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Title: **Street Lighting: A Visible Sign of Commitment to Sustainable Electricity Use**

Category: Delivering Sustainable Infrastructure: Energy / Transport

Abstract:

Do we need every street light on, all night every night?

Earth Hour 2008 prompted people to question why there is **no will to innovate**, and still use decades old "business as usual" practices.

This is an international problem as evidenced by responses to the "expert inquiry" in a Study for the European Commission DGTREN unit D3 Preparatory Studies for Eco-design Requirements of Energy using Products.

Street lighting cannot stay outside the normal energy efficient service delivery cycle that requires:

- Assessment of service need.
- Determination of how to supply that service as efficiently as possible.
- Implementation of energy efficient systems.
- Monitoring of performance.
- Implementation of corrective actions.
- Re-assessment of the service need.

Street Lighting:

- Consumes between 0.5 and 1% of all electricity generated.
- Should provide a safer environment for all users,
- Is almost never dimmed or switched off when traffic conditions allow.
- Has innovative technologies not being implemented.

This paper will share experiences introducing a monitoring system and management practices to bring street lighting under the normal energy efficient service delivery cycle, highlighting significant **institutional barriers** to adopting better practice.

Significant “sky glow”, service levels well below the design minimum, continued use of basic controls lacking innovation, and poor take up of energy efficiency measures are not acceptable.

As an opportunity for Councils to engage their stakeholders in an energy efficiency measure that is visible, can demonstrate innovative best practice, and lead to more sustainable cities, street lighting cannot be ignored.

Introduction:
The charges for street lighting often represent the largest single component of a council's electricity bill, but efforts being made to introduce better management practices, including energy efficiency measures often fail to recognise the importance of street lighting in the encouragement of a more sustainable lifestyle. It is a service visible to all, and can be used to demonstrate a clear commitment to sustainable energy use.

The UK Institute of Asset Management in association with the British Standards Institute, have published PAS55.1 Publicly Available Specification for the Optimised Management of Infrastructure Assets. This resulted from concerns over problems particularly with the maintenance of electricity network assets which were blamed for a number of serious power cuts. This specification recognises the importance of carefully defining the level of service required and clearly identifies true performance measurement as a necessary part of any good management system. As changes in levels of service are likely to take many years to implement, many operational managers are reluctant to engage with their communities to re-define those service levels, and persist with a "business as usual" approach based on past practice. This is no longer acceptable in today's world where more sustainable practices are being promoted, dependence on fossil fuels must be reduced, and stakeholders are encouraged to be more active. If public transport use, pedestrian and cycling activity is to be encouraged in our neighbourhoods, then present street light management practices must change.

A first step is to ensure the selected design performance is being delivered, and not to assume this on the basis of designs implemented many decades ago. To address the issue of measurement, our company was asked by Western Bay of Plenty District Council to develop a true performance measure for street lighting as part of their 10 year performance based contract known as In3Roads. This paper discusses how such a measure can be incorporated within street light management practice to ensure satisfactory service delivery with improved energy efficiency and recognising the wider influence it may have in building a more sustainable future.

Potential Energy Savings.
The most definitive assessment as to the potential savings from improved energy efficiency in street lighting comes from the European Union who have issued a directive that requires all its member countries to introduce energy efficiency measures with respect to all energy using products. In their report (Van Tichelen et al, 2007), prepared for the European Commission with respect to street lighting, significant energy savings were identified if best available technology, "bat", were to be progressively introduced over the next 10-12 years, particularly if an "accelerated" programme were to be used. (Figure 1) Even with a normal programme using "bat" energy savings of 21% over predicted demand are achieved. They also identified that, if present practices do not change, the European Union, EU's present demand of 35 TWhr per annum in electricity consumption could be expected to rise to almost 40TWhr, compared with 31TWhr for "bat" and 25TWhr for "bat" accelerated. To put the figures in context, a TWhr is sufficient electricity to supply approximately 150,000 homes for a year.

