member of the Waikato Energy Forum that established the draft Waikato Regional Energy Strategy. During a term as Business Development Manager with Counties Power he doubled its fibre optic network and investigated green generation projects achieving investment-ready status for an integrated building solar PV project and green data centre. He also assisted with the development of Wintec's student eco village. Drawing on his background as a CRI sector leader for bioengineering and agritechnology Godfrey has facilitated agritech start-ups to gain investment within the Waikato Innovation Park Technology incubator, and recently undertook a short assignment as GM R&D for animal health delivery systems manufacturer Simcro.

Crystal Beavis, MA (Hons), APR, MPRINZ

Crystal has more than 25 years' experience in marketing communications, public relations, advertising and journalism in New Zealand and the UK. She currently works in an advisory capacity for the University of Waikato to market the university's research institutes and specialist research services. Crystal has worked or consulted for organisations operating across a range of technical and industrial sectors including educational and research organisations, health, utilities and financial services. She is a former corporate and public affairs manager for Medicines NZ, a former President, now a life member, of national patient organisation Diabetes Youth NZ, and served for a term on the Auckland District Health Board. Crystal moved into marketing and public relations consulting after working as a business journalist for the NZ Herald and National Business Review.

Bridger Beavis & Associates Ltd,
49 Poplar Lane,
RD4,
Hamilton 3284, NZ.
www.bba.org.nz
E-mail consultbba@clear.net.nz
Tel. 07 859 0059,
Fax 07 859 0060,
Mobile 021 274 3437 (Godfrey) or 027 595 7927 (Crystal)

Lighting Management Consultants Ltd

Lighting Management Consultants Ltd (LMC) is a management consultancy specialising in lighting infrastructure - bringing new generation thinking to planning, procurement, operations and management.

LMC applies Life Cycle Management techniques for the holistic assessment of energy, economic and environmental effects on lighting infrastructure, identifying "low impact" approaches.

The new world of sustainable enterprise forces asset owners to look beyond lowest first cost procurement approaches and to seek solutions that deliver Best Value outcomes.

The Life Cycle Management approach quantifies energy and environmental impacts and provides tangible support information for Total Cost of Ownership based decision making.

LMC brings real world pragmatism and experience to determining the costs and the benefits of lighting investment decisions and to developing the business case for higher performing infrastructure.

LMC can provide focused and relevant expertise to help lower the economic and environmental cost of lighting asset ownership.

Recent Projects

In the past year LMC has undertaken a technology trial of LED luminaire and adaptive lighting controls for the Auckland Council, NZ, and designed, established and evaluated a Solar PV LED road lighting pilot program for Dallah Telecom in Jeddah, Saudi Arabia. LMC has also entered into a LED luminaire evaluation project for the Westlink M7, Sydney, Australia. Other recent technology trials have included a trial evaluation of new generation metal halide lighting systems for Waitakere City Council 2008-09. The consultancy produced the "EC Road Lighting Calculator" web-based assessment software for the ongoing Electricity Commission "RightLight" Efficient Road Lighting Program now run by EECA, Wellington, NZ, and is a development collaborator of the curriculum and collateral for EECA's commercial lighting control systems professional training program. It is also undertaking a collaborative Road Lighting Innovation Review for the NZ Transport Agency.

LMC is a founding member of the Community Lighting Group NZ, and is also a contracted member of EECA's Road Lighting Review Panel 2011-2012.

Bryan King MIESANZ, MBA, PGDip BIA, NZCE(Mech)

Bryan was the founding director (now non-executive director) of Modus Lighting Ltd, Auckland, which has delivered some of the most technically challenging and largest scale lighting projects undertaken in New Zealand, many with a focus on energy efficiency and sustainability using NZ-designed and manufactured equipment and technology. He was founding chairman of the Lighting Council NZ, is a member and former Board member of the Illuminating Engineering Society of ANZ, serves on the board of the Energy Management Association of NZ, is a foundation member of the NZ Life Cycle Association, and serves on the joint AS/NZS standards committee for road lighting. He has been principal of Lighting Management Consultants since 2008, and is an Alliance Partner of the Community Lighting Group Ltd.

Bryan is currently a researcher at the Massey University Centre for Energy Research undertaking a Master of Technology program in the Energy Management of road lighting.

Lighting Management Consultants Ltd, Auckland.
Mobile 021 300 111
email – bryanking@lightingmanagmentconsultants.com
web – www.lightingmanagementconsultants.com

Appendix 6. Type of road users Injured during daylight and darkness (Source: Ministry of Transport)

TABLE 8: TYPE OF ROAD USERS KILLED AND INJURED IN EACH SPEED LIMIT AREA DURING DAYLIGHT AND DARKNESS YEAR ENDED 31 DECEMBER 2010

ROAD USER	50 KM/H OR LESS				60-70 KM/H				80-100 KM/H				UNKNOWN SPEED LIMIT / LIGHT		TOTALS			
	Day		Dark		Day		Dark		Day		Dark				Day		Dark	
DRIVERS OF:																		
Car	2089	(14)	1030	(18)	262	(2)	106	(3)	1755	(57)	868	(39)	5	(1)	4106	(73)	2004	(60)
Taxi	7	(-)	17	(-)	1	(-)	-	(-)	2	(-)	4	(-)	-	(-)	10	(-)	21	(-)
SUV	151	(-)	68	(3)	26	(-)	15	(-)	339	(9)	174	(7)	-	(-)	516	(9)	257	(10)
Van	141	(-)	70	(-)	28	(-)	8	(-)	261	(5)	116	(7)	3	(-)	430	(5)	194	(7)
Truck	31	(1)	9	(1)	17	(-)	4	(-)	118	(6)	65	(5)	-	(-)	166	(7)	78	(6)
Bus	15	(-)	7	(-)	-	(-)	-	(-)	8	(-)	2	(-)	-	(-)	23	(-)	9	(-)
Motorcycle	511	(5)	176	(7)	54	(1)	15	(-)	371	(22)	83	(11)	2	(1)	936	(28)	274	(18)
Other	3	(-)	3	(-)	1	(-)	-	(1)	13	(1)	6	(-)	-	(-)	17	(1)	9	(1)
Unknown	-	(-)	-	(-)	-	(-)	-	(-)	-	(-)	-	(-)	-	(-)	-	(-)	-	(-)
SUBTOTAL	**2948**	**(20)**	**1380**	**(29)**	**389**	**(3)**	**148**	**(4)**	**2867**	**(100)**	**1318**	**(69)**	**10**	**(2)**	**6204**	**(123)**	**2846**	**(102)**
PASSENGERS FROM:																		
Car	558	(5)	433	(12)	112	(3)	43	(-)	676	(28)	407	(23)	2	(-)	1346	(36)	883	(35)
Taxi	2	(-)	5	(-)	-	(-)	-	(-)	-	(-)	5	(-)	-	(-)	2	(-)	10	(-)
SUV	66	(-)	24	(3)	10	(-)	7	(-)	189	(6)	89	(4)	-	(-)	265	(6)	120	(7)
Van	48	(-)	42	(1)	11	(-)	-	(-)	150	(5)	70	(4)	1	(-)	209	(5)	112	(5)
Truck	3	(1)	3	(-)	3	(-)	-	(-)	20	(2)	5	(-)	-	(-)	26	(3)	8	(-)
Bus	17	(-)	-	(-)	-	(-)	-	(-)	17	(-)	1	(-)	-	(-)	34	(-)	1	(-)
Motorcycle	24	(-)	11	(1)	5	(-)	1	(-)	42	(-)	4	(2)	1	(-)	71	(-)	16	(3)
Other	-	(-)	2	(-)	-	(-)	-	(-)	3	(1)	-	(-)	-	(-)	3	(1)	2	(-)
Unknown	-	(-)	-	(-)	-	(-)	-	(-)	-	(-)	-	(-)	-	(-)	-	(-)	-	(-)
SUBTOTAL	**718**	**(6)**	**520**	**(17)**	**141**	**(3)**	**51**	**(-)**	**1097**	**(42)**	**581**	**(33)**	**4**	**(-)**	**1956**	**(51)**	**1152**	**(50)**
OTHER ROAD USERS:																		
Pedal cyclists	608	(1)	116	(1)	40	(-)	11	(1)	60	(6)	7	(1)	-	(-)	708	(7)	134	(3)
Pedestrian	660	(10)	226	(7)	24	(3)	8	(2)	22	(3)	25	(10)	2	(-)	706	(16)	259	(19)
Other and unknown	45	(2)	2	(-)	2	(-)	-	(-)	1	(-)	-	(-)	-	(-)	48	(2)	2	(-)
SUBTOTAL	**1313**	**(13)**	**344**	**(8)**	**66**	**(3)**	**19**	**(3)**	**83**	**(9)**	**32**	**(11)**	**2**	**(-)**	**1462**	**(25)**	**395**	**(22)**
TOTAL	**4979**	**(39)**	**2244**	**(54)**	**596**	**(9)**	**218**	**(7)**	**4047**	**(151)**	**1931**	**(113)**	**16**	**(2)**	**9622**	**(199)**	**4393**	**(174)**

NOTE: The figures in brackets are numbers killed and are not included in the adjacent injury figures.

Appendix 7. Acknowledgements to people consulted for this report

First Name	Last Name	Company	Job Title
Richard	Aitken	Beca Group Ltd	Group Chairman and Chief Executive
Chris	Allen	Hamilton City Council	General Manager City Infrastructure
Nigel	Barbour	Powerco Ltd	CEO
John	Birks	evolve	General Manager
Kirk	Bracey	Waikato District Council	Roading Operations Manager
Bill	Brander	EECA Energy Efficiency and Conservation Authority	Lighting Programme Manager
Chris	Browne	Ministry of Economic Development (MED)	
Paul	Buetow	Kensington Swan	Managing Partner
Ian	Bull	Beca	General Manager -
Chris	Byrne	Modus Lighting	General Manager
John	Carnegie	Business New Zealand	Manager Energy, Environment & Infrastructure
Julian	Chisnall	NZ Transport Agency	National Traffic & Safety Engineer
John	Clare	Industrial Research Ltd	Scientist
Delwyn	Clark	University of Waikato Management School	Professor Executive Director Research
Andrew	Cleland	IPENZ, Engineers New Zealand	CEO
Shaun	Coffey	Industrial Research Ltd	CEO
Andy	Collins	Opus International Consultants	Team Leader Lighting Design
Phil	Consedine	Hamilton City Council	City Transportation Unit Manager
Graeme	Culling	Betacom NZ Ltd	Lighting Engineer
Jane	Cunliffe	NZ Trade & Enterprise	Director, NZ Inc Relationships
Kit	Cuttle	Independent Consultant	Ex University Researcher
Tim	Davin	IPENZ, Engineers New Zealand	Director – Public Policy
Michelle	Dawson	Auckland Council	Energy Manager
Peter	De Luca	Tompkins Wake	Partner
David	Deakins	Massey University	Professor of Small Business and Director of New Zealand Ce
Mike	Dilger	Betacom NZ Ltd	Joint Managing Director
Harry	Duynhoven	New Plymouth District Council	Mayor
Lyle	Earl	Hutt City Council	
Julian	Elder	WEL Networks	CEO
Geoff	English	Christchurch City Council	Asset Engineer
Tony	Fisher	Auckland Motorway Alliance NZTA	Project Director AMA
Steve	Fotios	The University of Sheffield	Professor of Lighting and Visual Perception
Bill	Frith	Opus International Consultants Ltd	Research Leader (Road Safety)
Jayne	Gale	Automobile Association	
Mark	Gatland	NorthPower	CEO
Ewan	Gebbie	Energy Management Association of NZ	CEO
Ian	Gooden	Waikato District Council	General Manager Roading & Projects
John	Groot	Commerce Commission	Chief Advisor Regulatory Branch
Brian	Hallinan	NZ Treasury	Team Leader Infrastructure
Duncan	Halliwell	Kensington Swan	Senior Associate (Qualified in England, not admitted in NZ)
Murray	Heyrick	Commercial Solutions Branch, Ministry of Economic	Manager, Procurement Policy & Development
Sarah	Holden	Ministry of Economic Development (MED)	Manager Economic Strategy Team
Lee	Hosking	GE	General Manager of Sales, ANZ, Lighting
Mike	Jackett	Independent Consultant	Consultant
Rob	Jamieson	Orion	CEO
Allan	Jenkins	Electricity Networks Association	CEO
Ben	King	Ernst Young	Executive Director
Lisa	Kinghorn	NZ Treasury	Exec Assistant to Vicky Robertson
Mark	Kirkham	Advanced Lighting Technologies NZ Ltd	Business Development Manager
Marcus	Kohn-Taylor	WEL Networks Ltd	General Manager Commercial
Rainer	Kunnemeyer	University of Waikato	Associate Professor
Bob	Lack	Counties Power Ltd	General Manager Commercial
Warren	Ladbrook	Canterbury Earthquake Recovery Authority (CERA)	Technical Manager
Charlotte	Littlewood	Powerco	Regulatory Manager
Roger	Loveless	Oddyssey Developments Limited	Ex Owner of Oddyssey
Simon	Mackenzie	Vector	Group CEO
Kate	Macnaught	Local Government NZ	Acting CEO
Brent	Meekan	Beca	General Manager Civil Infrastructure
Grant	Moodie	Advanced Lighting Technologies NZ Ltd	General Manager
Trish	Morgan	Ministry of Economic Development (MED)	Project and Personal Administrator
Jack	Morris	Wellington City Council	Strategic Adviser: Asset Planning
Steve	Muir	Connetics Ltd	Lighting Design Manager
Kathryn	Nield	Industrial Research Ltd	Project Leader
Mike	Noon	Automobile Association	General Manager Motoring Affairs
Phil	O'Reilly	Business New Zealand	CEO

First Name	Last Name	Company	Job Title
Brett	O'Riley	Ministry of Science & Innovation (MSI)	Deputy CEO Business Innovation and Investment
John	Odonnell	Orion	General Manager Infrastructure
Angela	Offord	Industrial Research Ltd	Personal Assistant to CEO
Mark	Ogilvie	AECOM	Group Leader - Buildings
Craig	Palmer	GE	Ex National Manager Lighting
Steven	Perdia	Independent Consultant	Consultant
Libby	Proctor	Ernst & Young Limited	Associate Director
Steven	Proctor	Morrison & Co Ltd	PIP Fund Manager
John	Raine	AUT University	Pro Vice-Chancellor – Innovation & Enterprise
Brian	Rainford	NZ Transport Agency	Principal Traffic & Safety Engineer
David	Raven	Odyssey Energy Limited	Director
Vicky	Robertson	NZ Treasury	Deputy Secretary Growth & Public Services
Simon	Robson	Hastings District Council	
Nick	Russ	Commerce Commission	Advisor
Anthony	Rutherford	Auckland Transport	Contract Commercial Executive
Stephen	Selwood	NZCID (NZ Council for Infrastructure Development)	CEO
Omar	Shahab	Switch Lighting & Design Consultancy	
Jamie	Silk	Powerco	Business Development Manager
Neil	Simmonds	Counties Power Ltd	CEO
Roy	Speed	Massey University	Senior Lecturer
Inspector Mark	Stables	NZ Police	Vehicle Crash Head
Philip	Stevens	Ministry of Economic Development (MED)	
Andrew	Stevens	Auckland Motorway Alliance	Traffic Safety Manager
Roger	Sutton	Christchurch Earthquake Recovery Authority CERA	CEO
Geoff	Swainson	Local Government NZ	Principal Policy Advisor for Tranport
Janis	Swan	University of Waikato	Acting Dean Science & Engineering
Fergus	Tate	NZ Transport Agency	National Traffic and Safety Manager
David	Taylor	Hamilton City Council	Asset Engineer
Murray	Thessman	Wellington City Council	Project Manager – Street Lighting
Derek	Todd	Counties Power Ltd	GM Network
Mike	Underhill	EECA Energy Efficiency and Conservation Authority	CEO
Mariana	Van der Walt	Wintec	Research & Development Manager
Tony	Walker	Connetics Ltd	Design + Engineering Manager
Bas	Walker	Ministry of Science & Innovation (MSI)	National Manager
Neil	Walker	Gerard Lighting	Executive Director
Ray	Wells	Techlight	Consultant
Gordon	Wiffen	Philips Lighting New Zealand Ltd	Commercial Manager
Greg	Williams	Beca	Technical Director, Building Services Electrical
Beth	Williams	EECA Energy Efficiency and Conservation Authority	Project Manager
Peter	Wilson	Vector	Group Manager Climate
Andrew	Woodwark	Ministry of Economic Development (MED)	
Lawrence	Yule	Hastings District Council	Mayor & Chairman of Local Government NZ
Total	127	Consulted but not all contributed	

Appendix 8. Lighting Technologies (Source: Clinton Found'n. & US DOE)

Figure 2.2: U.S. Lighting Electricity Consumption by Sector and Lamp Type in 2010
Source: *2010 U.S. Lighting Market Characterization. Prepared by Navigant Consulting, Inc. for the Department of Energy. Washington D.C. January 2012.*

Figure 50 US Lighting Consumption by Sector & Lamp Type (NB HID = HPS, LPS, MV & MH - see explanations below)

APPENDIX B: REVIEW OF TECHNOLOGIES

This paper focuses on the two most abundant incumbent technologies, mercury vapor and high-pressure sodium, as well as the newer technologies, LED and induction.

INCUMBENT TECHNOLOGIES

MERCURY VAPOR

In 1938, the first mercury vapor lamps were used for street lighting applications. Mercury vapor lamps – a gas discharge light source – offer relatively long lamp life of up to 28,000 hours at a low initial cost. Unfortunately, these limited benefits come at the price of low lamp efficacy (less than 60 lm/w) and color rendition (CRI less than 60). In addition, light output over the life of lamp (lumen depreciation) is extremely poor, resulting in lamps that use the same amount of energy for very little light output. For the past two decades, municipalities and utilities have regularly and successfully converted old mercury vapor streetlights to high-pressure sodium streetlights.

