Alternative ways of Lighting the UNESCO Sites

Save Energy and Recover the Stars

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STARLIGHT INITIATIVE

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MaB

Roque de Los Muchachos, La Palma UNESCO Biosphere Reserve © Astrotour

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Alternative ways of lighting the UNESCO sites

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Light and the stars

Recovering our vision of the starry sky

At present most people in the world do not have the opportunity to see the Milky Way and its stars in the sky, including astronomers. The increase in light pollution is blotting out the stars from our sky, causing the deterioration of a legacy with strong cultural, scientific, environmental and aesthetic repercussions. Clear night skies also provide sustainable income opportunities as tourists and visitors are eagerly looking for sites with impressive night skies.

The skies, which have been, and are, an inspiration to all humanity, are becoming obscured and even unknown to the younger generation. An essential element of our civilisation and culture is rapidly becoming lost, and this loss will affect all countries on Earth[5].

Much as artificial lighting provides a very useful service, it has also engendered a new problem, that of light pollution. The light emitted by outdoor illumination devices has become so pervasive and is so poorly directed that in most of our urban environments it is no longer possible to see the majority of stars at night because the glare from artificial light is scattered back from the sky vault. Light pollution is not only a waste of light energy but also diminishes our perception of the wider universe.

Whereas air, noise, or water pollution have been high priority policy issues for decades, light pollution remains scientifically, culturally, and institutionally in the dark.

In response to this lack of recognition was convened in 2007 the first International Conference in Defence of the Quality of the Night Sky and the Right to Observe the Stars, hosted by La Palma biosphere reserve and promoted by IAC (Instituto de Astrofísica de Canarias) with the support of UNESCO, UNWTO, IAU, UNEP-CMS, Council of Europe, SCBD, MaB Programme, European Commission and Ramsar Convention. The Conference adopted on 20 April the Starlight Declaration containing a set of recommendations for action in defense of the night sky and launched the Starlight initiative.

The Starliight initiative was designed as an internation-

Milky Way above the Hortobágy, World Heritage © Babak A. Tafreshi

al action in defence of the values associated with the night sky and the general right to observe the stars. The final aim of the initiative is to strengthen the importance of clear skies for humankind, emphasizing and introducing the value of this endangered legacy for science, education, culture, technological development, nature conservation, tourism and, obviously, as a quality-of-life factor.

Windows to the Universe

The scientific dimension of a starry night is an essential part of the legacy of the sky. The ability of the planet's astronomical sites and observatories to detect and interpret data from outside the world we live in should be considered as a resource of extraordinary value for the progress of knowledge, as it has been throughout history. Dark skies are still the windows to our knowledge of the greater universe. Unfortunately current areas devoted to astronomical observation do not enjoy appropriate recognition and some of them are threatened by light pollution.

Present-day technical and scientific requirements restrict suitable areas to very specific and limited locations offering good conditions for the development of astronomy, and for optical and infrared astronomy in particular. There are only a few places on the planet where we find this unique combination of environmental and natural circumstances: well-conserved spaces with very little alteration to natural starlight. These exceptional sites, including their natural components, can be considered as "landscapes of science and knowledge".

Having identified the best locations for astronomical observation throughout the planet, it is critically important to try to conserve and protect them. The case of Hawaii, the Canaries, Nanmibia and northern Chile are an ensemble of discrete sites that, within this context, have outstanding universal significance as a group[13].

Starlight Reserve concept

One of the final resolutions of the Starlight Conference was to develop the Starlight Reserve concept. Following the outcomes of several meetings and workshops, like

Window to the Universe. The Gran Telescopio Canarias (GTC) in the Roque de los Muchachos, La Palma (Spain) © Daniel López

the Working Meeting "Starlight Reserve Concept" held at the UNESCO HQ in Paris in 2007, the final document was adopted during the "International Workshop and Expert Meeting on Starlight Reserves and World Heritage" held in Fuerteventura in 2009. Participants were representatives of private organizations, enterprises, the tourism industry, NGOs, scientific bodies and research stations, as well as international organizations including the UNWTO, the IAU, the UNESCO Man and the Biosphere (MAB) Programme and the UNESCO World Heritage Centre.

A Starlight Reserve is a site where a commitment to defend the outstanding nightscapes and the access to starlight has been established. Its main function will be to preserve the quality of the night sky and its associate values, whether they are cultural, scientific, astronomical, natural, or landscape-related. The final document contains a comprehensive set of recommendations on intelligent lighting and light pollution[7].

Starlight destinations

The fragile light of stars can become a new driver for sustainable tourism in unpolluted rural communities and natural areas. Astrotourism is an activity of travelers wishing to use the natural resource of well -kept nightscapes for astronomy -related leisure and knowledge. This practice has increased in popularity during the past few years, adding value to offbeat tourism destinations offering high quality night skies and astronomical or archaeoastronomical heritage.

Astrotourism epitomizes the tendencies towards more meaningful tourism experiences, based on conservation of natural resources, knowledge, and science, potentially enriching the traveler and the host communities[2].

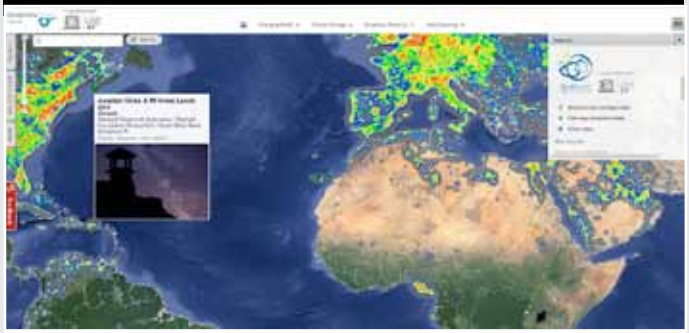
In 2009, the Starlight Foundation unveiled for the first

Stargazing in Fuerteventura biosphere reserve © Carlos de Saa

time the StarLight Tourism Certification System with the support of UNWTO. In recent years several UNESCO sites have been labelled by the Starlight Foundation as Starlight destinations, such is the case of biosphere reserves of La Palma, La Rioja, Fuerteventura, Sierra Morena (Spain), Fray Jorge (Chile) and South West Nova (Canada) or the Teide NP, the first World Herltage site labelled. Responsible lighting and light pollution control are key requeriments for the certification in these sites.

