DIDACTIC UNIT

CITIES AT NIGHT

CITIZEN SCIENCE PROJECT TO LOCATE LIGHT POLLUTION SOURCES

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In this teaching unit you will find

- **Teaching materials**
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CITIES AT NIGHT

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CITIES AT NIGHT TEACHING MATERIALS

CITIZEN SCIENCE PROJECT TO LOCATE LIGHT POLLUTION SOURCES

INTRODUCTION

This lesson plan is to be used in the classroom of 12 and 13 years old students and aims to educate its users on the topic of light pollution. Aside from gaining awareness, the students will be introduced to the Cities at Night citizen science project through which they will learn how to locate sources of light pollution and how to contribute to science as a citizen scientist.

https://citiesatnight.org/

These pages will discuss: artificial light at night in general, different types of light pollution, their negative effects as well as the most efficient way to install lighting sources in such a way that any negative impact is minimised.

The Cities at Night project with its objectives as well as its relationship to citizen science are explained during the course. Theory is accompanied with suggested activities adapted to the level of the students. In addition the document contains internet links to further information interesting for both students and educators.

With this unit the authors intend to gather contents that can be implemented in the classroom, and which can serve as a guide so that both students and teachers can participate in this citizen science project.

In order for a citizen science project to grow the input of researchers, disseminators and a wide range of volunteers are needed. The participation of the students and teachers will directly help the study of light pollution.

1 LEARNING OBJECTIVES

The main objectives of this text are listed below:

To promote environmental awareness by highlighting the importance of quality artificial lighting at night as well as the impact of artificial light at night on all living things and by underlining the need to preserve regions without light pollution.

To promote cooperative work by appreciating the development of a project with the participation of all its partners.

To promote citizen awareness and social responsibility by assessing the importance of individual actions in the development of a global environmental project.

To develop scientific ability by participating in a real scientific project.

To obtain an understanding of the main sources of light pollution, as well as the mechanisms to avoid light pollution.

To create awareness concerning the negative effects of artificial light on human health.

To familiarise students and teachers with the concept of citizen science and to create awareness of the importance of citizen science as a tool for transforming society.

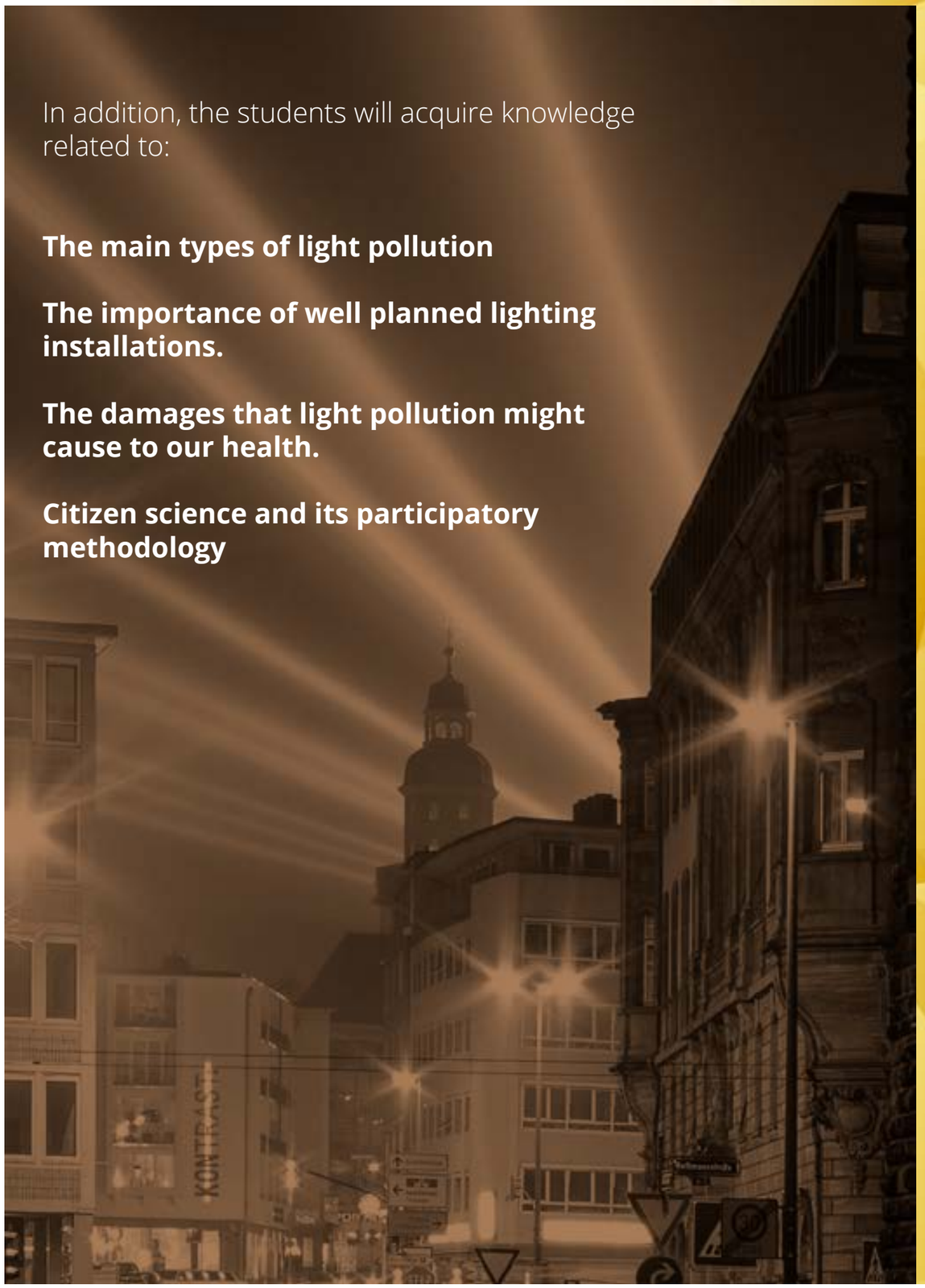
In addition, the students will acquire knowledge related to:

