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light  
pollution  
a global  
discussion



# About the book

- Light pollution – a global concern
- Introduction

## Three international expert discussions

- Dark skies – how can they be protected in the long run?
- Street lighting – what color temperature should we choose?
- Commercial lighting – do we want hard law?

## A global expert survey

- The survey – our approach
- How the respondents perceive the problem
- The dilemma – where interests clash
- The way forward

## Appendix

- About the authors
- Credits
- List of images and figures
- Discussion background
- General background
- Imprint



Lights on the river in Frankfurt/Main, Germany

# About the book

## Light pollution – a global concern

**In recent years, artificial light at night is increasingly recognized as a multifaceted problem that is expanding on a global scale.**

Astronomers were the first to criticize the loss of the dark, star-filled night. In recent years, biologists, physicians, and scientists from many other disciplines have joined the protest against light pollution.



**"Light pollution accelerates climate change, impacts circadian rhythms and decreases the health and well-being of all living things. Not being able to see the stars robs us of our cosmic heritage and light trespass creates social problems."**  
Dark-sky activist, Canada

**"Light pollution does not have to be a topic at all: use proper lighting products and designs."**  
Industrial engineer, The Netherlands

**"This topic, that is very fundamental for our future, should be shared and studied together by all stakeholders and professionals."** Lighting designer, France

**"Without the use of comprehensive standards and ordinances worldwide, the quality of the night sky will continue to decline."** Light planner, USA

Scientists are observing the negative effects that artificial light is having on wildlife and our environment. Concerned citizens are complaining about lights in front of their homes and on their streets that are too cold or too white. Lighting designers are increasingly confronted with the issue as well. For this e-book, we brought together experts from different countries and disciplines to discuss important aspects of light pollution. We also conducted an international survey in which we asked people from light-related industries to share their opinions and insights. The e-book sums up our findings and is designed to provide information and inspiration, and serve as a tool for anyone who is concerned or confronted with light pollution.

**"The aim to ensure that the star-lit sky should be seen in urban areas strikes me as an unwanted fundamentalism and fails to appreciate the distinctiveness of urban environments"** Geographer, Australia

**"Light pollution should become a compulsory subject in all light-related fields of education."**  
Lighting designer, India

**"Promoted high unnecessary levels of illumination should be corrected in a global discussion."**  
Environmental protectionist, Chile

**"It would be advisable to connect with off-grid lighting companies in the 'Global South' now, in order to avoid some of the mistakes of industrialized countries."** Solar systems PR manager, Tanzania

# About the book

## Introduction

**Nona Schulte-Römer, Etta Dannemann,  
Josiane Meier**

This book addresses anyone who is interested in the positive and negative effects of artificial lighting. In recent years, what is known as light pollution has become an issue of growing concern.

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Astronomers have been criticizing light-flooded night skies since the early 20th century when cities became brighter and brighter in the course of electrification. In the early 21st century, they are no longer alone in their plea for natural darkness. Scientists from various disciplines are investigating the unintended negative effects of artificial light at night on flora, fauna, human well-being and our

society.<sup>1</sup> Critical citizens are complaining about the introduction of blue-rich LED lighting or disturbing luminous advertising and are campaigning against the introduction of public lighting infrastructures in places where these previously did not exist.<sup>2</sup> Amateur astronomers, astrophotographers and stargazers increasingly travel to remote places to admire and observe the star-filled night sky that is no longer visible from their homes. Last but not least, mass media have also picked up on the issue.<sup>3</sup>

## **Artificial light at night as an environmental problem**

These concerns are grounded in an emerging awareness of lighting as an environmental problem.

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There is increasing evidence of various adverse effects caused by artificial light at night. Street lights and illuminated skyscrapers can be fatal traps for animals. Attracted by brightness, birds, moths and other insects change their flight paths and circle light sources to the point of total exhaustion. Light also works as a migratory barrier in rivers, lakes, woods and open fields. Illuminated

bridges prevent fish from swimming upstream and brightly lit streets in the countryside can be an immaterial frontier for wildlife.<sup>4</sup> The consequences for the affected species at the population level are still unknown. For humans, hormonal effects are an increasing worry. Chronobiologists warn that exposure to light at the wrong time disturbs the circadian rhythm that orchestrates all life on our planet, including the biological clock in humans.<sup>5</sup> But the problem has yet another, cultural and emotionally charged dimension.

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Artificial illumination of the industrialized world prevents us from experiencing natural darkness and the night sky. In major cities worldwide, children are growing up without ever having seen the Milky Way. The cultural loss of this development cannot be enumerated, but can hardly be overestimated.<sup>6</sup> Looking back at the history of mankind, the moon, the stars and the observation of the night sky have always been a crucial point of orientation in both time and space and a source of knowledge about our world.

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Within one generation, lighting characteristics have changed dramatically and this cultural reference is now fading into the background.

Like most forms of environmental pollution, these negative effects, including the fading visibility of starry skies, are subtle and often hard to prove. Biologists and doctors are still trying to understand the complex hormonal interactions and mechanisms that light can trigger in living organisms. Meanwhile, the risk of chronobiological effects is intensifying due to profound technological changes in lighting. The introduction of energy-efficient light-emitting diodes (LEDs) is accompanied by an increase in cold-white lighting in streets and buildings that contains more blue wavelengths.<sup>7</sup> The unwanted side effects of this technological development are, firstly, rebound effects, as more light can be produced at lower costs. Secondly, the large amount of blue-rich light in the spectrum of most LEDs has a greater impact on living organisms than longer wavelengths do. In 2016, the American Medical Association (AMA) warned

that the introduction of LED lighting may pose a public health risk by disturbing our sleep and circadian rhythm. Hypothesized but scientifically unproven consequences include an increased risk of cardio-vascular diseases and obesity. In response, the Illumination Engineering Society (IES) pointed out that such potential effects also depend heavily on factors like brightness, spectrum and exposure time. Scientific evidence of these adverse effects is not only controversial but also difficult to produce.

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In comparison, nuisances caused by glare, blinking or moving lights or disturbingly bright advertisement signs are much more obvious and a key cause of controversies over light pollution.

## **Light and darkness – conflicting goals**

While scientific evidence is still being gathered, the environmental problem is growing. Recent scientific data suggests that natural darkness is receding and our planet is getting brighter.<sup>8</sup> The artificial illumination of our planet can be considered an unprecedented form of anthropogenic “global change”.<sup>9</sup>

# *The artificial illumination of our planet can be considered an unprecedented form of anthropogenic “global change”.*

Since industrialization, the establishment of gas and electricity infrastructure has made lighting cheaper, easier to operate and widely available.<sup>10</sup> The rapid and wide spread of lighting is not surprising given the generally positive connotations associated with light, its many possibilities and desirable functions. Artificial light makes societal life at night a lot easier and facilitates productive economic activities after dark. Lit environments make us feel safer and allow us to find our way after dark. Although the causality between light and security is contested,<sup>11</sup> lighting is and has always been a crucial aspect of policing strategies and municipal as well as private security concepts.<sup>12</sup> In addition, traffic safety is a requirement that has become taken for granted with the rise of the ‘automotive city’. As a result, urban road lighting has become highly institutionalized in industrialized countries, and lighting standards and products are designed and further developed to optimize visibility on streets.

But lighting does not only make us feel safe and secure. It can also enchant the human eye, allow-

ing for new perceptions of well-known places. Cities use lighting to create identities. They light up their landmarks to distinguish themselves from other cities, to highlight their built heritage and offer their residents an urban image they can identify with. An increasing number of municipalities are engaged in urban light planning and develop master plans and public lighting strategies to shape urban public places beyond road lighting.

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Illuminations are also a crucial factor for the night-time economy. They create vibrant and dynamic atmospheres that invite shoppers, bar and restaurant-goers, tourists and party people to spend time and stroll through cities at night. Media and glass facades add to the possibilities of staging nocturnal cities and their architecture or skylines. The image-creating communicative function and aesthetic appeal of stunning skylines and atmospheric neighborhoods has become an important means of 'place-making' and city marketing in the

global competition to create livable and attractive cities.<sup>13</sup> In this context, nocturnal events play an increasing role. Festivals of light are celebrated worldwide from Lyon to Shanghai, concerts are accompanied by elaborate light shows and sports events no longer take place only on Saturday afternoons, but after dark throughout the week thanks to floodlights.

### **A political issue worth a global discussion**

The advantages and pleasures of artificial light offer plenty of good reasons for using it. But they clash with the equally good reasons for reducing the use of artificial light.

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In recent years, astronomers and environmentalists who call for precautionary measures have received increasing support from social movements, advocacy groups and organizations worldwide who are acknowledging the value of dark skies and the natural rhythm of day and night.<sup>14</sup> Lighting designers and light planners who subscribe to this vision

advise their clients on how to save energy, install LEDs and find optimal illuminations and light levels that avoid light nuisance, glare and disturbing color temperatures. Lighting manufacturers have begun to respond to the rising demand with dark-sky friendly products. Scientists are developing new tools to assess the impacts of artificial light at night and are involving interested individuals in their research via citizen science projects.<sup>15</sup> Municipalities have begun to consider light pollution in integrated lighting schemes, and governments are developing binding regulations.<sup>16</sup> Policy makers have also discovered that their commitment to protecting the dark sky can have positive effects on their region as a destination for recreation, stargazing or night-time photography.

Yet, although these initiatives mark a change in public awareness and set new examples, they have not reversed the trend. Routine lighting practices and uses are not that easily changed. Reasonable demands, time pressure and budgetary constraints in lighting projects and technology development do not necessarily lead to the most ecological solutions. Moreover, socio-economic development is usually accompanied by a reduction of what is known as ‘lighting poverty’, through the establishment of lighting infrastructure in areas that used to be dark at night. Rebound effects resulting from efficiency gains are leading to more and brighter

lights rather than carefully administered lighting at the right time and right place.<sup>17</sup> Tackling light pollution is therefore anything but simple. Competing demands and clashing interests make it a political issue that calls for public debate, democratic deliberation, balanced decision-making and innovative solutions.

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**The project: expertise from around the globe**

“Light Pollution – A Global Discussion” is the title of this book and of our one-year-long research project. With this endeavor, we hope to offer inspiration and invite readers to learn more about lighting and its flipside, light pollution.

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The international and transdisciplinary expert exchange presented in this book lies at the heart of our inquiry. It maps numerous initiatives currently taking place and opens up novel perspectives by assembling expert views and voices from different lighting and light pollution-related fields and different parts of the world. It offers an overview of remarkable policies and takes into account parallel developments like the introduction of LED lighting. Furthermore, it outlines conflict lines, addresses clashing interests and discusses obstacles hindering the reduction of light pollution.

The idea behind this global discussion was sparked by two observations. Firstly, we saw that light pollution concerns are voiced all over the world. They appear in densely populated and broadly illuminated countries like Germany or South Korea, as well as in Australia and some African countries where there are still large unlit areas. Dark-sky activists engage with global light manufacturers and are connected with their peers around the world via social media.<sup>18</sup> Nevertheless, many initiatives against light pollution are highly place-specific. Their spokespeople actively engage in municipal or regional politics and have a profound knowledge of their local situation. This

book celebrates and multiplies this local knowledge by letting experts from around the world speak about and share their experiences, best practices and expertise.<sup>19</sup>

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Secondly, we observed that discourses on artificial light at night and its unwanted side effects come from different disciplines and have developed at different speeds. Among astronomers and environmentalists, light pollution is a well-established issue. Environmental research began addressing the problem about 20 years ago. Lighting professionals are concerned with over-illumination, badly angled or wasted light, light clutter and glare as part of their job description and professional expertise, but the negative terminology of light pollution makes it difficult for them to subscribe to this movement. Nevertheless, the problem is increasingly acknowledged within the practical lighting community. This awareness has further intensified since the introduction of LEDs.<sup>20</sup>

There are several factors contributing to the emergence of expert exchange, technical guidance and policy recommendations relating to the reduction or prevention of light pollution.

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They include dark-sky initiatives led by environmentalists and astronomers, growing awareness within the lighting industry, as well as environmental research into the adverse ecological effects of artificial light at night. These contributing factors are inevitably transdisciplinary. Light is not only an engaging subject, but also a multifaceted phenomenon. It taps into architecture and planning, physics, engineering, biology, medicine and psychology, art and culture. It is also closely intertwined with everyday routines and professional practices. Any constructive discussion on light pollution has to acknowledge and cope with these multiple perspectives and rationales. Any best practice or solution will have to be built on and mediate between multiple views and expectations. The creation of interlinkages and exchanges

between different perspectives is therefore a core concern of this book.

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It is also a heartfelt objective, as the idea for the book was inspired by our own transdisciplinary interest in the subject. Our three different professional perspectives include lighting design practice, urban planning research and social-scientific environmental research. These perspectives have shaped and enriched the project from the start.<sup>21</sup>

### **Three controversial key themes**

At the center of our project and part one of this book are three expert discussions on three themes that are crucial points of debate in the context of light pollution mitigation. They address the challenges of providing and reducing lighting on very different levels, and reflect the complexity of the issue.

The first theme is the protection of dark skies. It focuses on the challenge of preserving natural nocturnal environments. Such dark places still exist on our planet, but are coming under increased

pressure as socio-economic patterns of nocturnal activity change and lighting infrastructures are expanded or refurbished.

*Such dark places still exist on our planet but are coming under increased pressure.*

For this discussion, we invited four experts to tell us how they protect dark skies through their work in international networks and organizations. Our experts discuss the Chilean Atacama Desert and the Canary Islands, where international research teams are conducting astronomical research, as well as the Namib Desert in Namibia, which is developing into a new destination for dark-sky tourism. Their approaches range from hard law to education and offer an impressive overview of what is being done and the challenges that need to be overcome in order to save natural darkness in the long term.

In the second discussion, we ask: what is the ‘right’ correlated color temperature for LED street lighting? Since LEDs make it possible to choose between a wider range of light spectra, this question has become a critical issue in lighting projects.

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In many places, the installation of efficient cool-white LED lights has triggered complaints from citizens. Municipalities find themselves in a difficult situation, given that the cultural, technical and environmental aspects are hard to reconcile and knowledge claims on the issue are controversial. To add more clarity to this discussion, we also invited four experienced researchers and practitioners who look at the issue from ecological, light engineering, lighting design and managerial perspectives. Their expertise and examples of the light color choices being made in India, Germany, China and the United States offer a wide range of arguments and orientation for decision-makers tasked with the selection of appropriate color temperatures.

The third theme tackles the problem of disturbing private and commercial illuminations in the urban public realm. New technological possibilities in architectural lighting and media animation mean that cities are increasingly confronted with the challenge of balancing the clashing interests of commercial actors and residents.

# *Cities are increasingly confronted with the challenge of balancing the clashing interests of commercial actors and residents.*

In our discussion, we focus on municipal and regional approaches for keeping private lights in nocturnal public spaces under control. Our four experts share experiences from Italy, China and the UK. They discuss hard law in the form of legally binding regulations and soft law in the form of non-binding professional standards and technical guidelines. They also envision more sustainable products, greener procurement and responsible lighting design, which could complement hard law and reduce compliance problems.

## **A worldwide expert survey**

The relevance of the discussion themes and the concerns they raise are also reflected and further explored in an online survey that we conducted prior to the three discussions. It represents expert voices and visions from different geographical, professional and personal backgrounds, revealing both differing and shared perspectives. Our invitation to participate was addressed to anyone who felt they had something to say about lighting and light pollution and was willing to share

their expertise and ideas regarding how this complex issue can be tackled. The link to the online survey was shared and forwarded in professional networks and via social media. In March and April 2018, around 250 people accepted our invitation to participate and 205 respondents completed all the questions.

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Their answers and observations have spurred our fascination for the evolving worldwide debates around light pollution. They have made us aware of persistent problems, including the fact that there is still no widely agreed definition of light pollution. Last but not least, they have given us very kind and encouraging feedback about the idea of a global discussion on light pollution. The results and insights we gained from this survey are presented in part two of this book. They not only confirm that the loss of darkness and inappropriate use of lighting are growing global concerns, but also suggest that a shared understanding of the issue is evolving across professions, scientific disciplines and around the world.

To conclude, we would like to invite you as readers of this book to engage with issues of lighting and light pollution, conflicting views and the question of how this problem and its environmental implications should be dealt with in the future. We hope you will join us in continuing and shaping the global discussion of which this book is a part.

## Notes and References

- <sup>1</sup> The acronym ALAN – artificial light at night – stands for a growing body of literature and a conference series that explores these effects.
- <sup>2</sup> See survey section "The dilemma – where interests clash" in this e-book and the forthcoming article: Meier, Josiane. Contentious Light: An Analytical Framework for Lighting Conflicts. *International Journal of Sustainable Lighting*.
- <sup>3</sup> Our quick media search for "light pollution" in the Nexis® news database (August 2018) shows that there were ten times more articles on this issue in 2017 than in 2000.
- <sup>4</sup> See for instance: Riley, William, Davison, P., Maxwell, D., Newman, R., & Ives, M. J. F. B. (2015). A laboratory experiment to determine the dispersal response of Atlantic salmon (*Salmo salar*) fry to street light intensity. *60(5)*, p. 1016-1028. For a pioneering study see: Lowe, Rosemary H. (1952). The Influence of Light and Other Factors on the Seaward Migration of the Silver Eel (*Anguilla anguilla* L.). *Journal of Animal Ecology*, *21(2)*, p. 275-309.
- <sup>5</sup> In 2016, the American Medical Association (AMA) reported that "much has been learned over the past decade about the potential adverse health effects of electric light exposure, particularly at night. The core concern is disruption of circadian rhythmicity. With waning ambient light, and in the absence of electric lighting, humans begin the transition to

night-time physiology at about dusk; melatonin blood concentrations rise, body temperature drops, sleepiness grows, and hunger abates, along with several other responses." See: CSAPH Report 2-A-16, <https://www.ama-assn.org/sites/ama-assn.org/files/corp/media-browser/public/about-ama/councils/Council%20Reports/council-on-science-public-health/a16-csaph2.pdf> (last access Nov. 2018). See also: Kantermann, Thomas & Roenneberg, T. (2009). Is Light-at-night a Health Risk Factor or a Health Risk Predictor? *Chronobiology International*, 26(6), p. 1069-1074. doi:914388593 [pii] 10.3109/07420520903223984.

- <sup>6</sup> Pottharst, Merle & Wukovitsch, F. (2015). The Economics of Night-Time Illumination. *Urban Lighting, Light Pollution and Society*, edited by Josiane Meier et al., p. 203-223. New York: Routledge.
- <sup>7</sup> LEDs are solid-state technology. In contrast to conventional light sources, which emit light through heat generation or electric discharge in gases, LED semiconductor chips emit light through electronic excitation. This solid-state electroluminescence transforms almost all supplied energy into visible light. White LED lighting has a peak in the blue wave spectrum, as it is produced mostly from blue-light emitting semiconductor chips covered with a phosphorus coating that converts the blue into white light. The less phosphor that is covering the light source, the more efficient the light. Therefore, LEDs with higher color temperatures (cold-white) emit more lumen per watt. The effect adds up, because the human eye is more

sensitive towards blue wavelengths in very dark surroundings, which makes cold-white LEDs or blue light content in very dark places appear even brighter.

- <sup>8</sup> Falchi, Fabio, Cinzano, P., Duriscoe, D., Kyba, C. C. M., Elvidge, C. D., Baugh, K., Portnov, B. Rybnikova, N., Furgoni, R. (2016). The new World Atlas of Artificial Night Sky Brightness. *Science Advances* 2(6), e1600377.  
<https://doi.org/10.1126/sciadv.1600377>.
- <sup>9</sup> Longcore, Travis. Light Pollution as Global Change. Presentation held during ALAN 2015. 3rd International Conference on Artificial Light at Night, May 29-31 in Sherbrook, Québec, Canada. <https://artificiallightatnight.weebly.com/uploads/3/7/0/5/37053463/alan-booklet-final.pdf>, p. 22 (last access Nov. 2018).
- <sup>10</sup> Brox, Jane (2015). Out of the Dark: A brief History of Artificial Light in Outdoor Spaces. *Urban Lighting, Light Pollution and Society*, edited by Josiane Meier et al., p. 13-29. New York: Routledge.
- <sup>11</sup> Although people tend to feel more secure with artificial light, the relationship between light and actual security remains to be proven and is highly situation-specific. See: Mosser, Sophie (2007). *Eclairage et sécurité en ville: l'état des savoirs*, *Déviance et Société*, 31(1), p. 77-100. Dark-sky proponents argue that lighting may even facilitate situations for criminal offenders, and thus encourage robberies, assaults and burglaries.
- <sup>12</sup> Schivelbusch, Wolfgang (1987). The Policing of Street Lighting. *Yale French Studies* (73), p. 61-74.

- <sup>13</sup> Schulte-Römer, Nona (2011). Enlightened Cities. Illuminations for Urban Regeneration. Understanding the Post-Industrial City, edited by Frank Eckardt & Sophia Morgado, p. 128-165. Würzburg: Königshausen & Neumann.
- <sup>14</sup> A list of organizations and initiatives is available in the appendix of this e-book.
- <sup>15</sup> See for instance the "Loss of the Night" app [http://www.verlustdernacht.de/Loss\\_of\\_the\\_Night\\_App\\_engl.html](http://www.verlustdernacht.de/Loss_of_the_Night_App_engl.html) or the apps of the Cities at Night project <http://citiesatnight.org/>.
- <sup>16</sup> The Cities & Lighting magazine (No. 4) issued by Lighting Urban Community International (LUCI), an international network of cities and lighting professionals, provides an overview of municipal initiatives and projects involving light pollution. Retrieved in Nov. 2018 from: <http://www.luciassociation.org/magazine/Cities-Lighting-004/>.
- <sup>17</sup> Kyba, Christopher C. M., Kuester, T., de Miguel, A. S., Baugh, K., Jechow, A., Hölker, F., Bennie, J., Elvidge, C. D. Gaston, K. & Guanter, L. (2017). Artificially Lit Surface of Earth at Night increasing in Radiance and Extent. Science Advances 3(11), e1701528. <https://doi.org/10.1126/sciadv.1701528>
- <sup>18</sup> See for instance the facebook groups "light pollution", "Ban Blue-Rich LED Streetlights and Headlights" and "Noche Zero", or twitter groups @RASC\_LPA and @IDADarkSky.
- <sup>19</sup> The survey section "The way forward" in this book offers worldwide examples. For more data see back-

ground information on the survey at: [www.ufz.de/  
light-pollution](http://www.ufz.de/light-pollution)

<sup>20</sup> See the survey part in this e-book, especially the section "The dilemma – where interests clash", Conflicting views towards LED lighting.

<sup>21</sup> See "About the authors" in the appendix.

# The first discussion

Dark skies – how can they  
be protected in the long run?





# **The first discussion**

## **Dark skies – how can they be protected in the long run?**

**June 2018**

**moderated by Josiane Meier & Etta Dannemann**



**Dr. John Barentine,  
astronomer, USA**

John Barentine is Director of Public Policy at the International Dark-Sky Association (IDA) in Tucson, Arizona, and previously headed its International Dark Sky Places program. He is also a member of the steering committee of the University of Utah Consortium for Dark Sky Studies and the International Union for Conservation of Nature Dark Skies Advisory Group.



**Paulina Villalobos,  
lighting designer, Chile**

Paulina Villalobos is based in Santiago de Chile, where she founded the lighting design firm DIAV in 2005. Her interest in bringing together lighting design and the conservation of darkness led her to initiate the project "Noche Zero" with an interdisciplinary event in the Atacama Desert in 2012.



**Javier Díaz Castro,  
industrial engineer and electrical  
engineer, Spain**

Javier Díaz Castro is Head of the Sky Quality Protection Office (OTPC) at the Canary Islands' Astrophysics Institute (IAC) on Tenerife Island. The OTPC supports and regulates the application of the Canary Islands' "Sky Law", which was passed in 1988 as one of the world's first laws for the protection of the night and day sky.



**Murray Tindall,  
ecologist, Namibia**

Murray Tindall is Control Warden at NamibRand Nature Reserve, a private conservation area in South-Western Namibia and the first IDA-designated Dark Sky Reserve in Africa. He oversees the park's dark-sky efforts and collaborates closely with its educational partner, Namib Desert Environmental Education Trust (NaDEET).

# **The first discussion**

## **Dark skies – how can they be protected in the long run?**

**LPGD: Each of you are working towards the goal of protecting the night sky in a different way, so we'd like to begin by gaining a better understanding of your different approaches.**

**Javier Díaz Castro, you work at the Canary Islands' Sky Quality Protection Office (OTPC) where you are responsible for regulating the application of the Canaries' Sky Law. How would you describe the OTPC's approach for protecting dark skies above the Canary Islands?**

**Javier Díaz Castro:** Our Sky Law protects the sky's astronomical quality for the observatories in the Canaries. Next to light pollution, it also deals with problems like radioelectric interference, atmospheric pollution and airspace protection from aviation traffic. The area that is protected from light pollution is La Palma Island, where the main nocturnal observatories are located. Tenerife Island is 100 km away from La Palma, but it is also protected because its light can reach La Palma. To control light pollution, we do instructive work as well as technical work.

We speak with lighting engineers, politicians and urban planners, and provide them with advice if they want to install outdoor lighting in the protected areas.

*We speak with lighting engineers, politicians and urban planners, and provide them with advice if they want to install outdoor lighting in the protected areas.* **Javier Díaz Castro**

We spend a lot of time doing this. We also develop technical information. It defines the basis for any lighting permits or installations from the local government or local authority. So that's the way we try to prevent problematic lighting from being installed in the first place. Then, on the other hand, we can complain to the authorities if something is done incorrectly. But most of the time we work on providing advice. Our main approach is first to define what is permitted, and then we inform people. We have established criteria for each case – how much light can you use? How do you have to install the lights? What are the exceptions? Or when do you have to use low levels or low flux installations?

**LPGD: Lighting technology has changed a lot since 1998. How has the Canaries' Sky Law adapted to these changes over time?**

**Javier Díaz Castro:** Well, LEDs are driving us crazy right now. We started defining criteria for LEDs in 2015. Last year, the Spanish government agreed to the set of criteria that we proposed, so this gives us the necessary legal protection. We differentiate between four types of LEDs. One is amber, without blue radiation – this can be phosphor converted (PC) Amber or 4000 Kelvin LEDs with an amber filter. Then we have two types of white LEDs: One is a normal warm-white LED and the other is a super warm-white LED. We use this super warm-white LED in pedestrian areas in La Palma. The problem we had first with LEDs was that we were trying to find an LED with the same radiation as low pressure sodium – but for ten years the kind we found with a narrow bandwidth had the problem that its efficiency is very low and that it is too sensitive to temperature. Even if it has more than 80 lumen/W, an hour after you turn it on it goes down to half of the lumens. So we are now using a PC Amber type of LED for street lighting.

**LPGD: And what do the regulations in the Sky Law focus on?**



Street lighting, Santa Cruz de La Palma, Canary Islands

**Javier Díaz Castro:** We have a good situation in Spain: there is a general regulation that limits light levels. Through this, we have avoided the problem of light levels increasing when technologies become more efficient. On La Palma, we reduce the light levels as of midnight to 1/3 or 1/4 of the levels before midnight, to compensate the use of amber LED, which contains a wider light spectrum (yellow, amber and red), instead of pure amber LED, which has a narrower, monochromatic amber spectrum. We also have a very helpful ratio that we use for judging light fixtures: It is the ratio between the light that reaches the target area, divided by the emitted flux. This has to be at least 75%. In a normal installation, only about half of the light ends up in the target area. We demand that it is 75%.

*In a normal installation, only about half of the light ends up in the target area. We demand that it is 75%.* **Javier Díaz Castro**

This is a good thing, because no more than 25% is lost outside the target and reflected up. And, of course, there should be no upward flux at all, and all unnecessary light – like sports, ornamental or advertisement lighting – must be switched off before midnight. We also control

the brightness of advertisement lighting to 50 candela/m<sup>2</sup> in La Palma and 200 candela/m<sup>2</sup> in Tenerife. Specifications for all different types of lighting are written down in our criteria.

**LPGD: John Barentine, as Director of Conservation at IDA, you coordinate its International Dark Sky Places Program. Would you outline for us what an International Dark Sky Place is?**

**John Barentine:** Sure. The goal of the program is to recognize the efforts of people in various locations around the world who are actively trying to either preserve dark skies where they still exist, or to bring them back in places like cities where they have been lost because of light pollution. So that's an important distinction to draw: We designate places like parks and nature reserves – protected areas, generally speaking, where natural dark skies still exist. But we're also working with populated areas like municipalities to change the ways their policies are written in order to promote better lighting practices that we hope, in the long run, will slowly change the conditions over those cities at night. The International Dark Sky Places program was established in 2001.

