Institution: University College London

Unit of Assessment: 16 – Architecture, Built Environment and Planning

Title of case study:

Reduction in UK carbon emissions through use of white light for street lighting

1. Summary of the impact

Research by Raynham et al has led to the adoption of white light in residential roads and city centres throughout the UK, enabling an energy saving of 30–40% while providing better quality of street lighting. As a result, today there are now c.1,200,000 conventional street lights with white light sources and a further c.220,000 LED lanterns that emit white light. Conservative estimates suggest that this changeover to white light saved 113 GWh of electricity in 2012, and thus reduced the UK emissions of CO_2 by 45.5 megatons.

2. Underpinning research

The research was overseen and led by Professor Tadj Oreszczyn (then Head of the Bartlett School of Graduate Studies; and who has worked at UCL since 1989), and was conducted by Peter Raynham (then a Research Fellow and now a Senior Lecturer, and a lighting specialist who has worked at UCL since 1996). Raynham's work has been undertaken as part of the Light and Lighting research group in the Bartlett School of Graduate Studies.

In terms of the theme of the underpinning research, it had been noted anecdotally that white light appeared to be better for street lighting than the traditionally used yellow or orange lighting, but there was no hard evidence. To test this idea, in 2002 researchers at the UCL Bartlett Faculty of the Built Environment drew upon the pioneering work of Caminada and van Bommel in the early 1980s, who identified facial recognition as important to pedestrians on the streets at night and proposed that the ability to recognise other people at a distance of at least four metres indicated an adequate level of street lighting.

The Bartlett's research team used the same basic methodology as Caminada and van Bommel, asking subjects to walk towards another person until they could just recognise the face of that other person. At this point they were asked to stop and the distance was measured. However, in order that the research investigation could be more spatially controlled, and also permit rapid changes in light sources, the Bartlett study used a dummy street that was set up in a disused office building. Due to good relations with the UK's two leading lighting societies, it was possible to appeal for volunteers from all their members, resulting in a large number of test subjects with ages ranging from 16 to 70 years old. A range of light sources were tested, including high-pressure sodium bulbs and two types of compact fluorescent light sources. Each of the light sources was tested at least at two levels of illumination, as previously done by Caminada and van Bommel. For the white light fluorescent sources, very similar results were obtained to those reported previously by Caminada and van Bommel. However, through the Bartlett's research the real discovery was that, with high-pressure sodium bulbs, it was necessary to use significantly higher illuminances, with much higher energy use, to obtain the same recognition distance.

The Bartlett's research was first published in 2003 in *The Lighting Journal* **[a]**, a non-peer review journal which nonetheless has a very wide circulation among public lighting engineers. This was done deliberately to ensure that the research findings would be in the public domain ahead of a review of the British Standard on road lighting, which was just then about to be republished. The findings also formed part of an invited talk given by Raynham to the Society of Light and Lighting in 2003, published subsequently in a journal essay tiled 'An examination of the fundamentals of road lighting for pedestrians and drivers' **[b]**. Raynham's paper challenged the fundamental principles of street lighting on main roads and suggested use of task performance in a similar manner to that used for pedestrian lighting. The findings of this research project, coupled with other parts of the Urban Lights project, were also reported in at a number of conferences and perhaps the best overall review of the work was given at Lux Europa in 2005 **[c]**.

The results of this research project at the UCL Bartlett, coupled with the continuing downward pressure on energy use in the UK, and the desire to reduce carbon emissions, has kick-started a much closer examination of the needs of pedestrians on streets at night, and work on that particular subject is now being undertaken by Raynham et all in the EPSRC-funded MERLIN project (EP/I003584/1). Its initial findings about the way in which pedestrians changed how they looked at the street scenes in which they walked around at night, as they became more concerned about the environmental consequences of high energy usage, were published in 2012 **[d]**.

3. References to the research

[a] Raynham, P. & Saksvikrønning, T. (2003) 'White light and facial recognition', *The Lighting Journal*, 68: pp. 29–33. [Available on request]

[b] Raynham, P. (2004) 'An examination of the fundamentals of road lighting for pedestrians and drivers', *Lighting Research and Technology*, December 2004; 36 (4): pp. 307–313. [DOI: 10.1191/1365782804li125oa]

[c] Mansfield, K. & Raynham, P. (2005) 'Urban Lights: Sustainable Urban Lighting for Town Centre Regeneration', conference paper given at Lux Europa 2005 in Berlin, pp. 491–493. [Available on request]

[d] Davoudian, N. & Raynham, P. (2012) 'What do pedestrians look at at night?', *Lighting Research and Technology*, December 2012; 44 (4): pp. 438–448. [Output submitted by Raynham to REF 2014].

The quality of the underpinning research is demonstrated by the following grant:

- Oreszczyn, T. (PI), Urban Lights, ESRC L487254007, December 1999 – November 2003 (£228,488). This grant led to outputs [a] & [b] above.