Benchmark sites - GIS web map launched on occasion of IYL2015

Interactive web map provided by BiophereSmart Initiative in partnership with UNESCO Man and the Biosphere Programme (MAB). **Click here >**



Ayui. Fuerteventura Biosphere Reserve © Carlos de Saa

Light and life

Protecting biodiversity and people's health

Light pollution has a negative effect on many species of plants and animals, including migratory species, both in protected areas and in urban or rural areas. Too much light can affect people's health, by changing circadian rhythms. Thus, reducing the emission of artificial light may help to protect biodiversity and improve health conditions for the general population.

Humans have radically transformed the physical characteristics of the nighttime hours in ways that would have been unimaginable only a hundred years ago. The cost of industrial development, affluence, and mass consumption has been the loss of natural patterns of darkness over vast expanses of the Earth's surface, both on land and at sea[6].

A substantial and growing body of research on the ecological effects of artificial night lighting is now available. The loss of quality of nocturnal skies, caused by the negative effects of atmospheric emissions and of the increased intrusion of artificial lights, has become a serious threat for many species, disturbing their habits and habitats, as well as the basic functions of ecosystems.

Darkness and natural night light are indispensable for the healthy functioning of organisms and ecosystems. We usually forget that life lives 24 hours a day and that ecosystems adapted themselves to the natural rhythms of the moon and stars during millions of years of evolution. As over half of the creatures living on this planet are nocturnal, any degradation in the quality of sky, by day or by night, is having a profound effect on their behaviour and on the equilibrium of the biosphere. In addition, many diurnal species adjust their vital cycle according to night duration.

Light pollution, in particular, has been shown to have a widespread, negative impact on many different species. Scientific evidence for this impact in migratory birds, hatchling sea turtles, and insects is striking, because of the large-scale mortality that has occurred as a result of artificial night lighting. Light pollution can confound animal navigation (many species use the horizon and stars for orientation), alter competitive

The night life in Socotra biosphere reserve © Giuseppe Orlando

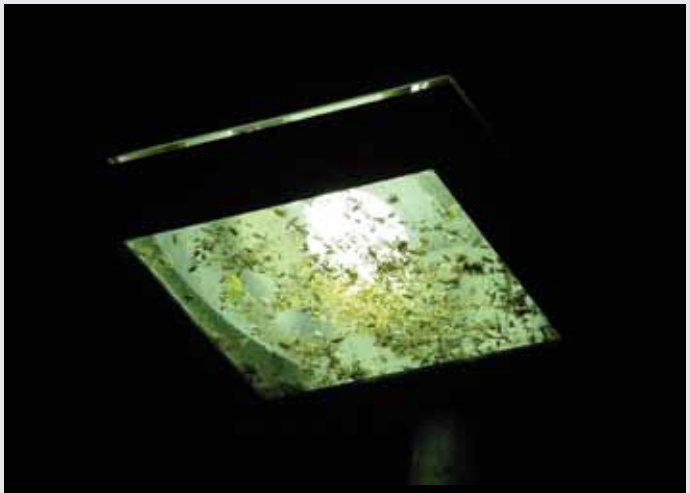
interactions, mutualisms and reproduction behaviour, change the natural predator-prey relationship and even affect animal physiology. Amphibians are well-studied in this sense, as well as a number of nocturnal or crepuscular mammals such as bats, some primates, many rodents and marsupials, which all suffer from what is now called “biological photopollution”. Disturbing data on light pollution effects on flora and phytoplankton are also being obtained.

This is because many plants time their development, growth and flowering behaviour by measuring the seasonally changing length of the night, which is impossible when there is light pollution.

Most natural protected areas and sites of importance for conservation were not designed or placed to ensure maintenance of ecological processes without disturbance from artificial lights or skyglow from distant cities. There are few sure havens on the planet where continuing evolution of organisms occurs in non-altered conditions.

Taking into account these considerations, the ecology of night should be urgently considered in relationship to artificial light in the existing networks of biosphere reserves, natural world heritage sites and geoparks.

Endemic flora in the Teide National Park at night, World Heritage site © Audrey Fischer



Bad lighting, bad environment © Javier Díaz

Light pollution human effects

Since life formed on our planet, it has developed with a predictable rhythmic environment. Every life form has evolved in coordination with the day-night cycle, developing the circadian system. The circadian system of mammals is synchronised by a deep part of the brain (the suprachiasmatic nucleus of the hypothalamus) and several peripheral clocks, passing its temporal signal to the organism via melatonin, a hormone produced by the pineal gland that peaks at night, with low levels during the day[11].

Light reaches this master clock through a nonvisual pathway consisting of specialised cells in the retina (melanopsin ganglionar cells), that are sensitive primarily to blue light. Their stimulation suppresses melatonin secretion during the day, and at night if light is present. A growing and increasingly convincing body of scientific evidence suggests that excessive exposure to bright light at night generates circadian disruption or chrono-disruption: impairments in the healthy internal temporal order. Evidence points to melatonin inhibition as the main culprit.

Blue light is most effective in melatonin suppression. Longer exposures are required with warmer (yellower or redder) light. Epidemiological studies show that chronodisruption is associated with increased incidence of metabolic syndrome, cardiovascular diseases, cognitive and affective impairments, premature aging and some cancers such as breast, prostate and colorectal, and with the worsening of pre-existing pathologies. Consequently, light cannot be considered harmless. More specifically, blue light should be avoided during the night in order to preserve our circadian physiology.

In conclusion, the wavelength range of the visible light spectrum under 540 nm, corresponding to high sensitivity of the melatonin suppression action spectrum, should be established as a protected range[1].

Light pollution kills millions of birds a year
© Kenneth Herdy, Fatal Light Awareness Program

Risco Caido and the Sacred Mountains of Gran Cnaria.
Aboriginal astronomical marker.
World Heritage Tentative List, Spain © Cabildo de Gran Canaria

Light and heritage

Preserve skyscapes and associated cultural and scientific values

When we look up at a dark night sky, we are essentially seeing the same sky that humans have looked upon for thousands of years. It is the same sky that has motivated cultures from around the world. For uncountable generations human beings have looked at the starry sky like a source of inspiration for the most diverse aspects of their cultural heritage.

Interest in astronomy, or simple contemplation of starry skies, has always had profound implications for philosophy, science, arts, culture and for the general conception of the universe in every community all over the world. The impression of a dark and starry sky has evoked myths, art, literature, and monuments. The night sky is a timeless and boundless resource important to many people, cultures, and religions.

Since the oldest ages, night sky observation was a basic dimension in all cultures worldwide. From Aristotle to Galileo, from Ur to Mesa Verde, astronomy has marked the pace of science history and of the cultural perception of the world. Several peoples' identities were based on cultural expressions related with stars. Major exploration and trade routes have been traced using stars as references. But we are nowadays facing a new situation, where we risk limiting our astronomical culture to a closed and threatened area only available to few researchers in distant technological spheres.