The main types of light pollution

The importance of well planned lighting installations.

The damages that light pollution might cause to our health.

Citizen science and its participatory methodology



2 LIGHT POLLUTION

The study of light pollution through the use of satellite images is one of the most innovative research methods that is currently having a great scientific and social impact. This type of research has been evolving rapidly in recent years. Some of the scientific results with the greatest worldwide impact have been carried out using this type of analysis.

The majority of satellite images taken by astronauts are not cataloged, located or georeferenced. Furthermore, space agencies publish less than 1% of these pictures through press releases or social media. The remaining 99% are stored in the NASA database where they are mostly left unused. These images also include photographs of stars, auroras, astronauts and sunsets. Many scientists want to use these images but do not have the resources to locate the data they need.

To make the data more accessible, the images need to be georeferenced so that it matches an map of the area. In order to start this process the cities, towns or areas depicted in the images need to be identified.

The ISS images that are taken of the Earth at night after 2003, high resolution and in colour are most useful for georeferencing.

The module will introduce students to the application 'Lost at Night' (v2) which is designed to substantially contribute to locating such images.

The application is part of the 'Cities at Night' project.

https://lostatnight.org

3 CITIZEN SCIENCE AT SCHOOLS

Science often appears to be disconnected from our daily lives. Without good communication between scientists and society, people can feel unqualified to understand the development of research, data collection processes or the results obtained from a scientific project.

Citizen science aims to bring science closer to society, train members of the public and encourage contributions to ongoing projects. In addition it allows people to be more involved in scientific activities that generate new knowledge and a better understanding of nature in general. Society can have a fundamental role in science by generating data, collecting, analyzing or describing research objects.

By bringing citizen science to schools, scientific research is encouraged and made more accessible. The students will obtain an improved understanding of science because they will interact with several stages of the research.

The main objective of the Cities at Night project is to apply the methodology of citizen science to solve a problem that would otherwise be unapproachable, namely identifying cities among the immense number of nocturnal photographs taken by astronauts from the International Space Station.

During this process, citizen scientists will:

Learn what light pollution is and become aware of the amount of city light emitted into space.

They will participate in a real scientific project.

A potential scientific career will be encouraged.

4 SCIENTIFIC EDUCATION IN SCHOOLS

The 21st century requires teachers to adopt innovative practices in the classroom as young students will be required to have scientific skills as well as critical thinking.

For someone to be scientifically literate he or she will need the three following abilities according to the Pisa 2015 technical report.

1) Being able to give a scientific explanation of phenomena
2) Being able to evaluate and design scientific research
3) Being able to interpret scientific data and evidence.

The implementation of research activities in the classroom is a very important aspect when developing such abilities as it will allow students to obtain a better understanding of science and how to apply scientific methods through experimentation. Furthermore, it can serve as a guide to help the students recognize that the science they perform in the classroom is connected with real scientific research and research institutions.

Citizen science covers all the following needs:

Scientific literacy, involving all students in the processes of science development.
The scientific research of the 21st century: perceiving scientific activity as something real, necessary and connected with society.
Social inclusion. Citizen science is aimed at all citizens regardless of gender, age, race, social status, etc.

It is important to highlight the inclusiveness of this project, both in the classroom as well as in society. Its design allows for the participation of people with severe disabilities and disadvantaged groups of any kind. It is suitable for schools of different levels and it makes no distinction between genders.

We are aware that for a school project to be inclusive it is necessary to respond to the diverse needs of the students, thereby encouraging a greater participation in the teaching-learning process. The Cities at Night project can be used as the backbone for such type of inclusive education, since the simplicity of the experimental activities facilitate a wide implementation of curricular adaptations depending on the needs of the students involved.

5 IMPLEMENTATION OF THE PROJECT AND METHODOLOGY

Each day astronauts onboard the International Space Station take photographs of our planet. Some have been published in the media, but almost half a million images remain uncategorised in a huge NASA archive, making images difficult to locate if wanted for research.