HIGH-PRESSURE SODIUM

High-pressure sodium lamps were first commercialized in 1970; the technology was touted as an energy-efficient alternative to incandescent and mercury vapor lamps, the prevailing street lighting technologies. It delivered this value, doing so at a low initial cost and with a comparatively high lamp efficacy. The technology gradually achieved broad global market penetration through the 1970s and 1980s due to its relative energy efficiency and significant lumen output, in spite of low color rendition. Relative to advanced technologies, high-pressure sodium offers shorter life, with rated lamp life of 20,000-24,000 hours.

A vast majority of cities still regard the familiar high-pressure sodium as the most inexpensive and energy-efficient lighting technology available. Some global lighting manufacturers reinforce this perception of high-pressure sodium and dismiss new technologies as ineffectual and with exaggerated claims.

The benefits of high-pressure sodium lamp efficacies of 70-150 lm/w are unfortunately diminished by their typical installation into cobrahead and shoebox streetlight fixtures that achieve only 40-50 percent optical efficiency, reducing net fixture efficacy to 35-68lm/w.[xxvii] Further, relative to wider-spectrum light sources, the technology's poor color rendition (CRI of 22) may compromise visibility and, according to some city residents, cast an aesthetically displeasing light onto city streets. When fixture efficacy and color of light are taken into consideration, high-pressure sodium looks less favorable.

ADVANCED TECHNOLOGIES

LIGHT-EMITTING DIODES

A light-emitting diode (LED) is a solid-state lighting device that generates a narrow band emission when direct current is applied. First developed by National Aeronautic and Space Agency (NASA) scientists in 1962, and initially utilized as indicator lights and signals, LEDs have recently been used in general illumination applications, including street and area lighting, parking lot lighting, and parking garage lighting. When properly utilized in street lighting fixtures, LED technology offers potential advantages, including:

- **Energy savings,** with potential for 50 percent savings over high-pressure sodium
- **Long fixture life,** with fixtures rated at greater than 50,000 hours operation until end-of-life, defined as less than 70 percent of original lumen output
- **Instant on/off**
- **Ability to integrate dynamic controls**
- **Directional light emission** that allows, with the proper optics, highly efficient fixtures
- **Improved color rendition,** often over 70 CRI
- **Potential for enhanced visibility** due to its broader spectral distribution (white light)

However, while the LED device itself is rapidly evolving, the use of LEDs for the aforementioned applications is still relatively new – early adopters must therefore take precautions to ensure that they select quality products.[xxviii] With some manufacturers making unrealistic claims about product quality and performance, the precautions must be even more deliberate. Critical technological pitfalls to beware of include:

- **Improper thermal management,** leading to undesirably high junction temperatures and driver operating temperatures that cause premature product failure
- **Poorly binned LEDs,** causing poor color uniformity and, over time, color shift
- **High blue light content** in higher color temperature products, raising environmental and aesthetic concerns [xxix]
- **Deficient fixture optics,** causing poor optical performance, including glare
- **Variable fixture warranties,** potentially exposing early adopters to undue risk of failure

These pitfalls can all be avoided through responsible project planning and specifications.

LED fixture efficacies have been improving and costs have been declining sharply. One multi-phase study in Oakland, California, found a 36 percent decrease in LED fixture cost over the course of 11 months, or one product generation. While prices will likely not fall at an equivalently steep rate in years to come, the decline will indeed continue, perhaps on the order of 5-15 percent per year. LED chip innovation and increased fixture manufacturing volume are the two most significant drivers of this cost decline. Volume purchasing is another driver for retrofit projects; 50 fixtures will be significantly more costly per unit than 5,000 fixtures.

Due to declining prices, a question about cost of delay becomes relevant: Could municipalities save more by delaying implementation for one to two years to allow prices to fall further? The economics of this decision will depend on each municipality, but analysis suggests that prices would need to fall nearly 15 percent annually for municipalities to recover the energy and maintenance savings lost by delay. Municipalities cannot recover the additional greenhouse gas emissions from a one-year delay, even if fixture efficiency improves by up to 15 percent during that time.[xxx]

INDUCTION LIGHTING

Induction lighting is an electrode-less fluorescent light source that, by exciting gas enclosed in the lamp via electromagnetic induction instead of a current applied through an electrode, reliably produces broad-spectrum light. Induction fixtures have been commercially available for more than two decades. With a rated life of 100,000 hours, many induction light sources are still illuminating roadways after more than 10 years of operation.[xxxi] The benefits offered by induction technology are manifold and similar to many benefits of LED:

- **Excellent energy savings,** frequently with 40 percent savings over high-pressure sodium vapor, and more than 60 percent savings over mercury vapor
- **Long fixture life,** with fixtures rated at more than 100,000 hours operation until end-of-life, at which point 50 percent of fixtures are still in operation
- **Instant on/off**
- **Ability to integrate dynamic controls**
- **Improved color rendition,** often over 70 CRI
- **Potentially enhanced visibility** due to a broader spectral distribution

As with LEDs, pitfalls exist for induction lighting as well:

- **Inadequate or improper thermal management,** leading to an undesirably high operating temperature in the generator that causes premature product failure
- **Less-efficient fixture optics,** with poorer fixture efficiency than LED

With effective project planning, these technology pitfalls can be overcome.

Unlike LED technology, induction technology has neared a plateau in fixture efficacy. Even so, decreases in cost with volume purchasing can be significant.

HIGH-EFFICACY CERAMIC METAL HALIDE

Another popular option, a new generation of high-efficacy ceramic metal halide product called CosmoPolis, has emerged as a viable, cost-effective alternative in the past five years. Traditional metal halide is a gas discharge light source that generates broad-spectrum light using either a quartz (older) or ceramic (newer) arc tube containing mercury, argon, and metal halides. Older quartz and ceramic metal halide lamps offered shorter lamp life of 14,000 hours and lower lamp efficacies of 61 to 85 lm/w; the new CosmoPolis equipment can achieve lamp efficacies of up to 120lm/w, with lamp life of 24,000 to 30,000 hours. The smaller lamps offer improved fixture optical efficiency, and electronic ballasts minimize ballast loss, preserving the high lamp efficacy. Savings over high-pressure sodium can span 20-40 percent, depending on the application. With integrated dynamic controls, the savings grow even larger.[xxxii] The technology is proprietary, limiting the pool of fixture suppliers.

The benefits of high-efficacy ceramic metal halide include:

- **Excellent energy savings,** with 20-40 percent savings over high-pressure sodium, and more than 60 percent savings over mercury vapor
- **Compact lamp and gear,** allowing for highly efficient fixture optics
- **Ability to integrate dynamic controls**
- **Improved color rendition,** over 60 CRI
- **Potential for enhanced visibility** due to white light

One drawback of this system, relative to other white light sources, is:

- **Poorer lamp life** than LED or induction at 24,000 to 30,000 hours.[xxxiii]

As with LED and induction, decreases in cost with volume purchasing can be significant.

CONTROLS AND CENTRAL MANAGEMENT SYSTEMS

While control technologies providing basic on/off functionality such as photocells and timers have long been available, a new approach to controls has developed the outdoor lighting market in the past five years: central management systems (CMS) that from a central terminal offer remote monitoring of equipment, allow remote on/off control, and can provide step dimming or continuous dimming of light fixtures. CMS offer two-way communication with fixtures by radio frequency (RF), wireless mesh network, existing power lines, or some combination of these channels. CMS technology is compatible with many lighting technologies: high-pressure sodium vapor, ceramic metal halide, incandescent, induction, and LED can all be dimmed with the appropriate system. However, some technologies lend themselves more naturally to dimming than others.

In Europe, more than 80,000 controllable fixtures have been deployed and are operating successfully today, allowing municipalities to monitor fixture performance in order to closely manage fixture outages and to dim fixtures during off-peak hours in accordance with International Lighting Committee adaptive standards.[xxxiv]

STANDARDS

Presently, two bodies are responsible for setting baseline street lighting standards internationally: the International Lighting Committee (CIE) and the Illuminating Engineering Society of North America (IESNA). CIE standards are more prevalent throughout Europe, Africa, the Middle East, and Asia. IESNA-recommended practices are cited throughout North and South America. While this broad regional breakdown is somewhat representative, it is by no means precise. Individual nations, states, and cities may craft from CIE or IESNA standards a modified set of standards all their own; others may adopt their own standards altogether.

Many cities are understandably cautious about deviating from local recommended practices for street lighting. However, a city can easily mitigate any liability risk stemming from the introduction of a new fixture technology or control system by developing its own specific municipal lighting code.[xxxv]

Most standards today, unfortunately, do not capture the full benefit of broad-spectrum light for visibility. As a research consensus has begun to emerge around improved vision under broad-spectrum light – first for peripheral vision, more recently for foveal vision – CIE and IESNA are revising their standards to allow for the benefits of white light to be accounted for in lighting system designs.[xxxvi] British Standards now require higher light levels on residential roadways when using narrow-spectrum fixtures like high-pressure sodium, than for broad-spectrum fixtures like LED or induction.

Appendix 9. Los Angeles Case Study (Source: Clinton Foundation)

CLINTON CLIMATE INITIATIVE

CITY OF LOS ANGELES
LED STREET LIGHTING CASE STUDY

EXECUTIVE SUMMARY

It has been two years since the city of Los Angeles launched a major public works project to retrofit the city's street lighting with energy-efficient LED (light-emitting diode) fixtures, making this a good opportunity to assess progress. The project is still the largest LED street lighting retrofit ever undertaken globally; its implementation is ahead of schedule and the energy cost savings are surpassing original projections, largely due to continued improvements in the energy efficiency of LED technology. The project is a collaboration between the Los Angeles Bureau of Street Lighting; the Los Angeles Mayor's Office; the Department of Water & Power; and the Clinton Climate Initiative (CCI) Cities Program, which is now a fully integrated partner with the C40 Cities Climate Leadership Group (C40).

Targeting 140,000 of the city's more than 209,000 street lights, the objectives of the retrofit project are to enhance the quality of municipal street lighting, reduce light pollution, improve street safety, and save both energy and money. The city budgeted $57 million for the project, to be carried out over a five-year period. Upon full implementation, the project is expected to return an estimated $10 million in energy and maintenance cost savings to the city while avoiding at least 40,500 tons of CO_2e emissions each year.

As of July 2011, the city has installed 51,035 LED street lights, achieving energy savings of 59 percent, reducing CO_2e emissions by 12,560 metric tons annually, and cutting utility costs by $1.9 million annually. Feedback from the community, including residents, politicians, and law enforcement officials, has also been positive. This new data strengthens the business case for the project and provides a roadmap for other cities to develop similar projects around the world.

SUMMARY TABLE: ORIGINAL PROJECT PROFILE

NUMBER OF STREET LIGHTS BEING REPLACED	140,000
TECHNOLOGY	Converting old HPS cobrahead style fixtures to new LED cobra-head style fixtures; implementing a remote monitoring system
PHASE-IN PERIOD	5 years
TOTAL PROJECTED PROJECT COST	$57 million
PROJECTED PAYBACK	7 years
ENERGY & MAINTENANCE COST SAVINGS (TOTAL)	$10 million / year
ENERGY USE SAVINGS	68,640,000 kWh / year
CO_2E EMISSIONS SAVINGS	40,500 tons / year
FINANCING	7-year, $40MM loan at a rate of 5.25% repaid through energy and maintenance savings; loans provided by City Utility (LADWP) and City Funds; Bureau of Street Lighting to contribute $3.5MM directly from the Street Lighting Maintenance Assessment Fund; LADWP to provide a rebate based on the kWh reduced by the project, totaling $16.39MM

PROJECT UPDATE

As of July 2011, the Bureau of Street Lighting has used city labor to install 51,035 LED street lights on residential streets throughout the city. Results from this initial phase of the retrofit project show higher energy and maintenance cost savings and faster installation than had been expected, as well as positive feedback from residents. In addition, the project has resulted in the creation of 11 new jobs at the Bureau of Street Lighting and has created an estimated 300 jobs for the manufacturers of LED street lighting products, according to information provided by the manufacturers.

PROJECT IMPLEMENTATION AT 2 YEARS
PROJECT INSTALLATION FIGURES JULY 2011

TOTAL UNITS INSTALLED	51,035
ENERGY COST SAVINGS	$1.9 million / year
ENERGY USE SAVINGS	21,241 MWh / year
CO_2 EMISSIONS SAVINGS	12,560 metric tons CO_2e / year

The installation of 51,035 LEDs in the first two years of the project has produced energy savings of 59 percent in the retrofitted fixtures, yielding annual energy savings of 21,241 MWh and annual cost savings of $1.8 million. These figures are higher than originally expected and are largely the result of continued improvements in LED fixture efficacy over the period of project implementation. The additional energy savings, combined with the continued fall in the price of LED fixtures in the U.S. market and the ability of the city to auction removed street lighting units (as opposed to simply recycling them), means that, upon completion, the project payback will be notably less than the seven years originally anticipated.

The installation of the LED street lighting fixtures has also been faster than expected; this is in part due to the fact that the installation crews were able to improve the installation process as they gained experience with the LED fixtures and became more familiar with the technology.

SELECTED TWO-YEAR GOALS VS. ACTUAL

	FIRST 2 YEARS PROGRAM GOALS	ACTUAL (AS OF JULY 2011)
TOTAL UNITS INSTALLED	50,000	51,035
ENERGY SAVINGS	40%	59%
CREW PERFORMANCE	20 units / day / crew	30 units / day / crew
REMOVED UNITS	Recycle old units	Auction units to generate revenue

The retrofit project is focusing on the city's cobrahead style fixtures—the most abundant type of streetlight fixture—located on residential streets. The LED fixtures primarily replace high-pressure sodium vapor cobrahead fixtures, although metal halide, mercury vapor, and incandescent cobrahead fixtures will also be replaced as part of the project. High-pressure sodium vapor fixtures are some of the most prevalent outdoor lighting technologies used around the world; almost 62 percent of all outdoor lighting is provided by high- and low-pressure sodium vapor lights. The city is also focusing on cobrahead fixtures because current LED technology is highly compatible with these fixtures; LED technology for decorative post-top fixtures is less ready for implementation at a large scale. The LED fixtures meet or exceed current illumination levels and comply with all relevant lighting standards while providing white-light at 4,300 Kelvin color temperature in the process. All LED fixtures installed as part of the project are full cutoff, Dark Sky Friendly fixtures. These full cutoff fixtures reduce light pollution and sky glow (the unnecessary illumination of the night sky by artificial lighting) over the city.

The Bureau of Street Lighting has received favorable feedback from city residents on the initial phases of the project. Residents have reported improved visibility from the broad spectrum LED light source.

PROJECT BACKGROUND

The city of Los Angeles owns the second-largest municipal street lighting system in the United States with over 209,000 streetlights and more than 400 distinct fixture styles, including the cobrahead style, which is the most popular style of streetlight. Each year, these streetlights consume approximately 197,000,000 kWh of electricity. The system is operated and maintained by the Bureau of Street Lighting, which was established in 1925 and today employs 250 people.

FINANCIAL DRIVERS

Faced with increasing budget constraints, the Bureau of Street Lighting has looked for ways to reduce operating costs while preserving the quality of service delivered, and the retrofit project has played a key role in meeting this objective. The Bureau pays a variable rate per fixture to the municipal utility company, the Los Angeles Department of Water and Power, which calculates rates based on the real kWh usage of the fixture as determined through field tests. Prior to 2009, the Bureau's annual electricity bill totaled approximately $15 million — nearly 29 percent of its $52 million operating budget. The Bureau itself renders maintenance services to the system. Funding for the Bureau is provided primarily by the Street Lighting Maintenance Assessment Fund (SLMAF), a yearly assessment paid by city residents for the operation and maintenance of Los Angeles' street lighting system; the SLMAF generates $42 million per year for the Bureau operations. In 1996, the passage of Proposition 218 froze SLMAF revenues; rising inflation and operating costs led to the projection of a future deficit for the Bureau, stimulating the need to reduce operating costs.

TECHNOLOGY OPTIONS

CCI/C40 helped the Bureau of Street Lighting consider both LED and induction technologies for its street lighting retrofit project. Both had the potential to match the city's requirement for long-life, white light products that improve color rendering and reduce maintenance costs relative to high-pressure sodium vapor street lights, the prevailing technology used in Los Angeles. Through its New Technology Group, the Bureau had already accrued substantial experience piloting LED and induction technologies, and CCI/C40 helped the city to model and understand the economic implications of the technologies' performance.

LED LIGHTING

An LED is a semiconductor light source that generates light at a precise wavelength when a current is applied; multiple LEDs are networked together in a single fixture in combination to generate the appropriate light output for each particular application. LEDs were initially utilized as indicator lights — it was for this purpose that NASA developed the first LEDs in 1962. Market penetration first occurred for colored-light applications like traffic signals, which became popular in the late 1990s; LED traffic signals now comprise an estimated 52 percent of the U.S. traffic and pedestrian signal market. In recent years, LEDs have begun to penetrate the street lighting market, with early street lighting deployments in Ann Arbor, Michigan (1,000 LED fixtures installed in 2007); and Anchorage, Alaska (4,000 fixtures installed in 2008; plans to install 16,000 total). Rapid improvement in the luminous efficacy (lumens/watt) of white-light LEDs — the majority of which are created by applying a phosphor coating to a blue LED light — has partly facilitated this market penetration. Innovations in fixture design — particularly optical efficiency and thermal management — as well as improved fixture warranties have also contributed to market growth. The LED fixture market is still highly fragmented, however, and fixture quality can differ starkly from one manufacturer to the next. Even so, many of today's LED fixtures boast lifetimes of 50,000 hours, or almost 11.5 years when operated 12 hours per night. In addition, unlike all other street lighting technologies, LED fixtures contain no mercury.

INDUCTION LIGHTING

An induction light is an electrodeless light source in which gas contained within a glass tube is excited by electromagnetic induction. Because of the absence of an electrode, a principal failure point for a gas discharge light source, these white-light sources can theoretically last up to 100,000 hours before replacement is necessary. High-pressure sodium, mercury vapor, metal halide, and fluorescent technologies are all examples of gas-discharge light sources.