A large part of world has lost the reference of stars due to light pollution. Nevertheless, the vision of the stardome and the study of astronomy have allowed humankind create calendars, navigate offshore through sky mapping and making substantial changes in science as a global language.

In this context, the heritage related to astronomy is much broader than we usually believe. Putting into value, protecting and promoting the tangible and intangible cultural heritage associated to night sky, usually poorly known and little valued, and often in danger, would be an essential function of some UNESCO sites.

Astronomy and World Heritage Thematic Initiative

Created in 2003 within the framework of the Global Strategy for the balanced, representative and credible World Heritage List, as a pilot activity for the identification of the sites connected with astronomy, the Thematic Initiative on Astronomy and World Heritage, aims to establish a link between Science and Culture towards

The Starry Night by Vincent Van Gogh

The Megalithic monuments of the Cromlech of Xerez in Alqueva, Starlight Destination, Portugal © Alqueva Dark Sky

recognition of the monuments and sites connected with astronomical observations dispersed throughout all the geographical regions, not only scientific but also the testimonies of traditional community knowledge.

The close and perpetual interaction between astronomical knowledge and its role within human culture is a vital element of the outstanding universal value of these properties. These material testimonies of astronomy, found in all geographical regions, span all periods from prehistory to today. They are places of mystery and wisdom based on the "knowledge of stars". Teotihuacán, Stonehenge, Giza, Carnac, Chichen Itza, Delos, and Jaipur are only a few examples symbolizing this legacy made up of an infinity of artistic, scientific and ethnographic manifestations conserved at all latitudes.

Understanding the role of these properties connected with astronomy, as well as promoting them through public awareness-raising campaigns, are crucial and vital steps in the efforts to safeguard them for future generations. An important aspect in this process would be to restore or maintain the quality of the night sky in these places.

For obvious reasons, dark skies and celestial objects can not be recognized as specific types or categories of World Heritage cultural or natural properties since no criteria exist for considering them under the World Heritage Convention. Instead, we must consider this issue in terms of improving site management: a dark sky is an aspect of the quality of the environment of a cultural site. Establishing appropriate measures to limit light pollution on these places will contribute to have a better appreciation of their intrinsic values.

In 2010, it was published the first thematic study "Heritage Sites of Astronomy and Archaeoastronomy in the context of the UNESCO World Heritage Convention". The Thematic Study results from a collaborative project between the International Council on Monuments and Sites (ICOMOS), an advisory body to UNESCO for cultural heritage, and the International Astronomical

Union (IAU)[13]. The main aims of this project are to gain an improved understanding of the character and composition of different forms of astronomical heritage.

Following this study, the Portal to the Heritage of Astronomy[10] has been developed in partnership with the World Heritage Centre to support UNESCO's Thematic Initiative "Astronomy and World Heritage". It exists to raise awareness of the importance of astronomical heritage worldwide and to facilitate efforts to identify, protect and preserve such heritage for the benefit of humankind, both now and in the future.

An eroding nightscape

The light of stars and other heavenly bodies has always enriched terrestrial nature's display as well as human habitat, creating reference landscapes traditionally perceived by people as an integral part of their natural and cultural heritage. Nevertheless, the nocturnal dimension of skyscapes, in spite of its diversity and magnificence, is still the most hidden aspect of the concept of landscape.

Nightscapes can be very diverse, starry landscapes related to rural or natural areas, deserts, high mountains, geological monuments or sites associated with

Chaco great house at night. Chaco Culture World Heritage site and International Dark Sky Park © NPS

Chankillo, Peru. WH National Tentative List
© Servicio Aerofotográfico Nacional, Lima

astronomical heritage, all of which are worthy of special attention because of their increasing deterioration rate caused by light pollution. In spite of their extreme beauty and rich diversity, when cultural and natural landscapes of outstanding beauty are described, there are very few references to nightscapes.

However, the need to protect and recognize these landscapes has gained strength in recent years. Some American national parks inscribed on the World Heritage List as Yosemite, Mesa Verde, Yellowstone or Chaco, are good examples. Actually, part of the NPS mission is to share these natural lightscapes with the public and to protect and restore them. Likewise, the nightscapes have been considered by the European Landscape Convention. There are best European practices in parks as Hortobágy (Hungary) or the Teide (Spain). In Africa is remarkable the experience of Nami Sand Sea (Namibia).

Finally, It should also be noted that, for the first time, a cultural landscape which includes archaeoastronomical sites integrated in the skyscape has been proposed in a national tentative list: it is the case of Risco Caido and the Sacred Mountains of Gran Canaria (Spain).

Roque de los Muchachos on La Palma Biosphere Reserve, certified as a Starlight reserve © Astrotour

UNESCO designated sites

Towards a new culture of light

Reducing light pollution, saving energy and recovering starry sky should be part of a new culture on the UNESCO sites protection committed to acting on climate change and sustainable development. Eight years after the Declaration of La Palma (Declaration in Defence of the Night Sky and the Right to Starlight), over thirty biosphere reserves, world heritage sites and geoparks have now developed successful initiatives to ensure night sky quality and promote sustainable lighting.

World Heritage sites

For more than forty years, UNESCO has been working with countries all over the world to identify sites suitable for classification as world heritage and to ensure that they are protected for future generations. There is currently a total of 1031 cultural, natural and mixed sites on the World Heritage List. Their splendour is the best testimony to the diversity of our planet and its inhabitants.

Understanding the relation between man and nature in order to preserve it is one of the fundamental objectives of the World Heritage Convention. The sky belongs to us all and forms a whole with the environment perceived by man. Associating nightscapes with natural and cultural heritage protection is a logical step in the relationship between man and nature.

Given that an important aspect of the heritage of many ancient and historical sites is the observation of certain naked-eye astronomical phenomena, the possibility of actually observing those phenomena today is a relevant consideration in valuing and preserving that heritage.

The dark sky may not always be part of the intrinsic value of a cultural property but, where it is still present, it is certainly part of the intrinsic natural value of the place in question. The same argument would apply to several natural and mixed World Heritage sites. In any case, preserving the nightscapes from light pollution is certainly a relevant issue in many cases[13].