The Cities at Night project aims to use these images to make the first high resolution world map of earth at night in colour. Currently, a map of the earth at night exists but in much lower resolution, providing us only with blurred views of cities when zoomed in. Furthermore, the existing map contains only original black and white images. Cities at Night is working on a new map that will not only be a drastic improvement in terms of the resolution, but by using colour images the map will be an invaluable new source of scientific data.

The Cities at Night project has already passed several stages in recent years and has previously launched different applications that aim to realise specific tasks necessary to complete the full process.

Currently, the Lost at Night application is asking users help identify cities by presenting them with a list of possible cities based on the nadir of the ISS (the location that the ISS flew over at the time the photograph was taken). For example, by using the nadir of an unidentified image that was taken over the city of Zaragoza in Spain the app will likely indicate that this could be Madrid, Bilbao or any other city in the approximate area of Zaragoza.

The visual outline of cities at night is different from how we are used to seeing them on a geographical map. However, the shape of the Thames as it passes through London, the strong illumination of the Nile in Egypt and the different streetlight colours of East and West Berlin will soon become familiar to all who decide to contribute to this project.

APPENDIX: SOLUTIONS TO THE PROPOSED ACTIVITIES

Please find below the solutions to the proposed activities

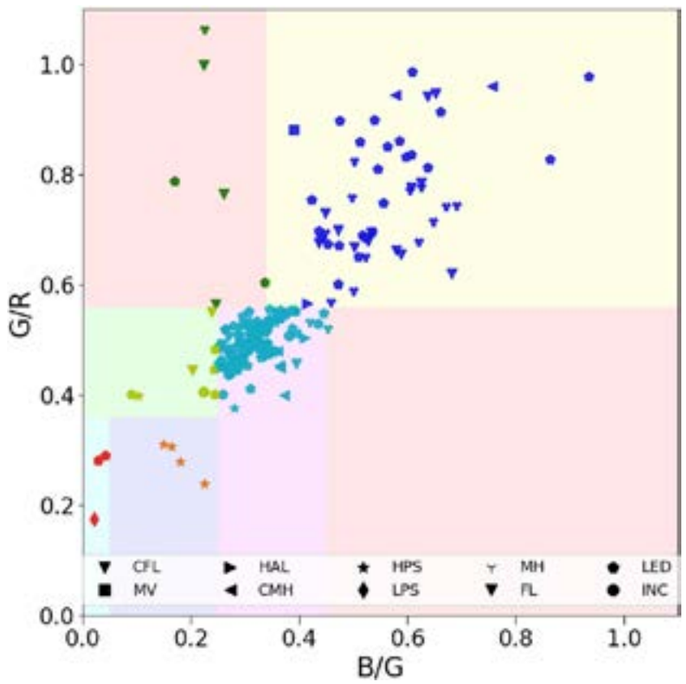
ACTIVITY 1

To minimise the amount of light emitted towards the sky and reduce light pollution it is necessary to avoid lamps with a design that allows the light to shine upwards (images b and c).
In that respect lanterns a) and d) are fairly well designed, however, part of the light is emitted horizontally and its dispersion both within the luminarie as well as into the atmosphere will still cause a percentage of the light to pollute upwards.

Therefore, in terms of direction, the best option to minimize light pollution would be e)

ACTIVITY 5

Light sources will be placed on the graph depending on the technology of the emitting point. The points, therefore, should appear grouped in clouds similar to the ones shown in the graph below:



ACTIVITY 6

The first image shows a case of **light intrusion**; streetlights emit light into the bedroom of a home preventing them from sleeping in darkness.

In the second image we see an **unevenly illuminated street**. Although the streetlight allows us to see the boy with the dog, the car closeby on the right side of the image is far less noticeable.

The third image shows **the glare produced by a powerful photo flash. Intense glare** impairs our vision. Therefore, in order to avoid unsafe situations, these kinds of bright lights should be used with caution. In the case of this image it is a photograph taken in a park during the day. If it had been taken inside a moving car for example it could impact the drivers vision.

The last image shows an example of **agglomeration**. In order for the library to have a sufficient amount of light far less bulbs are needed.

CITIES AT NIGHT STUDENT MATERIAL

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INTRODUCTION

This lesson plan is to be used in the classroom of 12 and 13 years old students and aims to educate its users on the topic of light pollution. As well as gaining awareness, the students will be introduced to the Cities at Night citizen science project through which they will learn how to locate sources of light pollution and how to contribute to science as a citizen scientist.

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With this document the authors intend to gather contents that can be implemented in the classroom, and which can serve as a guide so that both students and teachers can participate in this citizen science project.

In order for a citizen science project to grow, the input of researchers, disseminators and volunteers is needed. The participation of the students and educators will helps cience and society.

1- WHAT IS LIGHT POLLUTION?

Did you know that in addition to soil, air and noise pollution, artificial light can have serious environmental consequences for humans, wildlife, and our climate?