# *The International Dark Sky Places program was established in 2001.* John Barentine

**LPGD: What different types of designations exist within the program?**

**John Barentine:** We currently have a total of six designation categories – one of them is brand new. There are International Dark Sky Communities, Parks, Reserves, Sanctuaries, Dark Sky Friendly Developments of Distinction, and the new category that we have just rolled out is called an Urban Night Sky Place. It is meant to be the bridge between populated areas that are represented by Dark Sky Communities, and the darker locations like the Dark Sky Parks. We are trying to extend the reach of the program to be able to designate more kinds of places. In the case of the new type, we had places like city and regional parks where all the lighting was done correctly, and efforts existed to educate park visitors about the night sky. But because these places are situated close to urban areas, the quality of the night sky is not sufficient to qualify them for the Dark Sky Park category. So we felt that because the underlying philosophy of the program is to reward the efforts people are undertaking, we wanted to give people working

in these kinds of parks recognition for what they are doing, and to still make a clear distinction between these kinds of places and the ones that are much further away from cities where much natural darkness remains.

## **LPGD: How can places receive one of your Dark Sky labels?**

**John Barentine:** The designations are made on the basis of written applications that are submitted to IDA. We do not actively solicit them, so we don't look at maps of the world at night, for example, and locate places that are dark and try to encourage people working in those areas. Rather, the program has become sufficiently well known, so the traffic comes to us without us having to do a lot of marketing. We have a system of what I like to think of as a peer review to look at the nominations and judge them against sets of criteria that we publish on our website. So the process is very transparent. The places that go through these review processes successfully then receive accreditation by IDA, and they are able to use our name, our logo and other information as part of their own marketing plans. This will hopefully drive some tourism their way and elevate the visibility of these communities and protected areas throughout the world. I think we have been very successful

with this to date. We have made just over 100 designations in the lifetime of the program and brought about 80,000 km<sup>2</sup> of land worldwide under some form of protection for the benefit of dark skies.

*We have made just over 100 designations in the lifetime of the program and brought about 80,000 km<sup>2</sup> of land worldwide under some form of protection for the benefit of dark skies.*

**John Barentine**

International Dark Sky Places is also important in terms of visibility for our organization. It's certainly our most publicly visible program and I think it's the way a lot of people first encounter IDA.

**LPGD: Murray Tindall, you are working for one such designated area, NamibRand, the first International Dark Sky Reserve in Africa. Could you tell us about the light pollution situation in Namibia, and why NamibRand decided to work on dark sky protection?**

**Murray Tindall:** Namibia in general is an incredibly sparsely populated country, and the majority

of the population is concentrated in a few centers. So you have these vast tracts of land, especially in the south of the country, where there are very, very few people. As a result, there is not a lot of light pollution. Our reserve borders on Namib-Naukluft National Park, which is an area of approximately 50,000 km<sup>2</sup>. And there are no people living in these 50,000 km<sup>2</sup>. The only access to the area is based at one location, Sossusvlei, it's a main tourist attraction and we are located about 60 km from that. So, with an increasing tourism market in Namibia – Namibia is definitely growing in popularity – there has recently been an explosion in lodges and accommodation facilities surrounding this area. Seven years ago, one of the lodges that was based here was taking advantage of the dark skies and running an astronomy program where they had a big telescope and visiting astronomers. One of the astronomers, a guy called George Tucker, drove the process initially. He was really blown away by the quality of the dark sky here, and saw the increasing number of lodges and accommodation facilities and thought “we need to get in early to protect what is already here”.

*He was really blown away by the quality of the dark sky here, and saw the increasing number*

*of lodges and accommodation facilities and thought “we need to get in early to protect what is already here”.* Murray Tindall

We're very fortunate here in that our closest center is about 140 km away, and the closest major center is 350 km away. So we really have a very high quality of night sky and it is important to preserve that as the area becomes more popular. Our reserve is small, it has 215,000 hectares, but we are trying to reach out to our neighbors in order to get them to buy into this concept and set an example.

**LPGD: Were lighting changes necessary for NamibRand to qualify for certification?**

**Murray Tindall:** A few lighting changes were necessary. You know, we rely here on solar electricity. In the very early days, there wasn't a lot of external lighting in the first place, because the solar systems that were initially installed couldn't cope with a high amount of electricity. So it became a question of choosing between keeping your refrigerator running or having a lot of light, and most people chose the refrigerator. So the use of lighting – and especially external lighting – was quite conservative. As

solar technology improved, it became possible to run more than just your refrigerator, so you could have some extra light. Here, a couple of external lights were removed and a couple were deemed to be necessary. These were shielded and the wattage of the light bulbs was reduced. The reserve has a lighting management plan and we monitor any developments very closely to be sure that they conform.

*The reserve has a lighting management plan and we monitor any developments very closely to be sure that they conform.*

Murray Tindall

**LPGD: How would you describe NamibRand's approach to the protection of dark skies?**

**Murray Tindall:** Our focus is mainly on education and outreach. We work through our environmental partner, the Namib Desert Environmental Education Trust (NaDEET), which runs a whole program based on sustainability and environmental efficiency. They include information on Dark Sky Reserves and a large program on the appreciation of night skies. And then there's outreach to our neighbors through a landscape level project that encompasses a lot of the lodges

called the Greater Sossusvlei-Namib Landscape Association. Through communication in that forum, we are trying to encourage a lot more people to buy into the concept. Something that helps us keep light pollution at a minimum is that we operate on a slightly different model compared to a lot of others – we focus on the higher end of the tourism market, so low volumes of people at a high cost rather than high volumes of people.

**LPGD: Paulina Villalobos, you initiated the project Noche Zero in Chile. Its motto is “Our time to embrace the darkness”. What inspired you to do this – to embrace the darkness as a lighting designer?**

**Paulina Villalobos:** Well, it is a thing of very mixed emotions. I grew up watching the stars. They were part of my daily environment. I grew up in a small town in the Atacama Desert, which is a very nice place to see the stars. So, when I moved away to study lighting design in Europe and Japan, I was missing something.

*I grew up in a small town in the Atacama Desert, which is a very nice place to see the stars. So, when I moved away to study*

# *lighting design in Europe and Japan, I was missing something.*

**Paulina Villalobos**

When you are educated as a lighting designer, you don't really get any advice on light pollution. Even after meeting with people who care about light pollution, like astronomers here in Chile, lighting designers didn't realize that their profession can influence things, you know? So I realized that it is very important to approach the problem of light pollution in a holistic way. It's about recovering the dark sky for astronomy, and the stars as a heritage of humanity. But it is also about health, about nature and quality of urban life. Because if you have good lighting in the city, it shouldn't be polluting, right? If you do things well, you have a beautiful outcome for the city and don't have to pollute everything. That connection was very attractive to me; to include and involve the people who are actually doing the light in cities and buildings, and not just those who are especially sensitive about stars because it is their job, in order to have better lighting for everybody. So that is what Noche Zero is about – taking a holistic approach, focusing on how we can improve our work as lighting designers.



Atacama Desert, Chile

*So that is what Noche Zero is about – taking a holistic approach, focusing on how we can improve our work as lighting designers.* Paulina Villalobos

**LPGD: And what is your way of working towards this aim? Are there particular activities you have done?**

**Paulina Villalobos:** We have organized four seminars, including one in the Atacama Desert. I also speak about these issues in different countries. Right now I am trying to connect the people who are making the decisions, so politicians, mayors and ministers, who have to know about light pollution. So I'm trying to provide information in a very simple way, to make them understand. At the first big seminar we included people from many different disciplines. We involved astronomers – there are important astronomers in the Atacama Desert – people dealing with heritage and archaeoastronomy, and very, very amazing lighting designers. We also invited neuroscientists, because since the discovery of the third receptor we know that if you receive light with a large amount of blue it is bad for your health, because it can disrupt your circadian rhythm.

And, of course, we invited people dealing with nature – because light pollution also causes a lot of damage to animals.

## **LPGD: What kinds of problems has artificial light caused for animals in Chile?**

**Paulina Villalobos:** Here is a small story: Last year, they started exchanging all the lights in a specific city with LEDs that have the worst color temperature, 6600 Kelvin, and a huge lumen output. They suddenly realized in the morning that a lot of birds were dead around the lamp posts.

*They suddenly realized in the morning that a lot of birds were dead around the lamp posts.*

**Paulina Villalobos**

The ornithologists thought that it must somehow be because of the posts. You know, these birds, Markham's storm petrels, are a kind of migratory bird that is here in our summer. They arrive in September, October to breed. In April, the baby birds leave their nests and join the big family that flies back to the northern hemisphere to follow the summer. So, last year, they found out that approximately 20,000 birds, baby birds, were dead, lost around the posts, because they

are nocturnal, they fly from the sea to the land during the night and were distracted by the lights. And just a couple of years ago, this was a very recent discovery, they found out that these birds nest in the cracks of the deserts. And then the next year: alles kaputt. It's a very sad thing, because the Chilean bird and wildlife protection organization ROC estimated the total population of these birds was 60,000. And then within one year an estimated 20,000 were dead. So, it's dramatic.<sup>1</sup>

**LPGD: A sad story indeed. So, do you think LED lighting is a problem?**

**Paulina Villalobos:** These kinds of LEDs are now the super cool thing. There is like an avalanche of change towards the worst possible type of LED. If they keep on changing at this rate, then it's not just the stars – we are going to erase all nocturnal life. And that is, I think, extremely relevant for anybody who is involved in building the environments of the future – as an urban planner, an architect, or as a lighting designer. It is very important to be aware that every decision we take about light could cause damage during the night while we are sleeping.

*It is very important to be aware that every decision we take about*

*light could cause damage during the night while we are sleeping.*

Paulina Villalobos

**LPGD: Do people also come to you to ask for advice or lighting design solutions?**

**Paulina Villalobos:** Yes! For instance, I was invited to talk about this on TV at the beginning of this year. After that, I started receiving calls. For instance, two organizations of ornithologists contacted me for more information. I am trying to help them – we are doing our best to avoid extinction. And other things are also happening. The lights are slowly affecting insects and other types of birds. It seems we don't care about this. But if you really do care, we have all the tools to do it right, but people don't know how to do it. Another topic is health. I have been contacted by people who live in high-rise buildings. A big billboard was suddenly put on top of a shorter building in front of theirs, so they couldn't sleep any more. We went to court – and they won. It's very interesting to know how to help people.

**LPGD: Javier, judging from your experiences: What do you see as promising? Where do you see progress for the protection of dark skies? And where do you see challenges that really**



Atacama Desert, Chile

**need to be tackled to protect them in the long run?**

**Javier Díaz Castro:** When I began this work 26 years ago, people thought I was a crazy person talking about light pollution. But in 2008 we started the Starlight Initiative, which also protects areas – similar to what the IDA does. And something changed. With the economic crisis, most politicians looked toward the economy and realized that astrotourists were a good thing for rural places or small islands, like La Palma. Meanwhile, we have a lot of tourists and also astrotourism companies in La Palma. Things have changed so much. Now, people in La Palma send me complaints about lighting directly. I hardly have to go out to look for things that are wrong. People told me ten years ago that this would be impossible.

*Now, people in La Palma send me complaints about lighting directly. I hardly have to go out to look for things that are wrong. People told me ten years ago that this would be impossible.*

**Javier Díaz Castro**

**LPGD: Roughly how many tourists travel there per year?**

**Javier Díaz Castro:** In La Palma we have about 200,000 and in Tenerife 5,000,000 tourists every year. The politicians now see that money can be made by protecting against light pollution. The return is about ten times what they invested.

*The politicians now see that money can be made by protecting against light pollution. The return is about ten times what they invested.* **Javier Díaz Castro**

So a lot of places in the Canary Islands are now being protected from sky glow, even if they are not in protected areas. For example, we have a big island on the other side of La Palma that has changed its lighting system, because they also want to have astrotourists. Another good example: One year ago, a technical committee of the International Commission on Illumination (CIE) met in Spain. Around twenty people came together – lighting designers, manufacturers, lawyers, biologists, urban planners – and we made a book.<sup>2</sup> It was just published and has three sections: sky glow and how to prevent it, human health, and the environmental impact of light. It's a big thing that all these different

people from different disciplines came together to make a book about it. So things have changed a lot!

**LPGD: Which areas do you think have a lot of potential for advancing this issue?**

**Javier Díaz Castro:** The most important thing, I think, is education; to let people feel that they can do something and to let them feel that what they are doing is good. I remember that in the beginning, because I was protecting the night sky for astrophysics, people thought that astrophysicists were some special kind of people that have to do something in the mountains and suffer from yellow lights, you know? And it was very difficult for me to enforce the law. Now, I think, things are moving in a good direction, because by protecting areas as IDA and the Starlight Initiative are doing, people are becoming aware that it's about protecting the environment, because we are killing millions of animals around the cities and also very far away from the cities.

*People are becoming aware that it's about protecting the environment, because we are killing millions of animals around the*

*cities and also very far away from the cities.* Javier Díaz Castro

**LPGD: And how has light pollution itself developed on La Palma since the Canaries' Sky Law was passed?**

**Javier Díaz Castro:** Well, we have seen a small increase in light pollution, but only in the spectrum of low pressure sodium lighting, which is what we use here. More lights have been installed because the population has grown. And you cannot say: “No light for your home!” A very good result of the commission I mentioned is what we call ‘Index D’. It’s similar to an astronomical magnitude – it’s the ratio between the portion of the electromagnetic radiation of a light source that is below 500 nm, divided by its luminous flux, so the lumens. In this way, if you have two sources with the same light output in lumens, you can identify which of them has less blue energy. It’s very helpful for protected areas, because when you compare, for example, an incandescent lamp and a 3000 Kelvin LED, you see that the spectrum of the LED has blue light, and it may seem that it has more blue than the incandescent lamp. But if you use them with the same flux, an incandescent light can have a higher blue content than the 3000 K LED – it’s crazy. So that has become clear: The correlated

color temperature (CCT) is not a good indicator of blue light pollution, because to produce the same amount of light, a 2300 Kelvin source could emit more blue than one with 3000 Kelvin.

*The correlated color temperature (CCT) is not a good indicator of blue light pollution, because to produce the same amount of light, a 2300 Kelvin source could emit more blue than one with 3000 Kelvin.* Javier Díaz Castro

**LPGD: John Barentine, where do you see promising signs for the future and where do you see challenges?**

**John Barentine:** I think the promising signs and the challenges are concentrated in two specific areas. On the 'promise' side, we see a lot of interest in protecting places for their natural darkness. Much of this is related to astrotourism. We're seeing indications that people are concerned about how all this exposure to light at night is impacting their health. So they are looking at it from a lifestyle perspective. But: they are still viewing darkness as something of an amenity or an add-on feature. It's not something that people are

necessarily internalizing. As I say to journalists quite often, you know, people who live in big cities – when they see the brown cloud hovering over their city, they know that’s air pollution, they think there is a problem and they demand solutions from their policy makers. They don’t view the loss of the night sky due to sky glow in the same way. Many people don’t even view light as a legitimate form of pollution. So we’ve not yet crossed the threshold where we’ve gone from awareness to a growing demand for solutions to the problem.

*Many people don’t even view light as a legitimate form of pollution. So we’ve not yet crossed the threshold where we’ve gone from awareness to a growing demand for solutions to the problem.* John Barentine

And that leads me to think that people have not yet really identified light pollution as a problem that they think needs to be solved in their own communities. The challenge, I think, really focuses on the notion of the out-of-control growth of the use of artificial light at night across

the world, which has been strongly abetted by the use of LED lighting and similar technologies.

**LPGD: What issues do you see regarding recent technological developments?**

**John Barentine:** There is reason to believe now that there is something of a rebound effect taking place, where the savings we are making thanks to better energy efficiency are being directed increasingly into introducing more light into the environment. So we may see the efforts that aim to improve environmental conditions by improving energy efficiency backfire somewhat. Energy efficiency is potentially creating more problems than it is solving.

*Energy efficiency is potentially creating more problems than it is solving.* John Barentine

And if I put these two things together, what I get is that there is still a particular human relationship with the use of light at night, and it is one that, right now, is not on a sustainable course. So I see our role, and the challenge that is put before us, in modifying that relationship over time to get to a point where it is sustainable. We know that we will never fully solve this problem, because there will always be human needs

for light at night that are very legitimate, and we know that we will have to accept a certain amount of it in our environment. The question is: Is there reason to believe that we can put an overall sense of control on lighting, so that we can limit the impacts and find a healthy balance between our needs as humanity and the needs of our environment?

**LPGD: Murray Tindall, what is your perspective on promises and challenges?**

**Murray Tindall:** I'd like to touch on something that I said a bit earlier, in terms of astrotourism. One of the growing trends that we see here, not just in our reserve, but in Namibia in general, is the growing field of astrophotography.

*One of the growing trends that we see here, not just in our reserve, but in Namibia in general, is the growing field of astrophotography.* Murray Tindall



NamibRand Nature Reserve, Namibia

In Namibia, tourism is the second biggest contributor to the economy and there is a lot of focus now on how to attract more tourists from a broader field. And with improvements in digital camera technology, more and more people are taking up astrophotography. And what we've seen here – even on the reserve, where we're quite careful with our lighting – is that even the smallest amount of light can really, really ruin a photograph of the stars, because the shutters have to be open for so long. So it's actually become a huge marketing tool for us to be able to have a certification regarding the quality of our night sky. Namibia in general is quite dark as I said, but to be able to stand out a little bit from other locations by having an actual certification, an actual guarantee that you're going to experience good conditions for astrophotography, has been a huge advantage for us. And I have seen a number of other establishments starting to consider their lighting with regard to photography in particular, and a lot of lodges have approached us in search of advice on how to go about protecting their skies. So I think that's hugely positive for us and for the country in general going forward. As tourism increases and more and more people are taking up astrophotography, we stand a better chance of preserving what we already have in remote areas.

*As tourism increases and more and more people are taking up astrophotography, we stand a better chance of preserving what we already have in remote areas.*

Murray Tindall

**LPGD: Do you see any particular challenges or difficulties when you look toward the coming years, for NamibRand or Namibia in general?**

**Murray Tindall:** Well, Namibia is still relatively undeveloped across most of the landscape and there is a big push by the government to try to attend to that fact. The challenge is clearly that the electrification of areas is seen as an indicator of progress – and obviously lights and electrification go hand in hand.

*The challenge is clearly that the electrification of areas is seen as an indicator of progress – and obviously lights and electrification go hand in hand.* Murray Tindall

So the focus really needs to be to try and get to the guys on the decision-making level to make

sure that development happens in a way that considers the night sky. I think that's probably going to be one of the bigger challenges across the country.

**LPGD: Paulina Villalobos, what is your outlook on where we currently stand?**

**Paulina Villalobos:** The first thing I observe is positive, namely that light pollution has very much been embraced and internalized by communities connected to astronomy and astrotourism. Thanks to the work done by IDA and the Starlight Initiative, and the laws that have been made in Chile for the areas near the observatories. Now it's easy to talk about light pollution in these communities; they are aware of the problem. But I think there has also been a big failure and there's still a huge challenge regarding light pollution in general. I think it is now worse than when I started working on the topic eight years ago and it is becoming even worse. And the LEDs—I thought they were going to be the solution, because it's a technology that gives you the possibility to control, to dim, to be connected with sensors. But it is being implemented as if it were the same as the technology of the 20th century, as if it were low pressure sodium.

**LPGD: So would you say the way LEDs are currently being used is a problem?**

**Paulina Villalobos:** Something I have seen not just here in Chile, but in every country I've travelled to, is that with the switch to LED, the lumen output is increased and also the color temperatures: 4000, 5000, or even 6600 Kelvin, which is promoted due to energy savings. So I think the really big challenge is to raise awareness in general, not just in the astronomy-related communities, but for everybody. The challenge will now be to not just focus on astronomy, but also on nature, on the quality of city lighting, and on human health in all environments – including the urban environment.

*The challenge will now be to not just focus on astronomy, but also on nature, on the quality of city lighting, and on human health in all environments – including the urban environment.* **Paulina Villalobos**

So glare is a problem, lighting quality and the value of the night. Because if you talk about the darkness, it's a scary thing – that's part of our nature, you know? I've been in total darkness and it's scary, it's an instinct. But the night has



Astronomers, Grand Canyon National Park, USA

another type of light, which is a value. Also the natural cycle is valuable: Daylight and night light both also have to be rescued as a concept.

**LPGD: Do you have any ideas about what would have to happen to improve the situation?**

**Paulina Villalobos:** Well, something that could be improved is the regulations. The problem is that all regulations for light pollution are focused on the qualities of the luminaire and not on the lighting project. For instance, you can have a luminaire that might be problematic when it's on its own, but if it's included in an architectural detail or in a detail of the urban environment, it does not pollute. It depends on how you use the luminaire. If regulations focus on the project instead of the luminaire, this opens up possibilities for designers to find better and more beautiful solutions.

*If regulations focus on the project instead of the luminaire, this opens up possibilities for designers to find better and more beautiful solutions.* **Paulina Villalobos**

Another big potential is, I think, to really use the possibilities of the technology that we have

now instead of planning with the criteria of 20th century technology – because you can use sensors in the outdoor environment in very easy and inexpensive ways, in the same way as it is already being done indoors. If, for instance, no one is in a building using an office, the sensors detect that and dim the lights. So, in cities, if there is no one there, that can be detected and the lights dimmed. These possibilities are generally not implemented, even though now with LEDs it would be very easy.

**LPGD: To finish, we would like to ask you to look further into the future. Imagine twenty years from now: What is your vision for the protection of dark skies? What would make you say “we’ve been successful”?**

**John Barentine:** If I were to look twenty years into the future, my metric for deciding whether we have been successful would be the following: does the average human being anywhere on Earth know and care about the notion of light pollution?

*Does the average human being anywhere on Earth know and care about the notion of light pollution?* John Barentine

So that some fraction of people take this seriously as an environmental pollutant, realize that there are ways to solve this problem and embrace those solutions. And a very specific way of telling whether we have been successful in our mission is: Do we have the attention of people who live in cities? In other words: Do people who live in places where there will always be a relatively high amount of ambient light care about this issue in a way that makes it possible, politically and socially, to really fundamentally solve it?

**Javier Díaz Castro:** At the moment, health is quickly becoming a big topic. People are talking about the screens of mobile phones, of computers, that they have to reduce blue light at night. Also, I think more regulation of light at night is now related to environmental and health issues, it's not as focused on astronomy anymore. This makes more people conscious, more involved in the problem – it's not only those crazy astrophysicists up on the mountain. Going forward, one thing we really have to control is the human tendency towards increasing the lumen output and light levels when you have a more efficient source. And another is: We have to find a balance between savings, environmental issues and health.

*We have to find a balance between savings, environmental issues and health.* Javier Díaz Castro

Because high-efficiency 6000 Kelvin LED are not healthy – you might say “other lights cost much money”, but then you will have to spend more on medical bills and environmental disasters, so it’s a zero sum game. There needs to be a balance.

**Murray Tindall:** I think we are moving towards a situation, hopefully in a much shorter time-frame than 20 years, where there will be a number of other places within Namibia and across southern Africa that are recognized, or that are at least aware of and working towards some sort of accreditation. And 20 years from now, a lot of the people that come through the education program here at the NaDEET center, who are now school children, will be in some sort of decision-making positions. And if we could see that they are taking something of what they learned here into their lives – as John said. An appreciation by the general public that light pollution is an actual pollutant – that would be a great achievement.

*An appreciation by the general public that light pollution is an*

*actual pollutant – that would be a great achievement.* Murray Tindall

**Paulina Villalobos:** In 20 years? Well, I'm not that optimistic, but I have a wish: I think the protection of the dark sky could be enriched by the protection and preservation of the quality of our night. We have the right to have a healthy quality of night – everywhere in our environment, in nature and in cities.

*We have the right to have a healthy quality of night – everywhere in our environment, in nature and in cities.* Paulina Villalobos

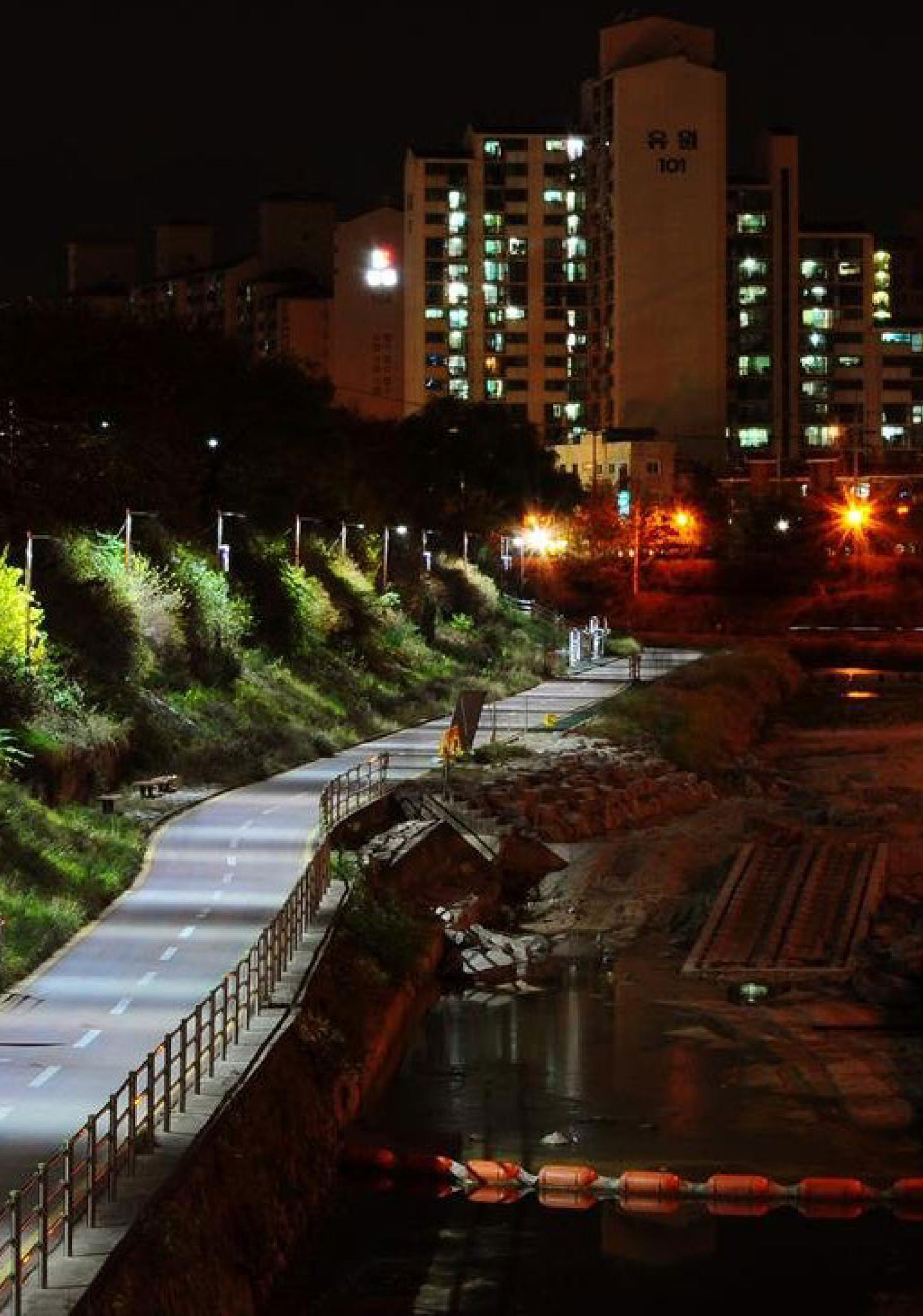
At the moment, most people who want to have a good quality of life have to use blackout curtains to sleep. So the protection of the quality of night is closely connected to the value and understanding of design. I think it's a big challenge to include design – urban design and lighting design – when finding solutions to light pollution, because most people don't even know that these professions exist.

**LPGD: Thank you all very, very much for sharing your thoughts and all the best for your further activities!**

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# The second discussion Street lighting – what color should we choose?





# **The second discussion**

## **Street lighting – what color should we choose?**

**June 2018**

**moderated by Etta Dannemann & Nona Schulte-Römer**



**Dr. Sibylle Schroer,  
ecologist, Germany**

Sibylle Schroer is part of the Light Pollution and Ecophysiology working group at the Leibniz Institute for Freshwater Ecology and Inland Fisheries in Berlin and coordinates the Loss of the Night Research Network (LoNNe) since 2010. She is a spokesperson for the STARS4ALL initiative that works to inform and educate about the protection of dark skies.



