traffic
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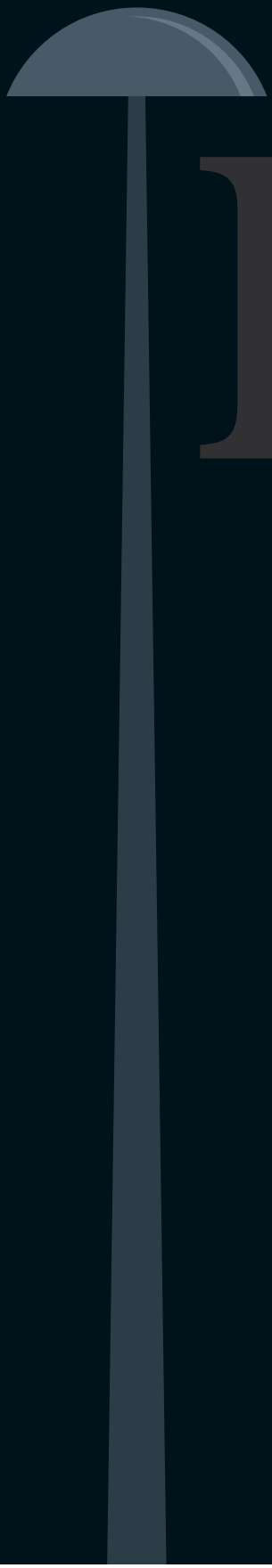


Dark matters

Timothy Compston discovers that there's a bright future for the above-the-road lighting market, with predictions of more intelligent solutions to deliver enhanced efficiencies and light when – and where – it's needed

Illustration courtesy of Patrick George

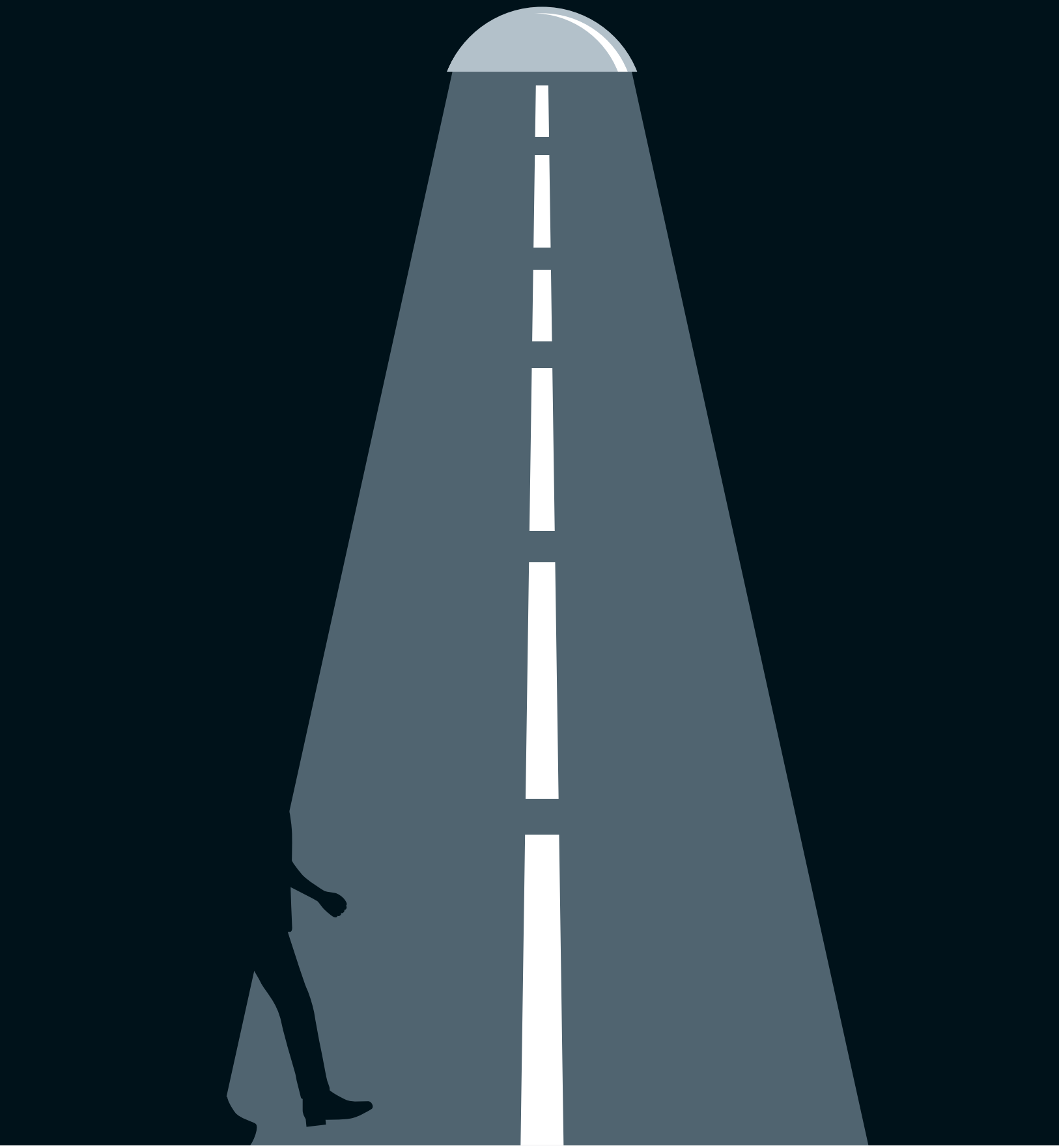
Not all that long ago streetlights were the forgotten assets of roadway infrastructure, given scant regard until a bulb gave up the ghost. Now, with a clear focus among DOTs and municipalities on making their budgets stretch further and minimizing wastage wherever possible, solutions with greater levels of control are sought – more proactive, smarter and green. But it's not about deploying for deployment's sake – in some cases we're questioning whether certain installations are needed at all.