Artificial lighting alters the environment's natural pattern of light and darkness. It is considered light pollution when light is excessively bright, misdirected, it dazzles people or when a specific area is unevenly lit (not uniform).

A good proxy to estimate the amount of light pollution is the sky brightness as various light sources send light upwards brightening the atmosphere, this is called sky glow. Cities produce artificial light not only due to their street lamps, but also due to the use of ornamental lights that illuminate facades, buildings and monuments.

Aside from cities, there are numerous sources of light pollution outside the cities as well, such as airports, industrial areas, motorways, vehicle headlights and fishing boats out at sea.

In order to lengthen the day artificially, our most common reaction to the sun setting is to turn on the lights. We illuminate houses, parks, streets and roads. We illuminate the interior of the factories where we work 24 hours a day and we illuminate greenhouses and farms to increase productivity.

We install artificial lighting excessively, wasting energy and money without being aware that it causes harmful effects on the health of people, who no longer get their nights sleep in complete darkness.

In addition, artificial light also negatively affects animals and plants, damaging nocturnal habitats by altering the biological rhythms of many species. And disorienting migratory animals, which again can have a severe impact on an ecosystem.

Light pollution includes all the adverse effects generated by artificial light.

Long exposure image of a city and its traffic

2- NEGATIVE EFFECTS OF ARTIFICIAL LIGHT

Light pollution not only prevents us from seeing the stars, but also affects our health, safety and the environment, generating an unnecessary increase of energy waste and atmospheric pollution associated with the production of electricity.

Brighter does not mean safer!

Nature offers fascinating spectacles during the night

AFFECTS SAFETY AND SECURITY

Strong lighting generates a psychological sense of safety and security, but this does not necessarily mean that real safety and real security have actually increased.

For example, if the lighting is not uniform and dark areas are combined with strongly lit areas it takes us more effort to distinguish objects around us and this can consequently decrease our safety. On top of that, too bright or poorly directed lighting can cause glare, which is especially dangerous on roads.

Another aspect to consider is that light can make us feel secure in unsecure situations creating a false sense of safety.

ALTERS ECOSYSTEMS

The vast majority of living beings use natural light and dark cycles to regulate some of their behaviours related to reproduction, feeding, sleeping or finding protection against predators. Artificial light at night has negative and sometimes fatal effects on many creatures including mammals, amphibians, fish, insects and birds.

THE STARS ARE VANISHING

For those of us who live in cities, the night is no longer dark and many of us have forgotten that above our heads we should be able to see thousands of stars. Many people have never seen the Milky Way and do not know that a starry sky without a moon emits enough light to be able to go for a walk in the countryside. Just the light of the stars is enough to make you cast a shadow. And a dark sky can be so spectacular it can turn any random place into a holiday destination.

The increase in skyglow, caused by the dispersion of artificial light in the gases and particles of the atmosphere, causes deterioration in astronomical observation conditions. Migratory species that use the stars to orient themselves are negatively affected as well.

ENERGY WASTE

Excessive bright lighting leads to unnecessary expenses. And such a waste of energy carries great economic and environmental consequences. If humanity invested in increasing the quality of artificial lighting at night, millions of living beings would be saved and we would reduce CO_2 emissions at the same time.