**Prof. Dr.-Ing. Tran-Quoc Khanh,  
lighting technologist, Germany**

Tran-Quoc Khanh has been the head of the Institute for Lighting Technology at the Technical University of Darmstadt since 2006. His research and recommendations include LED street lighting characteristics, color perception, mesopic vision and efficiency metrics.



**Nancy Clanton,  
architectural lighting designer, USA**

Nancy Clanton has managed her own lighting design firm since 1981. She has held many additional roles, including chairperson of the IES Outdoor Environmental Lighting Committee, the IES Mesopic Committee and the joint IDA/IES Model Lighting Ordinance Task Force.



**Venkatesh Dwivedi,  
electrical engineer, India**

Venkatesh Dwivedi is the Chief General Technical Manager of the Street Lighting National Programme (SLNP) operated by Energy Efficiency Services Limited (EESL) in New Delhi, the world's largest government-owned energy service company. He has overseen the replacement of six million conventional street lights with LEDs between 2015 and 2018.

# **The second discussion**

## **Street lighting – what color should we choose?**

**LPGD: In this discussion, we would like to gain insights about outdoor lighting, its light source spectrum characteristics and the decision-making processes involved in such projects. As research and practice complement each other very strongly, we have brought together two researchers and two practitioners.**

**Sibylle Schroer, you are working as a researcher in the field of ecology and you are the coordinator of the LoNNe<sup>1</sup> network: an interdisciplinary, international research network for light pollution. How is your research and activism related to light spectrum issues?**

**Sibylle Schroer:** A few years ago, I started working with the ‘Loss of the Night’ research network, LoNNe. I was not really familiar with physics, especially not the physics of light. Scientific research results about the ecological effects of light raised my curiosity. It was rather difficult to find the measurements for the light that was used in the studies, because it was either minimally described or not at all. The measurements

that were used in different studies are sometimes not comparable, for example values in wattage or lux with no explanation about the lamp type. We had to make a great effort with the LoNNe research network to define guidelines for research and to integrate knowledge from engineers, lighting manufacturers and the science of lighting technology into the projects that deal with chronobiology and ecology. That was a really interesting task and I learned a lot. It's a huge subject and I think there is still a lot to discover. The organisms' perception of the different spectra is so diverse.

**LPGD: So what have you learned so far regarding the relationships between the spectrum and animals or ecosystems?**

**Sibylle Schroer:** Well, the broader the spectrum you offer with artificial light, the broader the group of organisms you affect. Because light is never neutral, it affects organisms in different ways and some are more sensitive to short wavelengths, others to longer wavelengths. With a very broad spectrum, you will hit all of them.

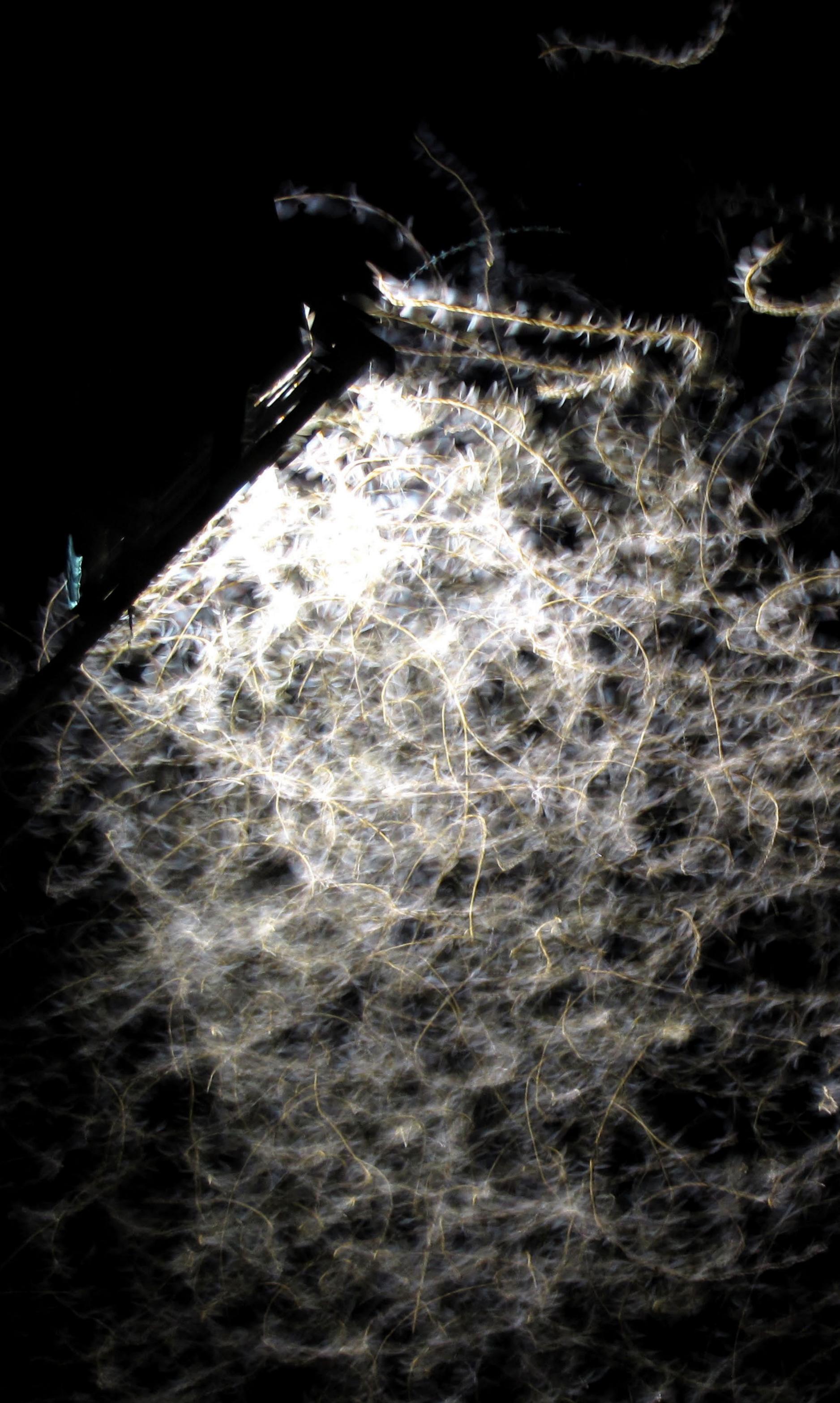
*Light is never neutral, it affects organisms in different ways and some are more sensitive to short*

*wavelengths, others to longer wavelengths. With a very broad spectrum, you will hit all of them.* Sibylle Schroer

Talking about special wavelengths, ultra violet (UV) radiation and the blue light content are maybe the ones that trigger the circadian rhythm of organisms the most, especially those of nocturnal organisms. Naturally, the highest ratio of blue light is typically provided by sunlight at noon. At dusk, the red part of the spectrum increases. This is the time when most artificial light is used. A high amount of blue light at the wrong time can suppress the zeitgeber of many organisms and affect their circadian rhythm. This includes higher vertebrates such as humans, as well as plants that continue photosynthesizing after nightfall. Furthermore, insects tend to be more attracted to short wavelengths, especially UV radiation and blue light. This attraction to light can lead to changes and disruptions in ecosystems and a loss of biodiversity.

**LPGD: Tran-Quoc Khanh, how is your work related to the spectrum of street lighting?**

**Tran-Quoc Khanh:** Since 2006 I have been a professor for lighting technology in Darmstadt and



Insects flying around a light at night

during this time LED technology was introduced in Germany and also worldwide. From 2007 to 2014, I developed some luminaires for several companies, because in the early years of LED technology many products had problems. In 2010, I also became the head of a project for 10 cities in Germany financed by the German Ministry of Education and Research.<sup>2</sup> We made a book out of our plans, our measurements and our experiences and suggested how to move ahead with lighting technology for street lighting in Germany. We then transferred our experiences to some projects with the government of China in Xiamen. This is a very big island in China and we developed a lighting plan for the city. The question of the right spectrum was part of this knowledge transfer.

**LPGD: What is the main focus of your current research activities?**

**Tran-Quoc Khanh:** Regarding the project side, we have many projects in street lighting. Regarding the scientific side, we have very good research on mesopic vision, which means the perception of visual tasks that occur in the range between very low light levels, like a dark moonless night, and bright lighting, like interior lighting or daylight. Street lighting is in the mesopic range between about one  $0.05 \text{ cd/m}^2$  and  $5 \text{ cd/m}^2$ . At

the moment, we are doing some experiments that investigate how humans process vision in the mesopic range in order to define the difference between sodium lamps, white LED lamps, warm-white, neutral-white and daylight LEDs.

**LPGD: You have also conducted groundbreaking research into light metrics...**

**Tran-Quoc Khanh:** Last year we started a project to calculate the efficiency of LED luminaires. Until now, there has only been one metric for luminaire efficiency: lumen per watt. It describes how many lumens are delivered by the luminaire if we invest one watt of electrical power. So far, it is the only worldwide metric to evaluate lighting, but at the moment we are developing two or three new definitions. We want to know: how can we calculate, how can we evaluate the efficiency of luminaires both in indoor lighting and in street lighting?

**LPGD: As we understand, your new metrics favor a more bluish LED spectrum.**

**Tran-Quoc Khanh:** Yes. Regarding our recommendations, we think in two different ways. The first way relates to user acceptance, the second way is the scientific aspect.

**LPGD: Let's start with the first one. What did you find out regarding the user acceptance of the lamp spectrum change in the German cities involved in your project?**

**Tran-Quoc Khanh:** In the time from 2008 to 2014, we did evaluations using questionnaires for older and younger people after LED installations were completed in the 10 cities I mentioned before. We went to Freiburg, Paderborn, Darmstadt, three smaller German cities, and I think also to Norden. Before our project started, there were sodium lamps or mercury lamps and after the installations there were warm-white or cold-white LEDs. We asked the citizens in these cities about how they felt about the beauty and the contrast of the streets before and after the installation. In my experience, if we're thinking about warm light or daylight, it's a question of culture.

*If we are thinking about warm light or daylight, it's a question of culture.* **Tran-Quoc Khanh**

In Darmstadt for example, we have daylight white LEDs of 5700 Kelvin and I was told at the beginning “uhh, it is so cold and the citizens won't like this color temperature”, but we didn't have any problems. We had the same experience



Street light replacement, 5700K, Darmstadt, Germany

in Freiburg, supported also by another study by a manufacturer in 2008 or 2009. These results gave us hints that the daylight color temperature is quite well accepted.

## **LPGD: What are the scientific reasons for favoring blue-rich white LED light?**

**Tran-Quoc Khanh:** If we don't think about culture and look at the scientific aspect of the new metric, we can conclude: if we have colder white LEDs, or colder white light sources, we have more blue content for the rods and other receptors of the retina. This is important, because at low light levels, when it is dark, our eyes are more sensitive to blue and every blue wavelength appears brighter than other wavelengths in this type of vision. With blue-rich white light, we have both – more brightness and a better contrast on the street with the same amount of wattage. This means that we could reduce our wattages and energy use in cities and get the same amount of visibility that we have today.

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*reduce our wattages and energy use in cities and get the same amount of visibility that we have today.* Tran-Quoc Khanh

This perspective is also supported by the International Commission on Illumination (CIE) and the German Society for Lighting Technology (LITG). The new efficiency metric that we are developing would reflect this aspect in numbers and would have consequences for all efficiency calculations in Europe.

**LPGD: Nancy Clanton, you have run your own lighting design business since 1981 and you also work with evaluations. Would you like to add something to that?**

**Nancy Clanton:** I am really enjoying this conversation, everything from “the broad spectrum is hurting the ecology more” to “bluer light is better for vision and gets higher subjective evaluations”. We have also done subjective and objective evaluations of color preference and driver performance under street illumination with different light colors in four different cities and found some very interesting facts.<sup>3</sup>

**LPGD: What were some of the subjective impressions people had in relation to the color of street lighting in your experiments?**

**Nancy Clanton:** We got over 400 people out in a very organized process and looked at different sections of a road and, almost like on a tour, asked people: “stand here and give us your subjective evaluation”. We found that there was a preference towards the lower color temperature, especially among women.

*We found that there was a preference towards the lower color temperature, especially among women.* **Nancy Clanton**

We found a huge gender difference. It was significant, in two of those cities, that women preferred lower color temperatures: they clearly favored 3500 K over 4100 K. Interestingly, there was no clear preference among the men. So I'd like to dig in more regarding how women actually perceive color, because color is associated with our X chromosome.

**LPGD: How did car drivers respond to the different color temperatures?**

**Nancy Clanton:** In our objective evaluation, people were asked to drive a car at 35 miles per hour (50 km/hour) down a road and were exposed to objects of different colors in the road. Every time you saw an object, you pressed the button. With this research design, we looked at foveal vision, that is, the perception of objects that are in the center of the visual field. To test a foveal task is a very interesting approach, because a lot of mesopic perception is influenced by our peripheral vision. We found that it was the 4000 Kelvin that significantly increased the reaction time, but the 3000 and the 5000 were also off the chart compared to high pressure sodium.

*We found that it was the 4000 Kelvin that significantly increased the reaction time, but the 3000 and the 5000 were also off the chart compared to high pressure sodium.* Nancy Clanton

And so we concluded that if you are driving at higher speeds, white LED light and a better color rendering helps to increase the visual performance of drivers compared to high pressure sodium. What we're doing with cities based on our extensive data is also looking at glare and how that affects the visual system. There are huge

differences between the glare ratings of different luminaires.

**LPGD: What is your opinion on metrics?**

**Nancy Clanton:** Right now the IES and the CIE basically use luminance as a metric, which means the amount of light reflected from a surface to a given observer. It indicates how bright a surface appears, but it does not distinguish between vision in dark or bright conditions, or differences in color sensitivity among individuals. We're saying that luminance might be the wrong metric – the right may be spectral contrast.

*Luminance might be the wrong metric – the right may be spectral contrast.* Nancy Clanton

That means contrasts between different colors instead of contrasts between 'bright' and 'dark' areas on a black and white scale.

**LPGD: Interesting. Why do you consider spectral contrast to be a better metric than luminance levels?**

**Nancy Clanton:** We went to the US national parks and did surveys. We went to the extreme of going with a very low color temperature,



Environmentally sensitive lighting, 1600K, Grand Canyon, USA

about 1400 Kelvin. In our evaluation, we just used spectral contrast as a metric in our spatial frequency analysis to figure out how close to each other contrasting areas should be in order to be perceived best. We wanted to know whether visitors could see the steps. And we were able to light them to an amount comparable with moonlight, which would be only 0.2 lux. And everyone could see perfectly.

**LPGD: So brightness doesn't seem to be the most important factor. How do such insights influence your designs?**

**Nancy Clanton:** We keep looking at light levels as the way of doing it, but our research is showing there is more to it. The mesopic range is a very interesting area of investigation. For example, we are looking at tuning the spectrum of lights. We are working on college campuses and, as the evening goes on, we actually tune the different lights to much longer wavelengths to get away from the UV and the blue. Anyway, that's just a snippet of what we are doing. Another issue is definitively IP addressable controls on every single light. With this, we can adjust the intensity, we can hopefully adjust the spectrum and, in the future, we will be able to adjust the distribution of light with a remote device.

**LPGD: We heard about a model ordinance task force realized by the Illuminating Engineering Society (IES) and the International Dark-Sky Association (IDA) in 2011, in which you were heavily involved.**

**Nancy Clanton:** Yes. We developed a group with people from the International Dark-Sky Association and IES to create a model lighting ordinance that first takes into account lighting zones. These zones are based on your ambient lighting conditions. We started with lighting zone zero, where there is not expected to be any ambient light. And lighting zone four is the extreme and in the US would be Las Vegas or Times Square in New York City. We basically helped communities to develop the lighting zones and helped them with the backlight, uplighting and glare ratings of their luminaires. We worked on the control systems and curfew controls. Each lighting zone determines the maximum for that area, so you cannot light too much. And that's now being adopted in many US cities and we've done it in a way that is extremely simple. No one has to go out and measure lighting levels. It is based on how much light per square foot of hardscape there is, and you would have to calculate this floor information for a drainage plan anyway, you know, given the permits process in the US. So that works out very well.

**LPGD: The model ordinance only provides recommendations on the amount of light and not on the spectrum, right?**

**Nancy Clanton:** Spectrum has not played a role in the commission, but it's about to play a role. The communities are adding this issue to their regulations.

**LPGD: Venkatesh Dwivedi, you are responsible for the implementation and exchange of millions of lighting fixtures in India. What is the main aim of the program that you are supervising at Energy Efficiency Services Limited (EESL), and on what basis do you decide which light color temperature to choose?**

**Venkatesh Dwivedi:** We started out on this program around four years back. Besides the financial aspects, there was a lot of discussion about the suitability of LEDs for this kind of application. Technical aspects like color temperature, the Color Rendering Index (CRI) and the Correlated Color Temperature (CCT) were also discussed. We felt that there was a bubble of voices on this subject. So we decided to speak to the industry in a more formal fashion. We had a few meetings in which we called representatives of the lighting industry and asked them for their input. It turned out that as far as color temperatures

are concerned, we had two or three options. Everybody said that you can either choose 3000 Kelvin to basically emulate the sodium vapor fixtures that were already there. Or you can look at higher color temperatures. In 2014, there had not yet been any major project of this kind. So we were not sure how the people, the citizens, the decision-makers would respond to the color. So one of the important aspects was that manufacturers indicated that the cool-white LEDs would be slightly more efficient than the warm-white LEDs. There was a pitch for 4000 Kelvin by some European manufacturers, but generally, everybody agreed that the 5700 Kelvin temperature looked good. We did some project trials, we did some pilot projects just to get feedback and everybody seemed to be happy with the 5700 Kelvin.

*We did some pilot projects just to get feedback and everybody seemed to be happy with the 5700 Kelvin.* Venkatesh Dwivedi

**LPGD: Did you also consider higher temperatures than 5700 Kelvin?**

**Venkatesh Dwivedi:** Yes, but our industry partners advised us not to use higher temperatures,

because they said that for outdoor applications, 6500 Kelvin may not stay 6500 in very high temperature conditions as there might be a color drift towards the bluer range, towards 7000 Kelvin. We also received a lot of questions like: how safe is this technology? How safe is it for the motorists and for human beings? Of course, we were looking into the photobiological reports and all those things, just to be sure that we are doing the right thing.

**LPGD: So, the decisive arguments are currently energy efficiency and visual preference?**

**Venkatesh Dwivedi:** Yes, we chose 5000 and 5700 Kelvin firstly for efficiency reasons and, secondly, because the color looked much better. Compared to the sodium vapor, the cold-white lighting looked better in photographs and was perceived better by the naked eye, and the industry also seemed to agree with that.

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Street Lighting National Programme, 5700K, India

Initially, we got very positive feedback with those cool color temperatures, because India is a warm country. You know, especially the coastal area is very hot and very warm. So the whiter colors, the 5000, 5700 Kelvin, were accepted more in those regions.

### **LPGD: Did anybody object to the choice of 5000 and 5700 Kelvin for street lighting in India?**

**Venkatesh Dwivedi:** As we went along, we hit some obstacles when we tried to put lights near heritage buildings and very iconic old structures where some people who are very sensitive to the culture of that place were not happy with the white color. They said it makes the area look very modern and very newly constructed, whereas it is a historical place and it should continue to look like that. And they chose the warmer color over the white color. In fact, we tried to do a pilot project in Mumbai on the Marine Drive, which is the iconic boulevard near the sea. We had to face a court case started by some citizen initiatives that claimed we had ruined the classic look and feel of that road by putting up white LED lights. So we left it to the citizens.

*We had to face a court case started by some citizen initiatives that claimed we had ruined*

*the classic look and feel of that road by putting up white LED lights. So we left it to the citizens.*

**Venkatesh Dwivedi**

We said, we have no problem if you want to use warm white. If you want some other color temperature, we are happy with that. There were hearings and there were lawyers who were fighting about the color of the light.

*There were hearings and there were lawyers who were fighting about the color of the light.*

**Venkatesh Dwivedi**

After a year of hearings, the court decided that the warm white won and we were asked to change the colors of the 6500 lights that we had installed on Marine Drive to warm white. So we asked our partner to replace the 5700 Kelvin with 3000 Kelvin.

**LPGD: Was the court case the only controversy over lighting color you faced in the course of the program?**

**Venkatesh Dwivedi:** We were also asked to change the color in a religious place called Varanasi on the steps of the parks where people come to pray.

People complained: “This looks very white and it is too bright, let’s have warm-white colors”, so we had to change all the lights there. There’s one more city in northern India, called Chandigarh, it’s a planned city and it’s unlike other cities. Instead of having buildings that are 500 to 3000 years old, this city is a planned city, it’s a modern city and the city government there asked us to use 4000 Kelvin and we had to really redesign our project. We had to procure 4000 Kelvin for that particular city. It looks very good.

**LPGD: It seems that, compared to the more than six million luminaires you have installed, these cases are a minority.**

**Venkatesh Dwivedi:** Yes, 90 to 95% of India is 5000 and 5700 Kelvin now.

*90 to 95 % of India is 5000 and 5700 Kelvin now.* Venkatesh Dwivedi

We’ve not found any major resistance from the public about a particular color and the lights have been generally accepted as long as the roads are well lit, and the maintenance responds to complaints and queries on time. Indian citizens still have low expectations of their municipal body and what we do tends to, after some time, satisfy the citizens, because they actually see the light levels are going up. Although there

are maybe some concerns that in some places the light seems too bright, the responses have been positive so far. We are sensitive to people's special needs and we are happy if people want a different color. That has been our approach and we felt that it is better that the citizens decide, because the lights are going to be around for the next seven to ten years and they should not be upset about the kind of color they got.<sup>4</sup>

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Venkatesh Dwivedi

**LPGD: Given the numerous arguments for and against blue-rich cool color temperatures, we would now like to look at the issue from the perspective of a municipal lighting engineer or a mayor. Nancy Clanton, you mentioned future technologies and new approaches, including spectral contrast and IP-addressable lighting. If a municipal lighting engineer came to you and asked you which priorities to set, what would you say?**



Street Lighting National Programme, 3000K, India

**Nancy Clanton:** I would say number one is to definitely pay attention to glare – to make sure that your glare ratings are low. That means you would never go over a G2 rating within the Backlight-Uplight-Glare (BUG) rating. The BUG rating is from IES TM-15-11 and is based on absolute zonal lumens at difference angles. We have found that if we go to a higher glare rating, to G3, it will affect the visibility of drivers and motorists. Number two is: In the United States, we have got a lot of complaints when we use higher color temperatures, so we are recommending 3000 Kelvin for street and roadway lighting and several states are doing that now in communities.

*In the United States, we have got a lot of complaints when we use higher color temperatures, so we are recommending 3000 Kelvin for street and roadway lighting and several states are doing that now in communities.* Nancy Clanton

But that's our experience and it's subjective. Maybe there is a cultural difference in the perception of color temperature. And then a third thing:

Make sure that all your lights have dimmable drivers or are ready to be dimmed in the future.

**LPGD: What about spectral tuning, is that already possible from your perspective? Is it a proven and mature technology, or is it something that is still in an experimental stage?**

**Nancy Clanton:** It's there – many products are available with spectral tuning, but there are two different types of spectral tuning.

*Many products are available with spectral tuning, but there are two different types of spectral tuning.* Nancy Clanton

One is what we call white tuning, which just involves placing two separate LED light sources with different color temperatures inside one luminaire and adjusting their levels. You can dim the warmer one and increase the other to 5000 Kelvin, or you can increase the 3000 Kelvin and dim the 5000 Kelvin. Then it looks like the spectrum is changing and to some extent it is, from a correlating color temperature (CCT) standpoint. But you are always going to have the blue bump in the spectrum, regardless of what you have. Some manufacturers have added a third diode, which would be more on the amber side.

With this, you can not only do white tuning with the blue spectrum, but you can also increase the ecological compatibility and do amber. This applies when you do not want to have the blue or the ultra violet wavelengths, like near coastal areas or in ecologically sensitive areas where sky glow is important.

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**LPGD: Sibylle Schroer, as a biologist you see advantages in the yellowish light spectrum of amber LEDs. How would you ‘sell’ them to a municipal engineer who does not see environmental issues as being at the top on his or her priority list?**

**Sibylle Schroer:** I think it is not only the ecologists, it’s also the astronomers that say that amber lighting and less blue light content is to be recommended, not only because of the effect on organisms, but also the effect on the light’s distribution. In clear sky conditions the sky

glow – the diffuse luminance of the night sky – can increase with blue content, because the short wavelengths can distribute over a longer distance. To a mayor, I would always say that energy efficiency is very important for a new lighting system, but energy efficiency is only achieved when you really decrease the electric current that runs through the lamp.

*Energy efficiency is only achieved when you really decrease the electric current that runs through the lamp.* Sibylle Schroer

If we have an amber LED that has 35 to 40 % less efficiency than a LED lamp with 4000 Kelvin, we only achieve that level of energy reduction if we really dim the light of the 4000 Kelvin lamp down to 35 to 40%. This is because then the visual effects are the same, but the energy use is different. If you use the same wattage for both luminaires, you will not really save energy regarding true wattage, you'll just have different lighting outputs. And the higher blue light emissions can increase the negative impact on the environment.

**LPGD: In your opinion, is there a common understanding that the more blue wavelengths**

**a spectrum contains, the more scope for dimming is given?**

**Sibylle Schroer:** 5700 Kelvin LEDs might provide the best perception, as the human eye is most sensitive to blue light. This gives you a great amount of leeway to dim the light. But most of the time this dimming technology is another investment for the authorities, which they often avoid.

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With dimming technology, we can actually decrease consumption of energy and I think we should all go in this direction and consider investing in research and technology to find ways of using the lowest intensity possible for outside lighting. With or without dimming technology,

lights with low levels of blue light are recommended for outdoor use in order to protect the environment.

**LPGD: Besides the astronomical and ecological side effects of blue light, what other aspects do you see?**

**Sibylle Schroer:** If there is a lot of traffic, where you really have to react to potential hazards, then maybe it is important to have a higher intensity to get humans to be more cautious. But if you have this bluish light out there, which makes you more alert, and you have 20 people hanging around who are slightly aggressive, the lights might have an activating effect on them. I heard an interesting talk just recently by a criminologist, Dunja Storp, about these effects. She claimed that you could guide people with the appropriate outdoor lighting.

**LPGD: So you are concerned about the side effects caused by the use of broad spectrum light outside?**

**Sibylle Schroer:** Yes, that is the thing. If we only say, it is very efficient and we can see very well, then we might ignore the effects of light intensity. And maybe the effects of different color spectra. By only considering the benefits in

terms of energy efficiency, we could overlook the non-beneficial outcomes, the negative effects that lighting can have on society.

*By only considering the benefits in terms of energy efficiency, we could overlook the non-beneficial outcomes, the negative effects that lighting can have on society.* Sibylle Schroer

**LPGD: Tran-Quoc Khanh, do you agree?**

**Tran-Quoc Khanh:** Not fully. I think we have many ways and more than one solution for saving energy and preventing ecological effects. The first aspect is, if you have only warm-white LEDs, 3000 Kelvin, or amber, the level of efficiency is not so good. If we have a higher color temperature, we have more energy efficiency, I think from warm white 3000 Kelvin to 5000 Kelvin, you can increase the efficiency by a factor of 20%. The second aspect is, if I have more efficiency, I have lower thermal energy inside the luminaire.

*I think from warm white 3000 Kelvin to 5000 Kelvin, you can increase the efficiency by a factor*



PC Amber light after replacement of 4000K street light, Sherbrooke, Canada

*of 20%. The second aspect is, if I have more efficiency, I have lower thermal energy inside the luminaire.* Tran-Quoc Khanh

That's very important for India, for China or for southern countries, because they are warm countries. And with higher temperatures, the lifetime of LEDs and electronic components is also shorter, because we have more thermal energy.

**Sibylle Schroer:** May I ask a question? To my knowledge, the difference in efficiency between the phosphor-converted (PC) amber LED and a 5000 Kelvin LED is not the thermal output. A 5000 K luminaire does not consume less energy. It is only the lumen output, which is related to the perception of the human eye, that is higher due to the spectral characteristics, because the peak intensity of the 5000 K source is closer to where we perceive the light better. As a consequence, we have the impression that we get more light out of it, or we might choose less wattage to produce the same perceived brightness that we would get from a standard amber luminaire. That would be the gain in efficiency. But considering that usually the wattage of street luminaires is not changed related to light color

choice, energy consumption would be the same for an amber LED and a 5000 Kelvin LED, is that correct?