REMOTE MONITORING SYSTEMS

As part of the retrofit project, the Bureau of Street Lighting is deploying a remote monitoring system that collects and centrally reports real-time performance data for each street light fixture; data is sent to the Bureau's GIS system, which was developed in-house. Equipment failures are tracked, logged, and synchronized with the Bureau's maintenance work orders. As part of the fixture performance data, the monitoring system will return the measured kilowatt-hour usage for each fixture, creating a hi-resolution picture of actual electricity consumption and verifying energy savings for the project.

PROJECT DEVELOPMENT

In surveying the potential for a retrofit project, the Bureau of Street Lighting had to tackle the following tasks:

- Confirm the efficacy of LED and induction technologies
- Quantify the potential cost and savings of the project
- Assess alternative financing mechanisms with a specific focus on energy and maintenance savings due to its already-burdened balance sheet
- Coordinate with other city agencies — the Los Angeles Department of Water & Power and the Los Angeles Mayor's Office — to organize the project
- Vet its internal projections of retrofit project economics
- Continue its rollout of a remote monitoring system to measure and verify fixture energy consumption and performance

The Bureau of Street Lighting requested CCI/C40's assistance in analyzing the potential for a retrofit project and in March 2008 the organizations began collaborating on this project.

CCI/C40 ROLE: ECONOMIC AND FINANCIAL ANALYSIS

CCI/C40 assisted the Bureau of Street Lighting in developing the street lighting retrofit project in two primary ways: 1) by developing a detailed economic cost analysis examining the street light retrofit opportunity for both LED or induction technologies, and 2) by assisting the Bureau in exploring the financing options available for the project. The analysis prepared by the CCI/C40 ultimately supported the city's decision to move forward on the LED retrofit project.

Using data provided by the Bureau of Street Lighting, CCI/C40 generated a detailed economic analysis of the retrofit project for LED and induction lighting systems that could be shared with municipal officers as well as potential financiers. (Select model inputs and model output can be found in Appendix A.). Key data inputs that CCI/C40 used to create the detailed economic analysis included: total street light fixtures to be replaced, cost per fixture for new equipment, cost per fixture for operation and maintenance, and useful life of old and new equipment.

The results of the analysis and economic modeling were then synthesized with project information and packaged into a "pitch book" which CCI/C40 used to solicit informal proposals from financial institutions for financing the retrofit project.

Key details included in the analysis were:

- Total project size
- "Cash Flows" produced from energy and maintenance savings

- Current flow of funds within existing system — How are payments allocated for street lighting between the customers, the city and the utility?
- Primary structural financing objectives for the city
- Preferred financing structure(s) focused on energy savings
- Required financing term in years
- Timeline and deadline for financing proposals

From these key details, as well as from the economic analysis and financing proposals that were generated from a number of different financial institutions, the Bureau was equipped to develop two alternative scenarios for the project based on 140,000 LED or induction fixtures. In both, the CCI/C40 model projected a seven-year payback period.

CCI/C40 successfully solicited proposals on behalf of the city from a series of financial institutions that were attracted by the measurable cost savings, the long equipment life, and the awareness that this could be the first of many future opportunities. Collectively, the proposals received outlined a range of ideas, from basic tax-exempt leasing to non-recourse debt/equity structures focused solely on energy and maintenance savings.

FINANCING OUTCOME

As the Bureau moved further along in the financing process, validating its business plan and demonstrating the potential upside of the investment for the city, the City Utility (LADWP) and the city itself saw the value of getting more directly involved in project funding to ensure rapid execution. As a result, even though external funding sources remained available, the city ultimately decided that it would fund the project internally, with a structure based on energy savings and utility rebates.

The city secured a seven-year, $40 million loan at a rate of 5.25 percent that is being repaid through energy and maintenance savings over the loan term. The loan is a combination of utility and city funds. Additionally, the Bureau of Street Lighting is contributing $3.5 million directly from the Street Lighting Maintenance Assessment Fund over the five-year implementation period. The Department of Water & Power is providing a rebate based on the kWh reduced by the project, totaling $16.39 million. A chart describing this structure is attached as Appendix B.

TECHNOLOGY OUTCOME

After considering the competing fixture technologies, the Bureau of Street Lighting selected LED technology for its retrofit project. This choice was driven by multiple factors. First, the rapidly declining cost of LED technology in 2008 — and the anticipated continuing decline in cost over the next five years — had made the LED fixtures more appealing from a cost perspective than high quality induction fixtures. Second, LED technology provided superior optical control to induction fixtures. LEDs are directional light sources that can, when properly oriented in a fixture, create precise and uniform patterns of light. Third, based on pilot tests managed by its New Technology Group, the Bureau affirmed that LED technology was both ready for deployment at scale and superior to induction for the purposes of retrofitting its cobrahead fixtures. Finally, the city of Los Angeles determined that LED technology represented a new paradigm in lighting that reflected its ambitions as a global leader on climate change.

In November 2008, the city apprised prospective LED street light fixture manufacturers of a three-month final product evaluation, to occur between November 2008 and January 2009, during which it would verify its previous four years of pilot testing and identify the LED products to be used in the initial phases of installation. These manufacturers were each invited to send four fixtures for testing to the Bureau of Street Lighting at no cost or at a significantly reduced cost to the city. The city released an RFI seeking fixtures in January 2009 and received strong interest from technology providers. (This RFI is included as Appendix C).

Testing occurred on residential streets in Los Angeles over a three-month period, ending in the first quarter of 2009. In addition to measuring light levels and evaluating fixture performance, the Bureau sent surveys to area residents to solicit feedback on the new LED fixtures. Based on all test results, the city selected manufacturers and drafted product specifications for its year one installation of over 20,000 fixtures. This method provided the city with enviable flexibility in product selection — a critical attribute given the rapid evolution of LED fixture technology that will occur during the 5-year implementation of the project.

Every six months, the Bureau reevaluates the LED fixture market, drafts specifications based on best-available technology, and purchases equipment, thus staying on the leading edge of fixture innovation. To date, the Bureau has conducted five phases of testing and evaluation of LED products. More information on the testing and evaluation of LEDs can be found on the Bureau's website at: www.ci.la.ca.us/bsl/.

FINAL PROJECT PROPOSAL

The final proposal outlined by the Bureau of Street Lighting for mayoral approval was for a $57 million capital project lasting from 2009 to 2013, to be executed in five discrete yearlong phases:

- Year one began in July 2009 and 20,074 fixtures were installed; the original goal was to install 20,000 fixtures.
- Years two through five will each encompass 30,000 fixtures, totaling 140,000 fixtures; in year two 30,961 fixtures were installed.

In October 2008, Mayor Villaraigosa approved the five-year, 140,000 fixture retrofit project, allowing the Bureau of Street Lighting to commence formal rollout by means of internal funding. The project was originally projected to deliver $35 million in energy savings and $13 million in maintenance savings from 2009 to 2015; preliminary results show that the energy savings figures will potentially be higher than original projections. The Bureau of Street Lighting is carrying out all planning and installation work for the project. This project requires 14 municipal employees, including 8 personnel to install fixtures in year one and an additional 4 personnel to install fixtures in years two through five. This represents $7.4 million in labor costs. The city is leasing six aerial lift trucks for five years to complete the project, costing a total of $630,000. In the process, the Bureau will avoid the risk of future budget shortfalls due to frozen SLMAF revenues and rising energy costs. Charts depicting originally projected energy savings and avoided CO_2e emissions are included in Appendix D.

ABOUT C40'S OUTDOOR LIGHTING PROGRAM

C40's Outdoor Lighting Program aims to help cities around the world improve the energy efficiency of street lighting systems and reduce the greenhouse gas emissions these systems produce. Services made available to cities include advising on project management, purchasing, financing, and technology as well as assisting cities to analyze the economics of a retrofit project and develop the business case. C40 works directly with cities to initiate new projects and to move existing projects forward more quickly and cost-effectively. Outdoor Lighting Program assistance to cities for street light projects will vary based on the city's technical expertise, staffing, and experience as well as the extent of the city's control over street lights.

Amongst C40 cities the opportunity to cut energy costs and greenhouse gas emissions by providing more energy efficient outdoor lighting is large. As outlined in the CCI lighting white paper, which can be downloaded at http://www.clintonfoundation.org/files/CCI_whitepaper_lighting_2010.pdf, existing street lighting can account for a significant portion of a city's electricity costs, while, at the same time, recent innovations in street lighting technologies enable cities to take action today to achieve near-term energy-efficiency, cost, and performance benefits. Furthermore, a report on C40 cities by Arup, found that, on average, C40 city mayors have strong powers over their street lights and that outdoor lighting is clearly a top priority for C40 Cities. Furthermore, the study found that 14 C40 cities currently have plans to expand projects to install energy efficient LED lighting and an additional 5 C40 Cities are looking to deploy LED lights for the first time. If you are a C40 city that would like to work with C40's Outdoor Lighting Program please contact: outdoorlighting@clintonfoundation.org.

APPENDIX A: CCI ECONOMIC MODEL

Included below are the core inputs and outputs from CCI's original economic model. This model, built using key data supplied by the Bureau of Street Lighting, was an assumptions model that focused on 143,172 city street light fixtures. Using the results from this model, the Bureau of Street Lighting honed its retrofit program to 140,000 fixtures and developed its business case. The included CCI cash flows still represent the original 143,172-fixture analysis.

INPUTS:

Fixtures — Assumed LED Equivalents

Mercury Vapor				LED	
Lamp Watts	Fixture Watts	$/fixture/mo	# of fixtures	Fixture Watts	$/fixture/mo
400	454	15.65	971	108	3.36
250	285	9.82	90	78	2.56
175	200	6.89	1,391	50	1.57
100	125	4.31	6	39	1.34

High-Pressure Sodium				LED	
Lamp Watts	Fixture Watts	$/fixture/mo	# of fixtures	Fixture Watts	$/fixture/mo
400	465	16.03	1,756	153	5.30
360	438	15.10	4	153	5.30
310	360	12.58	2,399	153	5.30
250	295	10.17	8,066	108	3.36
220	283	9.76	27	108	3.36
200	240	8.27	49,884	108	3.36
150	190	6.55	17,093	78	2.56
100	138	4.76	56,900	50	1.57
70	86	2.96	3,484	39	1.34
50	68	2.34	2	39	1.34

Metal Halide				LED	
Lamp Watts	Fixture Watts	$/fixture/mo	# of fixtures	Fixture Watts	$/fixture/mo
400	458	15.79	464	153	5.30
250	295	10.17	101	108	3.36
175	210	7.24	57	78	2.56
100	129	4.45	109	50	1.57
70	94	3.24	228	39	1.34

Incandescent				LED	
Lamp Watts	Fixture Watts	$/fixture/mo	# of fixtures	Fixture Watts	$/fixture/mo
860	844	29.09	2	108	3.36
620	599	20.65	1	108	3.36
405	371	12.79	122	108	3.36
295	263	9.07	7	78	2.56
189	189	6.51	7	50	1.57
103	102	3.52	1	39	1.34

Billing	
Annual change in Electricity Rate (%)	4%
Avg Night Only Operating Time (hrs/yr)	4,284
All Day Operating Time (hrs/yr)	8,736

Maintenance	
Labor Rate ($/Hr)	130.00
Annual change in Labor Rate (%)	2%
Vehicle Rate ($/Hr)	30.00
Annual change in Vehicle Rate (%)	2%

7

Technology Information	MV	HPS	MH	INC	Induction	LED
Expected Lamp Life (Hours)	24000	20000	14000	8000	50000	50000
Expected Lamp Life (Years)	5.5	4.7	3.3	1.9	11.7	11.7
Installation requirements						
Luminaire Cost ($)	150	150	150	150	425	425
Annual change in Luminaire Cost (%)	0%	0%	0%	0%	-1%	-5%
Maintenance requirements[1]						
Repair Frequency (over lamp life)						
Lamp	100%	100%	100%	100%	0%	0%
Photocell	100%	100%	100%	100%	0%	0%
Starter	5%	5%	5%	5%	0%	0%
Ballast	5%	5%	5%	5%	0%	0%
Fixture	1.5%	1.5%	2%	3%	6%	6%

[1] *Sources for this table: CCI assumptions based on BSL data; PG&E Application Assessment Report #0714, January 2008.*

OUTPUTS:

Project NPV										
Years	1	2	3	4	5	6	7	8	9	10
Discounted cashflow										
LED										
Installation Cost										
Material	(9,243,750)	(12,876,698)	(11,650,346)	(10,540,789)	(9,755,200)	-	-	-	-	-
Labor	(866,667)	(1,296,239)	(1,259,203)	(1,223,226)	(1,215,476)	-	-	-	-	-
Vehicle	(200,000)	(299,132)	(290,585)	(282,283)	(280,494)	-	-	-	-	-
Recurring Cost										
Electricity	1,038,659	2,612,709	4,156,682	5,671,010	7,156,116	7,087,962	7,020,458	6,953,596	6,887,371	6,821,777
Material	91,350	220,950	338,001	443,402	537,999	512,380	487,981	464,744	442,613	421,536
Labor	384,326	948,167	1,479,474	1,979,647	2,450,030	2,380,030	2,312,029	2,245,971	2,181,800	2,119,463
Vehicle	86,010	212,195	331,100	443,036	548,306	532,640	517,422	502,638	488,277	474,326
DSM Funding	2,443,084	3,761,495	3,761,495	3,761,495	3,761,495	-	-	-	-	-
Total cashflow ($)	**(6,266,986)**	**(6,716,552)**	**(3,133,383)**	**252,291**	**3,202,775**	**10,513,011**	**10,337,889**	**10,166,949**	**10,000,062**	**9,837,103**
NPV ($)	**(6,266,986)**	**(12,983,538)**	**(16,116,922)**	**(15,864,630)**	**(12,661,856)**	**(2,148,844)**	**8,189,044**	**18,355,993**	**28,356,054**	**38,193,157**
Payback (Years)	**7**									
10 Year IRR	**23.4%**									

8

APPENDIX B: FUNDING OVERVIEW

The following funding overviews were developed by the Bureau of Street Lighting for its 140,000 fixture retrofit program.

		PROGRAM FUNDING				EXPENSES		
Year	LED Units To Install	Total Project Capital Cost	DWP Energy-Efficiency Rebate	SLMAF contribution	Funding Needed	Labor Cost	Material Cost	Equipment/ Vehicle Cost
1	20,000	$9,998,081	$0	$3,600,000	$6,398,081	$1,012,521	$8,754,180	$231,380
2	30,000	$14,320,000	$2,400,000	$0	$11,920,000	$1,529,152	$12,670,848	$120,000
3	30,000	$12,120,000	$3,600,000	$0	$8,520,000	$1,575,027	$10,424,973	$120,000
4	30,000	$10,120,000	$3,600,000	$0	$6,520,000	$1,622,278	$8,377,722	$120,000
5	30,000	$10,120,000	$3,600,000	$0	$6,520,000	$1,670,946	$8,329,054	$120,000
TOTAL	140,000	$56,678,081	$13,200,000	$3,600,000	$39,878,081	$7,409,924	$48,556,777	$711,380

Program funding overview. Courtesy of LA BSL

Year	1	2	3	4	5	6	7	Accumulative Payback at End of Loan	Projected Savings during Years 8-12	Accumulative Savings at Year 12
Street Lights To Retrofit	20,000	30,000	30,000	30,000	30,000	-	-			
Capital Cost ($)	9,998,081	14,320,000	12,120,000	10,120,000	10,120,000	-	-	56,678,081		
Capital Sources										
DWP Loan ($)	3,199,041	5,989,389	4,304,083	3,304,083	3,304,083	-	-	20,100,679		
MICLA ($)	3,199,041	5,989,389	4,304,083	3,304,083	3,304,083	-	-	20,100,679		
Energy Rebate ($)	-	2,341,222	3,511,834	3,511,834	3,511,834	3,511,834	-	16,388,557		
Rehab Contribution ($)	3,600,000	-	-	-	-	-	-	3,600,000		
Total ($)	9,998,081	14,320,000	12,120,000	10,120,000	10,120,000	-	-	60,189,915		
Loan Debt Service ($)	1,102,590	3,451,039	5,418,944	7,813,144	10,207,344	10,207,344	7,813,144	46,013,549		46,013,549
Program Savings										
Energy Savings ($)	924,669	2,436,781	3,994,257	5,598,457	7,250,783	7,468,307	7,692,356	35,365,610		77,430,564
($)	177,921	1,014,258	1,424,687	2,214,687	2,956,561	2,420,790	2,493,414	12,702,319		22,921,719
Total Program Savings ($)	1,102,590	3,451,039	5,418,944	7,813,144	10,207,344	13,400,931	10,185,770	48,067,929		100,352,283
Net Savings ($)	0	0	0	0	0	3,193,587	2,372,626	2,054,380	10,000,000 to 12,000,000	54,338,734

Program funding overview. Courtesy of LA BSL

9

APPENDIX C: PILOT TEST RFI

LED STREET LIGHTING ENERGY EFFICIENCY PROGRAM (REVISED 1/13/09)

The city of Los Angeles has over 209,000 streetlights that light two-thirds of the City with light sources including incandescent, mercury vapor, metal halide, to high pressure sodium. This variety of lamps is an example of the evolution of roadway lighting that provides greater efficiency in lighting output and energy savings. Based on preliminary analysis and evaluation of the development of the LED industry the Bureau is strongly considering a large scale project to replace existing roadway fixtures into LED or any other high energy efficient light source.

In coordination with the Mayor's leadership on advancing energy efficiency throughout the City, the Bureau strives to be conscious of the impact of excessive energy use, light pollution, glare, hazardous materials, and other environmental impacts to the City. Due to the development of new lighting technology that promises increased energy efficiency, reduced maintenance, longer life span and light control it is incumbent upon the Bureau to actively explore these new lighting sources.

DEMONSTRATION PROJECT

Currently, the Bureau is in the midst of preparing a demonstration project to evaluate LED luminiares by replacing existing 100W HPS (cobrahead) roadway luminaires on local, residential streets with various manufacturers. It is expected that the first phase of this demonstration project will occur from November 2008 to January 2009 and will greatly impact the City's direction for large scale deployment.