Biosphere reserves

Biosphere reserves are areas comprising terrestrial, marine and coastal ecosystems. Each reserve promotes solutions reconciling the conservation of biodiversity with its sustainable use. There are currently 651 biosphere reserves recognized in 102 Member States of

Dorset and East Devon Coast World Heritage site © DorsetScouser

Dehesas de Sierra Morena biosphere reserve & Starlight Reserve © ADIT

UNESCO, including 15 transboundary sites.

Biosphere reserves are 'Science for Sustainability support sites' – special places for testing interdisciplinary approaches to understanding and managing changes and interactions between social and ecological systems. These sites aim to harmonize conservation of biological and cultural diversity, and economic and social development, through partnerships between people and nature. They also contribute to the transition to green societies by experimenting with green development options such as sustainable tourism.

Local communities are active in management, research, education and training projects in the Biosphere Reserves, making them sites of excellence for experimentation in sustainable development. In addition, they are considered as learning sites for Climate Change mitigation and adaptation.

Under these circumstances, biosphere reserves become sites of excellence to foster sustainable lighting. The scope of the World Network of Biosphere Reserves around the planet, in critical ecosystems ranging from small islands to mega cities, makes it possible to build and share a comprehensive knowledge base on good practices and policies on the use of environmentally sound lighting technologies.

In fact, it was in La Palma biosphere reserve where the first declaration in defense of the night sky was approved. Also this was the place that saw the birth of the first national law protecting astronomical observation in the world in 1988, called the Sky Law, promoted by the Institute of Astrophysics of the Canary Islands.

Some biosphere reserves are leading the research on biological photopollution, paving the way for the implementation of a holistic view that integrates the night in conservation policies. This is the case of Doñana, Fuerteventural or the Everglades.

Geoparks

UNESCO Global Geoparks are single, unified geographical areas where sites and landscapes of international geological significance are managed with a holistic concept of protection, education and sustainable development. Their bottom-up approach of combining conservation with sustainable development while involving local communities is becoming increasingly popular. At present, there are 120 UNESCO Global Geoparks in 33 countries.

Geoparks offer a unique opportunity to highlight the value of nightscapes related to the outstanding events of geodiversity.

In conclusion, UNESCO designated sites can therefore lead the way towards new initiatives of intelligent lighting, including eradication of adverse environmental impactcs of light pollution and recovering nighstscapes, acting as exemplars for other sites and foremost inspiring policies and practices of lighting sustainability for non-designated sites globally.

Learning sites for sustainable lighting

At least thirty UNESCO sites worldwide have adopted specific commitments on the protection of the night sky and light pollution control. These places can be understood as learning sites for the development of intelligent lighting solutions and the integration of night sky quality in their conservation policies.

List of UNESCO designated sites that include dark sky places recognised by the Starlight Foundation, IDA (International Dark Sky Association), RASC and other certifications:

BIOSPHERE RESERVES
South West Nova (Canada)
Fray Jorge (Chile)
La Palma island (Spain)
Fundy (Canada)
Big Bend (USA)
Galloway and South Ayrshire (UK)
Gran Canaria (Spain)
Braunton Burrows-North Devon (UK)
Rhön (Germany)
East Carpathians (Poland)
Dehesas de Sierra Morena (Spain)
Sila (Italy)
Fuerteventura (Spain)
Hortobágy (Hungary) /WHS
La Rioja (Spain)
Yosemite National Park (USA) /WHS
Luberon-Lure (France)
Karkonosze (Czech Republic / Poland)
Sierra Nevada (Spain)
Wadennsea Area (Netherlands)

WORLD HERITAGE SITES
Chaco Culture (USA)
Doñana National Park (Spain)
Teide National Park (Spain)
Hortobágy National Park - the Puszta (Hungary)
Mesa Verde National Park (USA)
Sceilg Mhichíl (Ireland)

GEOPARKS
Fforest Fawr (United Kingdom)
Luberon Regional Natural Park (France)
Sierra Norte de Sevilla (Spain)

Milky Way over Teide National Park, World Heritage site © J.C. Casado

Iberian Peninsula at night from the International Space Station (ISS)

Prevent Light Pollution

Promoting outdoor lighting with intelligent options

This would be based around three simple principles. First, only illuminate what needs to be illuminated. Second, make use of outdoor lighting only when needed. Finally, use luminaires that completely avoid light emissions towards the horizon or up to the sky. It is absurd to waste energy sending light to the stars.

© Needless - Light Pollution Simulator

Because of its special characteristics, the UNESCO designated sites could be pioneers models to foster implementation of environmentally friendly and sustainable lighting solutions. They should adopt effective measures to control and eradicate light pollution in defense of the integrity of their cultural and natural associated values.

Among the forms of light pollution, the most controversial and well known is the sky glow. Improper artificial lighting increases night sky brightness and is the human-made source of skyglow. Skyglow is mostly uncontrolled light that shines outward and upward into the sky, washing out the darkness of night and hindering stargazing.

The question is how an appropriate lighting can prevent this form of light pollution. The answer needs to make intelligent decisions within hand's reach. It would be enough to adopt the following criteria:

How to plan a responsible outdoor lighting

When formulating proposals for an outdoor lighting scheme or where outdoor lighting is integral to a development proposal, managers and designers should have regard to the following key principles:

- Where outdoor lighting is truly necessary and which useful service does it provide?
- How much lighting the areas and object to be illuminated need?
- Which unwanted effects can outdoor lighting lead to?. Assess the impacts and benefits.

Teide National Park, World Heritage site © OTPC

Effect on Skyglow and cut-off angle

Diagram to show relative impact of a luminaire's output contribution to skyglow

E 120-180° Critical area for skyglow experience from within urban and all areas but proportionally less impact to rural areas, distant from main light sources.

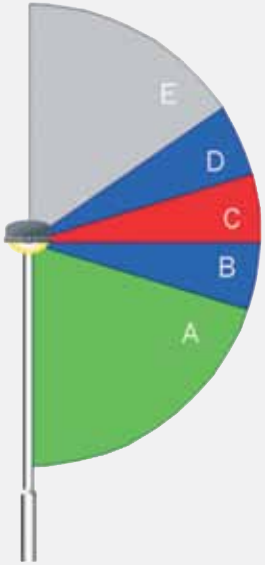
D 95-120° Significant contributor to skyglow, especially in rural areas. Less likely to be obstructed.

C 90-95° Critical zone for skyglow and obtrusion seen at 10s of km (in rural areas) where it is strongly dependent on aerosol scattering.

B 85-90° Significant contributor to skyglow seen at a distance through reflection but reflected light more likely to be obstructed by buildings, trees and topography. Produce also glare in the roadway users.