Changing requirements

In the UK, for example, the Highways Agency is trailblazing numerous measures in a streetlighting program to reduce carbon emissions and light pollution from its motorways, all while maintaining critical road safety standards. "Our original lighting policy was developed in the 1970s," reveals the HA's Stuart Thompson. "So in 2007 we started reviewing our practices and our requirements for when to install and operate lighting."

Putting the need for such a review into context, 40 years ago it was believed roadway lighting could reduce night-time incidents by around a third. But when the HA carried out a more up-to-date investigation – thanks to advances in areas such as vehicle lighting and general car safety – there was now, on average, no more than a 10% safety benefit from the existence of roadway lighting.

One of the practical outcomes of the review was for the HA to start switching off lighting at six sites across the UK between the hours of midnight and 5:00am, which was expanded to 15 locations by September 2012. As to how the sites were selected, a number of criteria were factored in as part of a strict safety analysis by the HA. "This ranged from the number of incidents, the type of road and the recorded traffic volumes," reports Thompson, adding that, to date, there haven't been any adverse effects on road safety, traffic volumes or speed at any of the sites in the big switch-off.



Seeing is believing

Mark Rea, director of **Rensselaer**'s **Lighting Research Center**, explains how a better understanding of how our retina and fovea help humans perceive roadways could usher in a new generation of street lighting systems

Highlighting the human element in the whole roadway lighting equation is Mark Rea, a professor in cognitive science as well as director of the Lighting Research Center at Rensselaer Polytechnic Institute in New York. "Most people think of driving as a monolithic task where you're looking at something and identifying hazards," he explains. "Although that is certainly important, from a visual perspective there are really dual systems working in parallel where 98% of your retina – which we call 'off-axis' or 'peripheral vision' – is for remote sensing, so any change in context, movement or color is picked up and then you automatically move your fovea to see whether it's a hazard or something to be ignored."