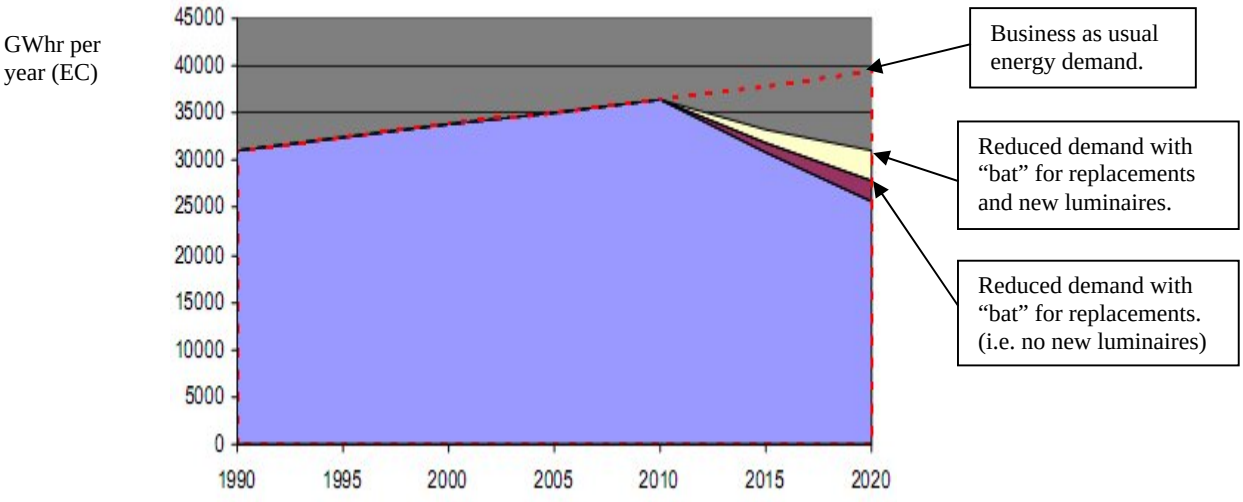

Figure 1: Annual electricity use in the EC of old stock versus new luminaires from 2010. (Figure 61, Van Tichelen et al, 2007.)

In a New Zealand context, annual electricity consumption could drop from an estimated 160 GWhr to 130GWhr, with an electricity cost saving of around $6million. Other significant and tangible cost savings come from removal of old technology luminaires that require higher levels of maintenance than modern ones. Provided the level of service is properly defined, significant savings could be accessed if designs did not have to include pre-defined fixed allowances for output depreciation over time (the maintenance factor) but used factors guaranteed by the manufacturers. The use of sealed optics with much higher Ingress Protection, IP, ratings (for prevention of dust and moisture ingress) and self cleaning glass with special coatings can lifting maintenance factors from the traditional 70% to 90% and above, introducing an immediate potential efficiency gain of almost 30%. However it should be recognised that a system with properly defined service levels may use more electricity than the system it replaces, this may simply be due to the original system being underspecified. Any increase could easily be offset by other factors identified under a quadruple bottom line, QBL, analysis which also incorporates social, cultural and environmental factors.

In addition to using "bat" to increase the efficiency of the existing inventories, there are other energy efficiency opportunities available through use of dimming systems and even switching off some lights when conditions allow. Other advances in street lighting can be expected to see the use of traditional discharge lamps reducing in favour of extremely long life alternatives such as induction lamp or Light Emitting Diode, LED, technologies. LED technology is particularly exciting, in that it can be repeatedly switched in response to very short term requirements such as pedestrian road crossing flood lights which could be operated by the users. Once widespread use of these technologies is adopted, routine maintenance costs could fall rapidly.

Better energy management with respect to street lighting could also be used as a means of demonstrating commitment to a more sustainable future by councils. By publicly acknowledging the potential for energy savings, and implementing well monitored improvements, they can be leaders in encouraging a paradigm shift in public acceptance of better energy management.