B 75° to 85° Produce glare in the roadway users.

A 0-75° Ideal light distribution.



Source: Chris Baddiley. British astronomical Association - Campaign for Dark Skies, Fabio Falchi, STIL

UFO luminaire. Design: Renzo Piano © iGuzzini

Do not allow luminaires sending any light directly at and above the horizontal

Smart recommendations

- Use luminaires with a percentage of upper hemisphere emission installed below 0% in relation to the total output flux of the luminaire, and be sure to avoid directing light near the horizon. The light emissions at angles close to the horizon can produce an skyglow effect up 160 times greater than the same flux reflected off the ground.
- Use luminaires with reflectors and clear covers, preferably of flat glass and avoid tilting the luminaires from their horizontal position.
- Use only asymmetric beam floodlights, with asymmetries adapted to the area to be lit, not installed at a tilt.
- Keep glare to a minimum by ensuring that the main beam angle of all lights directed towards any potential observer is not more than 70°.

Ensure all outdoor lighting are designed to cover the true lighting needs

Smart recommendations

- Do not waste downward light flux outside the area to be lit. Only light the exact space and in the amount required for particular tasks.
- Be no brighter than necessary.
- Avoid over lighting and redefine the lighting levels for road lighting, lowering them substantially.
- Shut off lights when the area is not in use.
- Reduce lighting levels or switch off the installation after certain hours at night when not justified its use.
- Look for products with adaptive controls like dimmers, timers, and motion sensors.
- Decrease of the total installed flux in the same manner as other pollutants are being reduced.

Old Town of Santiago de Compostela, World Henritage City.
© Composition: Astronomía na beirarúa

© Todd Carlson

Use the appropriate lamps and strongly limit the short wavelength blue light

Most people are familiar with incandescent or compact fluorescent blubs for indoor lighting, but outdoor lighting usually makes use of different, more industrial, sources of light. Common light sources include low-pressure sodium (LPS), high-pressure sodium (HPS), metal halide and light emitting diodes (LEDs).

LPS is very energy efficient, but emits only a narrow spectrum of pumpkin-colored light that some find to be undesirable. Yet, LPS is an excellent choice for lighting near astronomical observatories, outstanding nightscapes and in the surroundings of natural areas.

HPS is commonly used for street lighting in many cities. Although it still emits an orange-colored light, its coloring is more “true to life” than that of LPS.

In areas where it’s necessary to use white light, two common choices are metal halide and LEDs. One of the advantages of LED lighting is that it can be dimmed.

Types of light bulbs - Chromatic characteristics and efficacy

Type of lamp	Colour	luminous efficacy (lumen / W)
Low-pressure sodium (LPS)	yellow	180 - >200
High-pressure sodium (HPS)	rose / amber yellow - white	90 - 130
Metal halide (MH)	cool white / warm white	60 -120
Compact fluorescent (CFL)	white	45 -60
LED (light-emitting diode)	all colours	30->150 to increase
Mercury vapour (MV)	greenish blue / white	13 - 48
Incandescent/ Halogen	yellow/white	8 - 25

Spectrum of a low-pressure sodium lamp

Spectrum of a high-pressure mercury lamp

This feature both saves on energy and reduces light pollution during the night. However, for the environmental reasons, where possible, it is strongly recommended to avoid the use of white LED.

Smart recommendations

- Choose lamps whose spectrum has the lowest impact on skyglow and on night sky quality in general. Reflection of air borne particles and scattering by the atmosphere make artificial light visible in the sky. Since the shorter blue wavelengths are more strongly scattered than the longer red wavelengths, white light is the most harmful for night sky quality and the environment.
- Use LEDs with a very low colour temperature (<3000K) or no blue content.
- Choosing the most energy-efficient lamps that meet these requirements.

WOW iGuzzini A RESPONSIBLE ANSWER. Design: Piano design.

- Monochromatic LED warm white 3000 K - CRI 70
- Total luminous flux at or above an angle of 90° [Lm]: 0. High visual comfort: Glare Index Classes: ≥ Ga; Luminous efficacy (lm/W, real value): ≥ 98
- No photobiological risk. This luminaire is in the “Exempt Group” (no risk linked to infrared, blue light and UV radiation) in accordance with EN 62471:2008.
- The luminaire has luminous flux emission fully programmable directly from the product driver. The driver allows the use for different output lumen levels and different powers.
- Compatibility with Telemanagement systems thanks to “Power Supply”, dual-operation Flux regulator and “LED Driver DALI” (0-10V/1-10V) compatible with the systems on the market.
- An active control system modifies the current intensity to preserve the luminous efficacy and the lifetime of the LEDs under any ambient temperature conditions.
- Replaceable LED unit.
- LED Life Time: 100.000h L80 B10 (Ta 25°C)

Old Bridge of the Old City of Mostar, World Heritage site rebuilt with the assistance of UNESCO and the World Bank and enlightened with the support of iGuzzini. © iGuzzini

Ornamental lighting of monuments and historic structures

In present-day systems the way that light is directed has a crucial impact on the responsible performance of historic facades and monuments. Light is very often directed very imprecisely and the use of light causes light pollution. There is, however, a better alternatives than simply shining light on buildings.

Smart recommendations

- Lighting should not affect the integrity of the site. Many cultural and natural properties have a close relationship with the observation of the firmament and celestial objects.
- Monuments should not be illuminated from bottom up, except for historic buildings where it is impossible to light them from above. In this last case, the light flux should be completely intercepted by the building facade. This prevents stray light and the associated light pollution.
- In any case, these kinds of installations should be switched off when no longer fulfill their function, though luminous flux reducers are also an option, and should preferably be automatic with timer systems to guarantee operation.
- Such lighting is totally inappropriate in natural and rural areas where it can be damaging to biodiversity and nightscape quality.

“The intelligent use of artificial lighting that minimises sky glow and avoids obtrusive visual impact on both humans and wildlife has to be promoted. Public administrations, the lighting industry, and decisionmakers should also ensure that all users of artificial light do so responsibly as part of an integral part of planning and energy sustainability policies, which should be supported by light pollution measuring, both from the ground and from space. This strategy would involve a more efficient use of energy so as to meet the wider commitments made on climate change, and for the protection of the environment.”