Having extensively researched the causes of traffic accidents, Rea reveals they often occur through misjudging what the fovea tells the driver. "What we have come to believe is that illumination from streetlights is really important for 'figure-ground'. Is something moving toward or away from me?" This doesn't mean that peripheral vision isn't important, too, Rea stresses – it's just that they result in two qualitatively different types of accidents. "One is a failure to detect and the other a failure to judge speed and direction. Once you know this, you can design the most effective lighting systems."

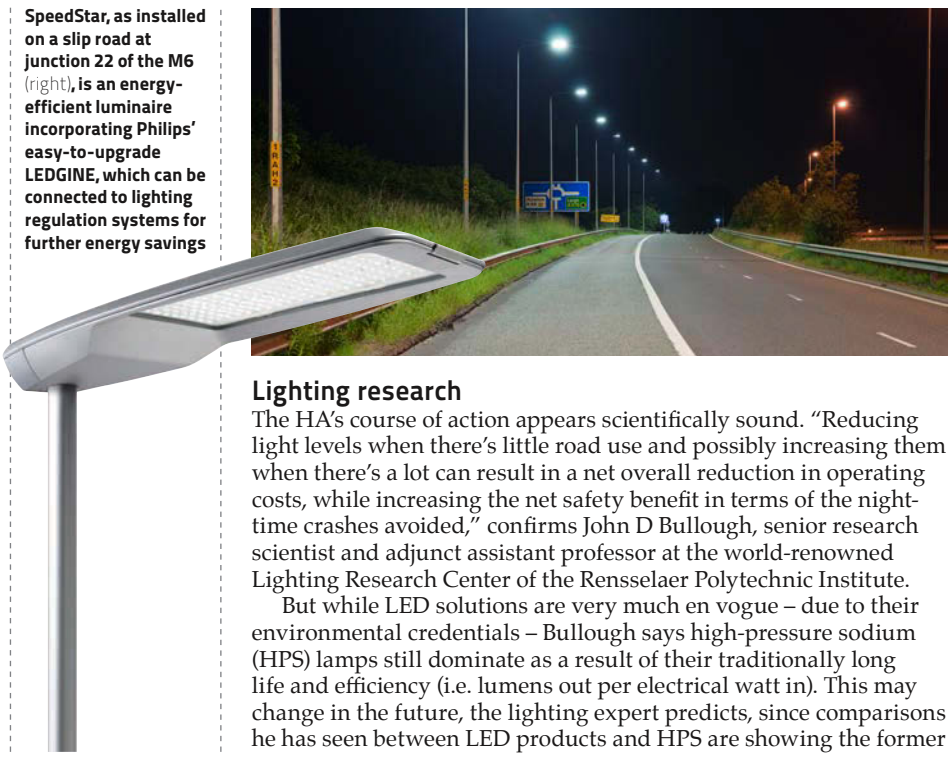
> "What we have come to believe is that illumination from streetlights is really important for 'figure-ground'. Is something moving toward or away from me?

A critical point raised by Rea is that key lighting standards have been based upon the assumption that roadway lighting needs

Following these findings, the HA decided to switch off lights permanently at a number of carefully selected locations. One of these was a stretch of the M6 motorway between junctions 15 and 16 near Stoke-on-Trent, a move that it is estimated will reduce annual carbon emissions by 148 metric tons.

Of course, there was a media frenzy concerning the potential safety impact, although at the time of the announcement the HA stressed this section of the M6 had boasted a good safety record overall and that the change was only sanctioned once it was deemed it wouldn't increase the risks to the driving public. In actual fact, had the roads been newly built under the design and appraisal standards for lighting on motorways and major A roads – published in August 2007[1] – none of the switch-off sites would have featured lights anyway.

Of course in critical locations it's a different story. Further north on an M6 slip road at junction 22, the HA has deployed Speedstar LED luminaires incorporating LEDGINE technology for connection to a lighting regulation system. In this case, the HA worked alongside service provider A-one+ and lighting manufacturer Philips.