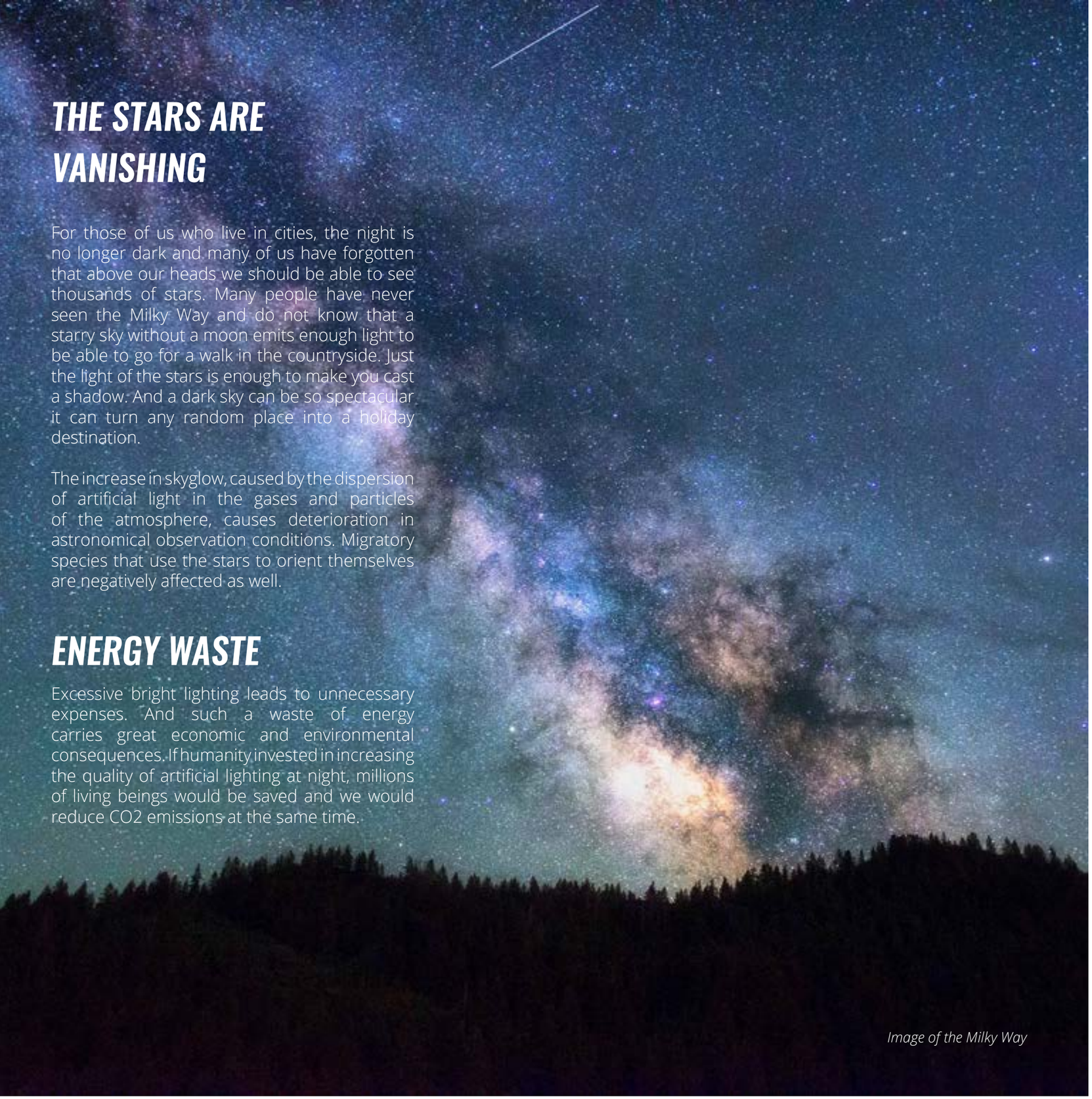


Image of the Milky Way

EFFECTS ON HEALTH

Humans need light by day and darkness by night in order for our biological clocks to work properly. Only when we are in the dark does our body secrete a hormone called melatonin that plays an important role in the regulation of circadian rhythms and sleep.

Computer and television screens as well as other electronic devices emit artificial light. Using these devices until late at night alters and can prevent us from generating the melatonin we need.

The mismatches in the segregation of melatonin can lead to problems such as stress, insomnia, diabetes and even obesity.

Have you ever noticed how hard it is to fall asleep after having used your cellphone in bed for a while?

If you want to minimize these effects, you should install warm light bulbs at home and use special applications to change the colour temperature of your electronic screens so that they emit cold light during the day and warm light at night.

Using any type of device with a bright display minutes before sleep can affect the quality of our rest and cause insomnia.

3 - TYPES OF LIGHT POLLUTION

A large portion of outdoor lighting is currently designed in a way that is not very efficient. It is usually either too bright, poorly directed and sometimes even completely unnecessary.

Among the different types of light pollution there are:

En las noches nubosas se aprecia claramente la luz artificial que emiten las ciudades hacia el cielo.

GLARE

Glare is caused by a light intensity that is too high or by badly directed light. It can cause discomfort and partially impaired vision. Dazzle is extreme glare, for example the flash of a camera or lightning during a thunderstorm,which can cause a photochemical reaction to occur on the retina of the eye causing temporary opsin bleaching, which can take several seconds to recover from.

LIGHT TRESPASS

Although street lights are meant to illuminate the streets, many poorly directed street lights shine into our homes and prevent us from sleeping in darkness.

Although, using blinds to cover the windows can stop the light from coming in, in hotter regions they are not convenient during the summer when the heat forces people to open windows and shutters during the night.

BRIGHTNESS OF THE SKY

Cities are generally bright. The light, when refracted in the molecules of our atmosphere, becomes diffuse and this prevents us from seeing the stars.

Out in nature where it's dark, night clouds appear to be black in colour. In large cities, however, they reflect the light directed towards the sky, consequently the clouds will start to appear orange or blue depending on the colour of the city lights.

Astronomers measure the sky brightness to determine the quality of the observations that can be made in a specific place. Such measures are usually expressed in magnitudes / arcsecond^2.

The highest sky brightness values correspond to the darkest skies, such as those in rural areas located far away from cities. Let us explain why this happens.

The ancient Greek astronomers named the brightest stars visible after sunset 'stars of the first magnitude', and they classified the other stars as 'stars of second magnitude' and so on with the weakest stars being 'stars of sixth magnitude'.

Although modified, the Greek system is still used today. The modern scale of magnitudes includes stars of magnitude 0, but the brightest celestial bodies are still categorised as those of lesser magnitude. In fact, the Sun has a magnitude of -26.74.