Article 7 of the Starlight Declaration 2007

Fostering Innovation

The future of lighting

"Today, LED lighting technology has come of age and is able to deliver benefi ts to cities and citizens alike. It offers more controllable and higher quality light, enhanced visual performance and improves the ambience and safety of urban environments. Moreover, LED lighting will make our cities 'greener' by saving up to 70% of lighting energy and reducing costs compared to existing lighting infrastructures. The larger roll-out of intelligent LED lighting systems in cities will be part of the creation of sustainable smart cities: cities where lighting innovation is interlinked to other smart city networks (communications, renewable energy, building or traffic management systems)."
Neelie Kroes, Commission Vice-President for the Digital Agenda for Europe.

The LED lighting revolution

The light emitting diode (LED) is transforming the way we light our cities and towns offering a once-in-a-life-time chance to radically improve how we use energy and our outdoor spaces at night. With this opportunity comes an obligation to manage these changes responsibly and sustainably.

LED-based lamps are extremely easy to turn on and off, and they dim down to 1%. New lighting systems are already being deployed that implement increased levels of intelligence, such as ambient light and motion sensing and remote control via radiofrequency (RF) communications.

These systems can be dimmed to low levels or even shut off when the system "knows" no one is present to use the light. Due to the significant increase in the utilization factor, overall lighting levels at night will see a sizable net decrease when these systems are more widely deployed.

Finally, in contrast to most traditional light sources LEDs provide extremely directional light rather than emitting light in all directions. These beam patterns can be finely tuned via secondary optics to only provide light where it's useful, increasing overall system efficiency and further decreasing light pollution.


Light on only when and where someone is there to see

There is another way to light up the night

LED lighting applications are moving towards high intelligence with specialised communications. Bringing intelligence into many LED outdoor lighting applications may advance in future "green" digital life:

Responsible lighting © Composition: Luis Mir

Intelligent lighting systems

Digital control already allows individual lighting devices to be controlled and offers direct communication between lighting devices and their local environment. This provides possibilities for improved control methods and granularity of lighting controls, such as user interfaces for manual and automatic adjustments in response to daylight availability, occupancy, or time of the day.

Adaptive lighting

LED can deliver instantly addressable, customised and adaptable light based on the needs or desired mood of the users. Dynamic lighting could be used to achieve better educational outcomes and improved health, safety and quality of life.

Integrated lighting, solar systems and networked lighting

The increased intelligence in lighting systems will allow integration with other city systems, such as energy, facility or mobility systems, to optimise power smoothing, generation, delivery and monitoring. Smart lighting also provides a data network, allowing for the flow of information between the different city networks, for example communicating maintenance needs. The lighting network could readily be used to supplement local citizen data networks, providing the infrastructure for city-wide wireless communications.

Wireless sensor fusion

Sensor fusion, combining many different sensor types and distributed intelligence within the lighting system, will open many new applications. Sensors could determine the optimum lighting by monitoring occupancy, temperature, energy management, daylight availability, or through presence of RFID (Radio-frequency identification) tags.

Solar-powered LED lights on Borobudur Temple, the world's largest Buddhist monument and UNESCO World Heritage Site.© Ulet Ifansasti / Greenpeace

Smart solar-powered LED lighting systems

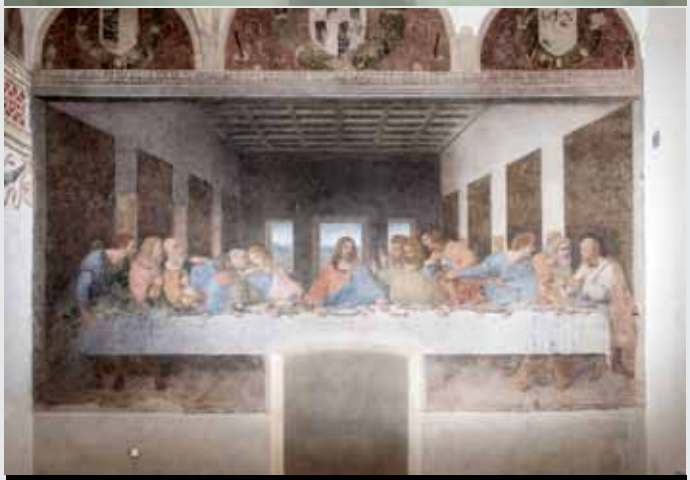
Increasingly, LED lighting systems and solar photovoltaic become a couple to provide dynamically adapted optimal lighting conditions at minimum energy consumption and ultimately to contribute to reinforce renewable energy communities.

The shift toward renewable energy and the growing demand for energy efficiency has pushed the market toward more energy-efficient products. Solar and renewable energy technologies moves towards the implementation of smart grids and LED technology is perfectly suited to these requirements.

Furthermore, solar LED provides reliable lighting options globally, particularly as a replacement to conventional fuel-based lighting options. LED lighting technology and smart grids are globally recognized and have proven very suitable for the rural population in some regions whose power supply is erratic and scarce.

Better lighting and a better environment

The design of modern lighting systems should not rely only on smart innovation or energy-saving considerations; environmental considerations must also be addressed, adapting the spectral distribution of the light, particularly in sensitive areas as UNESCO sites. Lamps that emit more energy in the blue than standard high-pressure sodium lamps should not be installed outdoors. Technological solutions, both classical (sodium) and solid-state (amber LED, filtered white LED), provide warm, less harmful light with excellent energy efficiency. These products, should be required by authorities, and specified by engineers and designers, to preserve a nighttime environment that is friendly to the sky, to nature and to ourselves[11].



LED lighting for a fragile masterpiece:
Leonardo da Vinci's The Last Supper

Leonardo da Vinci painted his masterpiece in the refectory of the Dominican Convent church, Santa Maria delle Grazie in Milan,both inscribed on the UNESCO World Heritage List.
Following an agreement with the Milan Architectural and Landscapes Heritage Office, iGuzzini has been responsible for enhancing the extraordinary beauty of this artwork. To achieve this it is designed a new lighting system with latest generation luminaires that highlights the rich colours and splendid details of Leonardo's masterpiece.
The new LED lighting system brings richer colour to The Last Supper while also guaranteeing better light distribution control and the correct conservation of the paintings.

Earth at night from the space © Barry Wilmore. NASA

Light and the climate

Sustainable lighting and climate change

The over-illumination has become a growing phenomenon in many towns and cities around the world. Inefficiency and excess of artificial light increases energy consumption and is economically unjustified. It also increases the level of emissions that contribute to climate change. By contrast, today more than 1.3 billion people worldwide lack access to electricity.

Greenhouse-gas emissions from the energy sector represent roughly two-thirds of all anthropogenic greenhouse-gas emissions and CO_2 emissions from the sector have risen over the past century to ever higher levels. Effective action in the energy sector is, consequentially, essential to tackling the climate change problem. In this context, the lighting sector plays an important role.

