given explicit recognition and credit in systems for assessing research quality (such as the UK Research Excellence Framework). Insight into the evolving research of the emerging economies will be limited without active engagement and collaboration. Relying simply on what is published in journal articles has long been recognized as a poor mode of knowledge transfer[9].

Third, collaboration must include European and US researchers in Asian and South American laboratories. The older economies can no longer rely on the best foreign researchers to come and visit. Maintaining a talent pool is necessary, but it is not sufficient: if a nation really wants to remain at the highest level scientifically, it needs to get its talent out and about — and then bring it back again. One way of doing this is to create worthwhile travel and exchange programmes that include an assured post for the returning researcher. The United Kingdom has a shocking record on mobility in European research programmes and the United States has the lowest level of international collaboration among the G7 countries. By contrast, the Netherlands achieves excellence by enabling its researchers to be much more mobile, despite its lesser resources[10].

Impact and innovation will flow from a coalition of the willing, not the straitjacket of international policy and coordination. Multinational programmes are not the answer, nor are academic memoranda of understanding. To maintain the dividend that governments garner from research excellence, they must ensure that universities and their researchers have the resources, facilities and incentives to create and sustain flourishing partnerships. ■

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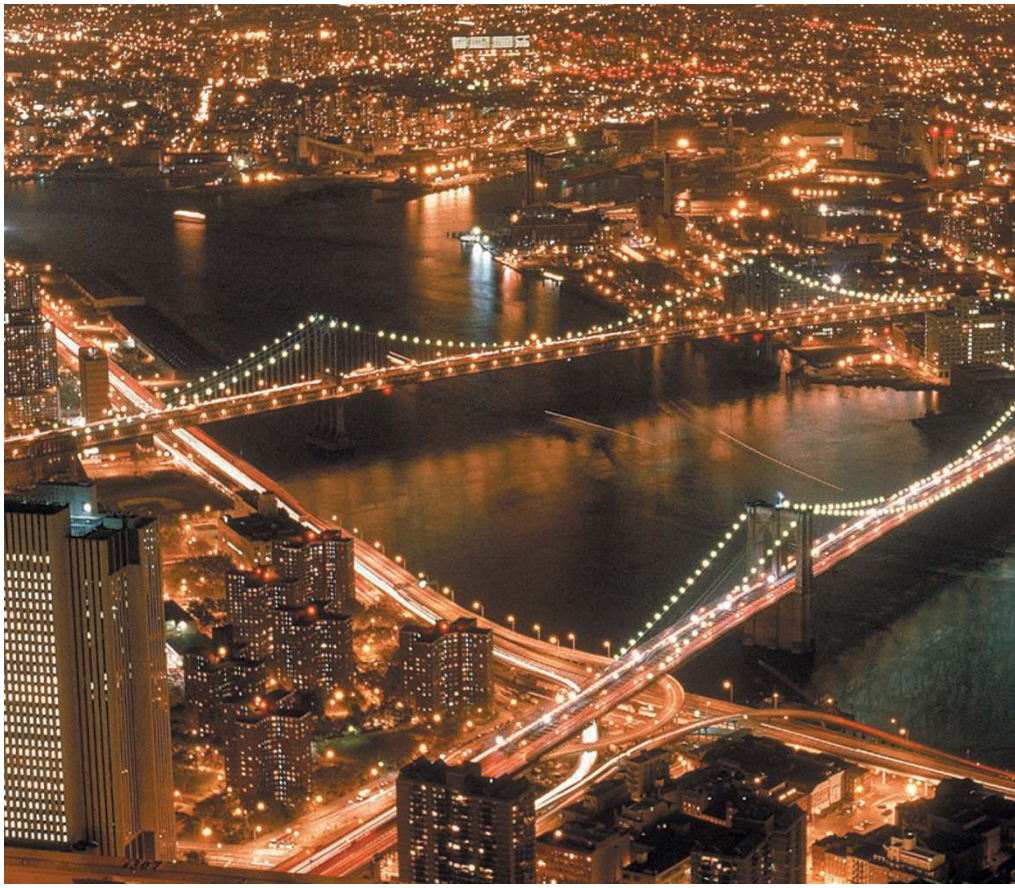


BENOIT PESLE/ANZENBERGER/EYEVINE

Wasted light from street lights, such as those in New York City, contributes to skyglow.

A green light for efficiency

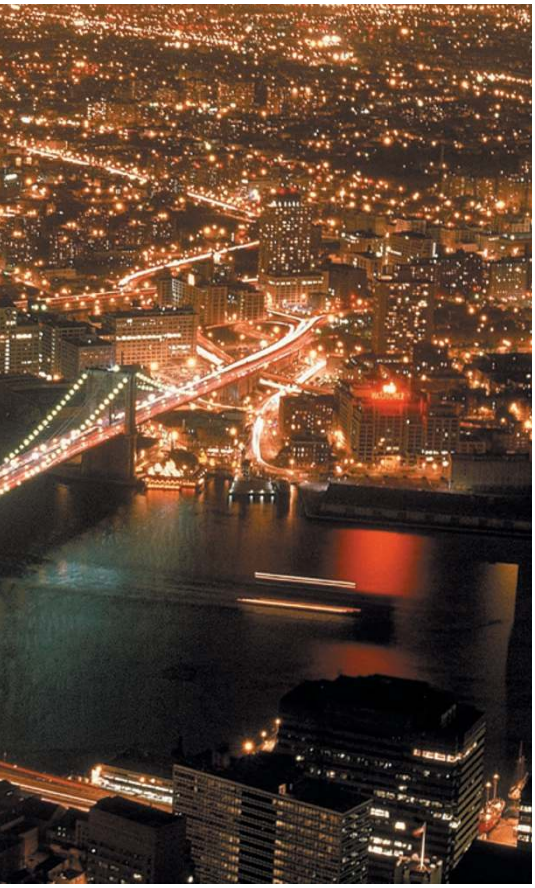
Efforts to improve street lights are providing a rare opportunity to cut both financial and environmental costs, argues **Kevin Gaston**.