In terms of magnitude, the brightness of the sky behaves the same as the brightness of the stars. For this reason, in a city environment with a sky heavily affected by light pollution, the measures would be around 17 mag / arcsec^2, while in places where there are fewer sources of light pollution and with darker skies the values could be up to 21 mag / arcsec^2.

Scientists use devices called photometers to obtain sky brightness measurements which help to evaluate the quality of astronomical observations.

The photometers can be installed for months or years in order to study the evolution of light pollution. And can provide us with specific measurements of a specific place at a specific point in time.

TESS photometer designed by the Complutense University of Madrid

Cities are, in general, strongly lit.

CLUTTER

Too much luminous advertising on roads can be dangerous as it might distract drivers.

Increasing the light intensity does not necessarily make roads safer. Installing an evenly spread uniform illumination definitely does make them safer as it allows people to see more clearly.

Las Vegas, Nevada (USA) is one of the most illuminated cities on the planet. Its brightness can be observed from 400 km away.

Lighting in the city of Las Vegas

The brightness in the cities is growing.

4- HOW TO INSTALL EFFICIENT LIGHTING

Every place and situation has different lighting needs. Our bedroom just before going to sleep does not need the same light as an operation room in a hospital just before a procedure.

To use only the necessary light for each place and situation, so that its use is sustainable and generates the minimum negative impact, a series of guidelines must be followed according to its different characteristics.

POWER

Light bulbs consume electricity. The energy consumed every second is called power, and it is measured in watts (W) is the International System of Units.

Of all the electrical energy consumed by a lamp while on, only a fraction becomes light. Some of the energy is emitted as heat and some as non-visible radiation.

The fraction of energy that is transformed into visible light, every second, is called radiant flow and its unit, in the International System, is the watt.

The sensitivity of the human eye varies according to light intensity. The perceived light power is called flux luminous, and in the International System of Units it is measured in lumen (lm).

Lámparas de distinta potencia encendidas.

EFFICIENCY

Efficiency is defined as the relationship between the luminous flux emitted by a bulb and the power that it consumes.

It is expressed in lumens per watt (lm/W). To minimize the energy spent on the production of artificial light and minimize the watts while obtaining the same lumens more efficient lamps should be used.

Technology	Efficiency (lm/W)
LED	4.5 - 200
High pressure sodium	85 - 150
Low pressure sodium	100 - 120
Fluorescent	60 - 104
Metal halides	80
Mercury vapor	40 - 55
Tungsten incandescent	5 - 17.5

Efficiency table of different lighting technologies

DIRECTION

Artificial light must be aimed properly at its target. Directing the light only to the place where it is needed is very important, especially outdoors, since emitting light in other directions is not only a waste of energy but has negative impacts for both the sky and ecosystems.

Street lamps are meant to illuminate roads or public outdoor spaces. And when lighting up a building the light should never point upwards so to avoid lighting up the sky with the reflection onto the facade.

"Balloon-type" street lamps are extremely inefficient. It is better to use shielded street lamps with the bulb installed horizontally and the flux luminous directed downwards.

COLOUR TEMPERATURE

Light is an electromagnetic wave whose energy depends on its wavelength. In the case of visible light, the most energetic is the blue one and the least energetic is the red one.

Bulbs can emit light with different "colour temperature", which is measured in Kelvin. The light is warm if its colour is orange or reddish and cold if white or blue colours predominate.

If we install warm lighting in our bedrooms and in relaxing areas we will help our body to generate the melatonin it needs to rest. Ideally, 2700K light bulbs should be chosen for the rooms where there is some activity while 2200K light bulbs are more adequate to use just before bedtime.

When performing activities that require a lot of precision or that are performed in the light of day the use of cooler lighting will help us as it allows us to make a clearer distinction between colours.

In the end it is about imitating natural light. On a clear day, the sunlight has a colour temperature of approximately 5800K. The light of fire used by our ancestors to light up their living spaces was between 2000K and 2200K.

Visual sensation of the colour of light bulbs with different colour temperature and 200 lux.

Light generates a psychological sense of safety, but for safety to be real light should be uniform.

UNIFORMITY

Uniformity is defined by the way the light flow is distributed on a lit surface. An adequate lighting design makes surfaces look evenly illuminated with the same intensity at all points, avoiding a strong contrast between bright spots and shadows.

A very intense but unevenly lit street (left) is unsafer than a uniform dimly lit street (right).

Uniform lighting produces visual comfort, facilitating vision.