**Tran-Quoc Khanh:** Yes. If I compare a warm-white LED, that means a blue LED with a warm-white phosphor coating, with a daylight LED, that means a blue LED with a daylight phosphor, then the difference in efficiency is anywhere between 20 to 30%. Phosphor-converted amber is a whole different thing. With amber LED, I have a color rendering index that is not so good and I have a color fidelity problem. In addition, if we think in terms of mesopic vision, I have a lower real mesopic contrast if I have longer wavelengths like amber or red, because in the mesopic range we rely on receptors, rods and cones. The rods reach their maximum sensitivity at about 510 nm, in the blue range of the spectrum. Amber LEDs do not offer any visible radiation in the blueish or greenish range of the spectrum. Thus, a lot of the rod-based perception of light, the perception of bright and dark spaces, is not provided. So with amber LEDs I'm not able to see the contrast in the street lighting like I can with cold-white or warm-white LEDs.

**Nancy Clanton:** What you're saying regarding mesopic vision is only true when the light level is extremely low. At higher light levels that differ-

ence is not there. If you are at 10 lux, it's not there.

**Tran-Quoc Khanh:** You are right, Nancy. We also have to differentiate between bigger and smaller streets in our German norm or in our European standard. From one Candela per m<sup>2</sup> to five Candela per m<sup>2</sup>, we don't see a very big difference between warm-white and cold-white LEDs. But 70% of all the streets in Germany are smaller streets. If you visit China, if you visit the US, most of the streets are bigger. They have a luminance of two or three Candela per m<sup>2</sup>. But in Darmstadt, in Frankfurt, in big parts of Berlin you have small streets. They only have a luminance of 0.3, 0.2 Candela per m<sup>2</sup>. In such cases my argumentation is true. You have a difference between warm-white and cold-white LEDs, and amber is not very suitable.

**Nancy Clanton:** What I'm confused about is that we are focusing so much on the energy efficiency, and lighting designs are not created with energy efficiency as the prime priority. Lighting designs are made to ensure the best visual system and for our health and for the health of the ecology.

*What I'm confused about is that we are focusing so much on the energy efficiency, and lighting designs are not created with energy efficiency as the prime priority.* Nancy Clanton

When we balance all of that together, you find small streets in most towns, like in Germany, with not a lot of traffic, but there are a lot of people sleeping there. What about the melanopic suppression that occurs with the blue light? I think all of this should be put together and we should not just focus on energy efficiency.

**LPGD: Venkatesh Dwivedi, what's your opinion on this from the practical side of lighting installations?**

**Venkatesh Dwivedi:** I tend to agree with Nancy and others that we need to balance energy efficiency with light levels and the lighting design,

because we can't go overboard with efficiency. It is not the only thing that cities want. Cities want better, safer and better-looking roads and the light should not be polluting. So there are many items on the checklist that you need to take into account to make citizens happy.

*Cities want better, safer and better-looking roads and the light should not be polluting. So there are many items on the checklist that you need to take into account to make citizens happy.* Venkatesh Dwivedi

**LPGD: Are you also into dimming?**

**Venkatesh Dwivedi:** Conventional thinking suggests that dimming is a good idea. And if the traffic is faster, let's have more light and when there's less traffic, let's dim the lights. In India, we're having a big discussion about this. Some decision-makers totally want to dim lights after 11p.m. when there is less traffic. But actually the speed of the traffic is higher at that time. In most Indian cities, like in Europe, the roads are not very broad. The cities are very crowded. But if you give me peak lighting at 7 p.m. when the

traffic is bumper to bumper, it doesn't matter if the light is 15 lux or 20 or 100 lux. But after 11 p.m., when it's hard to get a clear overview of the traffic, because of the road and everybody is going at 80 km/h, you cannot reduce the light levels.

**LPGD: Thank you all for sharing your past experiences and present views. With our last question, we'd like to turn to the future: What would we need to do worldwide, so that twenty years from now, we could say that we have been successful with regard to light pollution reduction?**

**Sibylle Schroer:** In twenty years we will know much more about the effects of light on humans and society and so I guess societies will want lighting that benefits them and is sustainable from an energy and health point of view. We will perceive lighting as a hazard when its intensity is too strong at night-time. I think in twenty years' time, we will laugh about the street lights that we use today: that the light came from above and that it was so bright and that it disturbed all the night vision that we can actually support by using different materials and technology.

*I think in twenty years' time, we will laugh about the street lights that we use today.* Sibylle Schroer

**LPGD: Venkatesh Dwivedi, what is your vision for your projects in India?**

**Venkatesh Dwivedi:** I think dimming can be used to increase the efficiency. But we also realize that, in India, and it must be the case in other countries as well, the backroads and the federal roads which suffer from high traffic need to be developed more in terms of safety than for actual traffic management. We don't want dimming at the moment, because the lights are important for the safety of the citizens.

*We don't want dimming at the moment, because the lights are important for the safety of the citizens.* Venkatesh Dwivedi

I also feel that the projects that we are doing are more like retrofits on poles designed to handle sodium vapor lamps with 360 degree output ranges, whereas the LED fixtures have 140 degrees or something in that range. So the pole infrastructure is not exactly in line with the requirements. Although the results are very

good for a retrofit, they could be much better: we could choose to replace the poles as well, but that will require massive investments nationwide. But when this part is done, lighting design will be able to incorporate more than just energy efficiency. We can have a combination of both in the future.

**LPGD: Tran-Quoc Khanh, in your opinion, what should happen worldwide so that 20 years from now, we are able to say that we were successful in dealing with the emerging issue of light pollution?**

**Tran-Quoc Khanh:** In 2038 or 2040, LED technology will be used in both areas of night-time road illumination – street lighting and automotive lighting (headlights, indicators). The question of how we can reduce light pollution can only be answered by adaptive lighting systems.

*The question of how we can reduce light pollution can only be answered by adaptive lighting systems.* **Tran-Quoc Khanh**

For instance, in cities or towns, street lighting will only be kept at the maximum brightness in the presence of pedestrians, cyclists and vehicles. LED headlights could be reduced to 30% of their

full capacity. Street lighting could be dimmed to 20-30% at times when there is no traffic flow of vehicles and pedestrians during the night. From 2025 on, we shall have autonomously driven vehicles worldwide with no or only low-power headlights causing only a small amount of light pollution.

**LPGD: Nancy Clanton, we'll close with your vision for street lighting. What would make you say, "we have been successful"?**

**Nancy Clanton:** I completely agree with Sibylle's statement that we will look at our street lighting and will be surprised in twenty years if we actually still have street lighting on poles. I think we will have lighting highlighting our destinations, and wayfinding light lighting our paths with lights embedded into the pavement or into building facades. And there will be devices, smart devices, which will be able to lay out a path and what we need in terms of lighting. I think we will look at lighting very differently and it's not going to be on a pole. Our poles are going to be multifunctional. They are going to be connectivity nodes more than anything else, and they will not just be holders for street lights. That's my vision.

**LPGD: Do you see any opportunities for reducing light pollution in urban environments?**

**Nancy Clanton:** I feel that we have been missing out on a lot over the last couple of hundred years – not being able to go to sleep and see the stars at night and benefit from their calming effect. I think that we can really dial down our lighting and have lighting that is personalized and only there when we need it.

*I think that we can really dial down our lighting and have lighting that is personalized and only there when we need it.*

**Nancy Clanton**

My dream is that we continually look into what causes sky glow. Yes, it is a certain bandwidth of light, and if we can eliminate that, all of a sudden we can see the stars and the galaxies. And we can reduce our stress levels. Yes, twenty years, let's do it!

**LPGD: Thank you very much for contributing your insights and key arguments on light color and spectrum to our global discussion on light pollution.**

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# The third discussion: Commercial lighting – do we want hard law?





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世博  
未来商店

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SHANGHAI  
PORCELAIN  
EXPO

珍珠城  
PEARLS CITY



工艺礼品  
ART & CRAFTS



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# **The third discussion**

## **Commercial lighting – do we want hard law?**

**June 2018**

**moderated by Etta Dannemann & Nona Schulte-Römer**



**Cinzia Ferrara,  
lighting designer, Italy**

Cinzia Ferrara is a lighting designer and architect. She is co-founder and head of the Milan-based lighting design studio and consultancy Ferrara

Palladino e associati together with engineer Pietro Palladino. They engage in lighting research, consult commercial clients and have also designed outdoor lighting systems. She is the past President of APIL, the Italian Lighting Designers Association.



**Martin Morgan-Taylor,  
professor, United Kingdom**

Martin Morgan-Taylor is Associate Professor at Leicester De Montfort Law School. Light pollution is one of his key research areas – together with

consumer protection law. His most recent work has helped the island of Saint Helena develop lighting legislation. His publications compare dark-sky legislation worldwide and link light pollution to carbon emissions, health, ecological effects, and financial impacts.



**Allan Howard,  
engineer, United Kingdom**

Allan Howard is technical director for exterior lighting and electrical systems at the international engineering company and consultancy WSP with a focus on sustainability. He also helps shape lighting standards and policies as an active member of the Institution of Lighting Professionals (ILP) and the International Commission on Illumination (CIE-UK). Until 2008 he worked for Hertfordshire County Council, located in south-east England.



**Fei Guo,  
lighting designer, Shanghai**

Fei Guo is president and design director at Innovision Design Group. His background is in architectural technology and electrical engineering. He has worked for international lighting firms and is an NCQLP Lighting Certified (LC) Professional. He is also former director of the Illuminating Engineering Society Shanghai and leader of the Shanghai chapter of the International Dark-Sky Association (IDA).

# **The third discussion**

## **Commercial lighting – do we want hard law?**

**LPGD:** The aim of our discussion today is to look at different approaches for tackling the problem of light pollution from commercial light sources. By commercial lighting we mean shop window illuminations, billboards, media screens, illuminated brand architecture, etc. We will also focus particularly on the question: “hard regulation or voluntary commitments – do we need hard law?” This question seemed relevant to us after we talked to city representatives who said that without legislation they cannot do much to prevent light pollution from private lights.

**LPGD:** To begin with, we would like to gain a better understanding of your activities and views on regulations concerning commercial lighting. Cinzia Ferrara, your lighting design company is based in Italy. How do you experience the Italian legislation on light pollution?

**Cinzia Ferrara:** In Italy, we do not have a national law, but at a certain point each region started working on this issue. Lombardy was the first

one in 2000. So, since then we have many regional laws.

*Lombardy was the first one in 2000. Since then we have many regional laws.* **Cinzia Ferrara**

They are trying to govern light pollution in outdoor areas, no matter if it's a public or private space. They govern road lighting, illumination in parks and gardens and also architectural lighting, but there is nothing specific about commercial lighting or media walls.

**LPGD: So do you think the laws are too weak?**

**Cinzia Ferrara:** With regard to commercial lighting, definitely yes. On the other hand, it's very strict legislation. Firstly, you must prevent direct upward light on surfaces, especially at low angles above the horizontal. So, whatever you do outdoors, you can only have projectors or lighting fixtures that point downwards. The only exception: 4500 lumens per installation with a maximum of three light sources. In the majority of cases, the correct application of the law creates a perception of spaces that is drastically cut in two – under and above the fixtures. Secondly, the law makes some exceptions for relevant buildings, mainly historical, only if it's clearly

impossible to do it differently, but the lighting fixtures have to be turned off before midnight. So as usual, when you set rules that are too rigid, they will not be applied in the end.

*So as usual, when you set rules that are too rigid, they will not be applied in the end.* Cinzia Ferrara

**LPGD: How do these laws affect your work as a lighting designer?**

**Cinzia Ferrara:** In terms of general lighting we try to find the best ways to follow the law and show the positive benefits to the client. When we are doing a lighting design for a public client or a big company – typically it is a corporate building – the client asks us to work on that topic during the project. Sometimes they ask us to do a technical survey especially for video walls. They want to know if and how they can use them. Sometimes they ask for calculations before installing lights, but most of the time it is the other way around.

*Sometimes they ask for calculations before installing lights, but most of the time it is the other way around.* Cinzia Ferrara

QUALCOSA DI NUOVO  
STA ARRIVANDO.

Illuminated poster, Milan, Italy

For example, somebody just decides to have a commercial media wall in the city and then people who are working or living around it are really, really bothered by that. So somebody goes to the municipality and complains. At that point we are asked to check if they're doing whatever they are doing according to the law or not, and if not, how they should modify their output. In the vast majority of cases they just install the media wall and then something happens and somebody comes to us asking for a survey. We do a report, sign the report and take responsibility by saying "everything is fine", or "you should do certain things". But again, nobody is actually able to verify if they are really modifying the media wall as they should. The major problem is that even if we have a law, nobody is there to control it and check what is going on.

*The major problem is that even if we have a law, nobody is there to control it and check what is going on.* Cinzia Ferrara

**LPGD: Would you say that the Italian laws have at least increased demand for professional expertise in commercial lighting?**

**Cinzia Ferrara:** I prefer to say that we have seen a moderate improvement since 2000. Nevertheless, the percentage of people that decide to ask for expertise in commercial lighting is less than 10% of all of our projects, and 80% of that are people who are obliged to ask for expertise because of a complaint.

*The percentage of people that decide to ask for expertise in commercial lighting is less than 10% of all of our projects, and 80% of that are people who are obliged to ask for expertise because of a complaint.* Cinzia Ferrara

**LPGD:** Allan Howard, you work on light planning at WSP, an international infrastructure engineering consulting firm. How did you come to care about light pollution?

**Allan Howard:** We saw it as a big business opportunity, which it is turning out to be. In the early 1990s, artificial light emitted from buildings became a nuisance in the UK.<sup>1</sup> Another challenge was that we've got to look after the environment. We've seen a big move now that lighting schemes are being included in environmental impact as-

assessments, which is very good. So, we thought about how we develop that part of the business and it has grown quite tremendously now.

*We thought about how we develop that part of the business and it has grown quite tremendously*

*now.* Allan Howard

We are working for local authorities that want assessments undertaken or advice on planning applications, or we're working for the other parties looking to make such applications. The planning requirements don't tend to pay too much attention to lighting and this is a concern. We've always wanted lighting to be a consideration within the planning regulations.

**LPGD: Can you give us an example of such a regulation?**

**Allan Howard:** Within the UK, we've got a document from the ILP, the Institution of Lighting Professionals. The ILP Guidance Notes for the reduction of obtrusive light<sup>2</sup> has always been taken as a benchmark for how we can control exterior lighting installations to make sure they fit the environment that they sit in.

*The ILP Guidance Notes for the reduction of obtrusive light has always been taken as a benchmark for how we can control exterior lighting installations to make sure they fit the environment that they sit in.* Allan Howard

These environments now run from Dark Sky Reserves, which are categorized as E0, all the way through to E4, which is the city center. Within that we've got different limitations on light onto windows, source intensity towards observers etc. The ILP document tracks back to the CIE 150 obtrusive light guide,<sup>3</sup> which has just been revised, and also CIE 126, which is the reduction of sky glow.<sup>4</sup> But there are a lot of other things going on.

**LPGD: How do these planning guidelines affect or apply to commercial lighting?**

**Allan Howard:** A lot of my work has to do with highway and public realm lighting. Obviously sky glow is quite a key area within that. But commercial lighting is the difficult one. There is very little there that controls that.

*But commercial lighting is the difficult one. There is very little there that controls that.* Allan Howard

As we've just heard, media walls are a great thing now. The ILP also produced some guidance that is their professional lighting guide PLG05, The Brightness of Illuminated Advertisements, which looks at the artificial lighting requirements of advertisement screens, which includes media walls.<sup>5</sup> It's a matter of ensuring that the contrast between the screen and the background you view it against is balanced. It tries to make sure they are not animated and also looks at how displayed images change to ensure they have a very slight transition. Because if you have an instantaneous change between adverts, it is potentially a distraction to the outer corner of the eye of the motorist; a brief transition is not so obvious. The last installation I looked at was 80 square meters next to the M25 motorway around London. As it was on a bend the main concern was that drivers were losing sight of the car ahead, because the media screen filled their forward view. So the concerns are not only about light pollution, but also the safety and distractions of motorists.

*The concerns are not only about light pollution, but also the safety and distractions of motorists.*

Allan Howard

**LPGD: Fei Guo, you make light as part of your work at the Innovision Design Group and you also campaign against light as the founder of the Shanghai chapter of the International Dark-Sky Association, IDA. How do these two roles go together?**

**Fei Guo:** I have been with the IDA for over ten years and established the Shanghai chapter in 2009. Since then, we have been actively fighting light pollution and protecting the night skies in as many ways as we can, including educational events for the community, promotions of best practice in social media, articles in professional publications, and consultancy for legislation, etc. In my professional lighting practice we do facade lighting, urban lighting master plans, as well as landscape lighting. We always put ‘Dark Sky Friendly’ as one of the top design criteria in our exterior lighting projects. But there is a kind of natural conflict between commercial lighting and light pollution if the boundary is missing.

Taking Shanghai as an example, commercial lighting has become more and more popular in the city since late 1990s.

*Taking Shanghai as an example, commercial lighting has become more and more popular in the city since late 1990s.* Fei Guo

Although there are voluntary standards emerging along with the extensive applications, including lighting design guides and technical recommendations, few commercial lighting projects took light pollution into account in reality. With more and more complaints about disruption from the commercial lighting, the authorities realized that some solid countermeasures have to be taken if we really want to change the situation.

**LPGD: What do Shanghai's countermeasures look like?**

**Fei Guo:** The Shanghai authorities have deployed and applied a bunch of compulsory local regulations regarding commercial lighting. These include a lighting master plan and approval procedures for individual lighting projects. In the designated areas, commercial lighting projects need to submit their lighting proposals for approval before they are implemented. Even after

the installation, regular audits may be applied and inappropriate lighting applications may be required to be changed. We have witnessed a progressive evolution of these hard regulations after their deployment. The Shanghai government is engaging more and more in comprehensive regulation to continuously improve the quality of artificially lit urban environments at night. Preventing light pollution has been made one of the top priorities.

*The Shanghai government is engaging more and more in comprehensive regulation.* Fei Guo

**LPGD: There are other cities like Hong Kong that have quite rigid lighting regulations. Are there also national initiatives in China?**

**Fei Guo:** There are no specific national regulations regarding commercial lighting. Some national lighting design codes apply to commercial applications, but provide only limited guidance on how to prevent light pollution. Shanghai released its local design code for urban artificial lighting and addressed light pollution issues in detail in 2004, with a revision of the law in 2012. To regulate the extensive use of LEDs in public space, especially in commercial lighting applications, Shanghai released a local technical standard in

2013. It provides a practical method for measuring and evaluating light pollution caused by LED displays.

*Shanghai released a local technical standard in 2013. It provides a practical method for measuring and evaluating light pollution caused by LED displays.*

**Fei Guo**

At the same time, the city administration has put a series of management regulations into effect to make sure that all these codes and standards can be enforced accordingly. There are different approaches in different cities across China, but Shanghai was really one of the pioneers.

**LPGD: How useful do you find the Shanghai legislation?**

**Fei Guo:** I think it's very necessary to regulate commercial lighting in cities. As the president and design director at the Innovision Design Group and as an advisor to Shanghai's urban lighting authority, I have the opportunity to be involved in many commercial lighting projects. We were also commissioned to draft some lighting regulations for the authorities in the past.



Skyline, Shanghai, China

To be honest, in most cases, especially for commercial applications, we have to find a balance between the benefits of artificial light for businesses and its negative impact on the environment, which is hard to do.

*We have to find a balance between the benefits of artificial light for businesses and its negative impact on the environment.*

**Fei Guo**

From the perspective of business owners, it's natural and understandable to expect a stunning lighting proposal that catches people's attention at night for marketing and branding purposes. In many cases, high illumination levels or special effects are preferred, which may cause light pollution including glare, sky glow, light trespass and clutter if we don't take the appropriate countermeasures to avoid it. Theoretically, there are always solutions to resolve the conflict, but this always implies extra costs, which becomes the biggest obstacle. The business owner will choose the economical optimum if there is no compulsory regulation. In my opinion, hard regulations are a must for better governing commercial lighting in cities.

*In my opinion, hard regulations are a must for better governing commercial lighting in cities.*

Fei Guo

**LPGD: Martin Morgan-Taylor, as Associate Professor for law, do you have a clear-cut opinion on whether hard law, like in Italy or Shanghai, or soft law, like the ILP guidance, is the better option?**

**Martin Morgan-Taylor:** I think we need both soft and hard law. We need to start off by saying “what is the problem that we want to address?”

*I think we need both soft and hard law. We need to start off by saying “what is the problem that we want to address?”*

**Martin Morgan-Taylor**

Because any legislation has got to be dealing with the whole problem and not just one aspect. The most obvious issue is the loss of the night sky. But if we hang any attempt at legislation on just protecting the stars at night, I think we’re destined to fail. So I think that we’ve got to look at the problems of ALAN, of artificial light at night.

*I think that we've got to look at the problems of ALAN, of artificial light at night.* Martin Morgan-Taylor

We've got energy waste and excess carbon emissions due to over-lighting. We've got the issue of myths that light at night is good for safety and security, therefore the more light the better. We've got problems of human health with links to cancer, problems with nuisance or general irritation and a lowering of quality of life due to light shining into windows. We've also got ecological health with nocturnal species being disturbed. And then of course, we've got the loss of the night sky and nightscape. We should try to engineer some law that has a look at all of these and attempts to balance those negative effects with the benefits we get from light. Because clearly, we can't just switch all the lights off. But we need to begin by trying to be minimalistic.

**LPGD: Do you have a vision regarding how such legislation could be engineered?**

**Martin Morgan-Taylor:** We've got to find a system that will work. To work, it has got to be understood by people. I think if people can understand the collective problems of light at night, they are more willing to follow the law. Then we also have to think of the enforcers. If you have local

authorities or judges deciding on these cases, they've got to understand the issues as well and be willing to get involved in the process. What I would not recommend is how we proceed in Britain with an approach that is based purely on this idea of nuisance, that light at night can cause problems if you reach a particular subjective threshold. What we need instead is a mixture of hard metrics and soft guidance. So in other words, you can or you can't do this. And we need an obligation that lighting is considered during the planning stage for commercial developments and can be figured in to lighting master plans. All of that can help to prevent problems in the first place. Because what commercial light users really want are some form of clear and transparent rules and regulations.

*What commercial light users really want are some form of clear and transparent rules and regulations.* **Martin Morgan-Taylor**

So that they know what they need to do rather than get tripped up and “haha, you've just broken the law. We're now going to have you.”

**Allan Howard:** I agree, when you deal with advertising lighting you need a good balance between the positive benefits to business of the



Docklands at night, London, UK

advertising versus any negative potential effect. So, lighting guidance with metrics like we've got with the ILP's PLG05 document on advertising. Then businesses can see what they can and can't do based upon a proper understanding of the balance between the competing interests of light users.

**Martin Morgan-Taylor:** And then we also need lighting management. I think, there we're looking for some rules on installation, how you actually install lights. Every time I go out and have a look around I can see some wonderful lighting that is fitted badly. We are now getting more and more LED lights – and this is great, as LED light is highly directional. But that's assuming it's been directed in the right direction.

**Allan Howard:** We have the ILP's design guidance document which tries to persuade designers to design light in a way that it is contained within the premises.<sup>6</sup> But with more and more architects deciding to build greenhouses as offices, avoiding obtrusive lighting effects is very, very difficult. At the end of the day, we can't specify how someone does the lighting inside their house and we can't control the light that comes out of it.

*At the end of the day, we can't specify how someone does the lighting inside their house and we can't control the light that comes out of it.* Allan Howard

They can go and buy whatever they want and fitting curtains is not necessarily an answer. So that's a big concern in the UK at the moment. The EU is currently coming up with a smart building indicator, to make sure that the light is suitably controlled and only actually used when it's needed.<sup>7</sup>

**Martin Morgan-Taylor:** It's similar to going back to the 19th century and seeing a cityscape with chimneys belching out black smoke, which we now regard as environmentally polluting. Maybe in 50 years we may say "look at that city there, all those buildings are empty, the businesses are shut, but all of the lights are still on". Curfews could be very beneficial. Let's say that lights go off between 1 a.m. and 7 a.m. as they do in France, and not just for external commercial lighting, but also for internal commercial lighting.

*Curfews could be very beneficial. Let's say that lights go off*

*between 1 a.m. and 7 a.m. as they do in France, and not just for external commercial lighting, but also for internal commercial lighting.* Martin Morgan-Taylor

**LPGD: Talking about changing views on environmental problems – how was the first Italian law actually created, Cinzia Ferrara?**

**Cinzia Ferrara:** The initiative came from amateur astronomers, an Italian dark sky association. At the time, in 2000, it was quite incredible to achieve something like that. It was not such a big movement. But it was incredibly well done. They really worked very hard. They made public statements and also knew the right people in the local government in Lombardy. All this happened in one or two years.

**Allan Howard:** In the UK it was very similar. We had a very intense dark sky lobby led by some really well-known people focusing on the night sky including the astronomer, author and TV moderator Patrick Moore. Then, we have the bat conservation trust looking at the concerns of bats, which seem to be absolutely everywhere now including the center of London. They were

the big lobby groups that introduced the idea of artificial light emitted from premises as a nuisance.<sup>8</sup>

**LPGD: According to various newspaper articles, it seems that in Shanghai residents' complaints about light nuisance have also pushed political awareness about the issue of light pollution.**

**Fei Guo:** The engagement of local communities is always one of the most important driving forces of change. According to a statistic, there were 1,053 resident complaints related to light pollution in Shanghai from 2012 to 2015. Most of them (91.5%) were caused by commercial lighting.

*There were 1,053 resident complaints related to light pollution in Shanghai from 2012 to 2015. Most of them (91.5%) were caused by commercial lighting.*

**Fei Guo**

As dark-sky advocates, the IDA Shanghai chapter has been providing the city administration with volunteer consultancy on ways of dealing with light pollution since 2009.

**LPGD: Cinzia Ferrara, you not only work in Italy, but also in other countries. Can you make use of lighting design approaches that comply with the Italian laws in other countries or contexts too?**

**Cinzia Ferrara:** The Italian experience is quite helpful, because it changed the way we approach the design, even in other countries where there are no existing laws regarding light pollution, like Israel for example, where I'm working at the moment. So yes, our experience can lead us to better ideas and solutions overall, I think.

**LPGD: Have your lighting colleagues embraced that law or do they see it as restricting their work?**

**Cinzia Ferrara:** A lot of my colleagues complained. Because again, we went from nothing to a regulation that was very strict. And it was just metrics. A lot of what makes lighting design lighting design was a bit spoiled. With metrics, it is all about numbers at the end.

*A lot of my colleagues complained.* **Cinzia Ferrara**

**Martin Morgan-Taylor:** The problem for me is the actual enforcement.

*The problem for me is the actual enforcement.* Martin Morgan-Taylor

I tend to visit Italy once a year, the Veneto region. To be honest, if I was to visit the area and not know that there was this light pollution law, I wouldn't have thought there was one in place. I'm not that sure that it has made that much of a difference. That worries me – enforceability.

**Cinzia Ferrara:** I agree. The problem is that nobody is able to verify what has or has not been done. In public lighting projects, professional lighting designers are now much more accurate. But in commercial lighting it's a disaster. Clients do whatever they want. Nobody really cares.

**LPGD: Is Shanghai successful in ensuring that commercial actors comply with the regulation?**

**Fei Guo:** In general, I think Shanghai is on track to improve the quality of urban lighting and prevent light pollution by enforcing its regulations. If there is non-compliance, a correction request with a deadline will be made. The lighting facilities may be discontinued or removed if the deadline is exceeded and a fine may be issued. But as we know, light pollution is a complicated issue and sometimes it's really hard to identify and judge. Current regulations can be effective

in most of the cases where residents complain. But they are not successful enough in ensuring that commercial actors consciously comply. We are now facing the challenge of how to make the regulation more executable and effective.

**LPGD: Allan Howard, how do you persuade commercial clients to change their light levels or practices?**

**Allan Howard:** There is certainly a much greater awareness of artificial light and also of natural light these days. But there's very little at the planning stage.

*There is certainly a much greater awareness of artificial light and also of natural light these days. But there's very little at the planning stage.* Allan Howard

Mostly I'm called in where there has been a perfectly good design, but the contractor has substituted the equipment and it's an appalling installation. There was one that was fantastic on paper, but when I got there it was totally different to what had been designed and the only reason it was being looked at was because complaints had been raised. So, basically we try

to sit down with our clients and talk not only about the upfront cost of the lighting installation, but also how much it will cost in terms of energy and carbon throughout its life. We also talk about how we can create a flexible interior lighting infrastructure. Offices are never going to stay the same, you're moving things around. So, how can we design and consider the lighting to be future ready?

## *How can we design and consider the lighting to be future ready?*

Allan Howard

At the end of the day, the client wants something sustainable. They want a good building. If it's a commercial property, the chances are they will be able to lease it at a better rent. But the first thing they will get is the contractor who will say "well actually, I think we can do this cheaper". And the people who are procuring this will immediately think "oh, that's good!" So we need to look at how all of this can be brought together. Part of that includes ensuring that the contractor doesn't substitute the designers.