LED FIXTURES

The demonstration project will take four luminaires per manufacturer and install them side by side on consecutive residential city blocks. Manufacturers who wish to participate in this demonstration should strongly take into consideration the following suggested requirements:

- The fixtures should be controlled with a photoelectric control with standard socket per ANSI/NEMA C-136.10
- The fixture should connect like a standard cobra head into a typical pipe arm 2.5" in diameter
- The fixture should be designed to save 30% to 40% in energy
- The fixture should be designed to meet IESNA Standards for local/residential street with average roadway width of 36' and two sidewalks of 12' each. Pedestrian conflict area should be considered medium with pavement classification R3
- The fixtures should be a full cutoff with no significant glare
- Color temperature range 4500-6000 degrees Kelvin
- Warranty for complete units should be no less than 50,000 hours
- The fixture should have a minimum CRI index of 80
- The fixture should be designed to meet a power factor minimum of .95
- The fixture should be in compliance with LM-79 and LM 80
- The fixture should or within the next year be designed to provide dimming feature using a remote monitoring device

If your company is interested in this LED fixture demonstration you may contact Orlando Nova at Orlando.nova@lacity.org or (213) 847-1826. The Bureau would strongly encourage any company to participate in this project as the City of Los Angeles transitions into 21st Century lighting technologies.

REMOTE MONITORING UNITS

In addition to the evaluation of LED fixtures, the Bureau will be conducting a review and evaluation of remote monitoring units. This review will require units that can be mounted on 4 streetlights with all the devices needed to transmit data. Information submitted should include a description of the technology, the protocol used, all reporting aspects, warranty and associated costs for capital and ongoing. The ultimate goal is to have these units coordinate with the LED fixtures. The 4 units will be evaluated from January 2009 to June 2009

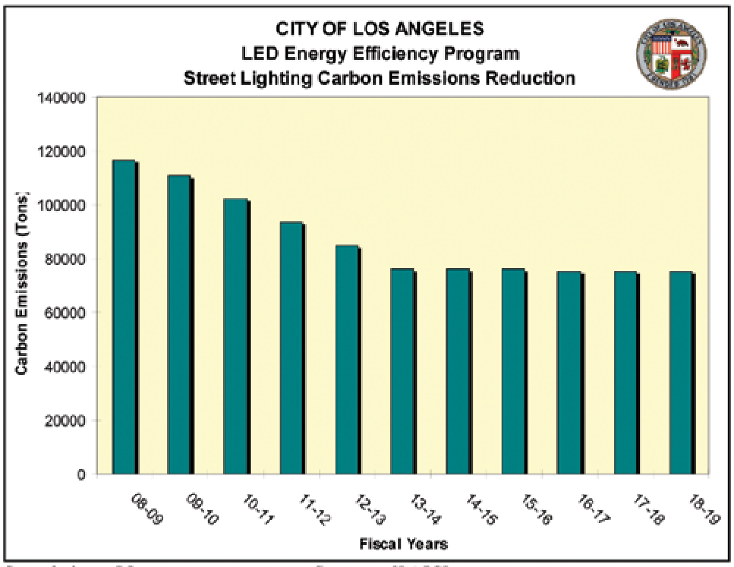
Manufacturers who wish to participate in this demonstration should strongly take into consideration the following suggested requirements:

- The final data must be available in XML format for the City to download on a daily basis
- The remote monitoring units (RMU) should have the capacity to turn on and off the fixtures
- The RMU should have some capacity to report on energy usage
- The RMU should have an automated GPS reporting system or associated remote device

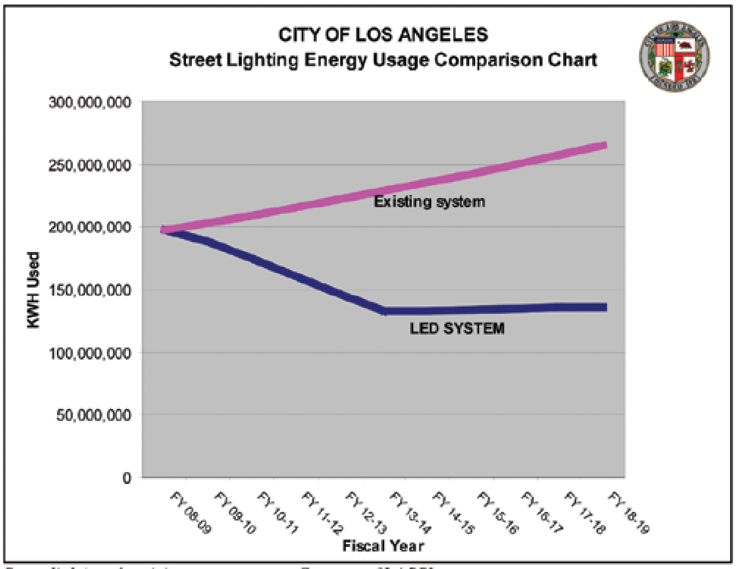
- The RMU should have the capability to be coordinated with an LED fixture for dimming purposes
- The RMU should be able to provide various reports including day burners, reduction in energy or no power available

If your company is interested in this remote monitoring unit demonstration you may contact Kurt Sato at kurt.sato@lacity.org or (213) 847-1502. The Bureau would strongly encourage any company to participate in this project as the City of Los Angeles transitions into 21st Century lighting technologies.

APPENDIX D: PROGRAM ENERGY SAVED & CO_2E EMISSIONS



Street lighting CO_2e emissions per annum. Courtesy of LA BSL.



Street lighting electricity use per annum. Courtesy of LA BSL.

12

APPENDIX E: KEY REFERENCE MATERIALS

OAKLAND, CALIFORNIA – 2008

This is Phase III of a long-running LED pilot test conducted by Pacific Gas & Electric Co., a utility company based in San Francisco, CA. The report demonstrates improvements in LED technology over time – it is remarkably comprehensive in its comparison of a 100W HPS street light and a 56W LED street light.

SAN FRANCISCO, CALIFORNIA – 2008

This report, also authored by PG&E, tests 4 different LED street lights to replace 100W HPS street lights in downtown San Francisco. The report contains an excellent hi-resolution analysis of these luminaires' photometric performances.

ANCHORAGE, ALASKA – 2008

In an effort to reduce light pollution, cut utility bills and enhance safety, Anchorage conducted two large pilot tests of induction and LED street lighting systems for residential and commercial areas, including dimming systems. Anchorage has begun the full retrofit of its 16,000 luminaires from HPS to LED – the first phase of this, encompassing almost 4,000 luminaires of 150W and 250W size, has been completed. Payback will occur in less than 7 years; energy savings have so far achieved a 58% threshold. LED luminaires are from Beta Lighting.

Figure 51 Comparison between yellow HPS Lighting and White LED Lighting

Appendix 10. Ernst & Young Paper on NZ Road Lighting PPP

ERNST & YOUNG

Shedding light on PPPs

The Ernst & Young 2011 Infrastructure Survey highlights the need for local government to develop new procurement and funding methods to deliver infrastructure.

It is time to consider long-term partnership arrangements such as Public Private Partnerships (PPPs) in the public sector project delivery environment.

Increasingly, the public sector is turning to private investors and contractors to share the costs and risks of investing in and operating infrastructure under PPPs. A street lighting PPP could deliver value-for-money and provide qualitative environmental benefits, increased safety and reduced crime.

Historic under-investment in street lighting stock in New Zealand, resulting in aging and deteriorating assets, and predicted population growth in urban areas also underlines the growing need for investment in this area.

Investment in new street lighting technologies is attractive because it generates significant long-term cost savings. So effectively it pays for itself - a genuine and perhaps unparalleled "spend to save" opportunity for councils.

However, a significant stumbling block to investment is often a lack of funds for significant upfront capital expenditure. The Public Sector tends to consider "conventional" procurement techniques rather than contemplating new methodologies. PPPs are normally financed through the private sector and using PPPs could be the catalyst for investment.

Under a PPP, the parties enter into a long-term output-based contract for complete service delivery. The Private Sector is responsible for the design, installation and financing of new assets, as well as ongoing asset management, maintenance and operational services. The assets are paid for over the contract period on delivery of the services, rather than upfront, and payment is based on performance.

For street lighting, PPP would mean a focus on the lighting service to be delivered, rather than the technical specification of the apparatus. If the lights are functioning and meet the specified lighting outputs, the Service Provider will get paid; failure to meet the service requirements would result in payment deductions.

The benefits of PPP (when compared to conventional procurement approaches) can be substantial:

(i) Access to private sector expertise, innovation and finance. Output-based delivery requirements encourage the spread of best practice and enable the private sector to be innovative in their proposals.

(ii) A long-term approach which encourages the service provider to optimise the whole life cost of the assets, thereby driving efficiencies over the long term.

(iii) Assets are provided efficiently and effectively with standards and cost certainty maintained over the contract period.

(iv) Significant risks are transferred to the private sector (design, construction, financing, technology and obsolescence and operating risk).

However, PPPs have several conceptual disadvantages :

(i) Transaction processes can be long, complex and costly. So the size of the project in terms of upfront expenditure and ongoing operational efficiencies must be sufficient to justify these costs. Joint projects between councils or "bundled" projects which combine a number of services can improve overall economics, and central guidance and experience from similar projects can reduce costs and timeframes.

(ii) Whilst private finance is more normally more expensive than public finance this only represents one element of the total cost of a project. Projects are subject to stringent value for money assessments and will only progress where the estimated cost of delivering the project as a PPP is lower than the estimated cost of delivering the project by traditional procurement methods.

(iii) There is a perception that the private sector makes super-profits; however, bidding competitions deliver competitive and capped pricing.

(iv) PPPs are long-term and typically not as flexible to change. However partnering arrangements can accommodate the requirements of the less dynamic street lighting sector.

The use of PPPs to deliver street lighting projects is not new. PPP has been used globally for more than 10 years with considerable success. Most notably, in the UK, it has been applied on around 30 street lighting projects since 1998 and is viewed as one of the most successful local government PPP sectors.

PPPs are emerging in New Zealand, with pathfinder projects for Wiri Prison and Hobsonville Schools. These demonstrate access to private capital, innovation and expertise. The transition to a new procurement approach is slow, but there is increasing support and appetite for banks to lend, and private sector investors looking for long- term opportunities that provide good security and low risk are willing to invest.

A street lighting PPP could be an illuminating next step in the evolution of procurement and delivery models in a New Zealand Public Sector setting. !

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Appendix 11. NZTA and Local Body Costs for Street Lighting as at 2007

			2000/01	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	Inflation Factor	2007/08	2008/09	2009/10	2010/11	2011/12
			TAPS	TAPS	TAPS	TAPS	TAPS	TAPS	TAPS						
			$expenditure	$expenditure	$expenditure	$expenditure	$expenditure	$expenditure	$expenditure						
Total expenditure - NZTA financial assistance plus local share										4.0%					
Expenditure - All	Auckland Region - TAs	Auckland City	3,498,533	3,717,247	3,547,119	4,086,697	3,708,721	4,346,492	4,952,470		5,150,569	5,356,592	5,570,855	5,793,689	6,025,437
Expenditure - All	Auckland Region - TAs	Franklin District	256,000	267,900	245,090	239,119	303,275	348,342	308,469		320,808	333,640	346,986	360,865	375,300
Expenditure - All	Auckland Region - TAs	Manukau City	2,067,023	1,891,300	2,245,945	2,195,601	2,916,076	3,089,191	3,359,403		3,493,779	3,633,530	3,778,871	3,930,026	4,087,227
Expenditure - All	Auckland Region - TAs	North Shore City	1,296,601	1,174,919	1,111,182	1,065,929	1,418,694	1,920,823	2,017,634		2,098,339	2,182,273	2,269,564	2,360,346	2,454,760
Expenditure - All	Auckland Region - TAs	Papakura District	153,712	203,173	201,081	220,000	247,000	482,400	239,000		248,560	258,502	268,842	279,596	290,780
Expenditure - All	Auckland Region - TAs	Rodney District	429,900	378,288	355,000	451,912	496,054	701,673	622,542		647,444	673,341	700,275	728,286	757,418
Expenditure - All	Auckland Region - TAs	Waitakere City	1,057,543	906,317	1,078,000	1,062,632	1,425,068	1,447,000	1,563,000		1,625,520	1,690,541	1,758,162	1,828,489	1,901,628
Expenditure - All	Bay of Plenty Region - TAs	Kawerau District	78,350	110,000	109,217	109,641	106,213	107,557	108,936		113,293	117,825	122,538	127,440	132,537
Expenditure - All	Bay of Plenty Region - TAs	Opotiki District	40,183	46,679	27,920	23,800	49,792	45,783	37,453		38,951	40,509	42,130	43,815	45,567
Expenditure - All	Bay of Plenty Region - TAs	Rotorua District	618,450	590,792	661,030	598,800	638,432	844,651	869,627		904,412	940,589	978,212	1,017,341	1,058,034
Expenditure - All	Bay of Plenty Region - TAs	Tauranga City	814,456	669,008	772,380	864,754	1,021,011	1,185,004	1,108,024		1,152,345	1,198,439	1,246,376	1,296,231	1,348,081
Expenditure - All	Bay of Plenty Region - TAs	Western Bay of Plenty District	160,115	194,194	176,434	177,000					0	0	0	0	0
Expenditure - All	Bay of Plenty Region - TAs	Whakatane District	232,500	232,500	241,218	281,800	290,400	304,000	376,461		391,519	407,180	423,467	440,406	458,022
Expenditure - All	Canterbury Region - TAs	Ashburton District	291,321	240,912	168,160	190,181	170,869	240,292	271,113		281,958	293,236	304,965	317,164	329,850
Expenditure - All	Canterbury Region - TAs	Banks Peninsula District	147,589	133,198	170,789	173,683	167,925	153,000			0	0	0	0	0
Expenditure - All	Canterbury Region - TAs	Christchurch City	3,460,400	3,561,055	3,322,633	3,659,909	3,580,727	3,735,036	4,590,462		4,774,080	4,965,044	5,163,645	5,370,191	5,584,999
Expenditure - All	Canterbury Region - TAs	Hurunui District	50,172	50,714	44,143	58,137	58,951	52,790	47,362		49,256	51,227	53,276	55,407	57,623
Expenditure - All	Canterbury Region - TAs	Kaikoura District	22,460	20,927	15,915	23,873	23,565	23,872	26,179		27,226	28,315	29,448	30,626	31,851
Expenditure - All	Canterbury Region - TAs	MacKenzie District	57,898	52,495	41,844	43,374	71,883	35,617	47,300		49,192	51,160	53,206	55,334	57,548
Expenditure - All	Canterbury Region - TAs	Selwyn District	177,087	172,567	192,522	187,716	215,000	183,256	384,751		400,141	416,147	432,793	450,104	468,108
Expenditure - All	Canterbury Region - TAs	Timaru District	351,822	351,389	294,658	311,727	425,625	386,672	417,040		433,722	451,070	469,113	487,878	507,393
Expenditure - All	Canterbury Region - TAs	Waimakariri District	185,204	129,975	271,284	204,826	231,776	237,022	283,021		294,342	306,116	318,360	331,095	344,338
Expenditure - All	Canterbury Region - TAs	Waimate District	31,423	16,530	10,733	12,627	11,260	12,292	32,610		33,914	35,271	36,682	38,149	39,675
Expenditure - All	Chatham Islands Region - TAs	Chatham Islands District	2,390	2,504	1,949	1,733	1,877	4,956	2,540		2,642	2,747	2,857	2,971	3,090
Expenditure - All	Gisborne Region - TAs	Gisborne District	316,649	405,156	432,857	383,447	453,990	591,132	535,757		557,187	579,475	602,654	626,760	651,830
Expenditure - All	Hawkes Bay Region - TAs	Central Hawkes Bay District	57,288	79,225	82,448	82,844	95,574	88,752	81,112		84,356	87,731	91,240	94,890	98,685
Expenditure - All	Hawkes Bay Region - TAs	Hastings District	327,753	330,302	329,954	468,440	630,884	584,565	742,827		772,540	803,442	835,579	869,003	903,763
Expenditure - All	Hawkes Bay Region - TAs	Napier City	573,542	644,104	605,022	654,232	1,074,323	963,431	959,610		997,994	1,037,914	1,079,431	1,122,608	1,167,512
Expenditure - All	Hawkes Bay Region - TAs	Wairoa District	123,317	128,336	120,437	124,605	145,804	162,625	190,156		197,762	205,673	213,900	222,456	231,354
Expenditure - All	Manawatu-Wanganui Region - TAs	Horowhenua District	145,180	203,666	184,077	201,350	303,159	304,737	184,148		191,514	199,174	207,141	215,427	224,044
Expenditure - All	Manawatu-Wanganui Region - TAs	Manawatu District	146,723	162,472	126,028	185,193	159,417	209,637	249,295		259,267	269,637	280,423	291,640	303,305
Expenditure - All	Manawatu-Wanganui Region - TAs	Palmerston North City	523,739	574,872	885,610	795,152	958,992	883,277	1,002,449		1,042,547	1,084,249	1,127,619	1,172,724	1,219,632
Expenditure - All	Manawatu-Wanganui Region - TAs	Rangitikei District	151,957	145,242	152,526	163,856	166,097	184,886	196,439		204,297	212,468	220,967	229,806	238,998
Expenditure - All	Manawatu-Wanganui Region - TAs	Ruapehu District	140,574	116,061	142,533	129,014	150,881	147,898	290,794		302,426	314,523	327,104	340,188	353,795
Expenditure - All	Manawatu-Wanganui Region - TAs	Tararua District	105,631	137,293	103,578	86,721	127,753	142,822	139,081		144,644	150,430	156,447	162,705	169,213
Expenditure - All	Manawatu-Wanganui Region - TAs	Wanganui District	431,634	534,489	572,709	598,432	543,774	517,020	669,732		696,521	724,382	753,357	783,492	814,831
Expenditure - All	Marlborough-Nelson-Tasman Region - TAs	Marlborough District	343,406	350,449	307,745	270,428	280,117	346,582	320,787		333,618	346,963	360,842	375,275	390,286
Expenditure - All	Marlborough-Nelson-Tasman Region - TAs	Nelson City	373,803	391,641	336,166	359,836	336,286	440,000	392,220		407,909	424,225	441,194	458,842	477,196
Expenditure - All	Marlborough-Nelson-Tasman Region - TAs	Tasman District	145,300	150,970	128,420	160,820	177,220	200,320	210,450		218,868	227,623	236,728	246,197	256,045
Expenditure - All	Northland Region - TAs	Far North District	266,731	459,984	393,070	414,000	460,000	460,000	575,440		598,458	622,396	647,292	673,183	700,111
Expenditure - All	Northland Region - TAs	Kaipara District	66,319	108,056	97,590	95,759	93,692	104,227	118,631		123,376	128,311	133,444	138,781	144,333
Expenditure - All	Northland Region - TAs	Whangarei District	413,685	410,231	377,200	493,774	520,000	344,201	318,248		330,978	344,217	357,986	372,305	387,197
Expenditure - All	Otago Region - TAs	Central Otago District	146,675	147,507	123,124	136,078	140,475	151,689	168,400		175,136	182,141	189,427	197,004	204,884
Expenditure - All	Otago Region - TAs	Clutha District	111,075	135,265	121,609	187,434	129,668	117,293	166,817		173,490	180,429	187,646	195,152	202,958
Expenditure - All	Otago Region - TAs	Dunedin City	790,000	737,899	600,733	659,659	668,874	760,869	1,011,456		1,051,914	1,093,991	1,137,750	1,183,260	1,230,591
Expenditure - All	Otago Region - TAs	Queenstown-Lakes District	137,177	161,142	135,330	133,914	151,422	218,331	212,805		221,317	230,170	239,377	248,952	258,910
Expenditure - All	Otago Region - TAs	Waitaki District	218,727	238,139	230,151	189,873	214,073	201,258	205,742		213,972	222,531	231,432	240,689	250,317
Expenditure - All	Southland Region - TAs	Gore District	41,190	95,981	38,901	42,865	42,958	61,124	48,528		50,469	52,488	54,587	56,771	59,042
Expenditure - All	Southland Region - TAs	Invercargill City	590,062	635,043	614,075	603,147	566,812	495,923	682,463		709,762	738,152	767,678	798,385	830,321
Expenditure - All	Southland Region - TAs	Southland District	141,218	114,739	113,851	111,634	138,926	133,234	139,292		144,864	150,658	156,685	162,952	169,470
Expenditure - All	Taranaki Region - TAs	New Plymouth District	528,064	738,230	485,604	433,754	370,163	531,710	552,480		574,579	597,562	621,465	646,323	672,176
Expenditure - All	Taranaki Region - TAs	South Taranaki District	267,902	247,855	197,027	150,273	172,263	123,110	161,577		168,040	174,762	181,752	189,022	196,583
Expenditure - All	Taranaki Region - TAs	Stratford District	85,532	20,416	43,043	38,458	40,864	87,939	56,806		59,078	61,441	63,899	66,455	69,113
Expenditure - All	Waikato Region - TAs	Hamilton City	1,185,767	1,215,524	1,151,342	1,183,032	1,456,060	1,778,280	1,559,703		1,622,091	1,686,975	1,754,454	1,824,632	1,897,617
Expenditure - All	Waikato Region - TAs	Hauraki District	343,423	174,316	137,719	137,422	157,756	188,634	197,331		205,224	213,433	221,971	230,849	240,083
Expenditure - All	Waikato Region - TAs	Matamata-Piako District	525,439	229,103	227,552	201,775	324,594	266,024	336,184		349,631	363,617	378,161	393,288	409,019
Expenditure - All	Waikato Region - TAs	Otorohanga District	58,653	80,000	51,127	60,842	75,000	54,094	61,812		64,284	66,856	69,530	72,311	75,204
Expenditure - All	Waikato Region - TAs	South Waikato District	472,781	259,720	246,235	203,771	250,422	220,752	271,845		282,719	294,028	305,789	318,020	330,741
Expenditure - All	Waikato Region - TAs	Taupo District	326,037	368,363	314,694	282,281	350,000	296,405	361,121		375,566	390,588	406,212	422,460	439,359
Expenditure - All	Waikato Region - TAs	Thames-Coromandel District	263,734	263,778	272,933	276,783	272,888	403,628	344,992		358,792	373,143	388,069	403,592	419,736
Expenditure - All	Waikato Region - TAs	Waikato District	189,550	196,269	192,105	188,865	201,498	183,963	358,973		373,332	388,265	403,796	419,948	436,746
Expenditure - All	Waikato Region - TAs	Waipa District	246,902	201,180	216,200	158,023	225,356	221,436	266,701		277,369	288,464	300,002	312,002	324,483
Expenditure - All	Waikato Region - TAs	Waitomo District	112,907	165,532	99,405	93,277	140,693	155,510	108,039		112,361	116,855	121,529	126,390	131,446
Expenditure - All	Wellington Region - TAs	Carterton District	49,581	33,586	31,305	44,059	18,835	26,208	36,253		37,703	39,211	40,780	42,411	44,107
Expenditure - All	Wellington Region - TAs	Hutt City	912,611	1,005,235	1,019,548	1,458,489	1,417,603	1,600,229	1,835,494		1,908,914	1,985,270	2,064,681	2,147,268	2,233,159
Expenditure - All	Wellington Region - TAs	Kapiti Coast District	307,562	299,995	400,546	413,651	340,102	371,818	376,642		391,708	407,376	423,671	440,618	458,243
Expenditure - All	Wellington Region - TAs	Masterton District	300,763	126,580	132,512	136,599	120,007	122,295	142,406		148,102	154,026	160,187	166,595	173,259
Expenditure - All	Wellington Region - TAs	Porirua City	436,724	396,971	428,190	536,014	505,870	534,693	619,714		644,503	670,283	697,094	724,978	753,977
Expenditure - All	Wellington Region - TAs	South Wairarapa District	50,568	51,072	34,290	49,524	58,887	71,734	50,839		52,873	54,987	57,187	59,474	61,853
Expenditure - All	Wellington Region - TAs	Upper Hutt City	240,986	265,234	290,902	361,763	343,944	373,478	407,460		423,758	440,709	458,337	476,671	495,737
Expenditure - All	Wellington Region - TAs	Wellington City	1,489,245	1,348,651	1,642,119	1,719,000	2,058,050	2,174,390	2,559,869		2,662,264	2,768,754	2,879,504	2,994,685	3,114,472
Expenditure - All	West Coast Region - TAs	Buller District	121,827	103,166	78,380	93,581	119,402	104,726	77,881		80,996	84,236	87,606	91,110	94,754
Expenditure - All	West Coast Region - TAs	Grey District	180,758	173,573	178,240	166,747	259,314	229,099	210,000		218,400	227,136	236,221	245,670	255,497
Expenditure - All	West Coast Region - TAs	Westland District	75,406	87,622	72,829	82,482	77,502	90,000	92,000		95,680	99,507	103,487	107,627	111,932
Annual totals for all local authorities			31,083,209	30,764,818	30,605,837	32,448,443	35,668,438	38,913,709	42,524,198		44,225,166	45,994,173	47,833,939	49,747,297	51,737,189
Annual totals for State highways (from next sheet)			2,319,737	3,287,707	3,849,429	4,235,107	4,247,667	3,395,461	2,785,299		2,896,711	3,012,579	3,133,083	3,258,406	3,388,742
National annual total expenditure			33,402,946	34,052,525	34,455,266	36,683,550	39,916,105	42,309,170	45,309,497		47,121,877	49,006,752	50,967,022	53,005,703	55,125,931