4. Details of the impact

Street lighting is a massive infrastructural undertaking that uses a lot of energy. In the UK in 2005, there were 8.12 million lighting points on the country's streets using approximately 3.14 TWH of electricity, which gave rise to CO_2 emissions of 1.32 megatons **[1]**. Of these 8.12 million lighting points, 6.31 million of them were street lights while the rest comprised sign illuminations or lit bollards – furthermore, by 2012 the number of street lights in the UK had increased to about 6.9 million in total **[2]**. Whilst of course street lighting is only one of many users of energy, it is a highly visible case, and with the rise in environmental concerns so many pressures began to grow on local authorities to reduce the level of public lighting so as to save energy. However, on the other hand, a higher amount of street lighting provides many important benefits related to crime prevention and public safety. This is where the innovative Bartlett research work by Raynham et al proved to be so useful. By showing that white lights with lower illuminance had the same benefits as brighter sodium lights, the research thereby provided an opportunity to maintain the clear social and public safety benefits of high amounts of street lighting – for pedestrians and motorists alike – but with a concomitant reduction in energy use by as much as 30–40% and with a resultant drop in greenhouse gas emissions estimated at 45.5 megatons in the UK in 2012.

<u>Change in British Standards on street lighting:</u>

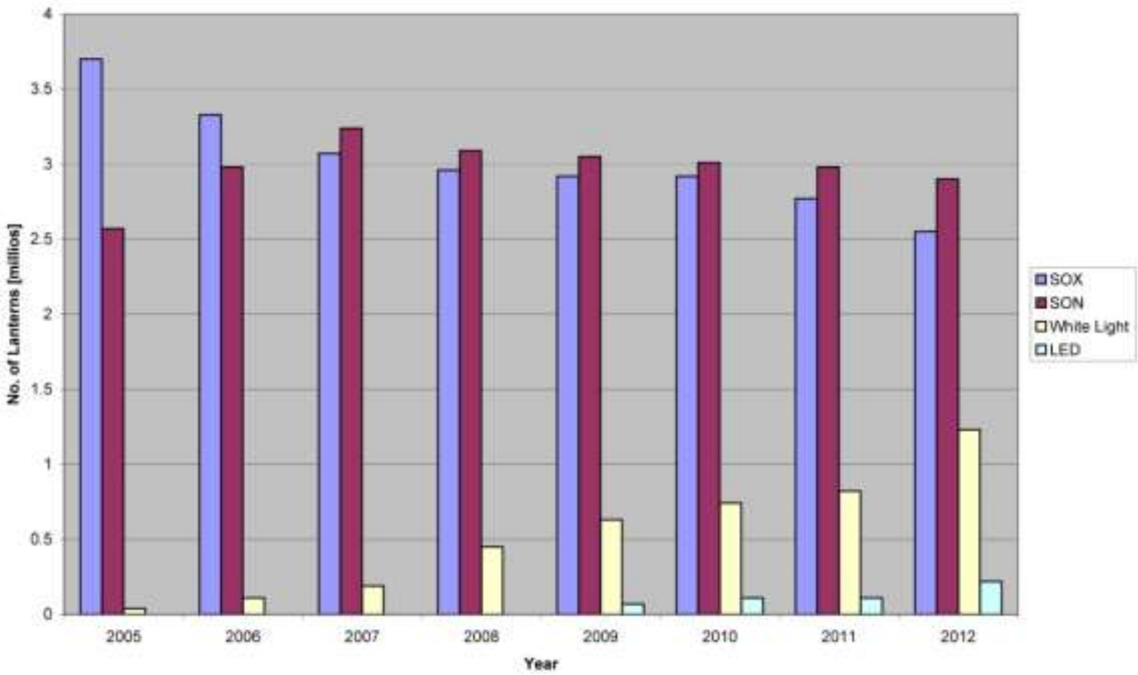
In 2003, the British Standard (BS) for street lighting, *Code of practice for the design of road lighting — Part 1: Lighting of roads and public amenity areas* (BS 5489-1: 2003), was published **[3]**. Drawing directly on research findings **[a]** that had been published in *The Lighting Journal* to coincide with the deliberations leading up to the revision of the code, the reissued standards gave revised guidance on the selection of lighting classes for subsidiary roads.

In particular, it permitted the selection of a lower lighting class, as defined in BS EN 13201-2 **[4]**, which in turn permitted these subsidiary roads to be lit with white lights which used a lower illuminance class than those lit with the traditional orange sodium lamps. This meant that energy usage lighting levels could be reduced by at least 30–40%. It should be pointed out that the Bartlett's research investigations outlined in Section 2 suggest that the energy needed to achieve the same lighting levels using white light can in fact drop by as much 50%; however, British Standard committees are notoriously (and rightly) cautious, hence the use of a slightly lower energy reduction figure in this case study. Nonetheless, as a result of this change in the codes, stimulated by the work of Raynham et al, there has since been an accelerating move towards white lights for street lighting. This is also partly attributable to the fact that since 2005 most of the major renovations of street lighting in the UK have been carried out using private finance initiative (PFI) schemes, with those in charge of those being keen to make savings. All of the PFI schemes started since 2006 that the Bartlett researchers were able to check use white light for residential roads, and this can be seen for example in Hampshire, Northamptonshire, Croydon and the London Borough of Lewisham **[5]**.