SpeedStar, as installed on a slip road at junction 22 of the M6 (right)**, is an energy-efficient luminaire incorporating Philips' easy-to-upgrade LEDGINE, which can be connected to lighting regulation systems for further energy savings**

Lighting research

The HA's course of action appears scientifically sound. "Reducing light levels when there's little road use and possibly increasing them when there's a lot can result in a net overall reduction in operating costs, while increasing the net safety benefit in terms of the night-time crashes avoided," confirms John D Bullough, senior research scientist and adjunct assistant professor at the world-renowned Lighting Research Center of the Rensselaer Polytechnic Institute.

But while LED solutions are very much en vogue – due to their environmental credentials – Bullough says high-pressure sodium (HPS) lamps still dominate as a result of their traditionally long life and efficiency (i.e. lumens out per electrical watt in). This may change in the future, the lighting expert predicts, since comparisons he has seen between LED products and HPS are showing the former

(Far left) **As roadway lighting becomes more sophisticated, so, too, does our understanding of its impacts beyond simply providing visibility** (Left) **Mark Rea says that although the finding that safety benefits from roadway lighting are highly related to the visibility improvements lighting provides is not novel nor unexpected, evidence for this direct link has been scarce in the literature**

only to provide information to the fovea by illuminating the roadway itself. "Lighting the edge of the road where the peripheral retina is used to detect potential hazards moving onto the roadway is also important to consider in lighting standards," he says. "In fact, many studies have shown the fovea and the peripheral retina respond best to different light spectra (i.e. colors of illumination). For example, at the same measured light level, a 3,000K light source will be equally effective for illuminating the road for the fovea but the 3,000K source will be less effective than a 6,500K source for detecting hazards by the peripheral retina."

has the potential to outperform the latter as far as efficiency goes, with modest energy savings, and possibly in terms of life as well. "That noted, LED solutions haven't really been around long enough yet to verify their designed lifetimes," Bullough cautions.

Lighting's impact on overall safety is an area of expertise for this Rensselaer scientist. One of his latest investigations shows that although the latest overhead lighting is useful at providing 'figure-ground' information to reduce vehicle-to-vehicle crashes – the most frequent crash types at intersections – it's less effective at making pedestrians stand out for drivers. "It tends to illuminate the ground rather than vertical surfaces such as pedestrians," says Bullough.

As a result of this 'lighting gap', the Lighting Research Center has been looking into bollard-level lighting to maximize the contrast between pedestrians in crosswalks and surrounding environments. "We've conducted several demonstrations – including a recent test in Aspen, Colorado, in conjunction with 3M and Intrigue Lighting, which developed the test fixtures," Bullough adds.

(Left and right) **A novel bollard-based approach was adopted in tests by the Lighting Research Center as an economical and viable way to increase crosswalk safety and visibility**

Pittsburgh pioneers

No discussion of LED streetlighting would be complete without mentioning the much-publicized strides made in Pittsburgh, Pennsylvania. Councilman Bill Peduto, who until being elected mayor of Pittsburgh at the end of November represented

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>
> **John D Bullough, Lighting Research Center, Rensselaer Polytechnic Institute, USA**

Pittsburgh City Council District 8, is a strong advocate of LED. So much so, he founded the Pittsburgh Climate Action Plan back in 2005. "Although important, the initial push wasn't so much financial – it came from the climate action plan to reduce the city's carbon footprint by 20%," he says. "Streetlighting was seen as one of the better ways we could achieve that since, even then, LED lights were about 60-70% more efficient than other solutions."

By 2008, the Pittsburgh LED Streetlight Project had been born, with a trial in the neighborhood of Shadyside that saw half of the HPS streetlights replaced by energy-efficient LED models. "There was an immediate response to the quality of the light and when we told the community that it would cost less to use the lights, we pretty much had automatic buy-in."