Electricity for lighting accounts for between 15 % (UNEP, 2014) and 19 % (IEA, 2006) of global electricity consumption and between 5 and 6 % of worldwide CO_2 emissions[15].

Lighting in 2010 accounted for 2,815 TWh (UNEP), an amount equivalent to 16% more than the electricity generated by all the nuclear power plants in the world in 2014[8] or 73 % of total hydro-power generation[12], and is growing rapidly. The largest share is used in commercial and public buildings, followed by residential lighting, industrial sector lighting and outdoor lighting. The overall estimate of lighting electricity consumption by outdoor stationary lighting is more than 250 TWh.

Considering the global population increase and the growing general standard of living, a path of no policy action would make electricity for lighting increase by 27% to 3,575 TWh in 2030.

It is not commonly appreciated that lighting is also one of the biggest causes of energy related greenhouse gas emissions. Emissions resulting of lighting amounts to 1,471 Mt CO_2 annually and are comparable to 18% of the CO_2 emissions of China alone, or 27% of the emissions of the United States (IEA)[4].

New York City at night shows skyglow

Earth's city lights from data acquired by the Suomi NPP satellite in April and October 2012 © NASA Earth Observatory/NOAA NGDC

The level of outdoor lighting is strongly related to affluence and as a result OECD nations use the most: 71% of energy and 75% of the light. This is immediately evident from looking at night-time satellite photos of Earth that show cities, especially densely populated OECD regions, emitting a disproportionate amount of light as a share of their population. Globally, the lion's share of outdoor stationary lighting is taken by two applications: street/road lighting and car-park illumination, which account for 53% and 40%, respectively. Traffic signals are the next largest contributors, taking 6%. Billboards and airport lighting account for just 1% each. Both street and car-park lighting are operated throughout the entire night, especially in the OECD, and hence will generally be used for between 3600 and 4400 hours per year[9].

Move towards a low-carbon lighting is a major challenge considering the current state of the lighting systems. 500 million outdoor lighting luminaires are installed in the world and most are more than twenty years old and do not meet current energy efficiency and environmental criteria. One third of the world's roads are still lit by technology dating back to the 1960s.

Given the importance of this challenge, the sustainable and advanced lighting has been considered a key issue in the current Decade of Sustainable Energy for All. This comes in addition to the UN Secretary-General's Sustainable Energy for All initiative (SE4All). The initiative was launched in 2012 to mobilize action from all sectors of society to achieve three interlinked objectives by 2030: ensure universal access to modern en-

ergy services, double the global rate of improvement in energy efficiency and double the share of renewable energy in the global energy mix.

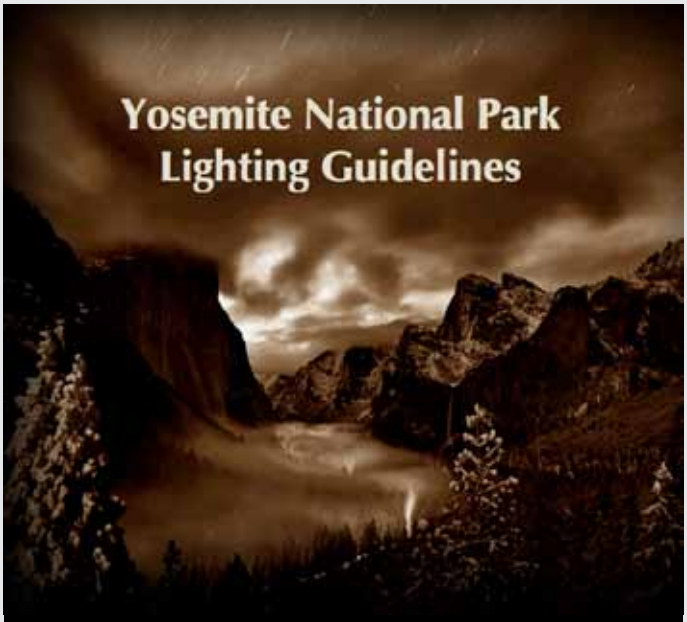
In this context, it is considered that energy efficient lighting would reduce the global electricity demand for lighting by close a third in year 2030. Given this tangible reduction and its economic, environmental and social benefits, SE4ALL identified advanced lighting as an "Accelerator" to help realize the energy efficiency goal[15].

Taking into account these projections, a global transition to widely available efficient solutions in all lighting sectors (residential, commercial/industrial and outdoor) by 2030 could reduce electricity demand for lighting by more than 32 %, and avoid 3.5 Gt of CO_2, while significantly cutting electricity bills, reducing fuel imports and black outs, and improving end-user welfare. The transition would save over $120 billion annually in avoided electricity bills to consumers, through a reduction of over 1,000TWh of electricity every year. It would also save over to $230 to 425 billion in avoided investment in 280 large (500 MW) base-load to 520 large peak-load power plants. Furthermore, if the world leapfrogged to LED lamps in all sectors, it would reduce global electricity consumption for lighting by more than 52 % and avoid 735 million tonnes of avoided CO_2 emissions each year[9].