**LPGD: Cinzia Ferrara, how do you think lighting designers can contribute to a new perspective?**

**Cinzia Ferrara:** We could offer a lot and make a difference, in terms of experience and also in

terms of how you look at a master plan or urban places. We can offer a different understanding of what we have around us. We cannot consider every building and every street the same. Usually things are much more complicated and we need more than two or three lighting schemes. But I think that we are ready to go on, we are on the right track and the European level is the perfect one.

**Allan Howard:** We are also confronted with the challenge of one building wishing to stand out from another building in cities.

*We are also confronted with the challenge of one building wishing to stand out from another building in cities.* **Allan Howard**

We're seeing more and more requests for lighting master plans. So we're trying to get the building facades and everything controlled. A proposed facade design I looked at last year put so much light onto the building opposite and actually became a source of light onto the road as opposed to just lighting up the facade. We stripped 250 luminaires off that building and then they achieved what they wanted. It was just overlit and absolutely appalling. We were lucky in that case that the local authority had a



Hong Kong skyline from Victoria Peak

lighting design manager who really talked to the planners and said if anything has external lighting we need to look at it.

*We were lucky in that case that the local authority had a lighting design manager.* Allan Howard

**LPGD: So you would like to see more municipal initiative and integrated light planning on an urban scale?**

**Allan Howard:** It would be nice if all new lighting had to be assessed in that way. But very few authorities in the UK have a lighting expert anymore. Things are put up and then we end up getting involved if this becomes an issue because someone is concerned and complains. But it is also, as Martin said, making sure the thing is commissioned properly and that the owner understands it. We see the most sustainable, energy efficient, fantastically performing lighting design on paper, but the lighting and other services such as air conditioning were never fully commissioned and the people in the building haven't the foggiest idea how to control it. This is one reason why the EU is now discussing a smart building, which sounds fascinating. But we also end up with lots of people not necessarily working together. I sit on the UK Lighting

Liaison Group and it's amazing that there's about 15 organizations around the table and they all agree exactly on the same thing, but they don't actually want to work together to address it.

**LPGD: Fei Guo, as a member of the Dark-Sky Association, why do you care about urban light nuisance in cities? In other words: Isn't the dark sky already lost forever in cities like Shanghai?**

**Fei Guo:** Although it's a long way to go, we are still optimistic about getting dark skies back in cities.

*Although it's a long way to go, we are still optimistic about getting dark skies back in cities.* **Fei Guo**

Along with rising awareness of the negative impacts of light pollution, a change is happening now. The lighting industry has been significantly changed by LEDs and the other emerging technologies. Dark sky-friendly or even light pollution-free lighting solutions are becoming more and more practical.

**Allan Howard:** The use of LEDs is helping, because it's more controllable in terms of where the light goes. But we have very interesting discussions

about color temperature, as to whether it should be 3000 Kelvin or 6000 Kelvin, whether we adjust the color temperature during the evening or during the different periods.

**Martin Morgan-Taylor:** It's not just a question of the right amount of light where needed when needed, but now it's about the type of light that's needed.

*It's not just a question of the right amount of light where needed when needed, but now it's about the type of light that's needed.*

**Martin Morgan-Taylor**

So if we're talking about the levels of light, we must also get involved in the debate over the type of light. It is clear that if we're dealing with 6000 Kelvin for street lighting, that's proving controversial due to emerging research linking blue-rich light at night to serious human (and ecological) illnesses. We're trying to save money by using the 6000 Kelvin which looks brighter to the human eye, because of the photopic effect. But, is that actually the right sort of light? Or are we actually dealing with what you could call junk light?

## *Are we actually dealing with what you could call junk light?*

**Martin Morgan-Taylor**

I mean, we're all familiar with high-calorie junk food. That's not really that good for you, but it's dirt cheap. Is there a possibility that we could be dealing with junk light under very narrow circumstances?

**LPGD: What do you suggest to reduce negative impacts from products that are available on the market?**

**Martin Morgan-Taylor:** I would start by saying try and act preventively. Try and control the sale of lights. If it's possible to say what is bad lighting, it is not allowed to be sold or only allowed to be sold under certain circumstances. That can be a bit problematic in Europe, because there's an argument as to whether or not this is a barrier to trade. But there is an exception to that on environmental grounds, with which I think you could argue. You can try to prevent sales of these lights, get retailers to offer guidance for the installation of the lights.

*You can try to prevent sales of these lights, get retailers to offer*

*guidance for the installation of the lights.* **Martin Morgan-Taylor**

**Cinzia Ferrara:** It's true, we have a big problem with junk products. But I also remember very well that when the law came out in Italy, the manufacturers felt immediately obliged to redesign their lighting fixtures, especially for street lighting. But the problem is that lighting does not only depend on the lighting equipment, but also on how you use it. You cannot prevent people from using lighting fixtures in the way they want. I can buy the best products on the market and then use them in the worst possible way.

*I can buy the best products on the market and then use them in the worst possible way.* **Cinzia Ferrara**

I think in general terms it's a problem of culture, of getting to know certain things. So, it is really an installation problem.

**Allan Howard:** I agree. I recently looked at security lighting in the urban realm.<sup>9</sup> Part of that was linked to a major seller of household equipment, DIY shop and light fittings. They don't actually have any security lights that are suitable.

Everything has gone to LED, but they want it to still look like an old security light and therefore there is no light control on these things at all. The light goes absolutely everywhere. So it's a question of how to address that. When we worked with planners we said, what we need is a sign-off clause that says that the designer must come back, check that everything has been installed properly, and equipment hasn't been substituted. But they will say we won't worry about it unless someone complains, which is not the right approach unfortunately.

**LPGD: Are there any approaches that can ensure that the right products are installed in the right way?**

**Allan Howard:** We try to persuade people to look at the good work the EU has developed in its Green Public Procurement (GPP) program. They've got GPP for road lighting and traffic signals, but also for building lighting.

*We try to persuade people to look at the good work the EU has developed in its Green Public Procurement (GPP) program.*

**Allan Howard**

If they just dropped the Public ‘P’ it would be fantastic. With the word ‘public’, the commercial people immediately say, “oh it has nothing to do with us ...” But it’s actually a very good approach for anyone. That’s why I don’t like the word public in there. If you read the GPP documents for building lighting or road lighting, everything makes total sense and it is very, very good practice. Because it looks at what do I need to light? Do I need to light it? And then if I need to light it, what are the right requirements for the lighting? And then it talks about getting a competent lighting professional in. This is one of the big drivers we’re trying to get through. Clients need to engage with competent lighting professionals and these are people that have got the experience, the training and the understanding of it all. As opposed to say, a manufacturer or an electrician who are just trying to sell products or just do something very quick. A competent professional would look at the whole life of the asset.

**LPGD: For our final round of statements, we’d like to look into the future. If you think of commercial lighting in urban spaces 20 years from now, what regulations should be in place so that you would say we have addressed this issue properly?**

**Martin Morgan-Taylor:** I suppose the biggest issue is the LED and spectral types of LEDs.

*I suppose the biggest issue is the LED and spectral types of LEDs.*

**Martin Morgan-Taylor**

We are seeing a lot of emerging research that artificial light at night is bad for human circadian rhythms and also those of certain animals, because of the blue part of the spectrum. So I think that what we're going to see over the next 20 years or so will be further corroborating research or denials. So we need to try and make any ideas for lighting legislation and guidance future-proof. At the moment that means feeding into guidance, into metrics and hard laws that blue-rich light at night is not really very good. Looking at commercial uses of light, I think it's about educating the public, and trying to stop the sale of poor lighting, so that consumers only have a choice of better lighting equipment that comes with built-in light controls and doesn't have a very high color temperature. It's trying to provide information on fitting the light. It's about getting the message out there about why we're actually regulating and why we're trying to control the problems of artificial light at night, so that people see there is a problem and they are more willing to really engage. I think we can resolve a lot of problems if we've got a

mixture of hard and soft laws including curfews and metrics in the form of “you can light to this level, but not over” or documents that help to inform understanding, so that people can see why the law is doing this.

*I think we can resolve a lot of problems if we've got a mixture of hard and soft laws.* **Martin Morgan-Taylor**

If we get all of this together, I think we've got a good chance of getting a sort of template that you will be able to move across different countries with different legal systems.

**Cinzia Ferrara:** I think that Martin has already touched on many important issues. We really need to raise awareness. I don't think we will be able to stop products from coming into the market. But I think we are becoming much more aware of what is happening to the planet and also of what lighting can do. Thus, we might be able to develop better guidance and, little by little, achieve some good results – especially when working on commercial lighting. Because at the moment LEDs are really spreading and the problem is that there are no limits.

*At the moment LEDs are really spreading and the problem is that there are no limits.* **Cinzia Ferrara**

The people I talk to, they always look at lighting as something temporary, because it's not always on, it depends on hours and seasons and all these sort of sneaky aspects – and this in a world that doesn't have any limits, in which things are always designed for having something more. That's what I'm afraid of.

**Fei Guo:** Thinking of the negative side effects of commercial lighting, my vision for the future night-time image in 20 years is functional, pleasant and inspiring. By then, all stakeholders should have developed a much better understanding of the downsides of artificial light.

*By then, all stakeholders should have developed a much better understanding of the downsides of artificial light.* **Fei Guo**

They should demonstrate a strong willingness to eliminate light pollution. By taking advantage of advanced lighting technologies, we can develop highly sophisticated designs. Well-proven methods of implementation and regulation will

make it possible to achieve adaptive and pollution-free artificial light environments with value-added services like smart lighting systems that can be used for commercial applications. That may allow us to say we have been successful.

**LPGD: Allan Howard, do you share this future perspective?**

**Allan Howard:** I think what we're seeing is that other technologies are getting involved in lighting, like LiFi, and that is another driver because you can communicate through it. We are still playing catch-up on the technology. We have been an industry that has been ready to leap on LEDs and chuck every other light source in the bin. We're now seeing a move in UK street lighting towards warmer color temperatures of around 3000 Kelvin. But there's a lot of lobbying around and sometimes it's a matter of getting people around the table to actually discuss and come to a reasonable joint understanding. The Institution of Lighting Professionals has just done this with the bat conservation trust. We are moving forward. But there's an awful lot of exterior lighting and commercial lighting that is just poor. If we could get this Green Public Procurement approach more widely adopted with competent

professionals, we would start making a good way forward.

*If we could get this Green Public Procurement approach more widely adopted with competent professionals, we would start making a good way forward.*

**Allan Howard**

There is good stuff out there! So let's try and find it and try to get the lobbyists gathered around the same table.

## References

- <sup>1</sup> See Morgan-Taylor, Martin & Hughes, D. (2005). Exterior Lighting as a Statutory Nuisance. *Journal of Planning & Environment Law*, September, p. 1131-1144. <http://hdl.handle.net/2086/404>.
- <sup>2</sup> <https://www.theilp.org.uk/documents/obtrusive-light/guidance-notes-light-pollution-2011.pdf>, retrieved in Nov. 2018.
- <sup>3</sup> <http://www.cie.co.at/publications/guide-limitation-effects-obtrusive-light-outdoor-lighting-installations>, retrieved in Nov. 2018.
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- <sup>5</sup> <https://www.theilp.org.uk/resources/ilp-general-reports/plg05-the-brightness-of-illuminated-advertisements/>, retrieved in Nov. 2018.
- <sup>6</sup> ILP Guidance Notes for the reduction of obtrusive light: <https://www.theilp.org.uk/documents/obtrusive-light/>, retrieved in Nov. 2018.
- <sup>7</sup> For more information on the EU smart buildings indicator see: [http://bpie.eu/wp-content/uploads/2017/11/Presentation\\_SmartBuilding\\_DG\\_ENER.pdf](http://bpie.eu/wp-content/uploads/2017/11/Presentation_SmartBuilding_DG_ENER.pdf), retrieved in Nov. 2018.
- <sup>8</sup> <http://www.gov.uk/guidance/artificial-light-nuisances-how-councils-deal-with-complaints>, retrieved in Nov. 2018.
- <sup>9</sup> See BBC Sky at Night Magazine, Issue 155, April 2018, <http://www.skyatnightmagazine.com/issue/april-2018>, retrieved in Nov. 2018.

# A global expert survey



*In March 2018, we launched an online expert survey. We invited people with expertise in lighting and light pollution to take part.*

*205 Participants  
36 Countries  
6 Continents*



*The survey was designed to gather different expert views on light pollution, define the problem, collect examples of lighting conflicts and best practices, as well as suggestions for improvement and visions for the future.*

# The survey – our approach

## Expert responses from 36 countries

**The survey invitation travelled around the globe for two months. Lighting-related organizations and multipliers in our international professional networks helped us spread the invitation worldwide, creating a snowball effect.**



**The survey reached a heterogeneous audience, providing us with voices from across six continents.** Lighting designers, environmental researchers, concerned citizens, amateur astronomers, dark-sky activists and policy makers took the time to respond and offer their valuable insights. The survey was completed by 205 participants aged between 22 and 79. About one third of them are women.



**Figure 1:** The participant numbers per country show a clear gravitation towards Europe, North America and Australia. The feedback distribution arguably reflects where light pollution is most established as a topic.

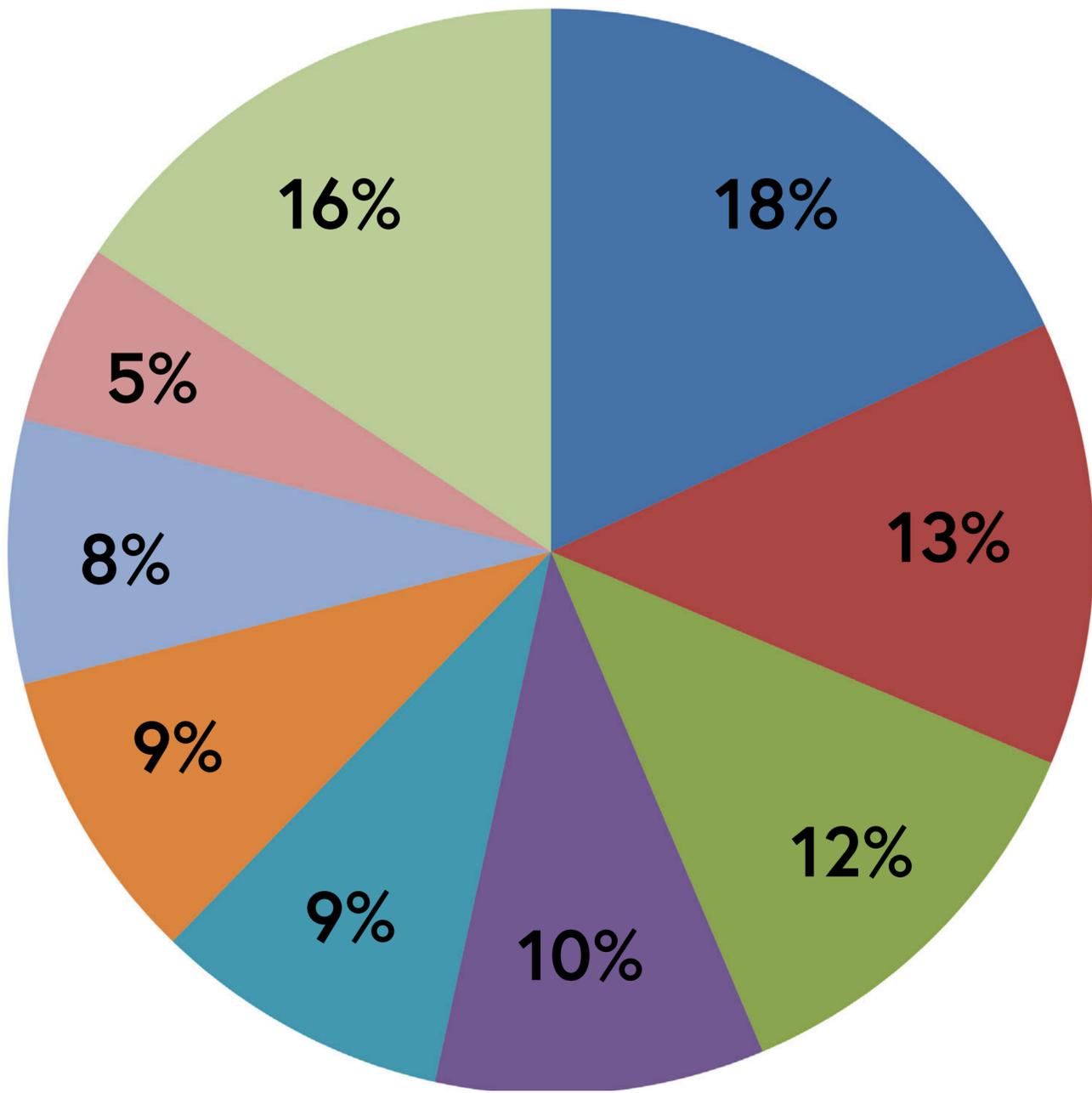
# The survey – our approach

## One worldwide survey, multiple expert perspectives

**The survey concept is unique in the sense that it integrates expert perspectives from various disciplines and multiple backgrounds worldwide.** The participants' expertise is grounded in professional light-related activities as well as personal interests and activities. Some respondents produce light and illuminate spaces as professional light planners, lighting designers or developers of lighting technology. Some work in fields that are affected by artificial light at night – such as astronomers, ecologists or educators in environmental contexts. Others feel personally affected by light pollution as they care about nature, enjoy observing the night sky or feel disturbed by lighting in their surroundings. Although they are not trained in lighting, we consider them experts as they have developed profound knowledge of light-related issues and use it to voice their concerns about artificial light at night or campaign against light pollution.

*For more information regarding the survey participants and our approach visit:  
[www.ufz.de/light-pollution](http://www.ufz.de/light-pollution)*

**Figure 2:** The survey participants' main occupations in percentages.



- Architectural and decorative lighting design
- Astronomy and environmental research
- Environmental protection related to lighting
- Politics related to lighting
- Raising awareness for light pollution
- Education related to lighting (student or professor)
- Lighting design research, technology development
- Light planning (urban and functional lighting)
- Other jobs or retired

# The survey – our approach

## Exploring different views

**We asked respondents to define light pollution and explain why and how they think the issue should be addressed.** To encourage the widest possible range of feedback, participants could not only tick boxes to agree or disagree with predefined answers, but were also invited to share their expertise and experiences in the form of written statements. Their feedback was anonymized and qualitatively and quantitatively analyzed.

**The survey results are not representative in statistical terms, but they present a broad variety of opinions, professional perspectives and worldwide activities related to light pollution.**

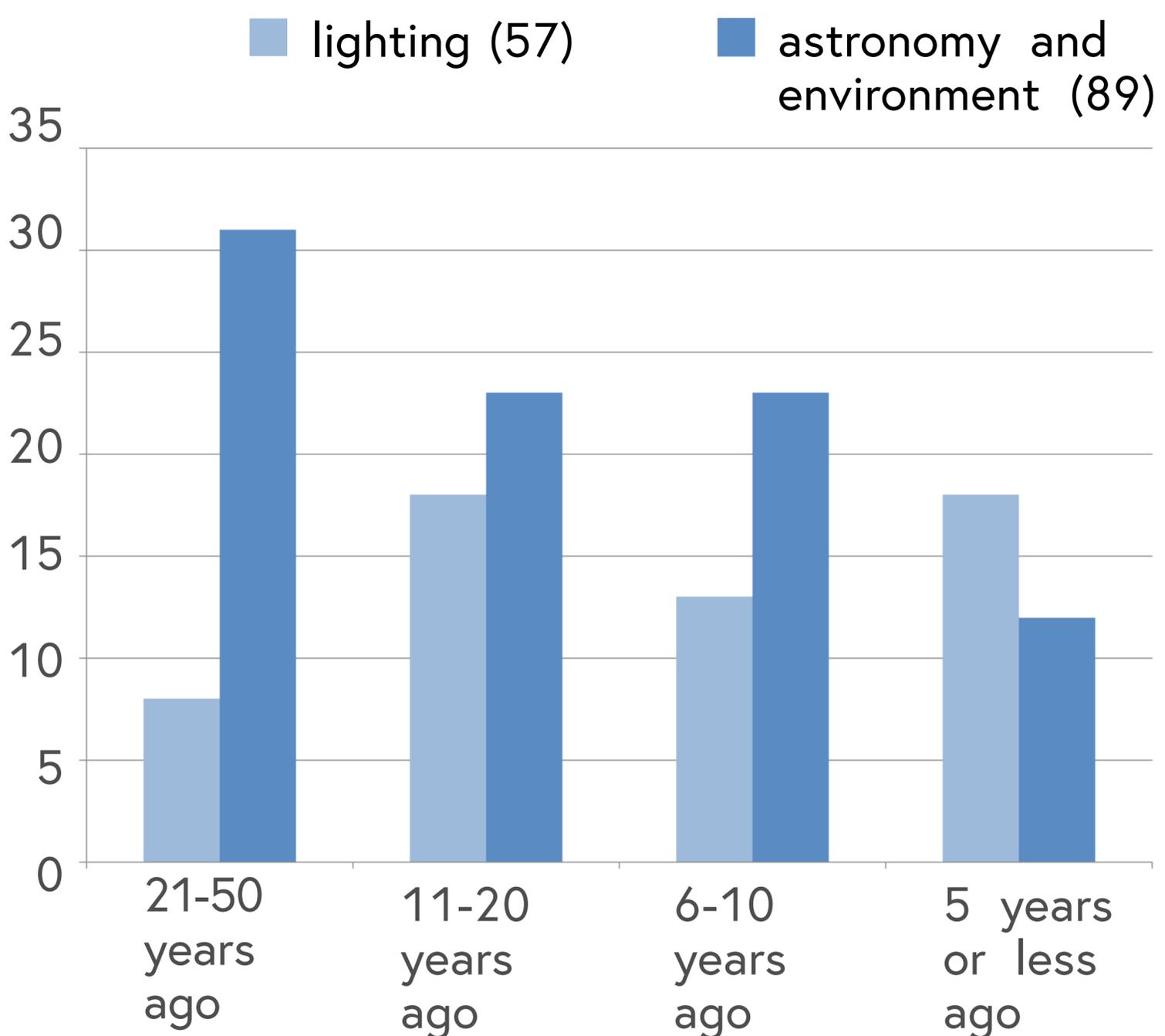
Respondents with an environmental interest expressed stronger opinions against artificial light at night than respondents who develop, plan and promote lighting as their main occupation. But they also share certain views. For instance, lighting professionals and dark-sky proponents both strongly recommend integrated light planning and more adequate technology to tackle light pollution. Among the lighting professionals, 59% responded that the low priority given to this issue in lighting projects constitutes a significant obstacle to effective light pollution mitigation.

The topic appears less well-established among lighting designers, planners and manufacturers.

**On average, respondents with a background in lighting first heard about the concept of light pollution 6.5 years later than respondents with an environmental or astronomical interest in the issue.**

The difference is smaller when we take into account that the lighting professionals among our respondents are on average younger.

### Respondents with a background in ...



**Figure 3:** When did you first hear about light pollution? Group-specific responses in total numbers.

# How respondents perceive the problem

## When does artificial lighting become pollution?

There is no clear-cut definition of light pollution. This is nicely reflected in some of the survey respondents' statements:

*“... when light shines directly into people's eyes, e.g. bright security lights, some LED headlights and bicycle lights”*

*“... when it obscures the effects of creative, artistic or atmospheric lighting”*

*“... light around bodies of water, natural areas and observatories”*

*“... 4000 Kelvin lighting, unless there is a genuine need for such a high color temperature”*

*“... it depends on the situation and the amount of light”*

They describe light pollution in functional technical terms, as a personal nuisance, an aesthetic problem or as an issue affecting specific places.

The lack of clarity underlying this concept is considered an obstacle that makes it difficult to tackle light pollution effectively.

**Almost 40% of the survey respondents agree that the lack of a clear definition can hamper efforts to reduce light pollution.**

One key goal of the inquiry was therefore to better understand where lighting experts and dark-sky proponents draw the line between useful and excessive lighting. One would have expected that lighting professionals would generally be in favor of qualified lighting solutions, but the results contradict this assumption: 39% of the respondents think “all outdoor lighting is a form of pollution”. One third of the survey respondents with a background in lighting share this view. Only four respondents believe that “light is never pollution”.

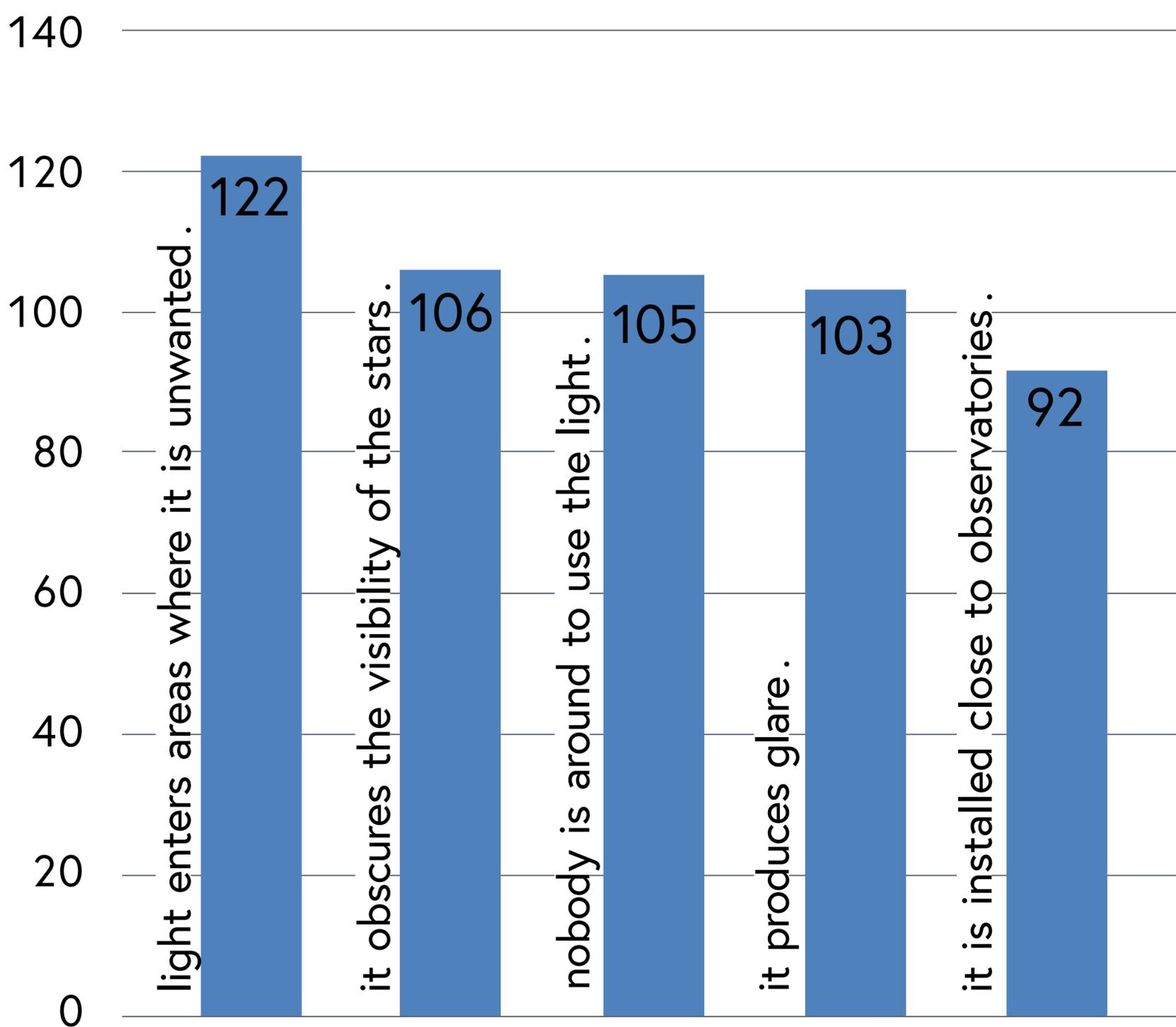
*“I don’t believe it is possible to draw a general conclusion.”* Lighting designer, Germany

The majority, 59% of survey participants, take a situation-specific perspective on the issue. They suggest that it “depends on the situation” whether or not light can be defined as pollution. They were given the opportunity to specify their view in a follow-up question (see Figure 4 on the next page).

# How respondents perceive the problem

## Light is pollution when ...

Over 75% of the respondents with a situation-specific definition of light pollution agree that light constitutes pollution when it enters areas where it is unwanted, when nobody is around to use it, or when it obscures the visibility of the stars (Figure 4).