The Status Quo: "Business as Usual"

Present "business as usual" management practices for street lighting have entrenched methodologies based on the assumption routine performance measurement is not possible. Once designed and installed, ongoing performance is generally assumed satisfactory and a so called "maintenance factor" is applied to the initial output of the luminaires which is intended to make sure minimum standards are maintained. Using this as means of ensuring proper performance, whilst seeking ways to conserve energy is counterproductive and prevents innovative manufacturers from having their products recognised. Whilst it may no longer be common practice, for important installations, some designers not only applied a 70% maintenance factor for lumen depreciation, but also over designed systems to provide an initial service at a higher level to allow even higher degradation before lamp changes. Systems are also now available that compensate for lumen depreciation over the life of the lamps.

Without an effective measurement system available, a number of poor management practices can become entrenched.

- Maintenance practices may become reactive in nature, merely allowing replacement of lamps on failure. Short cuts can lead to premature failure of entire luminaires, for instance when seals are not properly reinstated and even rudimentary equipment checks are overlooked.
- Contractors are paid on the basis of tasks completed, with limited auditing of the quality or frequency of those tasks. Some contractors may be able to undercut competitors who are more diligent in cleaning luminaires and patrolling to locate problems.
- Performance is deemed satisfactory based on what can be determined easily, and not on the basis of service delivery performance. Costs should not be contained by running down the level of service provided. Service requests relating to street lighting are over represented in relation to the asset value, yet few contracts include incentives to reduce them. For example, when a lamp failure is reported, is the asset management database interrogated to locate other aged lamps that should be replaced in the area and are likely to fail in the near future? This would reduce both repeated visits to replace single lamps, and service requests relating to street lighting. Service request costs should be considered assessing contractor performance
- A common practice involves bulk replacement of all lamps. Where this is on a timetable basis, as required by some public lighting codes, it encourages replacement with least cost lamps, and denies manufacturers of higher quality lamps, which could last up to 50% longer, the chance to sell their product, with obvious cost savings in materials, labour and plant. Apart from the benefits of accessing benefits from guaranteed increases in life expectancy for lamps, a timetable basis denies the opportunity to extend replacement intervals further, based on actual measurement. Contractors must be encouraged to use the best quality longest life lamps available to provide the appropriate light levels at minimum cost.

- Cost benefit analyses favour low capital cost installations, at the expense of electricity usage particularly where overhead power reticulation remains. Should a street light service provider pay the additional electricity charges for extra lights when those lights are only needed because an optimally designed lighting system cannot be used due to constraints imposed by that overhead electrical reticulation?

Performance Measurement Requirements.
Good management of any asset requires measurement of performance and also costs so that an assured level of service can be delivered at least cost.

From experience with surveying over 4000 km of carriageway within New Zealand, it would appear many areas with street lighting are not lit to acceptable standards. There are also other areas that are over lit, particularly where existing overhead electricity reticulation forces sub optimal light mounting geometry. Performance measurement clearly identifies deficiencies in service delivery, and can be used to develop strategic plans to ensure these deficiencies are remedied. Without performance measurement there is no means of assessing performance against appropriate benchmarks. Good asset management involves:

- Assessment of service need.
- Determination of how to supply that service at least cost.
- Implementation of least lifetime cost systems.
- Monitoring of performance.
- Implementation of corrective actions.
- Re-assessment of the service need.

The obligations placed on local government in New Zealand to consult its stakeholders has introduced a requirement to assess performance through consultation, but unless the results are used to identify remedial actions, they are of little use. For example, if the street lighting in an area is reported as satisfactory by the stakeholders, but does not comply with the designated standard for the area, then the designated standard category should be reviewed. This problem was identified by the Australian Greenhouse Office (Deni Greene Consulting Services et al, 2007) which advocated wider consideration of the lowest, P5, design category to AS/NZS 1158. In some situations, flag lighting at intersections may be sufficient to meet the stakeholders needs.

With the drive towards a more sustainable future, the energy efficiency expectations are placing further obligations on service providers. Stakeholders are beginning to demand asset owners identify situations where energy efficiency savings can be made. This could involve reducing lighting services when traffic volumes / pedestrian activity is low, for instance using with dimming systems or part night switching. With respect to this issue, many parties in the service delivery chain have been selective in bringing alternative ideas to the attention of street lighting managers who may not have an in depth knowledge of the technologies now available. These parties have also not been forthcoming in identifying institutional barriers that prevent changes with potential to improve energy efficiency. Greater co-operation between road safety, lighting and energy efficiency practitioners is needed to meet QBL objectives.