TIME OF USE

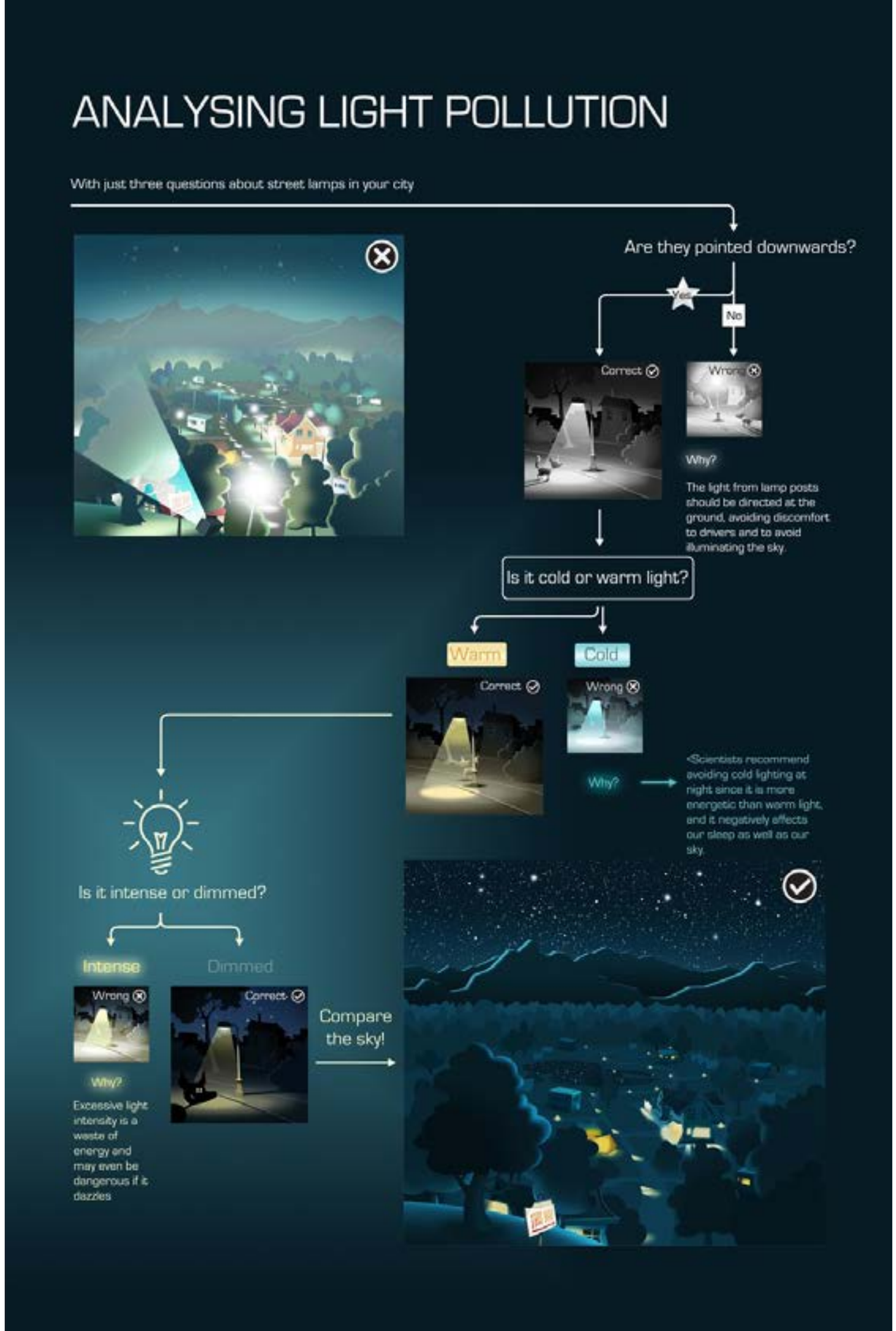
Light emitted by cities is a clear indicator of the activity of its inhabitants as our first reaction to the sun setting is to switch on all our lights, hence trying to artificially lengthen our day.

The first places where we tend to turn on the lights are in our homes, shops and places of work. Street Lamps are switched on shortly before sunset while boutiques try to draw our attention to their shop windows by lighting up their windows. Not long after that, the ornamental lights are switched on illuminating monuments and building facades.

The vast majority of light sources remain on all night, even if they are not being used. We could lower energy consumption by turning off or dimming the unnecessary lights at certain time slots and installing presence sensors on roads and streets with low traffic conditions.

Presence sensors are especially useful in low traffic areas.

All characteristics have to be analysed as a whole to install the appropriate lighting in each place.



5-CITIES AT NIGHT

Did you know that astronauts from the International Space Station (ISS) would be able to tell when you go to sleep? The nocturnal habits of the inhabitants of any city generate differences in lighting patterns that are easily spotted from space.

Astronaut Samantha Cristoforetti in the ISS Cupola.

The ISS takes 92 minutes to complete one full orbit around our planet, allowing its crew to fly over any specific continent several times each night. With commercial digital SLR cameras, similar to the ones any of us might have at home, astronauts take night photographs of cities through the observation module windows.

Nighttime photographs of cities have great scientific value since they contain valuable information about the light that is emitted into space. Images taken by astronauts onboard the ISS are especially interesting, since they are the only ones available with that resolution and colour information.

With these images scientists can detect the changes in intensity and colour temperature over time.