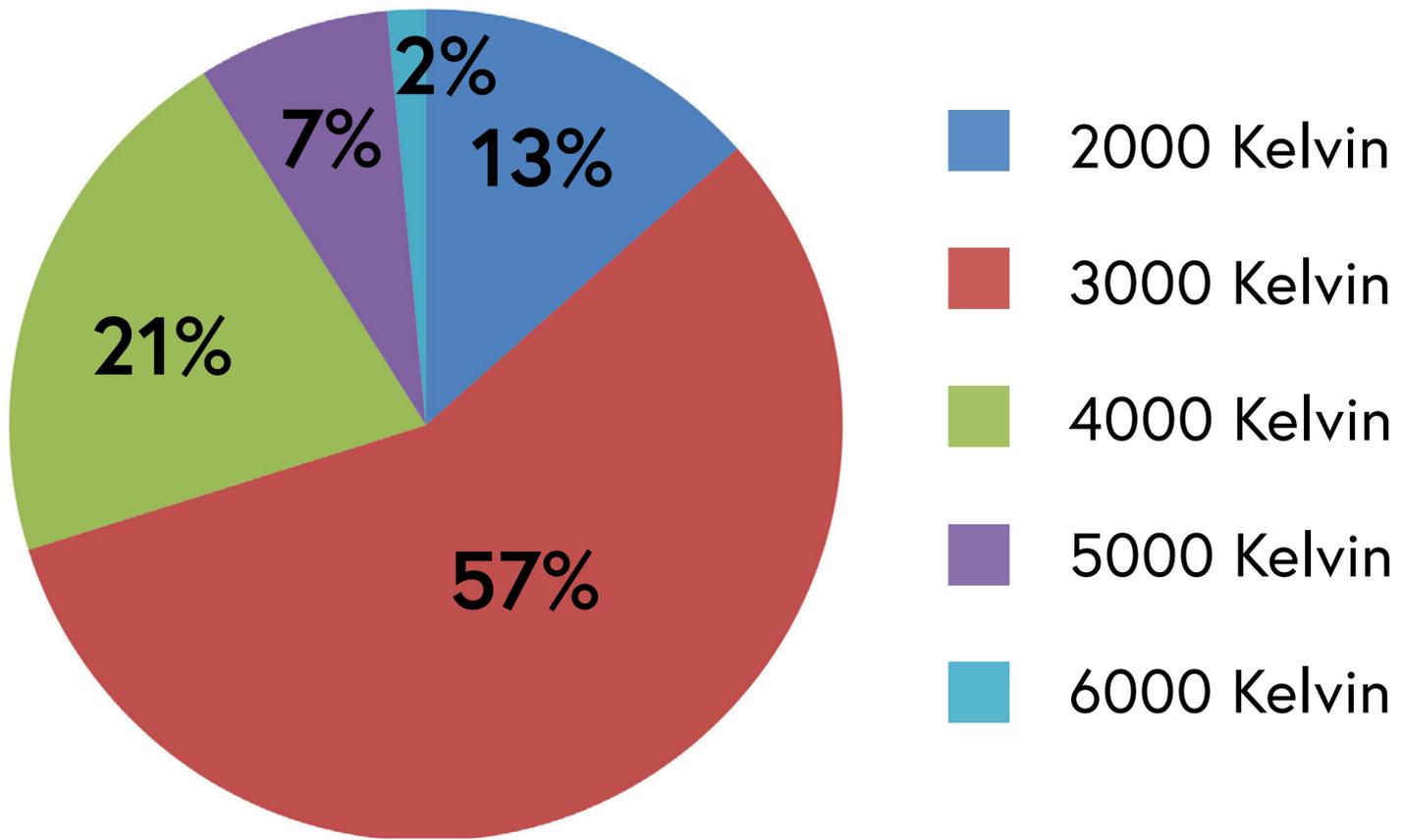


Figure 5: "Light is pollution, when the color temperature is above ..."

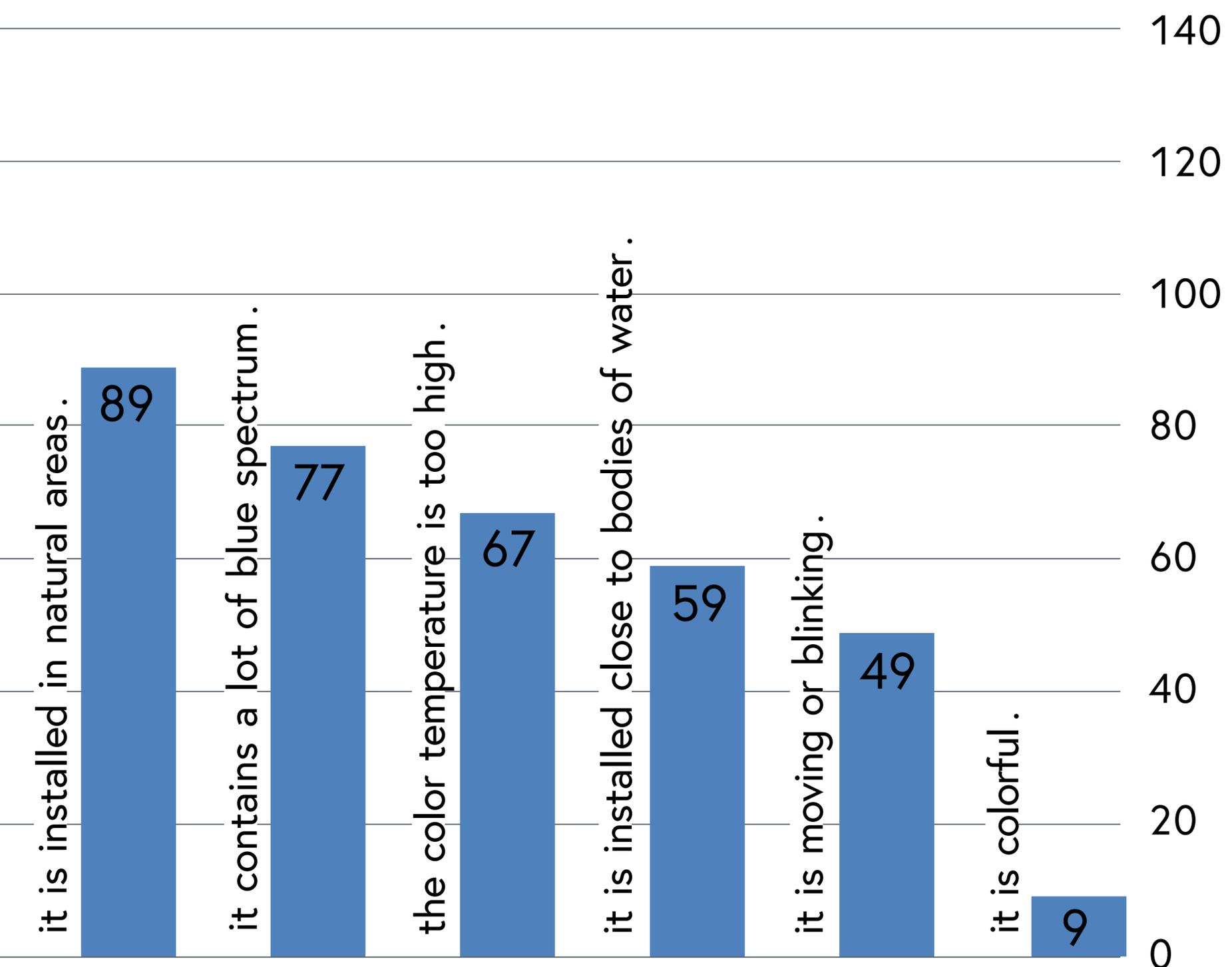


Figure 4: In which situations does light constitute pollution? The answers of 139 respondents to multiple-choice questions (several answers possible).

# How respondents perceive the problem

## Reasons for limiting artificial light at night

Just as there are many good reasons to illuminate the world at night, there are also many good arguments for restricting the use of light. We asked survey respondents to evaluate a selection of six arguments. Remarkably, 75% of respondents found all the reasons in our list to be at least “important”, if not “very important”.

### Why should lighting be reduced?

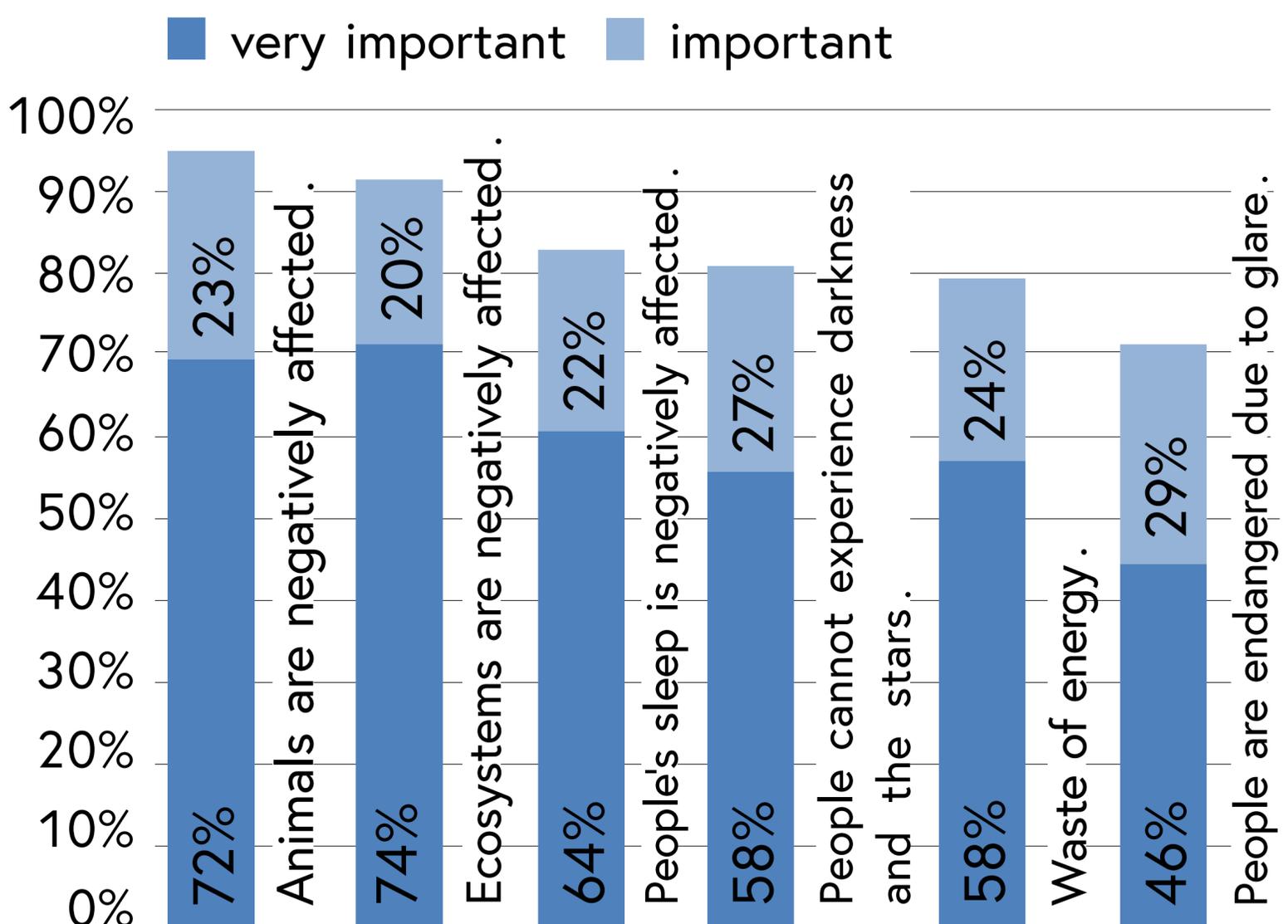


Figure 6: How important do you find the following potential negative effects? Percentages of respondents who rated the concerns listed above as "very important" or "important".

Negative effects on animals and ecosystems scored highest, offering key reasons why artificial light at night should be reduced. Potential negative effects on people's sleep are a salient argument for 86% of the respondents.

This feedback reflects widespread health concerns, notwithstanding the ongoing expert controversy on whether outdoor lighting can actually have an impact on people's sleep inside their bedrooms. This doubt was expressed in one response from a representative of the European lighting industry, who selected the answer "I doubt this is an issue" for this particular question. In addition to the arguments listed in the survey, the participants also added more reasons for reducing artificial light at night. In particular, they stress that too much lighting is not only a health risk and an ecological problem, but also a "waste of money" and can reduce the appeal of public spaces at night.

*"Poorly installed lighting degrades the ambience and character of neighborhoods and the quality of life."* Light planner, USA

An environmental scientist argues that leaving the planet in its natural state is an ethical issue. A respondent who describes herself as an activist against blue-rich lighting criticizes a lack of democratic deliberation: "Residents and citizens have not been really asked about these lights."

# How respondents perceive the problem

## Conflicts over artificial light at night worldwide

We also asked the survey participants whether they could give examples of situations in which a person or group publicly complained about lighting. A physicist responded: *“This is kind of a weird question. There are thousands of examples!”*

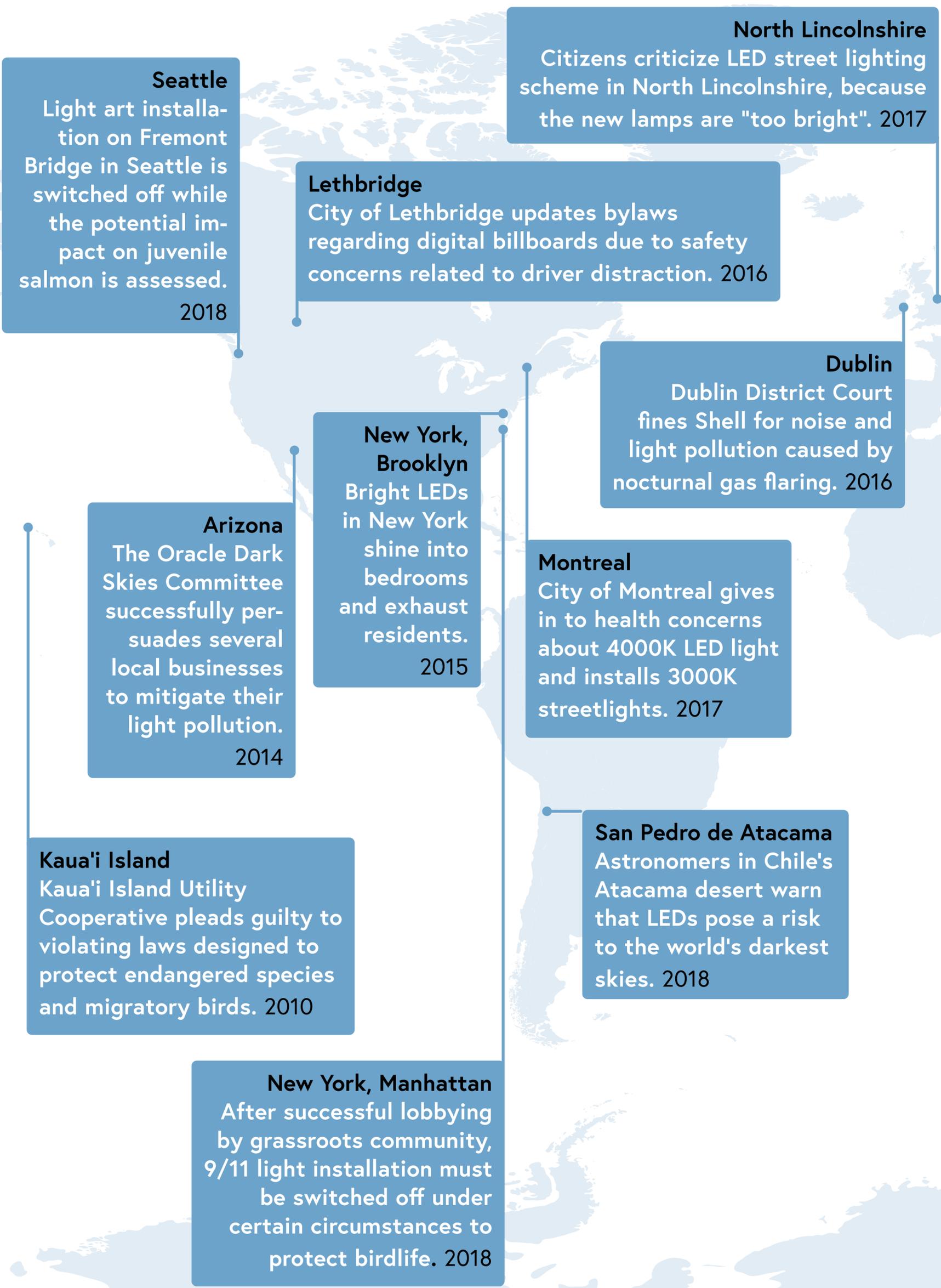
It seems that **light pollution has turned into a political issue**. The world map on the next pages shows some of the lighting conflicts that the survey participants shared with us.

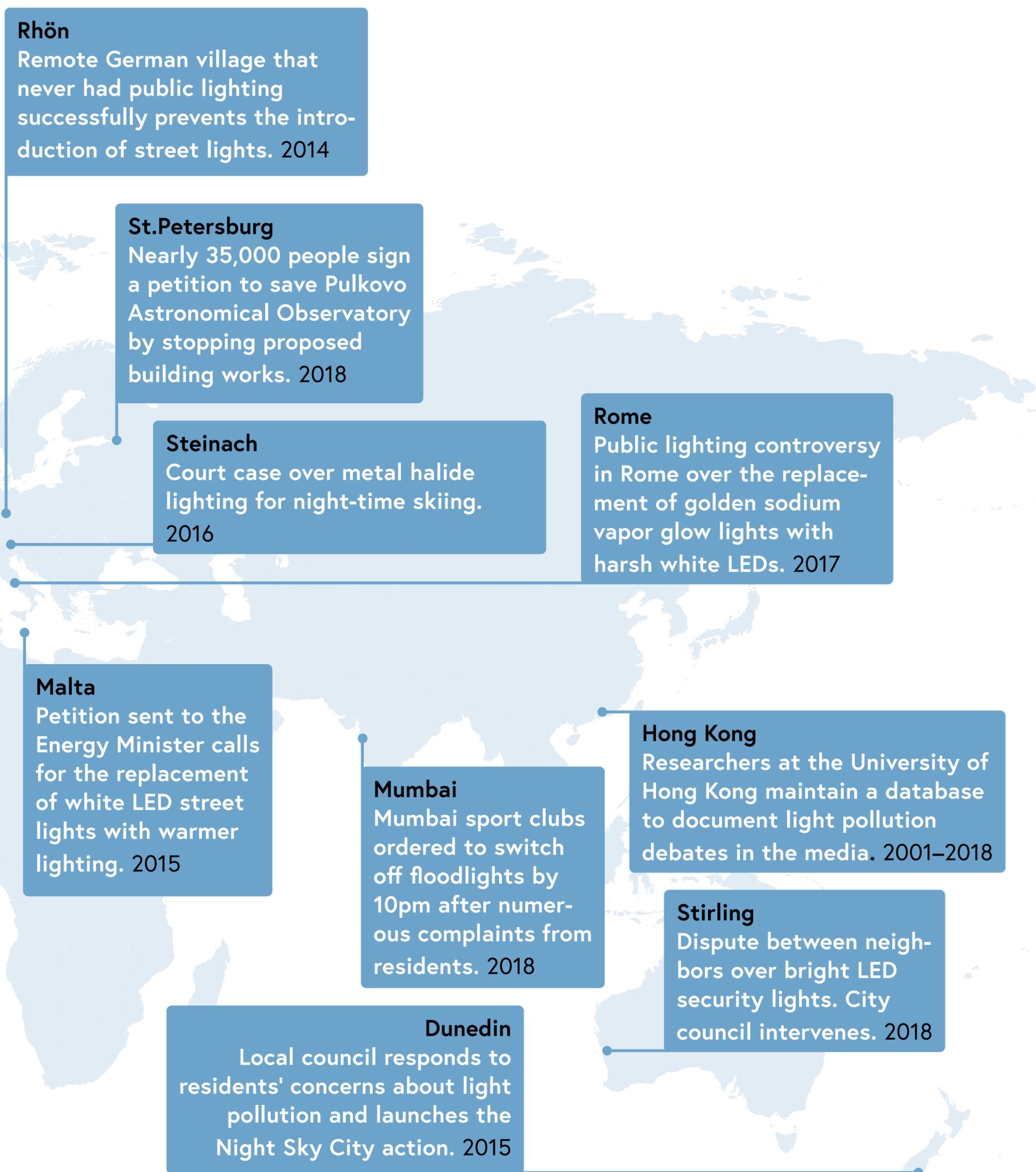


Stadium lights

# How respondents perceive the problem

## Conflicts over artificial lights at night worldwide





**Figure 7:** Can you give an example of a situation in which a person or group publicly complained about lighting? The map shows a selection of places where respondents reported lighting controversies. More data available at: [www.ufz.de/light-pollution](http://www.ufz.de/light-pollution)

# The dilemma – where interests clash

## Why is it so difficult to reduce light pollution?

Although there are many good reasons for reducing lighting at night, light pollution mitigation can be difficult in practice. In response to an open question, the survey participants outlined a number of obstacles.

*“Everyone assumes that ‘more light is better’ and that ‘all light is good light’. These perceptions are the biggest obstacles, which must be challenged and shown to be false.”*

**Astronomer, Ireland**

A lack of awareness of the problem, especially among light users, is the most frequently mentioned obstacle. A French lighting designer criticizes “the poor knowledge and the deficient light culture in politics and city administrations”. Another from the USA points out that “specifications and installation decisions are made by parties without appropriate training and expertise”. A third sees cause for hope: “There is a general ignorance and apathy in relation to the issue, although slowly but surely people are waking up.”

**Misconceptions regarding the positive effects of lighting are another frequently mentioned aspect.** This also concerns what some call the “myth” of light and safety, meaning that people’s sense of insecurity in the dark is misinterpreted as an actual lack of security. A German lighting designer explains:

*“People are afraid of the dark and often municipalities claim so much light is needed for traffic safety and to reduce vandalism and crime. However, there is often too much glare through which spaces are perceived as dark (adaption). And there is only an indirect link between light and safety.”*

**Lighting designer, Germany**

One of his colleagues argues: “People suspect that after changing the lighting system it will be darker than before on the streets, but it is only the pollution that will be missing!” An Italian physicist argues that “there is a lack of serious and independent research and statistics” on the relationship between light, safety and security.

# The dilemma – where interests clash

## Conflicting views on LED lighting

**Light-emitting diodes (LEDs) are another key theme. Almost 90% of the survey respondents feel that the LED revolution in lighting strongly affects their light-related activities.** LEDs are widely celebrated for their energy efficiency, adjustability and good color rendering. With regard to light pollution however, their role is more controversial. A researcher from the UK explicitly warns against the “presumption that new technology (especially LED) does not produce light pollution”. The survey participants explain why they perceive LEDs as both an obstacle and an opportunity.

*“Smart lighting technology will enable us to regulate light pollution.”* Conservationist, Japan

About 45% of the respondents support the proposition that LED lighting helps to reduce light pollution. They highlight the benefits of its directional light output, of smart solutions and customized correlated color temperatures (see discussion 2). A dark-sky researcher remarks: “LEDs are a key to reducing light pollution: directionality, dimmable, tailored spectrum. If one picks the right

LED, it will in almost all cases be better than old standard lamps.”

*“Potentially, adaptive lighting and PC Amber LEDs may enable a substantial reduction in light pollution.”* **Physicist, Italy**

But these new potentials for reducing light pollution are rarely fully exploited. Accordingly, 67% of the respondents (also) find that LED lighting contributes to more light pollution. They criticize rebound effects, the increasing use of cheap low-quality LED products and bad installations. They also express reservations against blue-rich LED lighting, which has stronger chronobiologic effects and scatters more in the atmosphere than longer wavelengths, thereby adding to sky glow. A biologist concludes: “It does not reduce light pollution, but it could if combined with dimming and other dynamic-use options or spectral manipulations to produce amber LEDs.”

*“Mindless installation of harsh, eye-gouging LEDs has become an epidemic worldwide and it just keeps getting worse and worse.”*

**University academic, Australia**

The survey feedback thus suggests that the introduction of LED lighting offers a window of opportunity for tackling light pollution, but also runs the risk of intensifying the problem.

# The dilemma – where interests clash

## Economic incentives at odds with light pollution reduction

**The survey participants also highlight a number of structural obstacles and economic factors that are detrimental to the reduction of light pollution.** In particular, they criticize the way in which lighting technology is produced, sold and installed. A civil engineer from the USA points out that “local retailers of lighting fixtures show little interest in limiting the number of non-dark-sky compliant fixtures they sell and in promoting dark-sky compliant ones”. A sociologist from Australia problematizes lighting demands: “24/7 shift work and global transport systems rely on artificial light.”

*“Everything is cost-driven and executed by people who need to finish their work very fast.”*

**Electrical engineer, Germany**

Economic considerations affect not only private lighting choices, but also light installations in public spaces. An electrical engineer from Romania criticizes how “public procurement is realized by imposing the lower price” while technical solutions and the quality of designs are “not important”.

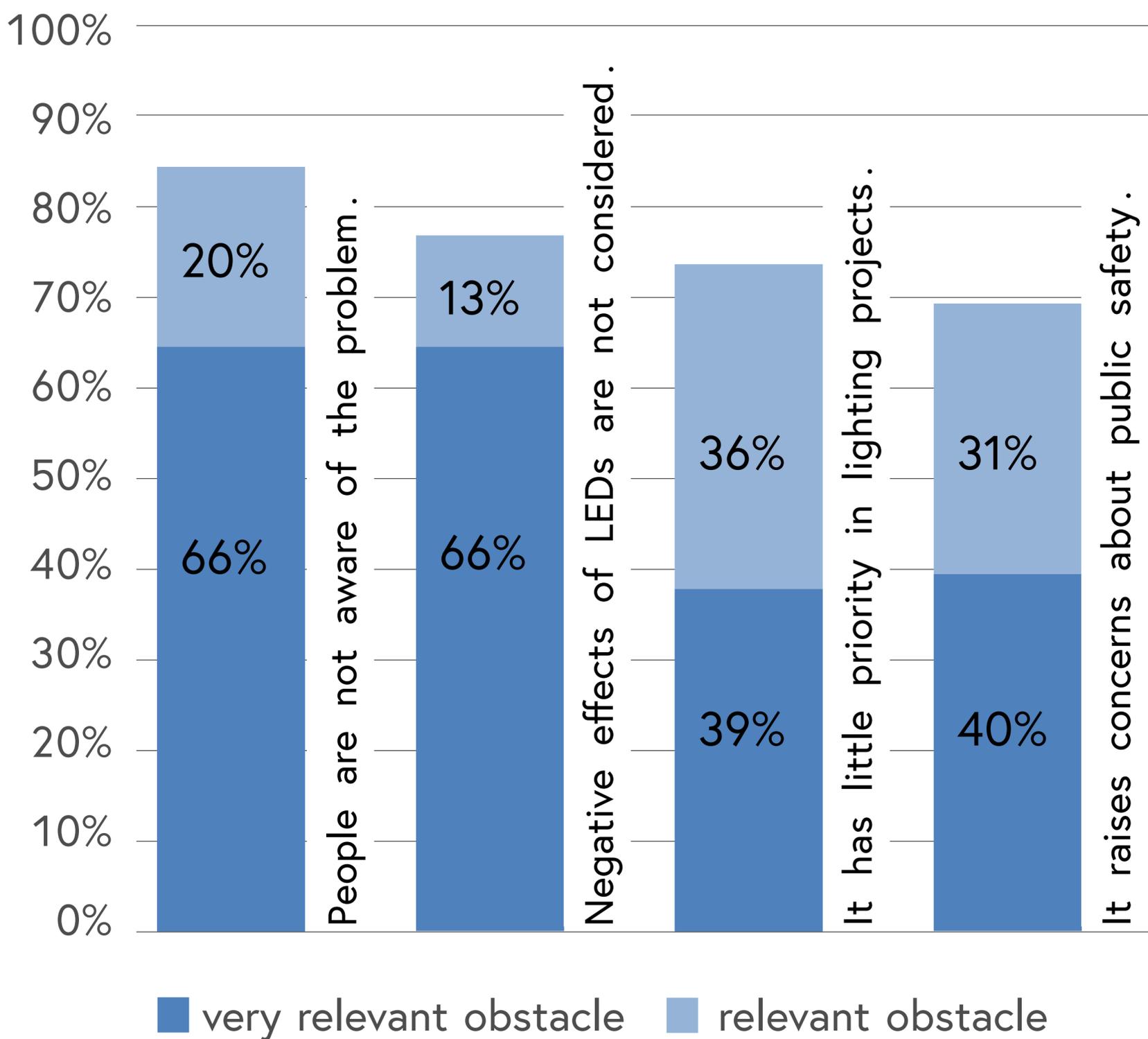
A Portuguese astrophysicist highlights the critical role of major energy providers and distribution companies that are in charge of public lighting infrastructure and “promote their own white LEDs, define standards for lighting and present advantageous maintenance plans to the municipalities”. Indeed, public-private partnerships play a crucial role in the procurement and use of lighting technology that has not yet been reflected in discourses on light pollution.