As street lighting is not normally metered, with revenue determined on the basis of design parameters and numbers determined from the inventory database, it is important to have robust system to ensure database accuracy and to audit luminaire electricity demand from time to time. A concern raised by one Network Company applied to power factor correction equipment that had failed in many luminaires and was being considered as a reason to increase charges. Whilst the occasional failure could be tolerated in the short term, the solution should be to require contractors to check the equipment and replace failed components. Whilst full revenue metering may not be justified, conducting a number of basic electrical tests on a sample of luminaires from time to time would not be difficult.

In addition to measuring physical performance, planners increasingly need to measure how well the service being provided meets the stakeholders' expectations. To determine levels of satisfaction, a pro-active approach to soliciting responses is essential and a holistic view to achieving societal benefits taken. Unfortunately many of these benefits are difficult to measure, and because of this they are excluded from traditional cost benefit analyses. The situation is further complicated by the fact that street lighting may be just one part of a wider initiative to change stakeholders' habits within a more sustainable community. For example, how are the benefits of increased walking and cycling evaluated? Do we consider only the avoided cost of motor vehicle use, or do we include the value of a more active population on the health sector? Other factors could include encouragement of public transport use, reduced crime and reduced accidents.

Recommended Performance Measurement Techniques.

The first step of best practice management, as defined in PAS55.1, is to properly define the required level of service. This requires surveying stakeholders and measuring their level of satisfaction with the status quo. An example of good consultation was a survey by Waipa District Council that asked whether stakeholders were prepared to pay extra amounts per week based on a range of improved services. Most were prepared to pay a modest additional sum for improvements. What sets this survey apart is the way a direct cost relationship with improved service delivery was identified, and acceptance by Council that the existing service could be less than desirable. We understand stakeholders indicated they were prepared to pay a modest amount to provide improved service.

There are many street lighting practitioners who rely entirely on the national standards and believe that road safety and crime prevention issues justify not considering the stakeholders views. Whilst road safety is a concern with high speed carriageways, this is not where most of the street lights are located. Even for high speed carriageways, there may be a case for reduced lighting outside peak hours or when the served facility such as a shopping mall or sports ground is closed.

Once the required level of service has been defined, it is then necessary to measure actual performance and to determine deficiencies. Western Bay of Plenty District Council, in conjunction with Transit NZ were the first to introduce true performance measurement for use in routine street light management under their performance based contract known as In3Roads. This contract is now in its seventh year and the system now marketed under the HiSLAT® (High Speed Lighting Assessment Technology) name is used for performance measurement. This system collects a line

sample of illuminance data from a moving vehicle and provides accurate and repeatable key performance measures, KPM's, averaged over the communities concerned. A number of supplementary KPM's ensure lighting complies with the AS/NZS 1158 standards. The method was assessed by Kean and Harte (2004) under a research project for LTSA New Zealand, now Ministry of Transport, Road Safety Trust. They state: "The measurement method is fast and safe, and uses relatively inexpensive off-the-shelf technology. Measurements are made in real-time and can be made at highway speeds," ….. "The current system has considerable merit as a maintenance and management tool. It has promise as a tool in determining design compliance requirements of AS/NZS 1158."

The system has been criticised by some street lighting practitioners as not providing a complete representation of the performance of street lighting. However the system was never intended to replace good design practice that is essential to the introduction of more energy efficient installations. It provides quick and simple performance assessment for a service where measurement has not previously been undertaken.