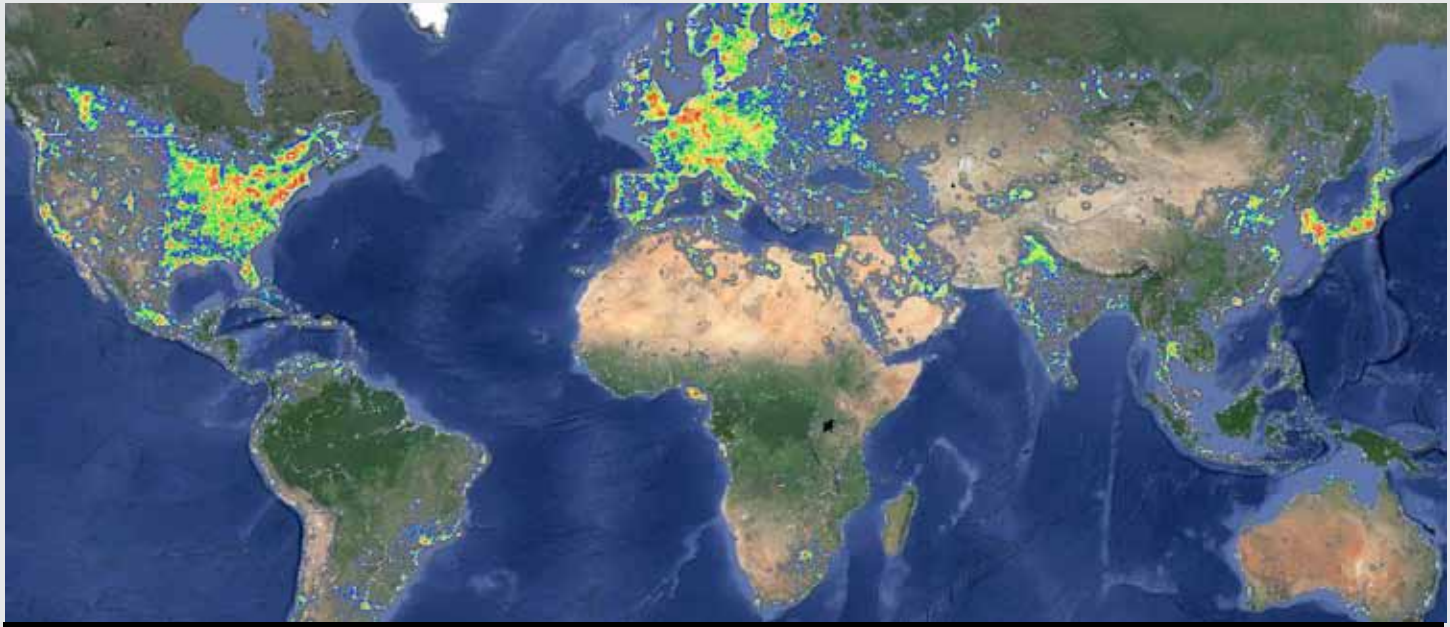
This strategy is in line with the vision and the role of UNESCO sites. Regarding biosphere reserves the Dresden Declaration on Biosphere Reserves and Climate Change states that: "Biosphere reserves are an effective instrument for mitigating climate change and serve as models for adaptation to the impacts of this change. This applies particularly in the domains of sustainable land use, green economies, safeguarding ecosystem services, energy efficiency and the use of renewable energies"[3].

In practice several biosphere reserves have integrated the dimension of lighting within of its commitment to climate change, energy sustainability and the reduction of light pollution. This is the case of Röhn (Germany) or Fuerteventura (Spain). It is worth noting that the Fuerteventura Biosphere Reserve, certified as Starlight Reserve, incorporates the sustainable lighting into its 100% Renewable Energy strategy and into its Biodiversity and Landscapes Management Plan.

Furthermore, in 2007 the General Assembly of States Parties to the World Heritage Convention adopted a Policy Document on the Impacts of Climate Change on World Heritage properties, aimed at providing the World Heritage decision and policy-makers with guidance on a number of key issues related to climate

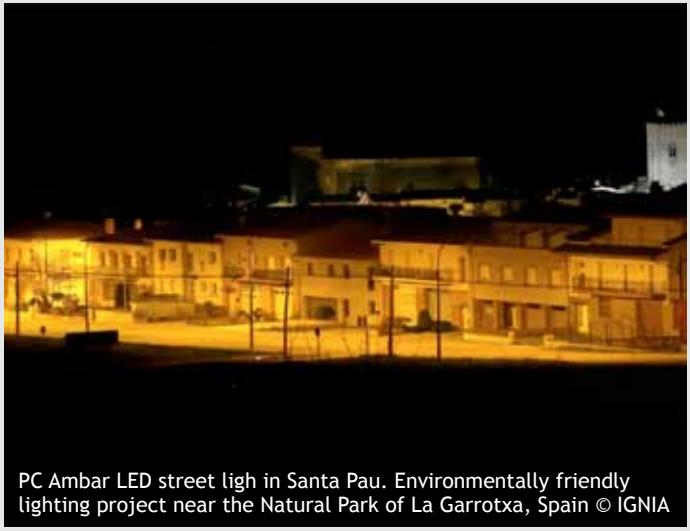


Intelligent lighting for Yosemite National Park, World Heritage site © NPS



The World Atlas of the Artificial Night Sky Brightness projected on the Biosphere Smart platform © Cinzano, P., Falchi, F., Elvidge C.D.

change[16]. Document mentions the Yosemite National Park as example. Lighting are included as a key component in the Yosemite NP Climate Action Plan and their Lighting Guidelines, approved in 2011, are a reference model of adaptive lighting for other natural or mixed World Heritage properties.



PC Ambar LED street ligh in Santa Pau. Environmentally friendly lighting project near the Natural Park of La Garrotxa, Spain © IGNIA

The same document also considers that the network of World Heritage cities offers an unparalleled opportunity to promote and highlight the use of energy efficient and carbon neutral technologies. In this field one of the best models is the Edinburgh Energy Efficiency and Sustainability initiative. On-going actions include a Sustainable Lighting Strategy for Edinburgh World Heritage City, demonstrating that energy efficient / smart historic street lighting is definitely becoming a more important topic for historic cities.

The other side of the coin is that 2.9 billion people have no access to modern energy services and over 1.3 billion have no electricity yet, relying on highly polluting solutions for their lighting needs resulting in substantial environmental and health impacts. We are

talking about greater number of people than living on the planet when Thomas Edison commercialised the incandescent light bulb in the 1880s. The paraffin and diesel-fuelled lighting they use is much less efficient than even the most inefficient incandescent lamp, is a large emitter of CO_2 and is very costly. These combined uses provide only 1% of global lighting but are responsible for 20% of lighting CO_2 emissions[9].

Solarize remote locations and villages without access to electricity to provide lighting and other electrical services is the best answer to eradicate energy poverty. The initiatives carried out in biosphere reserves as Dana (Jordan) and Sundarban (India) are a good indicator of the potential of these solutions.

However, in the context of the global transition to sustainable lighting it is important to consider the mentioned environmental requirements for the LED light used, particularly in outdoor lighting. This needs commitment from industry, developers and stakeholders.

Barefoot College bedouin women bring solar power to lighting Dana biosphere reserve, Jordan. © Arwa Aburawa

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United Nations Educational, Scientific and Cultural Organization

International Year of Light 2015

“The conservation, protection, and revaluation of the natural and cultural heritage associated with nocturnal landscapes and the observation of the firmament represents a prime opportunity and a universal obligation for cooperation in safeguarding the quality of life. For all decisionmakers, this attitude implies a genuine challenge involving cultural, technological, and scientific innovation, requiring a major constant effort to enable everyone to rediscover the presence of the night sky as a living part of the heritage of mankind.”

Article 3 of the Starlight Declaration (La Palma Biosphere Reserve 2007).

www.starlight2007.net

Fundación STARLIGHT

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