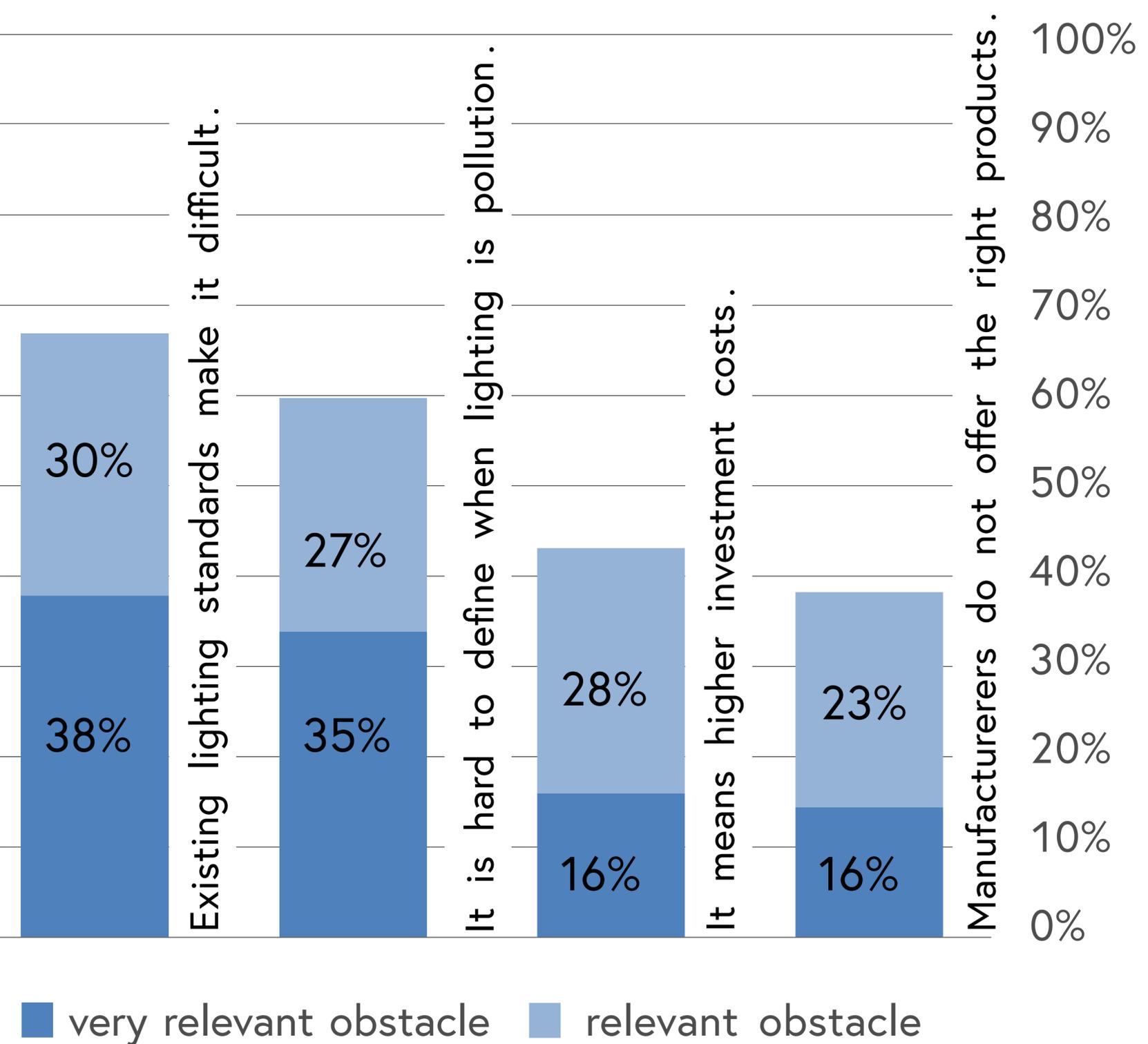
Given the number of potential obstacles to light pollution mitigation, we asked the survey participants to evaluate the relative importance of the most obvious ones, including the above-mentioned safety concerns and LEDs. People’s lack of awareness was rated as the key problem.

# The dilemma – where interests clash

## Multiple barriers to light pollution mitigation

Why is it so difficult to tackle light pollution?





**Figure 8:** How relevant are the following potential obstacles in reducing/avoiding light pollution in practice? Percentages of respondents that answered "relevant" or "very relevant".

# The dilemma – where interests clash

## Demand for lighting versus demand for darkness

**Even if people are aware of the negative side effects of artificial light at night, they may still find illumination necessary or desirable.** The survey explored where such demands clash. A biologist from Australia states that wildlife protection can clash with the goal of providing efficient safety lighting in industrial workplaces and outlines how this could be dealt with: “Industrial lighting for liquefied natural gas plants must be intrinsically safe, so this restricts the types of lights that can be used. Traditionally, high-pressure sodium and fluorescent lights are used. These lights have delays in strike time, warm up and warm down time and so it is necessary to keep them on all night, even when operators are not in the plant (they might do three-hourly checks, but the lights stay on all night). So, smart LED lighting technology is the solution to this problem – motion sensors, dimming, color, etc.”

*“In my opinion, there’s no interference, except for maybe when an observatory is located nearby. However, I believe lighting regulations do specify light levels that are frequently too high...and over the years we have become accustomed to having so much light.”*

**Lighting designer, Italy**

A respondent who helps distribute microfinanced solar and lighting systems in East African countries describes “culturally different perspectives on the benefits of lighting”. She argues that “rural East Africans really like ‘modern’ looking bright neon white light, also outside as security lights, or as blinking lights to deter predators (such as lions) near national parks. The tourism industry and Western tourists, on the other hand, prefer dark skies and being able to experience the stars in uninterrupted nature.”

A lighting designer wonders: “What if the existing city lighting is all upward directed, and those fixtures are part of the city’s identity?! When too much has to get changed to make it dark-sky compliant, it probably won’t happen.” She also points to a paradoxical clash of interests: “There is often a disconnect between what the client says they want and the design they choose (e.g. with competitions). This might be because of a lack of prioritization and/or an expert on the team.”

# The dilemma – where interests clash What about light art?

**A Spanish astronomer reminds us that conflicts of interest can also have temporary causes: “At several times of the year, such as Christmas, or during carnivals or local festivals in cities or villages, there is an enormous waste of light that citizens don’t want to give up.”**

Last but not least, a German chronobiologist raises the issue of light art: “There is also the issue of light installations in art, e.g. the Tribute in Light. Such installations need to be evaluated. In most cases, the prevention of light pollution should be more important than art.”

Birds attracted by the 9/11 memorial installation, see:  
<https://www.allaboutbirds.org/9-11-tribute-in-light-birds-night-migration/>

Photo © John de Guzman



"Tribute in Light" memorial New York, USA

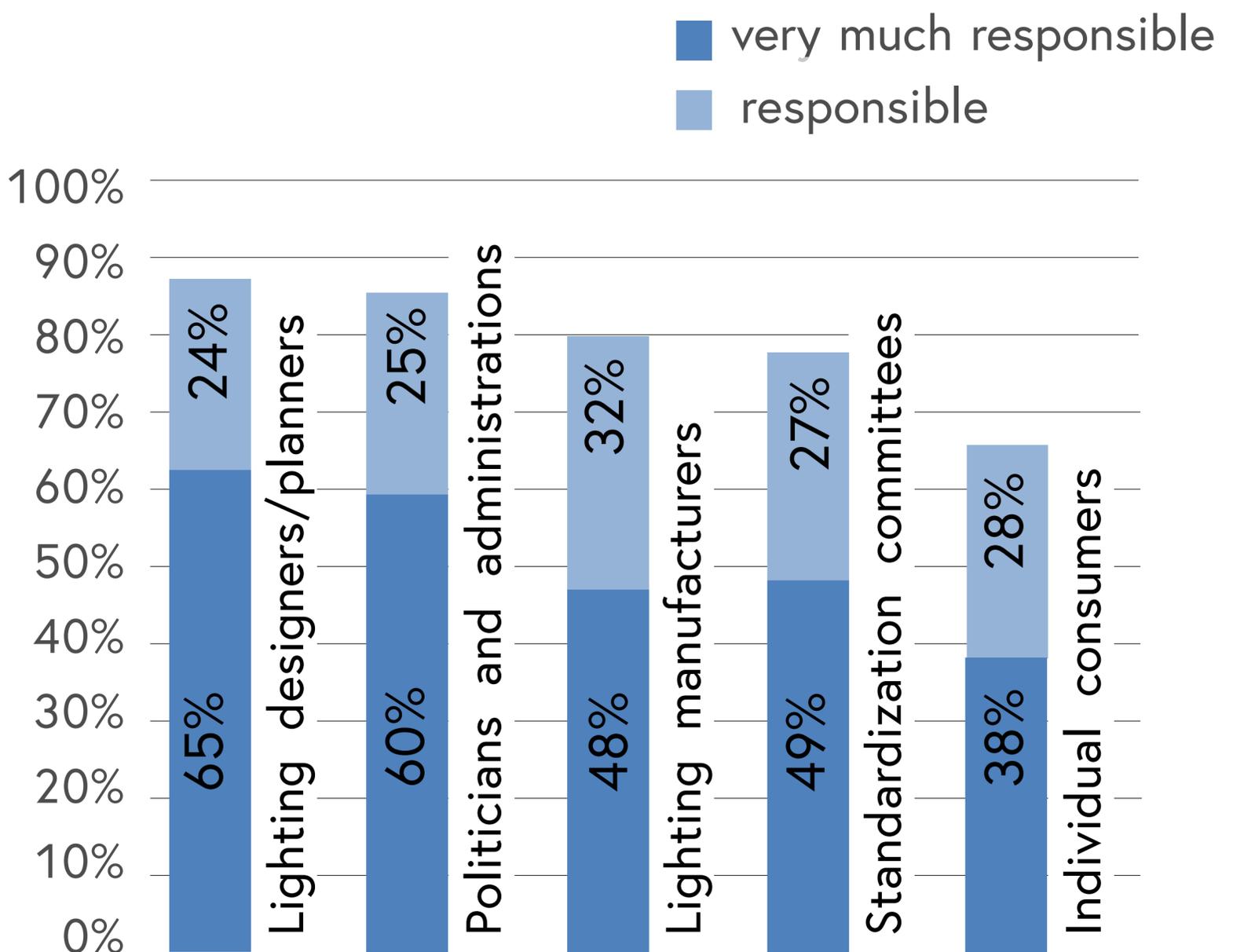
# The way forward

## Who should solve the issue of light pollution?

*“Everyone is responsible! Manufacturers, designers, planners, politicians and especially citizens!!”*

This statement from a French respondent nicely sums up the feedback we received to the question of who is responsible.

### Who is responsible?



**Figure 9:** To which degree are the following actor groups responsible for reducing/avoiding light pollution? Percentages of respondents that answered "very much responsible" or "responsible".

**70% of the survey participants assume individual responsibility** by actively reducing lighting in their light-related projects or private lives, by sharing information on the subject with citizens, colleagues and decision-makers or by contributing to luminaire designs and product choices. A US astrophysicist has “helped communities develop outdoor lighting plans, laws and codes to conserve energy and protect the night-time environment”. A representative of the Office for the Protection of the Sky of Northern Chile (OPCC) provides “technical support to municipalities, regional governments and industry”.

A Canadian dark-sky activist helped create a “conceptual design for a new type of efficient, effective luminaire”. The 2200 Kelvin LEDs “meet health concerns”, place “sufficient light only where it is required on streets and sidewalks” and are “controlled by computers and sensors”. Lighting designers with international projects in France, Russia, China and the USA explain that they “now always propose a dark infrastructure within our Lighting Master Plan studies”, as well as “diverse lighting temporalities depending on night usage”.

A Canadian astronomer contributes to data production initiatives (see appendix), arguing that “efforts to curb light pollution are hampered by a lack of data”, especially on light-related energy consumption and costs.

# The way forward

## Experts recommend leading by example and education

**On the whole, the survey participants were appreciative of any type of measure to reduce light pollution.** They generally demonstrated strong support for all the light pollution measures we asked them to evaluate. There is a broad consensus among respondents: 95% strongly or very strongly recommend the promotion of best practice. Similarly, investments in people's expertise and education – for both lighting professionals and light users – are strongly supported by over 90% of the respondents (see Figure 10).

The survey participants consider personal education more promising than transforming institutions or establishing lighting standards and legal frameworks.

**The emphasis on education mirrors the dominant view that a lack of awareness is the greatest obstacle to light pollution mitigation.** Yet, the results also reveal slight contradictions. Although more than 90% of the respondents prioritize individual education, only 65% recommend improved voluntary standards that can offer guidance and support knowledge transfer. Although many of them suggest in open statements

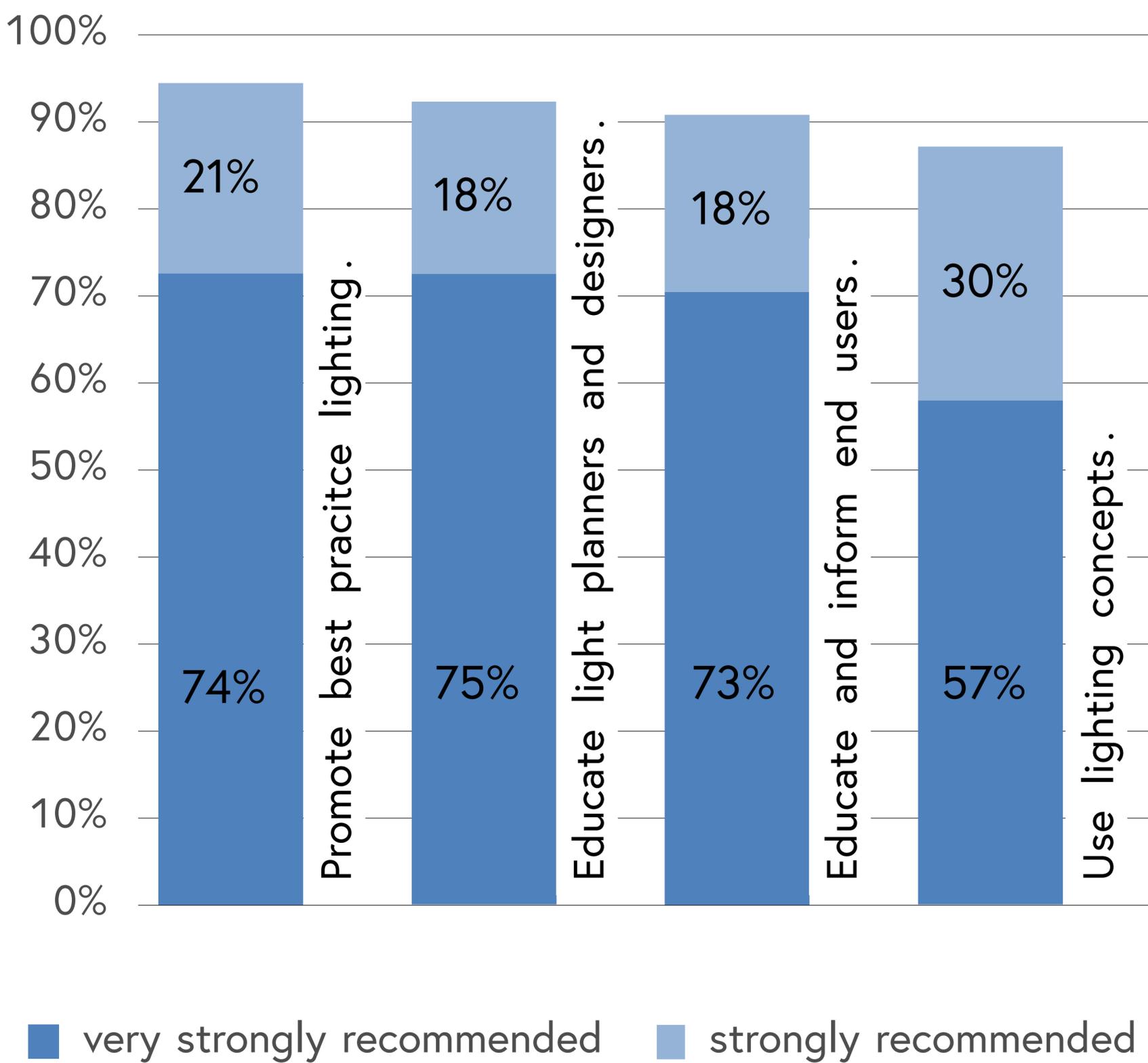
that light pollution is a systemic problem, there is a broad consensus for individualizing the solutions by educating and informing end users. On the other hand, education is a ‘no-regret’ solution and can be seen as an indispensable accompaniment to legal frameworks and voluntary standards.

**We were overwhelmed by the number of best practice examples from around the world that the survey participants shared with us (117 responses).** They include installations and lighting projects, dark-sky friendly luminaires and examples of local communities in which people come together to discuss and find sustainable lighting solutions (see Figure 11).

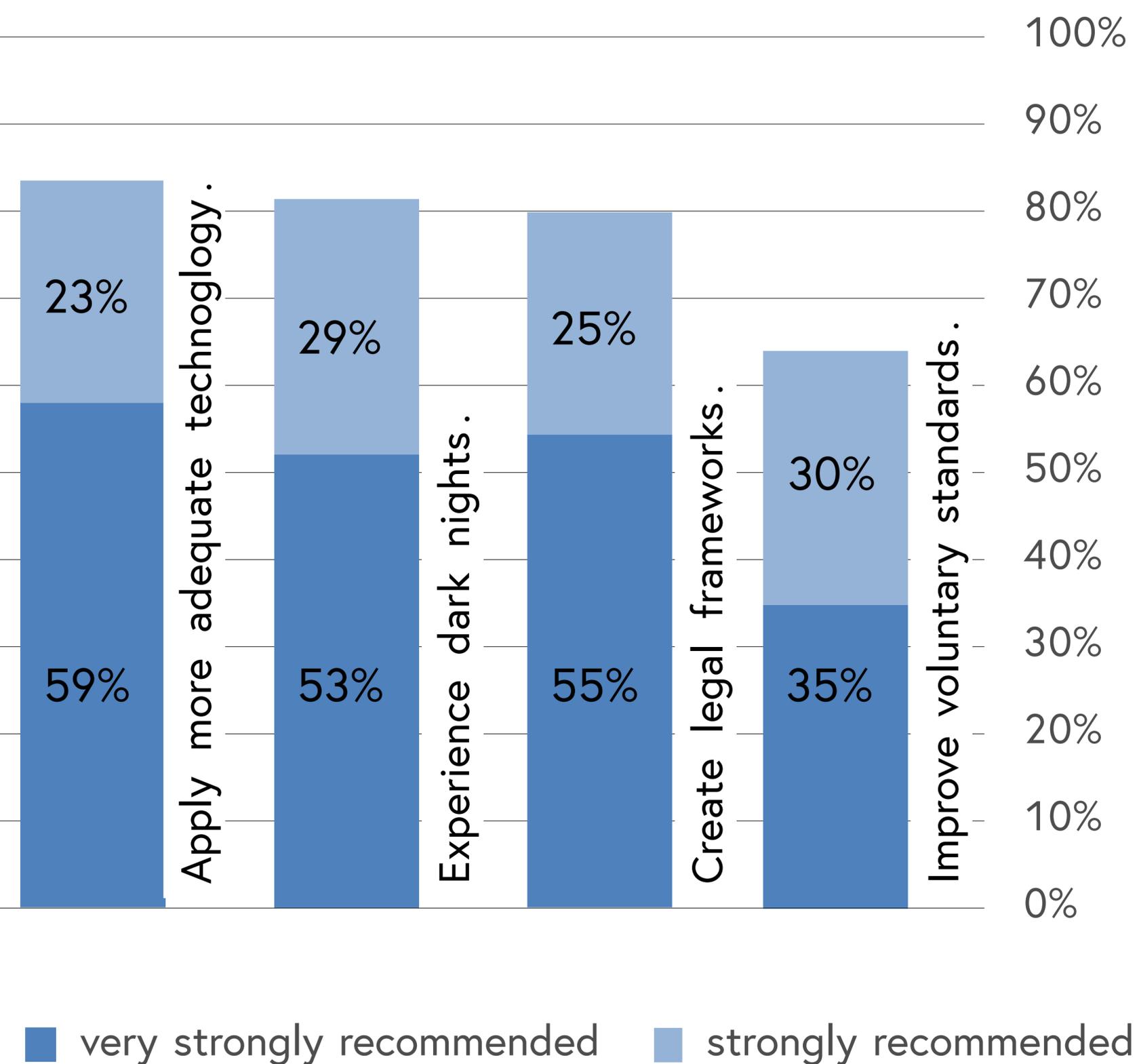
# The way forward

## Experts recommend leading by example and education

What should be done?



**Figure 10:** To which extent would you recommend the following measures to reduce/avoid light pollution? Percentages of respondents who "very strongly recommend" or "strongly recommend" the proposed measures.



# The way forward

## Best practices worldwide

London, UK

The illuminated river project will light up several new bridges and has asked several environmental organisations such as the London Wildlife Trust and the Zoological Society of London to provide advice for the project.

Stratford-upon-Avon,  
United Kingdom

The commemorative garden for Shakespeare has been illuminated with a low light level strategy.

Scott Monument,  
Edinburgh, Scotland

The monument has been illuminated with a sensitive distribution of lights where needed.

Cardiff, UK

Wales has made a strong effort to protect its night skies with many initiatives.

Canary Islands

La Palma introduced a law on light pollution in 1988 and the city of Los Realejos on Tenerife also has lighting regulations.

Rennes, France

The lighting masterplan from 2012 has an emphasis on darkness in town.

Alquines, France

One of the 574 communities in France that has been awarded ANPCEN's "star-filled community" certifications since 2009.

Sherbrooke, Canada

The area of Mont Megantic became the very first IDA-certified Dark Sky Reserve in 2007.

Fort Collins, Colorado

The National Park Services has issued an illustrated guideline to inform national parks about best practices.

Flagstaff, USA

World's first Intl' Dark Sky City since 2001, Dark Sky Movement since 1958.

Zona Norte, Chile

The Office for the Protection of the Skies of Northern Chile (OPCC) is a joint effort of many institutional partners.

**Figure 11:** Can you give an example of a lighting application that reduces/avoids light pollution in an ideal way? Selected examples and additions by the authors. More data available at: [www.ufz.de/light-pollution](http://www.ufz.de/light-pollution)



# The way forward

## The mobilizing power of experiencing a dark sky

**The survey reveals that the participants' perception of the problem and appreciation of natural darkness is closely linked to their love of star-filled night skies.** When we asked them what had brought the topic of light pollution to their attention, more than one third of the 177 respondents who answered that question explained that stargazing and astronomy raised their awareness. A lighting professional from Australia argues: **“WW drive reductions in light pollution we need to first establish the desire to do so, that is, an acknowledgement of the problem.”** Several survey participants suggest that all initiatives for reducing light pollution depend on a shared recognition of the issue, as the followings quote suggests:

*“Exposing the public to true dark skies can be an incredibly shocking experience for them, inspiring awe and a call to action. These people are the foundation of change ...”*

**Aerospace engineer, USA**



NamibRand Nature Reserve, Namibia

The way forward  
Visions for a darker future

*“My vision is a massive blackout so that people see the beauty of the night sky.”*

Coordinator of a Dark Sky Reserve, Germany

*“I offer triple E: Education about costs and benefits of lighting, Experiences of pleasant darkness, Enforcement of more stringent legislation.”*

Dark-sky educator, Finland

*“Turn the lights off in parks and have motion sensors on them. Turn off office lights at night. Do not make residential streets as bright as parking lots. Fully shield parking lot lights. Turn them off when business is closed.”*

Activist against blue-rich light at night, USA

The way forward  
Visions for a darker future

*“All lighting shall be of warm-white or amber color. I would like to see an EU Directive on the prevention of light pollution.”*

Environmental scientist, Malta

*“[My vision is] to have well thought out and discussed lighting master plans in place.”*

Lighting project manager, South Africa

*“The smart city is the future, with networks of intelligent sensors, with online interfaces and the Internet of Things (IoT).”*

Lighting designer, Romania

The way forward

Visions for a darker future

*“I would suggest that people should use LED technology better than they do today. And hire a lighting designer!”*

Lighting designer, Italy

*“Develop standards at United Nations level for recommended minimum lighting levels. Have a dedicated UN committee on light pollution.”*

Airglow researcher, Australia

A vertical photograph of a night sky filled with numerous stars. The stars are concentrated in the upper half of the image, appearing as a dense field of light points. The lower half of the image shows a dark, silhouetted landscape with a cityscape visible in the distance, illuminated by warm, yellowish lights. The sky transitions from a deep blue at the top to a lighter, hazy glow near the horizon.

*Thank you for continuing  
the discussion.*



El Roble, Vista Santiago, Chile

# Appendix

## About the authors

### Dr. Nona Schulte-Römer



Nona Schulte-Römer works as a researcher in the Department of Urban and Environmental Sociology at the Helmholtz Centre for Environmental Research – UFZ in Leipzig, Germany. She has a background in theater, cultural theory and journalism. She developed her sociological interest in light and cities at the WZB Berlin Social Science Center, where she studied the introduction of LED street lighting in her PhD project **"Innovating in Public", 2015, TU Berlin.** In her current work she focuses on light pollution, chemicals in the environment and what she calls the "sensory governance" of environmental problems.

### Dipl.-Ing. Etta Dannemann



Etta Dannemann works on bridging the gap between lighting design and other disciplines. She provides researchers and businesses with a practical perspective and initiates communication projects about lighting. After her studies in Architecture and Urbanism at TU Berlin and five years of experience as a lighting designer at Dinnebier + Blieske in Berlin, Etta worked as a "lighting designer in residence" with the R&D and marketing departments of Philips Color Kinetics, Burlington, MA, USA. She is especially interested in how lighting aspects can contribute value to other disciplines.

**[www.studiodannemann.com](http://www.studiodannemann.com)**

## Dipl.-Ing. Josiane Meier



Josiane Meier is an independent researcher and PhD candidate at the Technical University of Berlin (TU Berlin). With a background in urban and regional planning, she is particularly interested in understanding different societal views on artificial lighting as an essential component for the development of sustainable lighting policies and planning practices. She is the lead editor of **Urban Lighting, Light Pollution and Society**, Routledge, 2015, the first comprehensive volume on lighting and light pollution from a social sciences and humanities perspective, as well as an active member of the European research network **LoNNe** (Loss of the Night Network).

# Credits

**We would like to thank:**

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**SoSciSurvey and Flowpaper.com** for making their helpful software products available, and **Wikimedia and the creative commons movement** for their sustained commitment to sharing knowledge and media.