Thereafter, research was conducted to provide, in Peduto's words, "a 360° profile" of all the options of streetlighting and the first Lighting Code for the City of Pittsburgh. "We wanted to ensure we had the right lighting in place – it wasn't simply

Photograph courtesy of GE Lighting

a question of changing 'bulbs'." So far there have been 5,000 transfers to LED covering every business district in the city center and Peduto reveals that an impressive 53 different models of lights have been submitted for testing along the way.

As to the financial considerations, he acknowledges the upfront cost with LED but Peduto is adamant that in the longer run it makes sense to use "guaranteed energy-saving programs" where you can allocate the money saved in energy costs and maintenance.

Roadside assistance

Donald Carter, director of the Remaking Cities Institute at Carnegie Mellon University explains the institute's involvement in Pittsburgh's LED initiative. "The city didn't know which technology to use, which color spectrum to put in the specification, how far apart the lights should be and how they should be shielded," he says. Out of a request for assistance, the institute's research team drew up various recommendations, including how warm or cold white the lighting should be [on the Kelvin scale] to better reflect the daylight spectrum. "We also looked at the heights of the poles as well as how to work with the existing infrastructure. Essentially, they ended up replacing all of the 'cobra heads' (the streetlights that arch out over the street) and the 'acorns' with LED."

Since LEDs are highly directional, one aspect Carter's team was concerned about was glare. "One of our experts is very tuned into the issues of the elderly, whose eyes don't adjust well at night from bright to dark, whether they're on foot or behind the wheel," Carter says. A remedy to this was screening with 45° cut-offs. "What was interesting with these cut-offs was that, when driving down the street, you now only see the LEDs that are within 300ft (91m) of your position – the actual light source – yet down the road beyond that distance, you just notice that the street is illuminated, not the actual lights themselves."

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> **Donald Carter, director of the Remaking Cities Institute, Carnegie Mellon University, USA**

(Above left) **The US Department of Energy estimates the installed base of street and highway lights in the USA alone is around 52 million, of which only 1% is LED**

One element Carter was keen to put in place for the future was the capability to control every streetlight with its own IP address so, should funding become available, the groundwork's in place to enable a central monitoring and control of the lights through wireless technology.

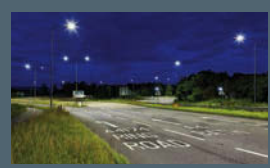
Northern Lights

Responsible for overseeing the city of Edmonton's signals, streetlighting and infrastructure rehabilitation, Vlado Cicovski says North America's northernmost metropolitan region has already switched 15,000 streetlights to LED, with many more in the pipeline. "We previously conducted some successful pilots with LED, so starting in 2013 our new standard is to have the technology for all new fitments on our

A drive for better lighting efficiency

Mike Simpson likes to emphasize the operational advantages of LED. "Today LED is ahead of some traditional light sources in terms of efficiency," reports the technical and design director at Philips in the UK. "You are also getting a better quality of light and as they are physically small light sources, there is good light control. Whereas in the past you would seek to control the edge of the beam – but always have a fade-off – with LED there is a really precise cut-off, meaning that more of the light you produce is cast onto the road."

Simpson thinks that every 12 months or so, there's a 10% uplift in LED efficiency – a trend that shows no sign of abating. "You can play that whatever way you want," he says. "You can either opt for more light output, or you extend the life of the LED or maybe even go for a better color. Basically the cooler a light source looks, the more efficient it will be."



Although the Philips man says HPS and LEDs are around the same in terms of efficiency, at about 140 lm/W, he says the big difference is when you're trying to get this light out of the lighting system. "A typical road lantern will lose maybe 20% through the optics – including the reflector – whereas with an LED you might lose about 4-5% because, in a sense, it is its own optics system.

"You need to compare apples with apples and think about the light on the road in relation to the energy that goes into the system in the first place."