Appendix 12. AA Comments: Strategic Road Lighting Opportunities for New Zealand

While acknowledging that lighting plays a role in all three areas of safety, value for money and economic development, the AA strongly supports the report's focus on lighting's potential role in safety as the key priority.

Literature has been around for decades supporting lighting's potential to significantly reduce road crashes in darkness (your report estimates by 30-65%). With about a third of NZ crashes occurring in darkness, this means reducing the road toll by 10-20% pa, using a relatively low cost, or even negative cost, treatment. It would be a pity to focus on cost savings at the expense of maximising the road safety potential.

Note that lighting poles also impacts on safety; frangible poles have a very high benefit-cost ratio but most local authorities resisting the move to frangible poles due to higher maintenance costs when struck by a vehicle. Frangible poles save lives, and cost minimisation is not the key objective. It is important that any lighting strategy does not solely focus on the light itself but also the pole design. Designs that use less poles will be safer and more forgiving of human error, as there are less roadside objects to hit. A vehicle vs pole side-on crash can be fatal at 30kph, so this is very relevant for urban areas (usually local Road Controlling Authorities rather than State highways, which are pretty good at installing frangible poles).

The Crash Analysis System records light conditions at the time of a crash and it would be relatively straightforward to assess the priority areas for attention. It would be useful to develop a **simplified evaluation methodology** for lighting retrofit projects. The AA is less convinced of the need for PPPs to fund these lighting projects, as this simply introduces a middleman and adds to the lifecycle cost.

Rather than investing in a piecemeal way based on crash locations, lighting treatments must first be in a **strategy that integrates with the State highway classification system and local road hierarchy.** Lighting design is a key **perceptual cue** to road users as to what speed or hazard level environment they are in. It is important that we develop a consistent strategy for the lighting design to fit into the rest of the roading design (lane widths, markings etc) to create a subconscious response to the cue ie “self explaining” driver behaviours and speeds. We also support the warning about a “patchwork” transition between yellow and white light, and the need to roll this out in a logically consistent way.

We support the recommendations to investigate use of LEDs for safety improvements, better colour and substantive cost savings. We also support the urgent need for an approach in Christchurch, with primary focus on **earthquake resilience** given predictions of 30 years of continued quakes and the social importance of utilities such as lighting staying operational after a quake.

Cost effectiveness of lighting is strongly affected by quantity and **economies of scale** – ie buying in bulk. A key issue with lighting is the wide range of local authority lighting choices resulting in expensive, specialised boutique installations with very expensive operating and light bulb replacement costs. Developing a consistent lighting specification has huge potential to reduce both installation and ongoing costs, but RCAs make independent decisions without being informed about the value for money benefits. We feel the best way to garner economies of scale and the potentially huge cost savings of standardisation would be for NZTA to take the lead on an RCA Forum subcommittee tasked with developing a standardised approach that could be adapted for local conditions, and works with local authority road hierarchies (eg design for 40kph Safe Speed areas vs 60 kph arterials).

Around the country there are many different arrangements for ownership and management of lighting installations, with the electricity provider the Council or the road controlling authority owning the poles and lights and paying the lighting bills, and any mixture of these. Any strategy has to accommodate the differing lighting ownership and management structures and the different incentives these create.

We note that the Insurance Council of British Columbia undertook a joint investment with BC Hydry to change over all the traffic lights to LED, while taking the opportunity at the same time to increase the size of the lights. ICBC research indicated a less than 12 month payback on this project from reduced intersection crashes. Hence we would strongly support including traffic light *size* in this lighting study (many traffic lights are already LED).

We also note that Hugh R Terry, who studied with Dr Sam Charlton at Waikato University, has undertaken considerable work on lighting design in the UK and could be a source of research.

A key issue in any lighting design strategy is to consider the interaction with human visual systems, so that measurements are subjective based on responses of real people rather than using objective instrument measures. This is important both because the human eye does not operate like a camera, and perceptual interpretations can differ between people. Lighting on a road is effectively a "moving target" as the light position relative to the eye moves as the vehicle travels. The design of the lighting has to take account of a wide range of persons and vehicle types. For example a lighting design that works for the height of a truck driver might dazzle the driver of a low slung sports car.

Also it is important to be aware of unintended consequences, such as the effect of dazzle on the conspicuity of vulnerable users such as pedestrians cyclists and motorcyclists. Lighting systems need to consider and minimise "light pollution" eg in residential areas or those near astronomy installations.

In summary the AA strongly supports recommendations that:

- NZTA needs to develop a lighting strategy for the State Highway Network, to develop *nationally consistent* lighting guidelines appropriate to the SH classification and speed limit environment that take account of the perceptual cues sent by the lighting installation (self explaining roads)
- The lighting strategy needs to consider the safety effect of minimising poles and improving their design to have more forgiving roadsides (as supported by the Safer Journeys strategy)
- NZTA leads a RCA Forum sub-committee to investigate how best to garner economies of scale from developing nationally consistent lighting designs appropriate for local bodies
- Investigate co-funding possibilities from electricity providers and insurance agencies eg ACC

Jayne Gale, Principal Adviser, Motoring Policy
NZ Automobile Association
30 March 2012

Appendix 13. Submissions to Commerce Commission on EDB Information Disclosure

59. In response to the Commerce Commission's call for submission on the Information Disclosure regimes for Electricity Distribution Businesses (EDBs) both NZTA and Bridger Beavis & Associates Ltd made submissions. These are provided below.

13.1 NZTA e-mail

From: Bernie Cuttance

Sent: Friday, 9 March 2012 5:26 p.m.

To: regulation.branch@comcom.govt.nz

Subject: NZTA interest in Information Disclosure Requirements for Electricity Distribution Businesses

As discussed with John Groot, the NZ Transport Agency (the NZTA) has an interest in this subject because funds managed by the NZTA are expended on road lighting to light state highways (operated by the NZTA) and local roads (operated by local authorities). The NZTA is a funding partner with local authorities for local roading activity. The annual investment by all road controlling authorities (RCAs) in street lighting is over $50m.

We are aware of a number of issues with the road lighting customer supplier relationship - where the RCA is the customer. I list some of those issues below.

We recently commissioned Godfrey Bridger of Bridger Beavis & Associates to report on the opportunities (and the barriers) to achieving better value for money through NZ's investment in road lighting. That reports concludes that there are significant opportunities but to maximise those opportunities Electricity Distribution Businesses (EDBs) would need to provide services at a fair price.

The options for future contractual arrangements include collaborative (risk sharing) delivery models. Some costs may prove to be volatile and others may fall significantly in the medium term. Contractual arrangements would need to be able to accommodate this. We cannot be definitive about the best arrangement at this time but it is likely that a complete understanding of the costs incurred by the various parties will be required to ensure best value for money. It is possible that a legal requirement for EDBs to disclose costs and other information would have a role in this.

Issues that we have been made aware of are as follows. They are based on what we have been told by RCA personnel. Many of these issues have been studied in the past (for example by the Electricity Commission) but we have not had time to fully study the previous work. We have no knowledge of the scale of the impact of any of these issues.

- Is the mix of fixed and variable EDB charges correct? Some RCAs express doubts.
- Street lights are usually not metered. Energy costs are sometimes 'assessed'. Technology based solutions to this are evolving. Some RCAs will have a role to play here in improving their own asset data.
- Energy savings should reduce costs but some RCAs consider that the cost reduction will be smaller than it ought to be. Without good information RCAs cannot judge fairness of the charges they incur. Uptake of energy efficient technology (including LED lights) has been slow in NZ - uncertainty around EDB pricing response is probably a factor.
- Ownership of assets (between the EDBs and the RCAs) is often complex. EDBs place restrictions (for safety reasons) on who can work on certain assets. If an RCA must purchase certain services (eg to maintain assets) then they need to be assured that the price is fair (and that the service is timely).

To take advantage of the opportunities that we have been advised of the purchasers of road lighting will need information. We will need to fully understand EDB costs. Given that we are only beginning work on this we have not approached the EDBs directly to obtain information. However, it may be that the best way to address whatever issues exist will be through a requirement for EDBs to disclose road lighting related costs and other information.

Please contact me if you like to discuss this further.

Bernard Cuttance
Road Maintenance Task Force and Investment Support
DDI 64 9 969 9856
M 021 247 9934
E bernie.cuttance@nzta.govt.nz

NZ Transport Agency
Level 6, HSBC House
1 Queen Street
Private Bag 106602
Auckland 1143
New Zealand
T 64 9 969 9800
F 64 9 969 9813
www.nzta.govt.nz

13.2 Bridger Beavis & Associates Submission

9 March 2012

John Groot
Chief Advisor
Regulation Branch
Commerce Commission
E-mail: regulation.branch@comcom.govt.nz

Submission on Information Disclosure Requirements for Electricity Distribution Businesses

1. This is Bridger Beavis & Associates' (BBA) submission to the Commerce Commission "Draft Reasons" Paper published of 16 January 2012. Note this submission does ***not*** cover disclosure requirements for the Gas Pipeline Businesses.
2. For questions and clarification relating to this submission please contact:

   Godfrey Bridger,

   Bridger Beavis & Associates Ltd,

   E-mail: godfrey@bba.org.nz,

   Ph (07) 859 0059, Mobile (021) 274 3437.

Background of Submitter - Bridger Beavis & Associates Ltd (BBA)

3. BBA principals are Godfrey Bridger, with Masters degrees in Engineering and Business Administration, and Crystal Beavis who has a Masters degree in Political Science. They both have governance experience on Boards with turnovers or assets in excess of $1 billion as well as on small organisations ranging from entrepreneurial start-ups to health

sector patient advocacy groups. Both have also served as senior executives in a range of organisations. A summary of their experience can be seen online[132].

4. BBA principals' experience cover a number of areas relevant to electricity distribution businesses including corporatisation and mergers of NZ's second and fourth largest Power Boards, board membership of NZ's largest electricity distribution company, leadership (as CEO) of the Energy Efficiency & Conservation Authority (EECA), business development for Counties Power and leadership of Research & Development and commercialisation.

Submission Context/Introduction

5. Most recently BBA has been commissioned to write a report for the NZ Transport Agency (NZTA) called "Strategic Road Lighting Opportunities for NZ". Draft 2.1 has been submitted to NZTA in January 2012 an is now available for invited comment from those with a material interest in the subject. The report is referenced extensively in this submission.
6. From BBA's experience witht the EDB sector and research conducted for NZTA, it appears that the relatively low value but important part of the EDB's monopoly business appears to have been overlooked by all parties including the Commerce Commission. Although the road lighting sector is relatively small in terms of asset value, the public benefits those assets provide, or more importantly could provide, are substantial.
7. *Strategic Road Lighting Opportunities for NZ*". Draft 2.1 suggests that there is a large opportunity for NZ to upgrade its road lighting to LED lighting in order to:
    a. save lives and reduce the annual $1.2 billion cost of accidents during dark time through increased use of white lighting;
    b. halve the annual $55 million cost of lighting NZ roads;
    c. use private capital to fund the upgrade; and
    d. provide serious opportunities for innovation and economic growth in the High Value Manufacturing and Services (HVMS) Sector.
8. However there are barriers to allowing the above beneficial outcomes to take place and one of the simplest to remove is by ensuring information disclosure by EDB's for the specific asset class of road lighting networks. This submission is about that issue.