# List of images

## Title image

P. 1–2 **Light pollution, Anittepe, Turkey** | wikimedia commons | © partunc | CC-BY 3.0

## Contents

P. 4 **Lights on the river in Frankfurt/Main, Germany** | pixabay | free use

## The first discussion

P. 31–32 **Image of the Milky Way with the Gran Telescopio Canarias (GTC) at the Roque de los Muchachos Observatory (Garafía, La Palma).** | © Daniel López, Instituto de Astrofísica de Canarias (IAC)

P. 38 **Street lighting, Santa Cruz de La Palma, Canary Islands** | © IAC-OTPC, Javier Diaz

P. 49 **Atacama Desert, Chile** | © Maria Cirano

P. 54 **Atacama Desert, Chile** | © Maria Cirano

P. 63 **NamibRand Nature Reserve, Namibia** | © Wolwedans, NamibRand Safaris

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## The second discussion

P. 75–76 **Theme image for light color choice** | Source: Reddit user "alreadytakenusername"

P. 82 **Insects flying around a light at night** | wikimedia commons | © Vaishak Kallore | CC BY 3.0

- P. 86 **Street light replacement, 5700K, Germany**  
© Institute for lighting technology, Darmstadt
- P. 92 **Environmentally sensitive lighting, 1600 K, Grand Canyon, USA** | © Dan Roedeker/Clanton Associates
- P. 98 **Street Lighting National Programme, 5700K, India** | © EESL
- P. 103 **Street Lighting National Programme, 3000K, India** | © EESL
- P. 111 **PC amber light after replacement of 4000K street light, Sherbrooke, Canada** | © Remi Boucher/Mont-Megantic Dark-Sky Reserve

## **The third discussion**

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- P. 184 **Stadium lights** | [wikimedia commons](#)  
| © Leon Brooks | CC BY 3.0
- P. 198 **Birds attracted by the "Tribute in Light" memorial, New York, USA** | [allaboutbirds.org](#)  
| © John de Guzman
- P. 208 **NamibRand Nature Reserve, Namibia**

## List of figures

- Figure 1: **Participant numbers per country, P. 171-172**
- Figure 2: **The survey participants' main occupations in percentages. P. 174**
- Figure 3: **When did you first hear about light pollution? Group-specific responses in total numbers. P. 176**
- Figure 4: **In which situations does light constitute pollution? The answers of 139 respondents to multiple-choice questions (several answers possible). P. 179-180**
- Figure 5: **Light is pollution, when the color temperature is above...." P. 180**
- Figure 6: **How important do you find the following potential negative effects? Percentages of respondents who rated the concerns listed above as "very important" or "important". P. 181**
- Figure 7: **Can you give an example of a situation in which a person or group publicly complained about lighting?**  
The map shows a selection of places where respondents reported lighting controversies.  
P. 185/186
- Figure 8: **How relevant are the following potential**

**obstacles in reducing/avoiding light pollution in practice?** Percentages of respondents that answered "relevant" or "very relevant".  
P. 193-194

Figure 9: **To which degree are the following actor groups responsible for reducing/avoiding light pollution?** Percentages of respondents that answered "very much responsible" or "responsible". P. 199

Figure 10: **To which extent would you recommend the following measures to reduce/avoid light pollution?** Percentages of respondents who "very strongly recommend" or "strongly recommend" the proposed measures. P. 203-204

Figure 11: **Can you give an example of a lighting application that avoids or reduces light pollution in an ideal way?** Selected examples out of 117 Responses P. 205-206

All **maps** created by Ilka Fugmann and Josiane Meier on a basis provided by Andreas Karsten and Josiane Meier  
All **figures** © Helmholtz Centre for Environmental Research – UFZ

# Discussion background

The following information relates to themes of the three expert discussions in the first part of this book. Internet links were retrieved and last accessed in November 2018.

## Examples of dark-sky protection – discussion #1

- The IDA's International Dark Sky Places (IDSP) Program was established in 2001.  
<http://darksky.org/our-work/conservation/idsp/>
- NamibRand Nature Reserve is Africa's only International Dark Sky Reserve.  
<http://www.namibrand.com/dark-sky.html>
- Noche Zero international and interdisciplinary initiative: Facebook: <https://www.facebook.com/groups/116913745047604>  
Overview with video: [https://lightcollective.net/do/project\\_detail/noche\\_zero](https://lightcollective.net/do/project_detail/noche_zero)
- The Canary Islands' Sky Quality Protection Office OTPC was set up by the Instituto de Astrofísica de Canarias (IAC) in January 1992.  
<http://www.iac.es/servicios.php?op1=28&lang=en>
- Canarian Observatories Updates (Cups) 1-2013; Oficina Técnica para la Protección de la Calidad. Technical background information about the choice of the OTPC for PC Amber LED for street lights in La Palma.  
<http://www.iac.es/adjuntos/cups/cup2013-1.pdf>

# Street lighting color temperature – discussion #2

- **Loss of the Night Network (LoNNe)**  
<http://www.cost-lonne.eu/recommendations/>  
Recommendations on how to reduce LP and assessments of existing guidelines (e.g. EN 13201). Light sources under 3000K are recommended
- **Vinh, Quang Trinh, Bodrogi, P. & Khanh, T.Q. (2018). Preliminary Measure for the Characterization of the Usefulness of Light Sources.** In: Optics Express, Vol. 26, No. 11: 14538 <http://tubiblio.ulb.tu-darmstadt.de/95034> A proposition for a "usefulness metric" redefining efficiency, based on the spectrum of light sources and their suitability for to the given task.
- **IDA-IES Model Lighting Ordinance (MLO) with User's Guide** June 15, 2011 – featuring lighting zones (LZ0-4) and BUG rating system <https://www.ies.org/product/model-lighting-ordinance-mlo-with-users-guide>  
Light color is not mentioned but has been added by communities, often as 3000K recommendation.
- **Handbook on Quality Control for Street Lighting projects of EESL, August 2017** [http://eeslindia.org/content/raj/eesl/en/Programmes/SLNP/Handbook\\_on\\_Quality\\_Control.html](http://eeslindia.org/content/raj/eesl/en/Programmes/SLNP/Handbook_on_Quality_Control.html) The handbook features color temperatures between 5000 and 5700K.

# Commercial lighting laws and guidelines – discussion #3

- **Italy:** Overview of laws against light pollution in 15 Italian regions by ISTIL <http://www.lightpollution.it/cinzano/en/page95en.html>
- **Shanghai:** The Shanghai Municipal Bureau of Quality and Technical Supervision (<http://english.shzj.gov.cn/>) offers local guidelines for controlling urban lighting (2012): [http://sh.lhsr.cn/Plugins/ueditor1\\_2\\_5\\_1-utf8-net/net/upload/2015-02-15/b284700d-5ad7-4323-b551-8fabff26bc18.pdf](http://sh.lhsr.cn/Plugins/ueditor1_2_5_1-utf8-net/net/upload/2015-02-15/b284700d-5ad7-4323-b551-8fabff26bc18.pdf)  
Public information about light pollution by the municipal government in 2008: <http://www.shanghai.gov.cn/shanghai/node27118/node27881/node27945/node27947/userobject22ai28751.html>
- **EU Green Public Procurement Program**  
Promoting good practice for 'greening' a public tender or procurement process. [http://ec.europa.eu/environment/gpp/index\\_en.htm](http://ec.europa.eu/environment/gpp/index_en.htm)
- Morgan-Taylor, M. (2015). **Global Approaches to Legislation for Light Pollution**. 1st International Conference on Sustainable Lighting and Light Pollution, Seoul 2014; proceedings, p. 80-89. <https://www.dora.dmu.ac.uk/xmlui/handle/2086/13545>

# General background

The following information includes information that was shared by the survey participants and discussion experts.

## Selected recommendations for lighting practices

- CIE, the Commission Internationale de l'Eclairage, offers a guide on the limitation of obtrusive light from outdoor lighting installations <http://www.cie.co.at/publications/guide-limitation-effects-obtrusive-light-outdoor-lighting-installations> as well as guidelines for minimizing sky glow: <http://www.cie.co.at/publications/guidelines-minimizing-sky-glow>
- ILP, the Institution of Lighting Professionals in the UK, provides free guidance notes for the reduction of obtrusive light <https://www.theilp.org.uk/documents/obtrusive-light/> and offers professional lighting design guides on The Brightness of Illuminated Advertisements <https://www.theilp.org.uk/resources/ilp-general-reports/plg05-the-brightness-of-illuminated-advertisements/>
- LEED – Leadership in Energy and Environmental Design, the international green building rating system, incentivizes the reduction of light trespass, sky-glow and glare: <http://www.usgbc.org/credits/ss8>

# A look at the legislation

## International

- The Loss of the Night Network (LoNNe) provides information on Legislation for Public Outdoor Lighting in the EU, including a list of countries with lighting legislations. <http://www.cost-lonne.eu/legislation/>
- An international report by the consultancy Parsons Brinckerhoff commissioned in 2009 by the Environment Bureau of Hong Kong, China, offers information on a number of Overseas Practices in Guiding and Regulating External Lighting. [https://www.enb.gov.hk/sites/default/files/en/node67/guiding\\_regulating.pdf](https://www.enb.gov.hk/sites/default/files/en/node67/guiding_regulating.pdf)
- National or regional legislation by country in alphabetical order. This list is inevitably incomplete and limited by the availability of English-language information.

## China (see third discussion)

Chinese municipalities are exploring voluntary and binding schemes for governing external lighting, including landscape illuminations and commercial lighting. See for instance:

- Shanghai: <https://www.shine.cn/news/metro/1711015734/>
- Guangzhou: [http://www.china.org.cn/environment/2010-04/22/content\\_19879268.htm](http://www.china.org.cn/environment/2010-04/22/content_19879268.htm)

## France

The French Ministère de la Transition écologique et solidaire offers an overview of the French regulation on light pollution, including the law of the Grenelle Environment, the French energy transition law and the biodiversity law. The legislation is flanked by educational measures like the Day of the Night (le Jour de la Nuit) and the competition Villes et Villages étoilés, organized biannually by the Association nationale pour la protection du ciel et de l'environnement nocturnes (ANPCEN). Infopage in French: <https://www.ecologique-solidaire.gouv.fr/pollution-lumineuse>

## Hong Kong

The Hong Kong Environment Bureau commissioned a Task Force on External Lighting to explore the possibility of binding law. In 2015, it recommended a "multi-pronged approach" [https://www.enb.gov.hk/sites/default/files/en/node3521/TFEL\\_Report\\_Eng.pdf](https://www.enb.gov.hk/sites/default/files/en/node3521/TFEL_Report_Eng.pdf) including the promotion of good practices, public education and campaigns, monitoring and reporting. A voluntary Charter on External Lighting <http://www.charteronexternallighting.gov.hk/en/index.html> is accompanied by Guidelines on Industry Best Practices for External Lighting Installations: [https://www.enb.gov.hk/en/resources\\_publications/guidelines/files/guidelines\\_ex\\_lighting\\_install\\_eng.pdf](https://www.enb.gov.hk/en/resources_publications/guidelines/files/guidelines_ex_lighting_install_eng.pdf)

## Italy (see third discussion)

- The Istituto di Scienza e Tecnologia dell'Inquinamento Luminoso (ISTIL), represented by Pierantonio Cinzano,

provides an overview of laws against light pollution in 15 Italian regions. Information platform in English: <http://www.lightpollution.it/cinzano/en/page95en.html>

- The region of Lombardy is one example with its 2015 Legge Regionale. Law in Italian: [http://cielobuio.org/cielobuio/leggi/LR\\_Lombardia\\_31\\_15.pdf](http://cielobuio.org/cielobuio/leggi/LR_Lombardia_31_15.pdf)

## Slovenia

Dark-Sky Slovenia representative Andrej Mohar gives an "unofficial, shortened summary" of the 2007 Slovene Light Pollution Law on the website Dark Skies Awareness: <http://www.darkskiesawareness.org/slovene-law.php>

## South Korea

The Korean Light Pollution Prevention Act offers guidelines for the proper management of light pollution. Scientific articles discuss the approach:

- Cha, J. S., Lee, J. W., Lee, W. S., Jung, J. W., Lee, K. M., Han, J. S., & Gu, J. H. (2014). Policy and status of light pollution management in Korea. *Lighting Research and Technology*, 46(1), p. 78–88.  
<https://doi.org/10.1177/1477153513508971>
- Morgan-Taylor, Martin & Kim, J. T., Morgan-Taylor, M., & Kim, J. T. (2016). Regulating Artificial Light at Night: A Comparison Between the South Korean and English Approaches. *International Journal of Sustainable Lighting*, 35(1), p. 21-31.  
<https://doi.org/10.26607/ijsl.v18i0.18>

## Spain

- The Instituto de Astrofísica de Canarias (IAC) outlines the 1988 Spanish Law for the Protection of the Astronomical Quality of the IAC Observatories (Law 31/1988, pdf). In 1992, the Spanish government approved the regulations for the law (R.D. 243/1992, pdf). <http://www.iac.es/servicios.php?op1=28&lang=en>
- The Catalan Sustainability Department of the Generalitat de Catalunya (2012) offers information on light pollution, including an overview of regional legislation, recommendations and education initiatives. Infopage in Spanish: [http://mediambient.gencat.cat/ca/05\\_ambits\\_dactuacio/atmosfera/contaminacio\\_luminica](http://mediambient.gencat.cat/ca/05_ambits_dactuacio/atmosfera/contaminacio_luminica)

## UK

- The Commission for Dark Skies of the British Astronomical Association (BAA) provides insights into Light Pollution and the Law, including a comparative view on British dark-sky legislation and references for further reading. Information platform in English: [https://www.britastro.org/dark-skies/cfds\\_advice.php?topic=law](https://www.britastro.org/dark-skies/cfds_advice.php?topic=law)
- For a comparative study of UK legislation on light pollution see: Youyuenyong, P. (2015). Comparative Environmental and Planning Law Relating to Light Pollution Control in England and Other Jurisdictions (Doctoral Thesis). De Montfort University, Leicester. Retrieved from <https://www.dora.dmu.ac.uk/xmlui/handle/2086/11434>

## USA

Over 18 U.S. states have passed dark-sky legislation. Numerous municipalities have adopted light pollution regulations as part of their zoning codes.

<http://www.ncsl.org/research/environment-and-natural-resources/states-shut-out-light-pollution.aspx-#State%20Legislation>

# Research clusters, networks and initiatives – a selection

- ALAN (Artificial Light at Night) International Conference Series: <http://artificiallightatnight.org>
- Astrolab du Mont-Mégantic: Light Pollution Theory modeling and measurements meeting, dark-sky atlas: <http://astrolab-parc-national-mont-megantic.org/en/>
- Collectif de recherche RENOIR (Ressources environnementales nocturnes & territoires): <https://renoir.hypotheses.org/1>
- Consortium for Dark Sky Studies, the University of Utah, Salt Lake City, Utah: <http://darkskystudies.org/>
- European Loss of the Night Research Network (EU Cost Action ES1204): <http://www.cost-lonne.eu>
- Globe at Night, an international citizen-science campaign to raise public awareness of the impact of light pollution by inviting citizen-scientists to measure their night sky brightness and submit their observations from a computer or smartphone: <https://www.globeatnight.org/maps.php>
- Hong Kong Night Sky Brightness Monitoring Network (NSN): <http://nightsky.physics.hku.hk/globeatnight/global-at-night-monitoring-network.html>

- Loss of the Night transdisciplinary research consortium (Verlust der Nacht: <http://www.verlustdernacht.de/>) and monitoring at Leibniz Institut für Gewässerökologie und Binnenfischerei (IGB Stechlin): <https://www.igb-berlin.de/monitoring/stechlin>
- LED research project Communes in New Light: <https://www.photonikforschung.de/projekte/beleuchtung-und-led/foerdermassnahme/kommunen-in-neuem-licht.html>
- The Spanish light pollution research network, Red Española de Estudios sobre la Contaminación Lumínica (REECL), brings together researchers from different disciplines and different Spanish institutions to facilitate interdisciplinary exchange and collaboration in scientific research on light pollution. Website in Spanish: <http://guaix.fis.ucm.es/reecl/>
- Stars4all Initiative: Comprehensive awareness platform on light pollution. <http://stars4all.eu>
- Skyglow measurements: Citizen Science Projects and Data: <http://www.myskyatnight.com/#map>
- Trinity College Dublin. Just How Bright Are We? Look at the Astronomical Costs of Our Light Pollution. [http://www.tcd.ie/news\\_events/articles/just-how-bright-are-we-look-at-the-astronomical-costs-of-our-light-pollution/5495](http://www.tcd.ie/news_events/articles/just-how-bright-are-we-look-at-the-astronomical-costs-of-our-light-pollution/5495)

# Organizations in the field

The participants in our three expert discussions and world-wide survey were associated with a number of organizations and initiatives, including astronomical, light-related, environmental, and dark-sky associations and groups. We have listed them in alphabetical order by continent and country.

## International

- Concepteurs Lumière sans Frontières (LSF): [www.concepteurslumieresansfrontieres.org/](http://www.concepteurslumieresansfrontieres.org/)
- Global Off Grid Lighting Association (GOGLA): <https://www.gogla.org/the-voice-of-the-off-grid-solar-energy-industry>
- International Association of Lighting Designers (IALD): <https://www.iald.org/>
- International Astronomical Union (IAU): <https://www.iau.org/>
- International Commission on Illumination (CIE): <http://www.cie.co.at/>
- International Dark-Sky Association, including IDA local chapters: <https://www.darksky.org/>
- International Union for Conservation of Nature (IUCN), Dark Skies Advisory Group: <http://darkskeyparks.org/dark-skies-and-nature-conservation/>
- LightAware – responding "to the needs of those whose lives and health have been profoundly affected by the ban on incandescent lighting and the development of new forms of light" <http://lightaware.org/>

- Lightmare – "fighting the growing road safety issue of blinding lights which diminish a driver's ability to perceive hazards" <http://www.lightmare.org/>
- Loss of the Night Network (LoNNE): <http://www.cost-lonne.eu/>
- Starlight Foundation and Initiative: <http://fundacionstarlight.org/>
- Stars4all Initiative: <http://stars4all.eu>
- Zoological Lighting Institute: <https://www.zoolighting.org/mission>

## Africa

### Tunisia

- Astronomical Society of Tunisia (IAU): <https://directory.iau.org/directory/934>

## Asia

### Japan

- Lighting Detectives: <http://shomei-tanteidan.org/en/welcome/>

### China

- Chinese Lighting Designer Association (CLDA): <http://www.alighting.cn/special/clda/en.htm>

# Europe

## Czech Republic

- Czech Astronomical Society: [var.astro.cz](http://var.astro.cz)

## Denmark

- Danish Lighting Center (DCL):  
<https://centerforlys.dk/english/>

## France

- Association de Concepteurs lumière et Eclairagistes (ACE): <https://www.ace-fr.org/>
- Association Française de l'Eclairage (AFE):  
<http://afe-eclairage.fr/>
- Association Nationale pour la Protection du Ciel et de l'Environnement Nocturne (ANPCEN):  
<https://www.anpcen.fr/>
- Cluster Lumière Auvergne Rhône-Alpes:  
<https://www.clusterlumiere.com/en/home-page/>
- Mountain Wilderness: <http://www.mountainwilderness.org/>

## Germany

- Gather Around Light [www.gather-around-light.net](http://www.gather-around-light.net)
- Lichttechnische Gesellschaft (LITG):  
<https://www.litg.de/>
- Verein der Sternenfreunde – Fachgruppe Dark Sky (in German): <http://www.lichtverschmutzung.de/>
- Verein Sternpark Rhön e.V.:  
<http://verein-sternenpark-rhoen.de/>

## Italy

- Associazione Professionisti dell'Illuminazione (APIL):  
<https://www.apilblog.it/>
- Agenzia Regionale per la Prevenzione e Protezione Ambientale del Veneto (ARPA):  
<http://www.arpa.veneto.it/>
- Cielo Buio: <http://cielobuio.org/>
- Ente Italiano di Normazione (UNI):  
<http://www.uni.com/>

## Ireland

- Astronomical Science Group of Ireland:  
<http://astrophysics.ie/>
- Mayo Dark Sky Park: <http://mayodarkskypark.ie/>

## Israel

- Israel Lighting Society:  
<https://www.light.org.il/en/home>

## Netherlands

- Nachtmeetnet: <http://www.nachtmeetnet.nl/>
- Platform Lichthinder: <http://www.platformlichthinder.nl/wat-is-lichthinder/>

## Romania

- Romania Green Building Council:  
<http://www.roghbc.org/en/>

## Slovenia

- Svetelne znečistenji: <http://svetelneznečistenji.cz/>
- Vihorlat Observatory:  
<http://www.visitslovakia.com/vihorlat-observatory>

## Spain

- Asociación de Astronomos Aficionados (ASAAF – UCM): <https://asaaf.org/>
- Asociación contra la Contaminación Lumínica (CELFOSC): <http://www.celfosc.org/>
- Barcelona Institute for Global Health (ISG): <https://www.isglobal.org/en>
- Calidade da noite, Galicia: <https://calidadedanoite.wordpress.com/>
- Instituto de Astrofísica de Canarias (IAC), with Sky Quality Protection Technical Office (OTPC): <http://www.iac.es/index.php?lang=en>
- Red española de estudios sobre contaminación lumínica (REECL): <https://guaix.fis.ucm.es/re ecl/>

## UK

- Blackrock Castle Observatory (BCO): <https://www.bco.ie/>
- Brecon Beacons National Park: <http://www.breconbeacons.org/stargazing>
- British Astronomical Association (BAA), Commission for Dark Skies <http://www.britastro.org/dark-skies/>
- Campaign to Protect Rural England (CPRE), Dark Skies: <http://www.nightblight.cpre.org.uk/>
- Cranbone Chase: <http://www.ccwwdaonb.org.uk/>
- Daylight Group (CIBSE): <https://www.cibse.org/networks/groups/daylight/about-the-group>
- Institution of Lighting Professionals (ILP): <https://www.theilp.org.uk/home/>
- Society of Light and Lighting (SLL): <https://www.cibse.org/Society-of-Light-and-Lighting>

# North America

## Canada

- Northeast Swale Watchers:  
<https://www.swalewatchers.org/>
- Royal Astronomical Society of Canada, Light-Pollution Abatement Committee:  
<http://www.rasc.ca/committees/lp>

## USA

- American Medical Association (AMA):  
<https://www.ama-assn.org/>
- Barnard-Seyfert Astronomical Society (BSAS):  
<https://www.bsasnashville.com/>
- California Energy Commission:  
<https://www.energy.ca.gov/>
- Illuminating Engineering Society (IES):  
<https://www.ies.org/>
- Light-Efficient Community (LEC):  
<http://www.light-efficientcommunities.com/>
- National Park Service – Natural Sounds and Night Skies Division: <https://www.nps.gov/subjects/nightskies/index.htm>
- Optical Society (OSA):  
<https://www.osa.org/en-us/home/>
- Oracle Dark Skies Committee:  
<http://www.weasner.com/ODSC/>
- Society of Automotive Engineers (SAE):  
<https://www.sae.org/>
- Transportation Research Board:  
<http://www.trb.org/Main/Home.aspx>

# Oceania

## Australia

- Astronomical Society of South Australia (ASSA): <https://www.assa.org.au/>
- Illuminating Engineering Society of Australia and New Zealand Ltd (IES): <https://www.iesanz.org/>
- Martinborough Dark Sky Association: <https://martinboroughdarksky.org/>
- River Murray Dark Sky Reserve: <https://www.rivermurraydarkskyreserve.org/>
- Sydney Outdoor Lighting Improvement Society (SOLIS): <http://www.solis.asn.au/>

## New Zealand:

- Aoraki Mackenzie International Dark Sky Reserve: <https://mackenzienc.com/scenic-highlights/dark-sky-reserve/>
- Dunedin Astronomical Society: <https://sites.google.com/site/dunedinastronomy/home>
- Royal Astronomical Society of New Zealand (RASNZ): <https://www.rasnz.org.nz/>
- Wellington Astronomical Society (WAS): <https://www.was.org.nz/>

# South America

## Chile

- Noche Zero: [https://lightcollective.net/do/project\\_detail/noche\\_zero](https://lightcollective.net/do/project_detail/noche_zero)
- OPCC, Office for the Protection of the Sky of Northern Chile: <http://opcc.cl/>

## Mexico

- Cielos Oscuros: <https://cielososcuros.org/>

# Further reading and viewing – the authors' picks

There is a growing body of information on artificial light at night and light pollution. The following is a list of the authors' must-read and must-see resources (available in English; in alphabetical order)

- Bach, Susanne & Degenring, F., Eds. (2015). **Dark Nights, Bright Lights, Night, Darkness, and Illumination in Literature.** Berlin, Boston: De Gruyter Mouton. An inquiry into the cultural meaning of night, light and darkness in 19th and 20th century literature.
- Bogard, Paul (2013). **The End of Night: Searching for Natural Darkness in an Age of Artificial Light.** New York: Little, Brown and Company. A prize-winning personal account of the disappearance of darkness through artificial lighting, with reflections on its reasons, effects, and possibilities of mitigation.
- Edensor, Timothy (2017). **From Light to Dark: Daylight, Illumination, and Gloom.** Minneapolis, MN: Minnesota University of Minnesota Press. A social-scientific exploration into societal and cultural ways of experiencing light and darkness.
- Ekirch, A. Roger (2005). **At Day's Close: Night in Times past.** New York: WW Norton & Company. A classic and incredibly rich historical perspective on light and darkness in premodern Europe.
- Falchi, Fabio, Cinzano, P., Duriscoe, D., Kyba, C. C. M.,

Elvidge, C., Baugh, K., Portnov, B., Rybnikova, N. & Furgoni, R. (2016). **The new World Atlas of Artificial Night Sky Brightness**. *Science Advances*, 2(6), e1600377. <https://doi.org/10.1126/sciadv.1600377>

A global assessment of the current extent of light pollution, including maps of continents and comparisons of countries.

- Gaston, Kevin. J., Visser, M. E. & Hölker, F. (2015). **The biological Impacts of Artificial Light at Night: The Research Challenge**. *Philosophical Transactions of the Royal Society of London B: Biological Sciences* 370(1667): 20140133. A compact overview of the state of knowledge and knowledge gaps regarding ways in which artificial light at night can affect plant and animal species.
- Longcore, Travis, Rodríguez, A., Witherington, B., Penniman, J. F., Herf, L. & Herf, M. (2018). **Rapid Assessment of Lamp Spectrum to quantify ecological Effects of Light at Night**. *Journal of Experimental Zoology Part A: Ecological and Integrative Physiology*, Volume 329, Issue 8-9. An overview of different organisms and their reaction to various lamp spectrums with the finding that blue light is most disturbing.
- **Manifesto of lighting designers for sustainable lighting projects (2016)**. <https://www.ace-fr.org/tous-les-articles/manifeste-des-concepteurs-lumiere/> (last access Nov. 2018) The charter of the association of French lighting designers (ACE) promotes responsible, human-centric lighting design that protects darkness.

- Meier, Josiane, Hasenöhrl, U., Krause, K. & Pottharst, M., Eds. (2015). **Urban Lighting, Light Pollution and Society**. Routledge: New York. A comprehensive overview of the state of research in the social sciences and humanities on artificial lighting and light pollution.
- Mt. Megantic ASTROlab (2014). **Practical Guide for Lighting**. [http://ricemm.org/wp-content/uploads/2014/04/astrolab\\_practical\\_guide\\_for\\_lighting.pdf](http://ricemm.org/wp-content/uploads/2014/04/astrolab_practical_guide_for_lighting.pdf) (last access Nov. 2018)  
Guidance for light pollution reduction with numerous best practice examples and before/after images.
- Nye, David E. (2010). **When the Lights Went Out: A History of Blackouts in America**. Cambridge, MA: MIT Press. A fascinating cultural exploration into the entanglements of light, technology and society.
- Rich, Catherine & Longcore, T., Eds. (2006). **Ecological Consequences of Artificial Night Lighting**. Washington, DC: Island Press. One of the first books that raised awareness on the wide range of impacts of artificial light on nature.
- Schivelbusch, Wolfgang (1995). **Disenchanted Night: The Industrialization of Light in the Nineteenth Century**. Oakland, CA: University of California Press. A socio-cultural history of the development of artificial illumination in the century of the early 'lighting revolutions'.
- Schroer, Sibylle, Kyba, C. C. M., van Grunsven, R., Celino, I., Corcho, O. & Hölker, F. (2018). **Citizen Science to monitor Light Pollution – a useful Tool for studying human Impacts on the Environment**.

In: Citizen Science: Innovation in Open Science, Society and Policy, edited by Susanne Hecker et al., p. 353-365. London: UCL Press. Description of a new approach to get more data about light pollution involving citizens, authored by experts from LoNNe.

- Vega, Catherine P. (2016). **The Environmental Influence of Lighting Design on Flora and Fauna.** New Perspectives on the Future of Healthy Light and Lighting in Daily Life, edited by Zielinska-Dabkowska, Karolina & Rohde, M., p. 70-77 Wismar: Callidus. Research on practical aspects of lighting design presented at Light Symposium Wismar 2016.
- Zielinska-Dabkowska, Karolina. M. (2018). **Make Lighting Healthier.** Nature, 553(7688), p. 274. <https://doi.org/10.1038/d41586-018-00568-7>  
An overview of the state of knowledge regarding linkages between artificial lighting and human health, as well as recommendations for future action.

### **Documentary films**

- Murali, Sriram, Gonzalez, J., Balasubramanian, P. & Lalkin, A. U. (2018). **Saving the Dark.** In association with IDA: [www.savingthedark.com](http://www.savingthedark.com). Documentary with global interviews about the problems associated with outdoor artificial light at night, covering dark skies, commercial lighting and the work of the IDA.
- Cheney, Ian (2011). **The City Dark.** In association with American Documentary | POV: <https://www.pbs.org/pov/citydark/> The story of a filmmaker and amateur astronomer who moves from rural Maine to New York City and explores a deceptively simple question: "What do we lose, when we lose the night?"

# Imprint

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