Institutional Barriers

In order to achieve the maximum benefits from a societal viewpoint, institutional barriers that distort market signals need to be removed. A number of these issues were identified by Merrifield (2007) for Land Transport NZ and are now being addressed by the regulators. Examples are:

- No approved organisation, AO, is responsible for switching of lights, this service normally being provided by network companies and energy suppliers using ripple control systems. Whilst ripple control systems do provide limited switching capability, modern radio systems are far more versatile, but are not acceptable to most electricity network companies. The AO's should have the right to introduce alternative systems without penalty and to own them where the incumbent supplier is not prepared to do so. In such cases network charges should be adjusted.
- The network companies have far less robust competitive pricing procedures than the roading industry, especially when they relate to consumer services where costs are not borne by the network companies. Specialist street light maintenance companies are required to hold multiple "warrants" to work near different network company assets, thus incurring extra costs when moving into areas where they have not previously worked.
- Charges are calculated in a variety of ways, with different ratios being applied between variable and fixed charges. In some cases it would appear the Optimised Deprival Value method of valuing assets used to supply street lighting leads to inflated costs. These assets are not managed in accordance with PAS55 principles.
- A mistrust between network companies and consumers often exists, and little, if any, sharing of information to calculate revenues occurs. Provided there were suitable independent audit provisions, revenue assessment requirements could be relaxed where the parties are in agreement.
- Different parties being responsible for only their own parts of the service supply chain often lead to demarcation problems causing delays in faults being repaired and new installations being livened. Electricity network companies should be required to meet response times agreed with the street light owners.

- The practice of defining specific maintenance factors within design standards, as opposed to use of certified performance at levels determined by independent tests locks in significant energy inefficiencies.

Management for Sustainability

Traditional management of street lighting has focussed entirely on direct costs with many of the decisions to provide lighting having been made many years ago. Management for sustainability requires a holistic approach that must take into account the QBL. Well designed street lighting is a part of the wider concept of environmental design which can encourage the safe use our streets, without fear of crime or accident.

The case for provision of good street lighting is similar to the case for introducing good public transport. In that case, acceptance of low patronage and subsidies are often necessary until potential users have seen the advantages and abandoned their earlier practices. Success is measured in terms of increased patronage, with financial performance being of secondary importance, especially in the early years. The difference with street lighting is that there is no simple means of measuring increased patronage by way of increased night time pedestrian and cycling activity, but nevertheless, a paradigm shift in user habits should be encouraged.

As levels of activity are not routinely measured, the definitions for categories from the standards become the default determinant of whether lighting is fit for purpose. Categories are usually selected without consultation, based on maximum expected usage, and without actively seeking stakeholder opinion on whether an acceptable service is being maintained. As with the uptake of public transport in societies traditionally dependent on the motor car, the uptake of increased pedestrian activity at night will require providing the appropriate service level in advance of expecting to see results. From a sustainable management perspective, all societal costs and benefits should be recognised, many of which could relate to a series of initiatives, all of which contribute to encouraging the desired result. These other initiatives could include dedicated cycle and walk ways, more traffic calming and other minor safety improvements. Energy efficiency should be incorporated to ensure the desired lighting level is delivered as efficiently as possible, at the times when it is required.

Management of street lighting for sustainability requires more than providing a service at an unknown level of performance at minimum cost. It requires designers and managers using “business as usual” practices to change and work towards providing the appropriate level of service using “best available technology

Conclusions:

This paper initially posed the question, “Do we need every street light on, all night every night?” Within a sustainable community using the innovative technologies now available the answer is clearly not. But the challenge is for us to consider street lighting from a different perspective. In specific public areas lighting is recognised as an important part of the infrastructure, and good designs for lighting must enhance the prestige of the area. In such areas it is recognised that the performance of an area depends on many factors. Performance measures such as pedestrian counts in shopping areas will be affected by poor lighting, but without attractive shops, safe footpaths, good security, adequate parking and public transport access, the benefits of good lighting will not be realised.

When considering street lighting, especially those in our residential areas where the majority are located, management for sustainability needs to start with clear definition of requirements, and only when that has been confirmed, consider how best to deliver the required service. There will be constraints imposed by present "business as usual" systems, but the time has come to challenge these systems and use the technologies now available to deliver the required level of service as efficiently as possible. There are significant parallels with providing public transport, where excellent service is an important factor in changing entrenched habits. Once installed, management for sustainability must not only ensure the design performance level is maintained, but must incorporate regular reviews of the design performance to determine if less tangible performance targets are still being achieved. The key to this must be greater engagement with the stakeholders, supported by local authorities in their role as leaders in moving society towards a more sustainable future.

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