Road Lighting in New Zealand

9. There are five fundamental components of road lighting:
    a. the network of cables that provide road lights with electricity;
    b. the poles or "columns" that support the lights;
    c. the "luminaires" that provide electrical, electronic and physical support to the next component:
    d. the "lamp" that converts electrical energy to light, and;
    e. the systems that control the supply of electricity to the road lighting, most often to many lights covering several km distance at a time.
10. As previously mentioned, road lighting in NZ does not appear to have had much focus so it is difficult to make authoriative statements. However, as far as BBA have identified it appears that most of the road lighting assets are currently in public ownership (owned by either the NZTA or the 76 City or District Councils) with notable exception of the network assets (item a in paragraph 9) which are owned by commercially driven EDB monopolies.

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[132] http://web.me.com/bridgerbeavis/Business_Development/Business_Development.html

11. Some exceptions include a very few EDBs like Counties Power who own most of the road lighting assets (a to e in paragraph 9) in their district, and some Energy Companies that own the systems that control the lights (item e).
12. *Strategic Road Lighting Opportunities for NZ* identifies that there were approximately 330,000 street lights in 2008[133]. More than three quarters of these are estimated[134] to be yellow High Pressure Sodium (HPS) lights originally developed in 1964 by General Electric (GE). The balance of NZ road lights are estimated made up of even older technology.
13. HPS road lighting represented a major advance in energy efficiency when they were introduced. However, the new powerful Light Emmitting Diode (LED) lights are, as the high profile international consultancy McKinsey & Co says in its report in 2011[135], a "*totally different technology" …* which *"is upending the role of the replacement business and transforming the landscape of the lighting industry value chain entirely …".*

LED Road Lighting

14. LED road lights have the following advantages over widely used HPS lamps:
    a. last up to three times longer;
    b. use half the energy;
    c. have no toxic Mercury (compared to <u>all</u> other road lighting technologies including the more advanced),
    d. are not sensitive to vibration (again, compared to virtually all other technologies)
    e. turn on and re-start instantly;
    f. are ideally suited to "finely customised" computer control,
    g. due to their semiconductor nature allow optics that shine light only where it is required (ie there is little "light pollution"), and;
    h. emit white light with high Colour Rendering Index[136] (CRI).
15. *Strategic Road Lighting Opportunities for NZ* suggests that the use of white road lighting in urban areas could save road accidents. Research has shown that peripheral vision and reaction times – required in urban road settings – are improved by white lighting over that of the HPS yellow lighting. (In Motorway environments with no side roads white light may not have this advantage).

Road Safety

16. As the Minister of Transport said in the Ministry's report on Road Safety137, New Zealand's safety record lags behind its international peers. The document states *"Based on 2008 results, we have 8.6 deaths per 100,000 population. This compares with 6.9 deaths per 100,000 population for Australia. Our fatality rate is double that of the safest nations shown (United Kingdom, Sweden and the Netherlands)*"
17. About 31.3% (4,393) of all injuries in NZ in 2010 occuring in the dark or twilight[138]. There are many studies that show reductions in accidents when appropriate road lighting is

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[133] New Zealand Local Government Street Lighting Technology Supplement, Page 11. See http://www.localgovernmentmag.co.nz/Portals/3/LG-Lighting%20Sup.pdf

[134] Merrifield, A.L.R, Review of Street Lighting , Land Transport New Zealand, November 2007.

[135] Lighting the Way: Perspectives on the global lighting market, McKinsey & Company, July 2011, Page 18.

[136] Colour Rendition is the ability of a lamp to illuminate objects in a way that their colours appear similar to when illuminated by light sources such as daylight and the incandescent lamp. In general the higher the CRI, the better – ie an incandescent lamp or daylight will have a CRI of 100 whereas High Pressure Sodium has a CRI of approximately 20.

[137] *Safer Journeys, New Zealand's Road Safety Strategy 2010-2020*, Ministry of Transport, 2010

[138] *Motor Vehicle Crashes in New Zealand*, Ministry of Transport, figures for the year ending 31st December 2010

used. An American study by Elvik[139] concludes "… *that the best current estimates of the safety effects of public lighting are, in rounded values, a 65% reduction in nighttime fatal accidents, a 30% reduction in nighttime injury accidents, and a 15% reduction in nighttime property-damage-only accidents*"

18. There are therefore several compelling economic and social reasons to invest in upgrading New Zealand road lighting.
19. Despite the above reasons and substantial road lighting LED replacement programmes taking place internationally – no substantive LED replacemnt programmes have taken place in NZ. Only very small "trials" are dotted around the country.
20. Quoting from the NZTA report Strategic Road Lighting Opportunities for NZ in paragraph 115 "Despite these encouraging technical and procurement advances together with increasing pressure to save energy, reduce pollution, and to do more with less financial and other resources, progress is very limited.
21. There are several reasons for this but there are two that relate to the Commerce Commission's role: fragmented decision-making and investment, and the lack of pricing signals and specific road lighting asset information.

Fragmented Decision-making and Investment

22. Each of the 76 "Road Controlling Authorities" (RCA) or Councils in New Zealand are responsible for road lighting in their own areas. These "RCA"s are the City and District Councils who do capital works and repairs and maintenance for roads and their road lighting. On average the Government, through the NZTA, funds about 50% of the costs of these Councils, and the local ratepayer funds the other half. The Councils however, make virually all investment and operational decisions as long as they are in agreement with long established NZTA gudelines and standards.
23. For their part the NZTA funds all investment in State Highways and other national road transport assets.
24. This fragmentation of decision-making and funding is significantly excarcebated by the fragmentation of ownership of the road lighting assets. As mentioned above, the distribution networks are owned by the 27 EDB's who charge the RCA's in a wide range of ways for the assets used.
25. Under these circumstances, either regulatory reform is necessary or transparancy and full information is required. Because the asset class is relatively small **BBA submits that the most effective and efficient change can be brought about by appropriate Information Disclosure**.

Lack of pricing signals and specific road lighting asset information

26. In a 2007 study of a sample of 20 Councils NZTA[140] shows that energy for street lighting ranged from fully fixed to almost fully variable. Figure 52 below is an extract from the report and shows the proportion of fixed versus variable costs. This graph shows that 25% of the sample[141] have virtually fixed energy costs. This strongly illustrates that an efficient electricity market to allocate road lighting investment is not in place. There are few incentive signals for investment where the energy costs are fixed. Furthermore, the wide range and significant gaps in information raise more questions and the NZTA study does not investigate any aspect of the electricy tariffs used. **BBA submits that the Commerce Commission needs to investigate these issues in depth**.

[139] Elvik R. *A meta-analysis of evaluations of public lighting as accident countermeasure*. Transportation Research Record 1995; 1485:112–23. (can be purchased at ***http://worldcat.org/isbn/0309061229***)
[140] Merrifield, A.L.R, *Review of Street Lighting*, Land Transport New Zealand, November 2007.
[141] But this rises to more than 40% of those that provided information

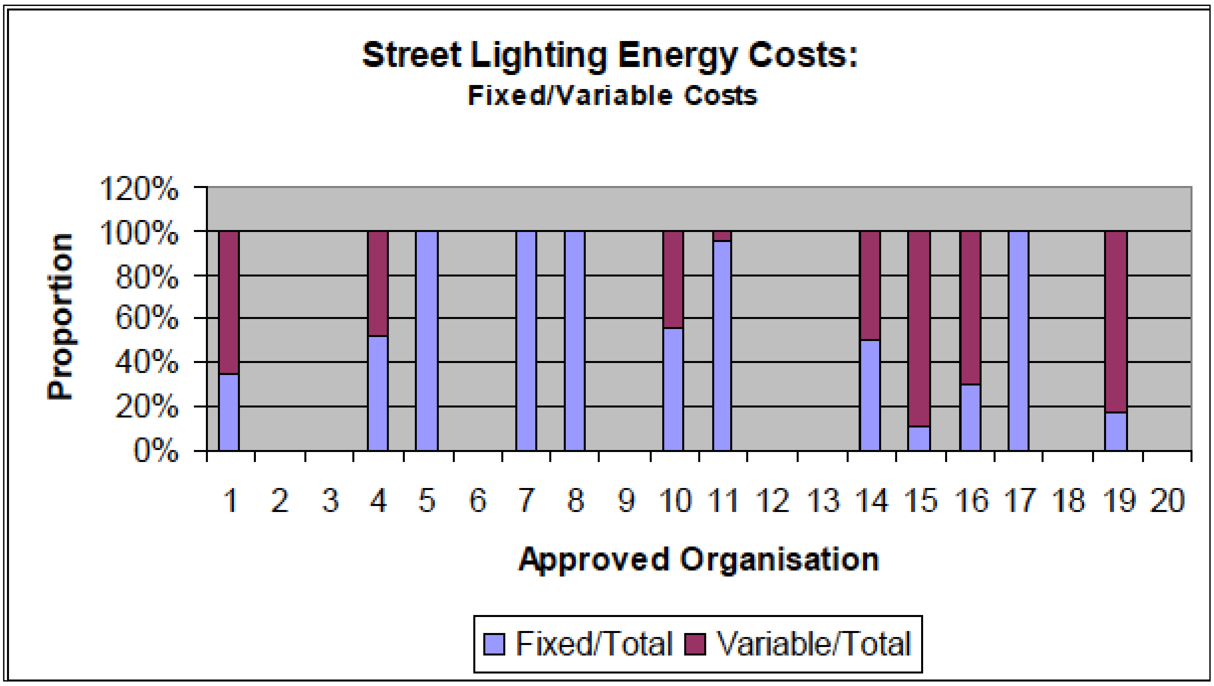

Figure 52 Fixed versus variable energy costs for road lighting in a sample of 20 NZ Councils in 2007

27. The same inferences can be extracted from other data collected in the 2007 study shown in both Figure 53 and Figure 54 below. The NZTA study calculated the cost of maintenance and energy across the sample of 20 Councils and charted them as shown in Figure 53 below. The widely varying energy cost per km of lighting in an infrastructure (monopoly) market is another indicator for investigation.

28. Figure 54 below shows the 20 Council's proportion of energy to maintenance costs. Energy costs range from about 80% of the total cost down to 30%. This wide range re-enforces the observations above that in a monopolistic infrastructure market one would not expect such a range. **<u>BBA submits</u> that the Commerce Commission needs to rapidly investigate and impose specific information disclosure requirements on the EDBs for road lighting to ensure efficient investment signals exist**.

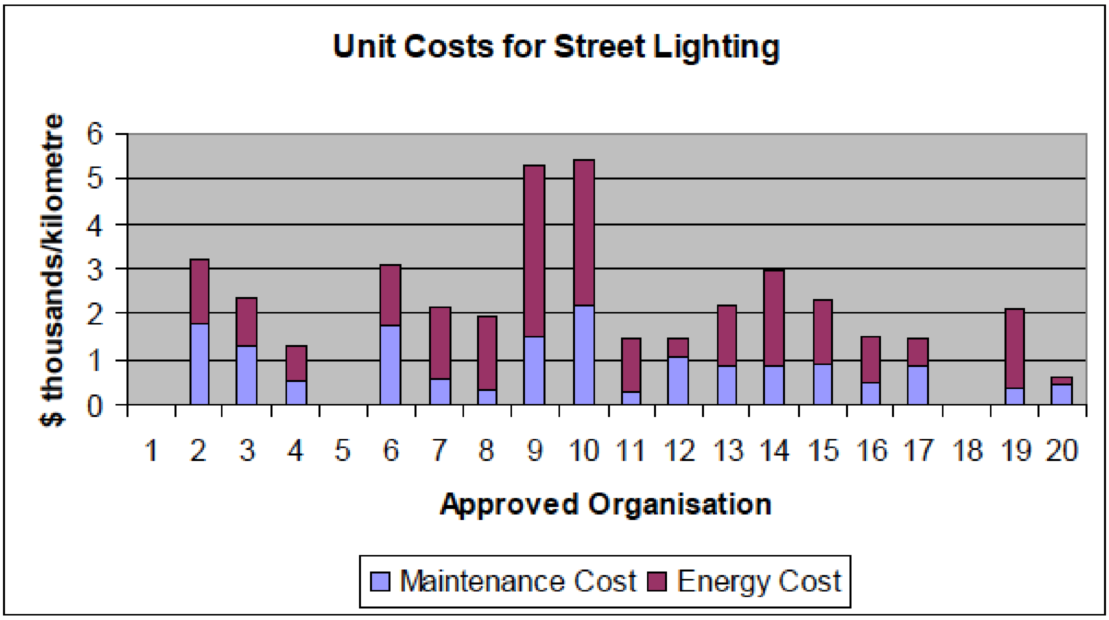

Figure 53 Widely varying maintenance and energy costs of road lighting across a sample of 20 Councils in 2007

Appropriate pricing for Stranded Assets

29. Another cause for concern is that road lighting – especially in NZ's low density population – could soon benefit from distributed solar PV. Solar panels are already visible on our roads to power flashing school speed limit signs, roadside bus transport signage and both Transpower and EDBs use them for powering or providing back-up power for remote control systems.
30. If the costs of Solar PV modules keeps reducing this should become an option for poweing individual road lights. In a non-monopolistic market the value of the embedded electrical cable networks owned by the EDB's will reduce, as will the asset rental they charge. Figure 55 shows that for the first time ever Solar PV pricing has dropped below 1 Euro per watt in September 2011.
31. **<u>BBA submits</u>** that this important global technological advance will be hindered in road lighting applications if the Commerce Commission does not act to ensure efficient investment signals are available to NZ's road lighting market.

Conclusion

32. As indicated in the NZTA report *Strategic Road Lighting Opportunities for NZ,* there are compelling safety, economic, environmental and social reasons for NZ to invest in the latest road lighting technologies that replace NZ's current technology developed 40 or 50 years ago. There are several reasons for the lack of road lighting investment but a significant contributor is the lack of asset management information and pricing signals. **<u>BBA Submits</u> that the Commerce Commission should require all EDB's to separately report their road lighting assets, their valuation, what they charge for those assets, and the methodology used to determine those charges.**

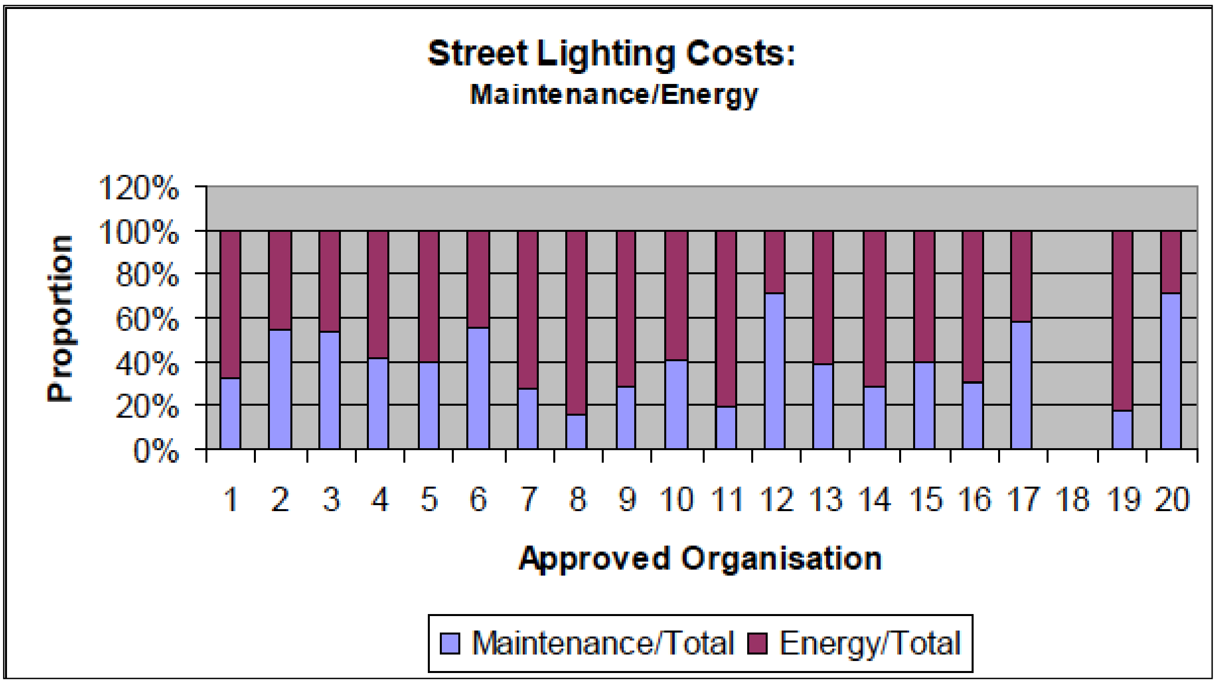

Figure 54 Widely varying proportions of maintenance and energy costs for a sample of 20 Councils in 2007

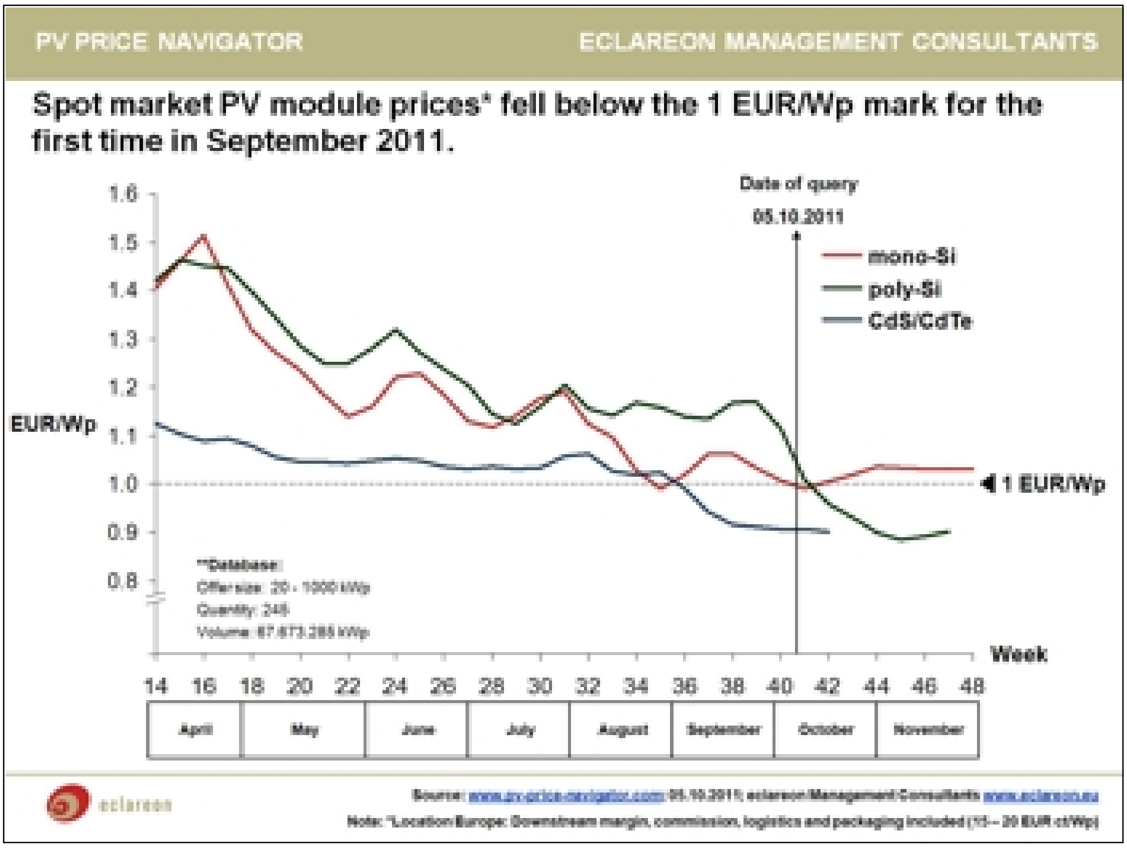

Figure 55 Solar PV module prices

Appendix 14. NZ LED Trials

60. The following City Councils have, or are, doing LED lighting trials. This information was provided by evolve and other sources including those identified Appendix 7.