Over the past few years, local governments in towns and cities across the world have been dimming street lights, turning them off for parts of the night, investing in more energy-efficient technologies and gradually modernizing old lighting systems. Hard times and tight budgets have helped to drive this flurry of activity.

The combination of financial pressures, a broad array of new lighting technologies and a richer understanding of the importance of natural-light cycles to the health of many organisms presents an unusual opportunity. To take advantage, environmental scientists must work quickly to gather and build on existing knowledge about the effects of artificial light on plants and animals, and must collaborate with those responsible for the development and implementation of public lighting schemes.

As well as disrupting the development, physiology and behaviour of many organisms, grid-based electric lighting is estimated to produce 1.5 billion tonnes of carbon dioxide each year globally. Moreover, artificial light disturbs people's natural circadian rhythms. Various studies have linked this disturbance to conditions such as breast cancer[1] and obesity. A notorious impediment to astronomical observations, artificial light also robs us of moonlit landscapes and properly dark or star-filled skies.

Most existing street-lighting systems are inefficient and expensive. Much of the light they produce is wasted, contributing to skyglow often tens and possibly hundreds of



kilometres away. Historically, some lighting systems were installed not to aid people, but because they were thought to add to the beauty of a city, or because they could be run at little extra cost by using excess electricity produced during periods of low demand. Likewise, the illumination of many roads has not been adjusted to account for the fact that headlights on modern vehicles are now some eight times brighter than those of cars and trucks built 60 years ago.

DIM THE LIGHTS

A global assessment[2] of artificial lighting, carried out in 2006, estimated that street lighting consumes about 114 terawatt hours of electricity globally each year. For comparison, this is almost 400 times the electricity that New York City consumes for street lighting annually. National and local governments in the United States, Europe and Asia have quickly recognized the potential for savings — not just by dimming and turning off street lights, but also by installing energy-efficient light-emitting diodes (LEDs) instead of conventional bulbs. As the cost of new technologies continues to fall, such efforts will increase.

There are various ways to cut the energy used by street lights. These generally involve reducing the time or extent to which lights are used, and their intensity[3,4]. Savings depend on the size and type of existing lighting systems, their purpose and whether systems are being newly installed or upgraded. If new roads, towns or cities are being built, for instance, investing in low-energy and centrally manageable lighting makes sense. The feasibility of retrofitting existing developments depends in part on how long it takes for the long-term savings in energy costs to cover the expense of replacement. For LED technology, this is currently about 10–20 years.

Those responsible for modifying lighting systems should consider other factors too. A nuanced approach would ensure that lighting systems do the least environmental harm, as well as providing the necessary benefits at minimal expense.

Artificial light can influence myriad biological processes, including sleep, metabolism, germination and flowering. It can alter the distribution and abundance of organisms and disrupt predator–prey relationships[5,6]. In fact, such effects are probably pervasive, given the importance of natural-light cycles on circadian clocks and organisms' physiological responses to day length.

In general, limiting the number of street lights, dimming them and turning them on for shorter periods reduces these negative biological effects[6]. But studies are needed to identify the best compromises. People are most in need of artificial light in the hours after dusk and before dawn — just when other species are most likely to perceive the day to be extended (if diurnal) or curtailed (if nocturnal). Adjusting these periods to better suit the needs of local ecology, within the constraints of human requirements, could reduce the negative impact of night-time lighting all round.

White-light LED systems and other white-light technologies are proving popular because they improve colour rendering for humans — objects look more as they would when viewed in natural light. But increasing the range of wavelengths of a light source also increases the overlap between the emitted light and the spectral sensitivities of a broad array of other organisms. Some white lights emit a lot of ultraviolet, making them more attractive to insects such as moths. These technologies should be limited to areas where they will be most useful and ecologically least destructive, such as in urban rather than rural settings. Parts of the light spectrum that are not useful to people should be avoided.

EFFICIENCY AND ECOLOGY

In Europe, major projects to improve the evidence base for ecologists' recommendations for lighting schemes are under way. These include the ECOLIGHT project, an investigation of the ecological effects of light pollution, which I lead at the University of Exeter, UK. The experimental components of this work need to be expanded to investigate the environmental effects of night-time lighting in a sufficiently broad array of ecosystems and taxa.

To ensure that everyone wins from the growing worldwide movement to reduce night-time lighting, a three-way dialogue is vital between those investing in new lighting technologies, those producing them and environmental scientists. My group and I have found that discussions with local authorities enable us to better envision and articulate how social challenges can be weighed against environmental ones. Equally, our findings offer such authorities more leverage to bring about changes.

"Artificial light can influence sleep, metabolism, germination and flowering."

Through these discussions I have come to believe that the biggest barrier that local and national governments face in their efforts to reduce night-time lighting is the public perception of its importance in reducing vehicle accidents and crime. Unsurprisingly, almost all of the evidence connecting the importance of lighting to safety and security comes from experimental studies conducted in extremely low-risk areas, or correlational studies that are notoriously difficult to interpret[7,8].

Determining the effects of lighting is also complicated by the fact that people alter their behaviour in response to lighting changes[9]. Brighter street lights, for example, can make people feel more confident and therefore induce them to drive faster. Thus, in addition to studies on the ecological impact of different lighting regimes, research is needed to investigate their societal impact.

This opportunity to install street lighting that uses less energy and is better for human, animal and plant health must be grasped now. It may not arise again for many decades. ■

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