Increasing the uptake of white light:

In the first few years, the uptake of white lights for street lighting was slow, but improvements in lamp technology soon led to the emergence of a range of white metal halide lamps that could take advantage of the changed British Standard codes. Already by 2007 – and definitely since then and during the entire REF 2014 impact census period – the situation in the UK developed to the point where virtually all new installations of street lighting installations were using white light.

Totally accurate data on the UK's population of street lights is very hard to come by as the lights themselves are run by a number of different authorities, and whilst there has been significant improvement in recent years many of the inventories made of them, the figures are still not entirely reliable. The following analysis is thus based on a chart covering road lighting that was provided by Philips Lighting **[2]**, from which data was extracted data and then confirmed in terms of general accuracy with that company. In many ways it is the most reliable source available, given that Philips is by far the largest vendor of street lighting lanterns in the UK. They supply both luminaires and lamps, and therefore have the greatest need to determine accurate data about light sources so that they can assess the size of the lamp replacement market. From this Philips data, it becomes possible to plot the rise of white light sources used in street lighting from 2005, when virtually none of them were being used, through to 2012, where they have become increasingly popular.



Number of street lanterns in the UK [Philips Lighting, Source 2]

Thus the chart indicates, the use of white light has risen dramatically during the REF impact period, and in addition it is necessary to note that white LEDs have also been used for street lighting since 2009. At the same time, the number of lamps based on older technologies which emit orange light (high-pressure sodium (SON) and low-pressure sodium (SOX)) has reduced gradually, as the Philips chart also reveals.

The most dramatic increase began, in fact, right at the start of the REF impact period. In 2008, the number of white light sources increased by c.260,000 units over the previous year. Since then, the use of white conventional lamps and white LED lighting has grown from 450,000 lighting units in 2008 to about 1,450,000 units in 2012, representing what is nearly a threefold increase.

Energy savings and emissions reduction due to white light:

As mentioned, this increase in the use of white lighting has had significant knock-on effects for the UK's energy usage and the reduction of carbon emissions. The orange-coloured 70W SON (high-pressure sodium lamp), which was for a long time the typical light source for street lighting, has a total circuit power of 79W, allowing for aspects such as gear losses **[5]**. This is in good correlation with the 2005 data which suggested an average power usage for all street lighting points of 76.26 W, but also included relatively low powered illuminated signs and bollards **[1]**.

The most conservative estimate of the energy saved by the use of white light assumes that the current population of c.1,200,000 conventional white light lanterns has replaced the old 70W SON lanterns with an average energy saving of 30% on each lamp. This gives a safe figure for a reduction of 28.4 MW in the energy load of these streetlights. Assuming that each lantern is on for 4,000 hours per year, then the changeover to white light can be calculated to have saved the UK 113 GWh of electricity in 2012. This reduction also saved local authorities in the UK over £10 million in electricity costs that year, and also reduced payments associated with their carbon reduction commitments. Taking again a conservative estimate of 0.4 kg of CO_2 emissions per KWh of electricity at night **[6]**, this represents a total saving of 45.5 megatons of CO_2 in 2012.

Hence the Bartlett research of Raynham et al has proved to be a major contributor towards helping the UK meet the EU’s set target of reducing emissions to 20 per cent below 1990 levels by 2020. Using UK government figures, it is estimated that the UK's net emissions in 2012 were 479.1 megatons of CO_2 equivalent – thus it can be seen that over 9 per cent savings in emissions were achieved through the changeover to white lights for street lighting **[7]**.

5. Sources to corroborate the impact

[1] Van Tichelen, P., Geerken, T., Jansen, B., Vanden Bosch, M., Van Hoof, V., Vanhooydonck, L. & Vercalsteren, A. (2007) ‘Final Report Lot 9: Public street lighting’, Study for the European Commission DGTREN Unit D3, January 2007 [See Table 16 and Table 129]

[2] Private communication from Philips Lighting. [The chart that they provided, and our extrapolated data table, are available on request]

[3] British Standards Institution, BS 5489-1: 2003+A2: 2008: *Code of practice for the design of road lighting. Lighting of roads and public amenity areas,* London: BSI. See especially Table B4, which permits the selection of a lighting class requiring lower illumination if the light source has a colour rendering of 60 and over.

[4] British Standards Institution BS EN 13201-2: 2003: *Road lighting. Performance requirements*, London: BSI.

[5] Correspondence with the former Technical Officer of the Institution of Lighting Professionals and now UK principal of Orange TEK.

[6] Data taken from http://realtimecarbon.org/ suggests that the value did not drop below 0.45 kg during the night of 25–26 June 2013.

[7] 2012 Greenhouse Gas Emissions Provisional Figures (statistical release). [https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/193414/280313_ghg_national_statistics_release_2012_provisional.pdf, PDF, p. 1]