61. It would be very useful to gather more details for the trials below. We recommend the following information be gathered:

a) trial road location, as some councils have more than one in operation

j) the type of technology under trial (eg NGMH, LED , Induction, Controls etc)

k) the trial start date (approx). Some trials are now up to 5 yrs old.

l) trial result. eg successful, unsuccessful, undecided, pending. Plus note achieved energy savings. Commentators suggest that some trials have been ill-conceived and some products have performed poorly/

1	Auckland City Council:
2	Waitakere City Council
3	NZTA Highway 22
4	Auckland International Airport
5	South Waikato District Council
6	Waikato District Council
7	Thames-Coromandel District Council
8	Taupo District Council
9	Gisborne District Council
10	Palmerston North City Council
11	Wanganui District Council
12	Napier City Council
13	Porirua City Council
14	Hutt City Council
15	Wellington City Council
16	Nelson City Council
17	Mackenzie District Council
18	Kaikoura District Council
19	Christchurch City Council
20	Waitaki District Council
21	Waimate District Council

Appendix 15. US Department of Energy Solid State Lighting R&D

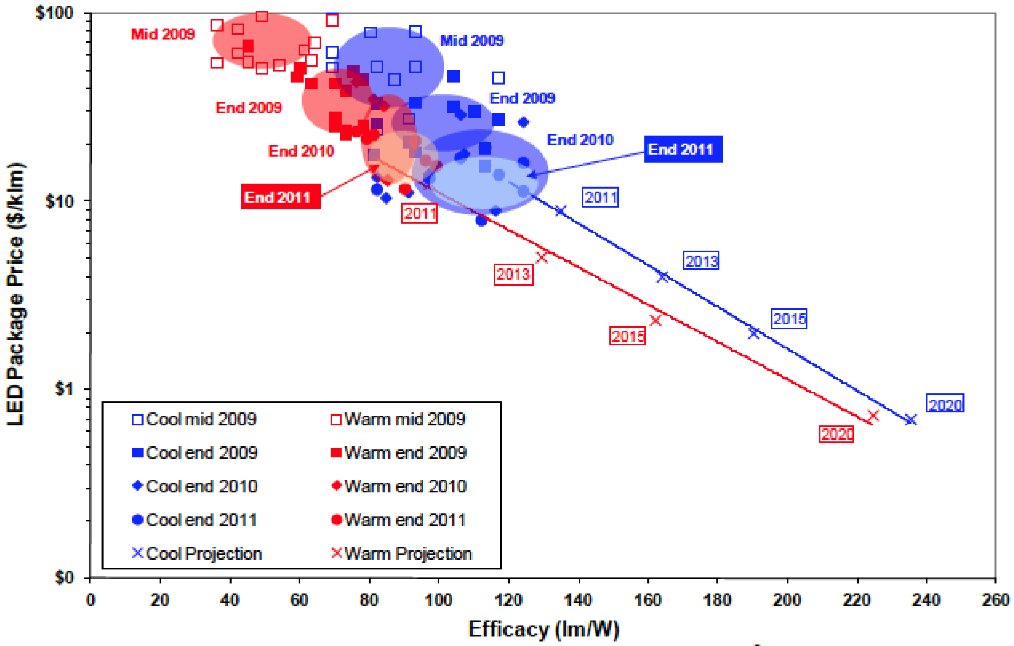

Figure 3.5: Price-Efficacy tradeoff for LED Packages at 35 A/cm²

Notes:

1. Cool white packages assume CCT=4746-7040K and CRI=70-80; warm white packages assume CCT=2580-3710K and CRI=80-90.
2. Ellipses represent the approximate mean and standard deviation of each distribution.
3. The revised MYPP projections have been included to demonstrate anticipated future trends.

Figure 56 LED Package Pricing trends (Source: US DOE[84])

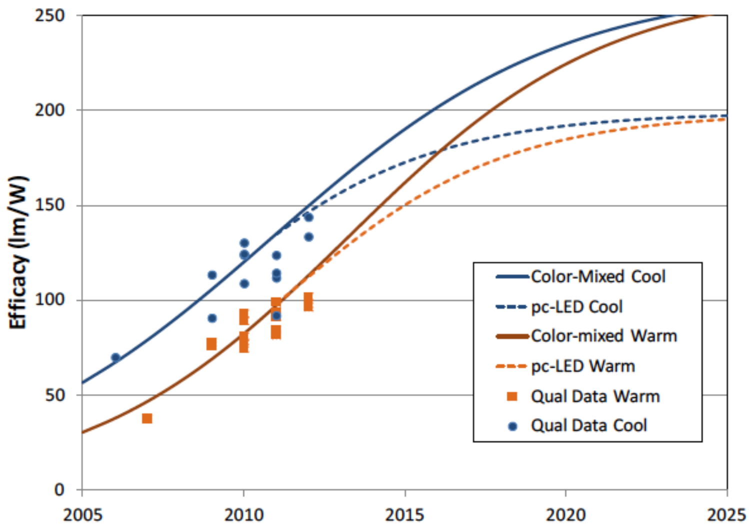

Figure 5.5: White Light LED Package Efficacy Projections for Commercial Product

Notes:

1. "Qualified" data points are confirmed to satisfy the following criteria or may have been normalized for current density if not reported at 35 A/cm²:
2. Cool White: CRI 70-80; CCT 4746-7040K
3. Warm White: CRI 80-90; CCT 2580-3710K
4. Current density: 35A/cm²
5. These results are at 25°C package temperature, not steady state operating temperature. Thermal sensitivity may reduce efficacies by as much as 24 percent or so in normal operation, depending on luminaire thermal management.

Figure 57 Projections of White Light LED Efficacy (Source: US DOE[84])

Appendix 16. UK, Surrey Street Lighting PFI Case Study

SKANSKA

Further information
Skanska AB
www.skanska.com

Contact
Noel Morrin,
SVP Sustainability &
Green Construction
noel.morrin@skanska.se

Surrey Street Lighting PFI, UK

Case Study 78

The Surrey Street Lighting PFI (Private Finance Initiative) involves modernizing the County of Surrey's entire street lighting system to provide higher quality and more efficient street lighting over a 25-year period.

Aspects of Sustainability

This project highlights the following:

Social Aspects
- Human Resources
- Corporate Community Involvement
- Business Ethics
- Health and Safety

Environmental Aspects
- Energy and Climate
- Materials
- Ecosystems
- Local Impacts

Economic Aspects
- Project Selection
- Supply Chain
- Value Added

Project Introduction

The Surrey Street Lighting PFI is conducted by a 50/50 Skanska Laing Consortium and involves the design, build, finance and operation of Surrey's entire stock of lighting columns over a 25-year period. Prior to the project, Surrey's lighting stock had suffered years of insufficient investment, and much of the stock had reached the end of its design life and was becoming increasingly expensive to maintain. Almost 40 percent of the columns before the project were installed during or prior to the 1960s, including 2,600 columns from the pre-1950s. Many lighting columns had been rendered unsafe due to internal corrosion and only 17 percent of the pre-project lighting columns complied with modern safety and lighting design standards. Many of the aging lamps were also inefficient and produced inadequate lighting, in some cases operating with half their original illumination. The council had received complaints from residents about the quality of lighting and a resident survey showed that over a third of respondents were not satisfied with their street lighting.

The Skanska consortium is conducting the US$ 202 million PFI for Surrey County Council and is responsible for modernizing and maintaining Surrey's street lighting from 2010 to 2034. Skanska Infrastructure Services is the sole service provider and are responsible for managing the entire project. The project will replace inefficient orange/yellow lamps with energy efficient white light sources, and install steel columns in place of old concrete and iron lamp posts. An initial survey was conducted in the first year of the project, which collated structural, lighting and column life expectancy data for the County's entire street lighting stock in a Management Information System (MIS). All the County's 89,000 streetlights will be modernized in the first five years of the project, including 70,000 column and lamp replacements, and 19,000 lamp

Skanska Color Palette™

Energy

Carbon

Materials

Water

Click here for more information

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replacements for relatively new columns. The columns are being replaced on a one-for-one basis, and whole districts will be upgraded simultaneously. A Central Management System (CMS) has been installed, which consists of monitoring and control equipment on every lighting column that communicates via encrypted mobile phone technology to a control center near Guildford. The system monitors individual lamp lighting performance and energy use, allows lamps to be remotely dimmed and controlled, and can help to automatically identify or predict lamp failure.

The Surrey Street Lighting PFI is the largest introduction of this type of energy efficient street lighting technology ever seen in the UK. The project moves away from the single 'brighter-is-better' objective of conventional lighting practices to a system that improves illumination through a more flexible and sustainable solution. The PFI also won the best public procurement category in the CIPS (Chartered Institute of Purchasing and Supply) Supply Management Awards in 2010.

Contributing Toward Sustainable Development

The Surrey Street Lighting PFI will provide higher quality street lighting and make significant energy, greenhouse gas emission (GHG) and financial savings throughout the 25-year PFI. The project will also enhance public safety and reduce light pollution. Skanska has established protocols to engage with stakeholders, and to minimize the social and environmental impacts of installation and upgrade work. The project benefitted the regional economy through local employment and the sourcing of regional subcontractors and materials. The lighting columns and lamps are designed and positioned to promote a long lifespan, and the old columns and lamps are entirely recycled by third party contractors.

Social Aspects

Stakeholder communication and dialogue

Stakeholders, including residents, the borough, district and parish councils, police, and local crime and safety partnerships, are communicated with and consulted as early as possible to give advanced warning of work that might concern them and to allow stakeholders to contribute toward the planning process and type of replacement streetlights. Residents are informed of scheduled work in their area through advertisements in local newspapers and letters sent to them 20 days prior to the commencement of the work. The program of scheduled work is also posted on a project website to allow stakeholders to learn when work will take place in their area. Skanska provide and maintain a free phone telephone number, which is available for anyone to report public street lighting issues.

Reducing public disturbance

New columns are placed in the hole left by the removal of the old column in most instances to minimize the amount of ground works and public disturbance. Although new columns may be located up to 4 m from the old column if it is poorly situated. Skanska also tries to coincide the program with other highways projects where possible to minimize public disturbance. Work

April 2011 78CS : V4

SKANSKA

is conducted according to an agreed protocol to reduce noise disturbance, minimize the time spent at each site, and to ensure that privacy issues are addressed. The remote CMS will ensure that faulty lamps are repaired more quickly and efficiently, which will provide consistent and reliable lighting for residents. The PFI has the objective of ensuring that at least 98 percent of the streetlights will be operational across the County at any given time.

Public safety

The project is contributing toward improved public safety by replacing the old orange/yellow lamps with modern lamps, which have a greater rendition of white lighting and improve street lighting levels. The enhanced visibility is expected to reduce street crime and the fear of crime, and decrease the number of nighttime road accidents. Prior to the project, urban areas had poor quality and insufficient lighting, and some nighttime CCTV (Closed-Circuit Television) images were almost unusable. The PFI is also replacing old and structurally unsafe concrete and iron columns, which pose potential safety issues to pedestrians and motorists. The new CMS dims lamps in selected areas to save energy, although areas excluded from dimming are highway intersections and high crime areas so as to not compromise public safety.

Long-life columns

All the new steel columns are hot dipped galvanized according to the latest BS EN (British European Standards Specifications) standard, which provides internal and external corrosion protection. The columns also have a thermoplastic finish that carries a 30-year warranty, and a painted glass flake root protection system, which provides a 30-year design life and exceeds the protection offered by a conventional bitumen coating.

Preserving heritage columns

There are a small number of designated conservation areas in Surrey with specially designed heritage columns and lamps. The project team and local conservation officers consult with residents to decide on suitable column and lamp replacements from a selection of approved models. Parts of specially designed columns will be refurbished and re-used where possible, and any heritage columns that are retained will be re-painted.

Economic Aspects

Regional employment, subcontractors and materials

Around 120 people are working on the PFI, including direct labor and subcontractors. Approximately 50 percent of the workers are from Surrey. The steel columns for the project are manufactured 230 km away in Derbyshire.

Reduced operational costs

The project will make initial savings of over US$ 550,000 per year for the council, compared to before through more efficient lamps, and the monitoring and control capabilities of the CMS. Skanska intend to introduce new and innovative solutions to the PFI throughout the 25-year period to make further operational savings. The system also promotes more efficient maintenance routines by planning schedules in a more targeted manner and preempting lamp failure. In addition, a CMS was chosen that uses a common open protocol and enables the team to consider alternative suppliers in the future to promote contractor competition and maintain low operational costs.

SKANSKA

PFI viability

The initial cost of the streetlight replacement and setting up the CMS and was met by a government PFI credit, worth approximately US$ 120 million. Without the credit, the County would be unable to afford to replace its aging and inefficient streetlight infrastructure. The landmark deal is expected to save Surrey taxpayers at least US$ 18 million in reduced operation and maintenance costs.

Environmental Aspects

Reducing environmental impacts during column installation

Skanska protects existing trees when installing new columns by avoiding damaging tree roots during the excavation of trenches and by covering roots with dry sacking if trenches are to be left overnight to protect them from frost. Roots that must be removed are pruned with a sharp tool to ensure a clean cut and roots over 25 mm in diameter are not cut unless the local council's Tree Officer agrees beforehand. New columns are also not positioned too close to existing trees and possible future tree growth is considered to minimize or avoid the need for tree pruning in the future. Skanska consults the Authority Arboriculturist when pruning is required and certified arboricultural contractors conduct all major pruning work. Sites are also inspected for nesting birds and bats before and during ground works. An Environmental Advisor oversees the work if nests are found and non-mechanical equipment and hand digging techniques are used to avoid excessive disturbance to wildlife. The relevant authorities are also consulted prior to work within or adjacent to Surrey's 221 conservation areas and 63 SSSIs (Sites of Special Scientific Interest).

Waste management

All project waste, including redundant columns, old lamps and excess excavated soil, is segregated and entirely reused or recycled. The redundant and dismantled concrete columns are crushed into secondary recycled aggregate, which is used as sub-base material for highway and construction projects. Old metal columns are cut up and converted into raw steel blocks at steel works either in the UK or abroad. Removed lamps are 100 percent recycled at a specialist centre in the region, which ensures compliance with COSHH (Control Of Substances Hazardous to Health) regulations and the WEEE (Waste Electrical and Electronic Equipment) directive. Excavated soil is reused on site as backfill for the new columns, and any excess soil is used to fill and reclaim a local sand pit. Waste tarmac and concrete from excavations is crushed off-site to create sub-base material.

Energy efficiency

The system is designed to provide optimal street lighting as energy efficiently as possible. Surrey's street lighting will use around 18 percent less energy and result in annual energy savings of over 5,300,000 kWh once the entire County's stock of streetlights has been replaced. The most energy efficient lamps currently available have been selected for the project and LED (Light-Emitting Diode) lighting is used for all sign and bollard illumination, which typically use half the energy of conventional lamps. The CMS promotes energy

April 2011 78CS : V4

efficiency by managing the power consumption of each lamp, remotely controlling on/off times and dimming off-peak lighting levels by 50 percent in selected residential areas. Individual lamp wattage is also customized in consideration of lamp spacing along each street to ensure that the luminance output specification is met as efficiently as possible. Skanska intends to make use of further technological advances in lamp technology that become available during the life of the contract, such as potential LED technology for residential streets. Specific areas have also been nominated as 'innovation zones', where new energy efficient solutions will be trialed.

Reducing greenhouse gas emissions

In the first few years of the project, the energy efficient solutions will annually reduce GHG emissions by over 750 tons, compared with prior to the project. Over the 25-year contract, the PFI is expected to save around 58,000 tons of GHG emission in total through more efficient operation and maintenance.