Driving control

Expanding upon how roadway lighting can be operated – and maintained – in a smarter way, John Charles traces such moves all the way back to the mid-1990s when the first iteration of Harvard Engineering's LeafNut was brought to market.

Charles, business development manager at the company, says that LeafNut can be fitted retrospectively to existing lanterns or via the OEM route. It has a fairly simple communication architecture using GPRS from an asset management center to the apparatus in the field, the so-called BranchNode main controller unit. According to Charles, such a solution

(Above) **John Charles from Harvard Engineering** (Right) **The LeafNut node**

greatly enhances maintenance procedures and practices. "The contractor can see lamp mortality or LED mortality data through the system," he says. "This enables much more effective planning of the plant and labor aspects of a contract. There's a lot of money to be saved on traffic management from this aspect alone."

A 'live' UK motorway scheme with LeafNut is currently entering its second phase. In this case the motorway lighting interface system tells the LeafNut system when to dim or ramp up the associated luminaires based on what's happening in the road. "The original trial was very successful," Charles reports. "We were dimming the system from 100 to 75 and then 50% depending on the conditions. Of course in the event of a road traffic accident, we can override the system and bring the lights up to 100%."

For the next phase of the project, Charles is excited by the prospect of a more granular dimming capability that is planned to enable changes in increments of only 1%. "It becomes much more dynamic and the client was keen to match as closely as possible the latest British standard."

streets," says the city's acting director in Transportation Services.

A few aspects in particular were especially pivotal, says Cicovski when explaining the rationale. "We are trying to limit light pollution and reduce greenhouse gas emissions," he says. "We have a very aggressive target to meet so streetlights are a key part of that; alone they account for around 21% of the city's power consumption and we are trying to reduce this by 40 to 50%, which is actually a major challenge."

The first LED trials in Edmonton were on residential streets rather than main roads: "This was mainly to gauge the maintenance element as well as to garner feedback from residents," Cicovski adds. "We have a 10-year warranty on the LEDs at this point in time and we anticipate they should last around 20 years, which – apart from all the energy and GHG savings and reduced light pollution – is a hugely important factor to the city's coffers."

A pilot test is under way and two more are in the works with different vendors in Edmonton to establish how to 'talk' or communicate with LEDs. "The whole city will eventually have controllable lights or lights that we can monitor based on actual road conditions," Cicovski says.

Lessons have already been learned and acted upon based on Edmonton's LED experience. "Where most of the light was focused on the road, there were some concerns that drivers wouldn't be able to detect pedestrians, so we've now changed the distribution of the luminaires so it's wider and casts light onto the sidewalks too. Pedestrians can now be seen more easily than with the first luminaires we deployed."

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>
> **Vlado Cicovski, acting director in Transportation Services, City of Edmonton, Canada**

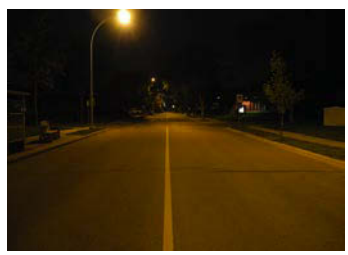
Looking ahead, Edmonton is keen to accelerate the conversion process, so rather than being limited to the current 4,000 or 5,000 lights a year – which might take 20 years to complete – a request has now been put out for proposals that would enable the city to achieve the goal in five years instead. Bright ideas are sought.

Lighting the way

As we have seen, strong cases are being made in cities such as Edmonton and Pittsburgh for lighting systems that more accurately reflect what's happening on our roads, sidewalks included, with illumination levels fluctuating accordingly based on traffic volumes or specific incidents. Sure, HPS still has a place – for the moment – but the big winner from this renewed drive toward smarter and more economical systems will undoubtedly be LED. If not quite yet the solution of choice, LEDs are very much in the driving seat.

References

[1] *www.standardsforhighways.co.uk*



Solid-state lighting solutions (far right) **offer significant energy savings over HPS by both eliminating light spill and delivering more effective and uniform lighting with lower overall lumen output**