Minimizing light pollution

The lamps selected for the project are designed to reduce light pollution, which can disrupt ecosystems and adversely affect human health. The lamps direct light downwards to ensure that only the streets are illuminated, and shields, baffles, reflectors and louvers help to reduce light spill to adjacent areas.

Learning From Good Practice

The state-of-the-art CMS is the cornerstone of the street lighting system, which enables the optimization of lighting quality and energy efficiency by monitoring and controlling individual lamps.

April 2011 78CS : V4

Appendix 17. Further PPP discussion

62. A PPP will never be able to borrow its capital at rates below Government, and possibly not below Council rates. Thus lending money to Government (ie Treasury) is the lowest form of risk (sometimes referred to as the "risk free" rate) and in numerical terms this is currently[142] 5.23% for 10 year Government Bonds (the most transparent way Government goes to the market to borrow money).

63. Local bodies will pay more for their 10 year loans, but a lot less than house mortgages which are at 7.1% for *five* years and made to riskier private borrowers (albeit with good security). Hamilton City Council reports that it pays 6% for its borrowing in its 2011 Annual Plan which is therefore likely to be what other Councils pay.

64. Thus when a Council (or NZTA) is considering capital projects that can be accomplished by PPPs, it compares the costs of financing the project itself plus the cost of managing the service provision itself (either through employees or subcontractors) against "outsourcing" everything to the PPP. A PPP will need to pass on the increased financing charge to Councils and NZTA (perhaps 1 or 2 percentage points more) for the financing aspect of the service.

65. *If* the figures for Hamilton are approximately correct, *if* they were applicable across New Zealand, and *if* it was valid to extrapolate them by 33 times to represent the reported 330,000 lamps in NZ[143], the financial saving alone to NZ might accumulate to be $330 million over 15 years. It should be remembered that this is in *addition* to the other substantial safety, technology and value for money benefits.

66. If PPPs were *not* used, the financial savings could be greater or lesser depending on the consequences of the risks taken over from the PPPs. Assuming the model is correct, the *maximum* financial savings would be increased by about $120 million to $450 million (ie for the scenario where no risks came home to roost and a PPP model wasn't used).

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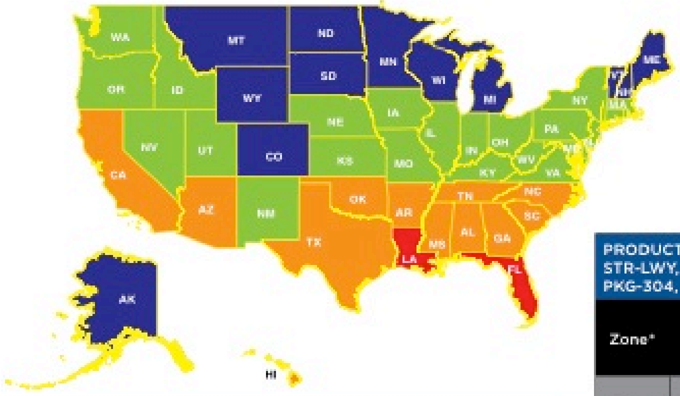
[142] NZ Treasury figures at ***http://www.treasury.govt.nz/economy/mei/nov11*** published 5 December 2011

[143] *New Zealand Local Government Street Lighting Technology Supplement*, Page 11. See http://www.localgovernmentmag.co.nz/Portals/3/LG-Lighting%20Sup.pdf

Appendix 18. 2012 Lumen Maintenance Factors for CREE LEDs

Series D – Recommended Cree® Outdoor Luminaire Lumen Maintenance Factors (LMF)



Series D

PRODUCTS INCLUDE:
ARE-EDG, ARE-EDR, SEC-EDG, CAN-EDG, PKG-EDG, INT-EDR, PWY-EDG, SFT-304, FLD-EDG

Zone*	Drive Current[1] (mA)	Initial LMF	25K hr LMF (Projected[3])	50K hr LMF (Projected[3])	100K hr LMF (Calculated[4])
-20°C† (-4°F)	350mA	1.11	1.07	1.03	0.95
	525mA	1.11	1.07	1.02	0.93
	700mA	1.11	1.06	1.01	0.91
-10°C† (14°F)	350mA	1.09	1.05	1.00	0.92
	525mA	1.09	1.04	0.99	0.89
	700mA	1.09	1.03	0.98	0.87
5°C (41°F)	350mA	1.05	1.01	0.96	0.87
	525mA	1.05	1.00	0.95	0.84
	700mA	1.05	0.99	0.93	0.81
10°C (50°F)	350mA	1.04	0.99	0.95	0.86
	525mA	1.04	0.98	0.93	0.83
	700mA	1.04	0.98	0.92	0.80
15°C (59°F)	350mA	1.03	0.98	0.93	0.84
	525mA	1.03	0.97	0.92	0.81
	700mA	1.03	0.96	0.90	0.78
20°C (68°F)	350mA	1.01	0.97	0.92	0.82
	525mA	1.01	0.96	0.90	0.79
	700mA	1.01	0.95	0.88	0.76
25°C (77°F)	350mA	1.00	0.95	0.90	0.81
	525mA	1.00	0.94	0.89	0.77
	700mA	1.00	0.93	0.87	0.74
40°C (104°F)	350mA	0.96	0.91	0.86	0.76
	525mA	0.96	0.90	0.84	0.72
	700mA	0.96	0.89	0.82	0.67

PRODUCTS INCLUDE:
STR-LWY, STR-SLM, STR-SLM66, ARE-SLM66, CAN-227, CAN-304, PKG-304, FLD-OL, INT-304, SFT-227

Zone*	Drive Current[2] (mA)	Initial LMF	25K hr LMF (Projected[3])	50K hr LMF (Projected[3])	100K hr LMF (Calculated[4])
-20°C† (-4°F)	350mA	1.11	1.07	1.03	0.96
	525mA	1.11	1.07	1.03	0.94
	700mA	1.11	1.06	1.01	0.92
-10°C† (14°F)	350mA	1.09	1.05	1.01	0.93
	525mA	1.09	1.04	1.00	0.91
	700mA	1.09	1.04	0.99	0.88
5°C (41°F)	350mA	1.05	1.01	0.97	0.88
	525mA	1.05	1.00	0.95	0.86
	700mA	1.05	0.99	0.94	0.83
	1000mA	1.05	0.98	0.90	0.76
10°C (50°F)	350mA	1.04	0.99	0.95	0.87
	525mA	1.04	0.99	0.94	0.84
	700mA	1.04	0.98	0.92	0.81
	1000mA	1.04	0.96	0.89	0.74
15°C (59°F)	350mA	1.03	0.98	0.94	0.85
	525mA	1.03	0.98	0.93	0.82
	700mA	1.03	0.97	0.91	0.79
	1000mA	1.03	0.95	0.87	0.71
20°C (68°F)	350mA	1.01	0.97	0.92	0.83
	525mA	1.01	0.96	0.91	0.81
	700mA	1.01	0.95	0.89	0.77
	1000mA	1.01	0.93	0.85	0.69
25°C (77°F)	350mA	1.00	0.96	0.91	0.82
	525mA	1.00	0.95	0.90	0.79
	700mA	1.00	0.94	0.88	0.75
	1000mA	1.00	0.92	0.83	0.66
40°C (104°F)	350mA	0.96	0.92	0.87	0.77
	525mA	0.96	0.91	0.85	0.74
	700mA	0.96	0.89	0.83	0.69
	1000mA	0.96	0.86	0.77	0.57

[1] Consult spec sheet for actual drive current availability for all listed products

* Average Nighttime Temperature
† Provided for freezer applications only
Use the LMF values in this chart when performing lighting calculations for Cree® products ONLY.

[2] 1000mA available on 20-40 SLM and SLM66 only

[3] In accordance with IESNA TM-21-11, **Projected Values** represent interpolated values based on time durations that are within six times (6X) the IESNA LM-80-08 total test duration (in hours) for the device under testing ((DUT) i.e. the packaged LED chip).

[4] In accordance with IESNA TM-21-11, **Calculated Values** represent time durations that exceed six times (6X) the IESNA LM-80-08 total test duration (in hours) for the device under testing ((DUT) i.e. the packaged LED chip)

Recommended Cree® Outdoor Luminaire Lumen Maintenance Factors (TD-13) (1 of 3)

Rev. F Expires: 06/2012

Appendix 19. LED penetration in NZ for Advanced Lighting Technologies NZ (CREE/BetaLED) and Modus Lighting (Philips)

Advanced Lighting Technologies NZ Ltd

67. Advanced Lighting Technologies NZ Ltd (ALT) are the exclusive distribution agents for BetaLED lights manufactured by CREE in the USA. CREE have rececently vertically integrated by purchasing the luminaire manufacturer and distributor RUUD Lighting[144] which owned the BetaLED brand. ALT have provided the attached list of projects where about 2,500 LED luminaires has been used throughout NZ. Note that the list below includes all types of lighting not just street lighting.

Modus Lighting Ltd

68. Modus Lighting are the exclusive distribution agents for Philips lighting products in New Zealand and the table below provides their assessment of LED installations in NZ. Philips is reputed to be the largest lighting company in the world.

Supplier	Location	Region	Type	Road Type	Luminaires
ALT	Kingdom Hall, Kerikeri	Northland	Carpark		
ALT	Twin Streams Walk/Cycleway, Henderson, Akld	Auckland	Walk/Cycle Path		
ALT	Orewa Estuary Cycleway, Orewa, Akld	Auckland	Walk/Cycle Path		
ALT	SH16 Cycleway, Kingsland, Akld	Auckland	Walk/Cycle Path		
ALT	Olympic Park, New Lynn, Akld	Auckland	Path & Carpark (Solar)		
ALT	Mayn Ave, Sandringham, Akld	Auckland	Road	P	
ALT	Yarborough St / Selby Square, St Marys Bay, Akld	Auckland	Road	P	
ALT	Ryle/Gunson/Margaret/Renal/Wood Sts, Freemans Bay, Akld	Auckland	Road	P	
ALT	High St, Akld	Auckland	Road	P	
ALT	Eden Park Surrounds, Sandringham, Akld	Auckland	Road	P	
ALT	Sandringham Rd Realignment, Akld	Auckland	Road	V	
ALT	Westwood Tce, St Marys Bay, Akld	Auckland	Road	P	
ALT	Dornwell RdWalkway, Mt Roskill, Akld	Auckland	Path		
ALT	Ngahere Tce, Parnell, Akld	Auckland	Road	P	
ALT	MatiatiaWharf, Waiheke, Akld	Auckland	Wharf		
ALT	Carrisbrook Cr Walkway, Papakura, Akld	Auckland	Path		
ALT	SH22, Drury	Auckland	Road		
ALT	Remuera Library, Akld	Auckland	Floodlighting		
ALT	Manukau Tennis, Manukau, Akld	Auckland	Path		
ALT	Kem Maunder Park, New Lynn, Akld	Auckland	Path		
ALT	Sudima Hotel, Mangere, Akld	Auckland	Car Park		
ALT	Leonard Isitt Dr, Akld Airport, Akld	Auckland	Road	P	
ALT	Campervan Park, Akld Airport, Akld	Auckland	Campervan Park		
ALT	Telecom Head Office, Akld	Auckland	Interior		
ALT	Te Arai/Mangawahi Rd, Mangawhai	Auckland	Road Flag Lighting (Solar)		
ALT	ARTA Rail Station, Kingsland, Akld	Auckland	Railway Station		
ALT	ARTA Rail Station, Newmarket, Akld	Auckland	Escape Path		
ALT	ARTA Rail Station, Grafton, Akld	Auckland	Railway Station		
ALT	ARTA Rail Station, New Lynn, Akld	Auckland	Railway Station		
ALT	ARTA Rail Station, Manukau, Akld	Auckland	Railway Station		
ALT	ARTA Rail Station Baldwin Ave, Mt Albert	Auckland	Railway Station		
ALT	ARTA Rail Station, Remuera, Akld	Auckland	Railway Station		
ALT	Kiwirail Back Shunt Yard, Papakura, Akld	Auckland	Shunting Yard		
ALT	Transpower, Otahuhu, Akld	Auckland	Security Gate Ltg		
ALT	Babich Hills Subdivision, Ranui, Akld	Auckland	Road	P	
ALT	Millwater Subdivision, Silverdale, Akld	Auckland	Road	P	
ALT	Pokeno Village Estates Subdivision, Pokeno	Auckland	Road	P	
ALT	Long Bay Subdivision, Akld	Auckland	Road	V & P	
ALT	Te Kura Te Kotuku School, Ranui, Akld	Auckland	Carpark		
ALT	Marina View Primary School, West Harbour, Akld	Auckland	Carpark / Security		
ALT	Millenium Institute of Sport & Health, Mairangi Bay, Akld	Auckland	Carpark		
ALT	Parakai Home for the Elderly, Parakai	Auckland	Private Road & Path		
ALT	St Dominics School, Hsn, Akld	Auckland	Carpark		
ALT	North Shore Hospital, Takapuna, Akld	Auckland	Road	P	
ALT	Molly Green Place Park, Mt Roskill, Akld	Auckland	Path		
ALT	BP Lunn Ave, Mt Wellington, Akld	Auckland	Petrol Station		
ALT	Z, Lakeside, Takapuna, Akld	Auckland	Petrol Station		
ALT	Shell, Waiuku	Auckland	Petrol Station		

[144] See ***http://www.ruudlighting.com/en/home.aspx*** and ***http://www.cree.com/***

Supplier	Location	Region	Type	Road Type	Luminaires
ALT	Ryan Ave, Hamilton	Waikato	Road	P	
ALT	Cowen Pl, Hamilton	Waikato	Road	P	
ALT	Woodstock Rd, Hamilton	Waikato	Road	P	
ALT	Banbury Cr, Hamilton	Waikato	Road	P	
ALT	Dalethorpe Av, Hamilton	Waikato	Road	P	
ALT	Enderley Ave, Hamilton	Waikato	Road	P	
ALT	Claudelands Event Centre, Hamilton	Waikato	Carpark		
ALT	Fonterra Cool Store, Te Rapa	Waikato	Cold StorageWarehouse		
ALT	Kimihia St, Huntly	Waikato	Road	P	
ALT	Kingdom Hall, Tokoroa	Waikato	Carpark		
ALT	East Taupo Arterial, Taupo	Waikato	Road Flag Lighting (Solar)		
ALT	Warren Cole Cycleway	Bay of Plenty	Path		
ALT	Flag Lighting	Bay of Plenty	Road Flag Lighting (Solar)		
ALT	Ferguson Park	Bay of Plenty	Path		
ALT	Urban Ridge Subdision, Tauranga	Bay of Plenty	Road	P	
ALT	Strand Carpark, Tauranga	Bay of Plenty	Carpark		
ALT	Bellevue Park Walkway, Tauranga	Bay of Plenty	Path		
ALT	Walkway, Katikati	Bay of Plenty	Path		
ALT	Shell, Bethlehem	Bay of Plenty	Petrol Station		
ALT	Cascade Cres, Palmerston Nth	Manawatu-Wanganui	Road	P	
ALT	Bowen St, Fielding	Manawatu-Wanganui	Road	P	
ALT	BP Bay View Napier	Hawkes Bay	Petrol Station		
ALT	Constable St Play Area, Wgtn	Wellington	Park		
ALT	Lindum Tce, Oriental Bay, Wgtn	Wellington	Path		
ALT	Homebush Rd, Khandalah, Wgtn	Wellington	Path		
ALT	Maifrieght Wgtn	Wellington	Floodlighting		
ALT	BP Roadmaster, Wgtn	Wellington	Petrol Station		
ALT	Bus Station, Tuam St, Chch	Canterbury	Bus Station		
ALT	Edinburgh St, Chch	Canterbury	Road	P	
ALT	NewWorld, Ilam, Chch	Canterbury	Carpark		
ALT	NewWorld, Rangiora	Canterbury	Carpark		
ALT	Queenstown Gardens Path, Queenstown	Otago	Path		
ALT	Marine Parade, Queenstown	Otago	Path		
ALT	Works Depot, Queenstown	Otago	Service Yard		
ALT	Gorge Rd, Queenstown	Otago	Pedestrian Crossing		
ALT	Kingdom Hall, Mosgiel	Otago	Car Park		
TOTAL ALT (Approximate)					**2,500**
Modus	West ho Road	Auckland	Road	V	
Modus	Nelson – Richmond	Nelson	Road	P	
Modus	Paraparumu	Auckland	Road	P	
Modus	Tokoroa		Road	P	
Modus	Wellington City	Wellington	Walkway		
TOTAL Modus (Approximate)					**500**
KEY					
ALT	Advanced Lighting Technologies Ltd - Exclusive Distributors of RUUD & CREE				
Modus	Modus Lighting Ltd - Exclusive Distributors of Philips Lighting				

Drury trial for NZTA with BetaLED luminaires (Source: Beca)

69. The original HPS based design had 119 x 250W (~274 system Watt) lights + 6 x 150W (~149 system Watt) lights. Total 33.6kW. The “new” LED based design had 130 LED lights, with a system wattage of 221W. Total 28.7kW. Design was to Category V3 of the road lighting standard AS/NZS1158 (when the LED’s are at full power).

70. These energy numbers exclude cable losses, relay losses, metering losses etc. (that are likely to be insignificant on the HPS design, but may be a bit more significant on the LED design due to the method of control being utilised – one relay per pole).

71. The Luminaires are BetaLED LEDway “Series C” generation 120 LED (per luminaire) fitted with twin drivers to enable them to be operated at 350mA or 500mA. The drivers run in parallel so all LED’s are running at full power or are dimmed proportionally.

72. The trial was aiming to provide the following benefits:

    a) Reduction in power consumption

    b) Whole of life cost savings

c) Environmental benefits relating to the rural environment (ie reduction in spill light)
d) Provide a project for the monitoring of energy savings/performance against the rest of the network
e) Provide a test bed for improved understanding of this technology in our general State Highway environment

GE NZ Ltd

73. GE NZ also offered to provide information but were not able to meet the deadline for this version – probably due to recent change in senior staff within NZ .