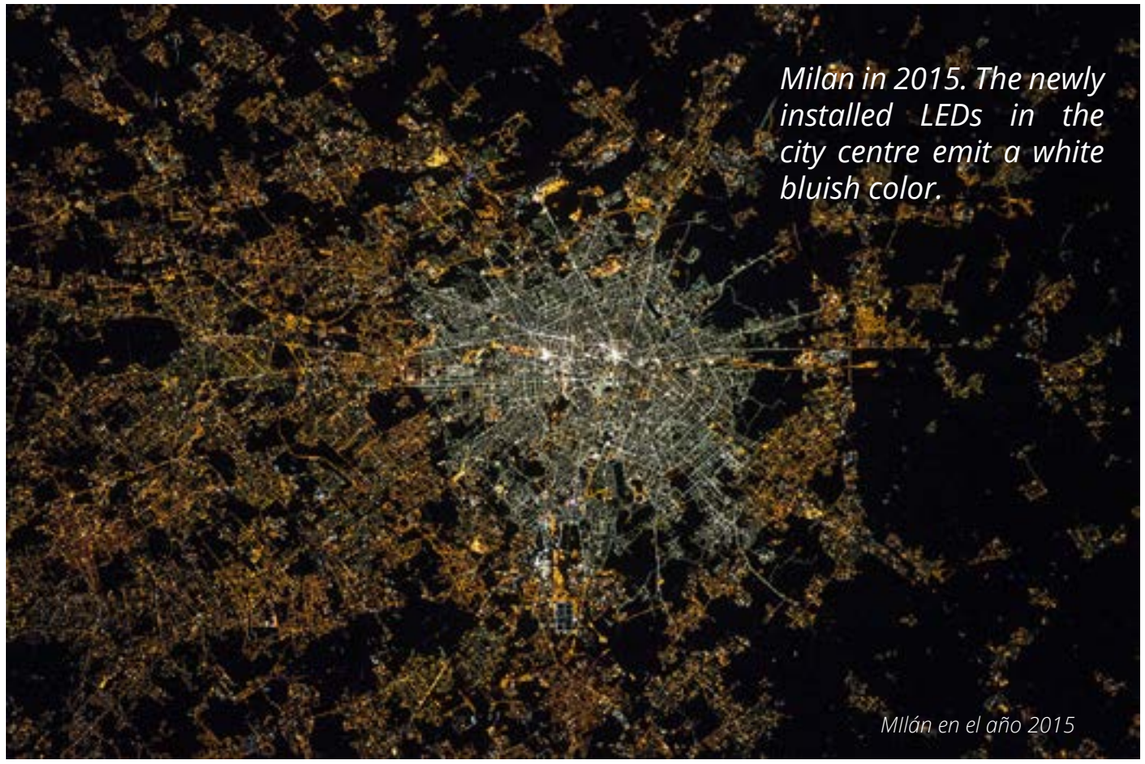
For example, with the help of these images, an increase of light pollution caused by newly installed LED bulbs was detected. This was an unexpected find for many since they are said to be more efficient than the orange bulbs they replaced. The colour data of ISS images allowed scientists to detect that the LED bulbs were causing an increase in pollution due to their cooler colour temperature.

The city of Madrid as seen from the ISS

With the transition to LED technology, the colour temperature of city lighting is becoming much colder.

Milan in 2012. The city center used to be illuminated with orange incandescent lamps.

MIlán en el año 2012



Milan in 2015. The newly installed LEDs in the city centre emit a white bluish color.

MIlán en el año 2015

CITIZEN SCIENCE FOR LOCATING IMAGES

The photographs taken by astronauts onboard the ISS are the best source of data available that allows scientists to study light pollution and its evolution through time. However, currently most images remain unused in the NASA data base because the images are stored unclassified making it extremely difficult to find an image of a particular city among the more than half a million photographs.

The objective of the Cities at Night project is to locate all the nocturnal images of cities taken from the ISS and use them to make a map of the world at night.

Sorting images automatically requires a lot of resources and would be too complicated for algorithms. However, people can easily distinguish between city shapes to see if they are the same or different cities.
For this reason, various applications have been launched since Cities at Night began so that everyone can help solve the world's largest puzzle. The example presented below is from the Lost at Night application and presents several options to identify which city is a match with the unclassified image.

Furthermore, thanks to the project we can now also compare lighting between cities. On the next page you will be able to study 6 images of European capitals taken on the same night with the same camera, objective and exposure time. For example, with this data experts have been able to verify that Madrid is three times brighter than Berlin.

Screenshot of the Lost at Night app - lostatnight.org

6 - ACTIVITIES

ACTIVITY 1

The shape of the street lamp is very important to minimize light pollution.
Among the lanterns that you can see in the following images, which ones would you choose for your back garden? Why?

farolillo a

farolillo b

farolillo c

farolillo d

farolillo e

Your answer:

ACTIVITY 2

The colour temperature must be adequate for each situation. What colour temperature light bulbs would be suitable for a bedroom? And for the kitchen? Which ones do you think should be installed in your street? And in the park?

Tu respuesta:

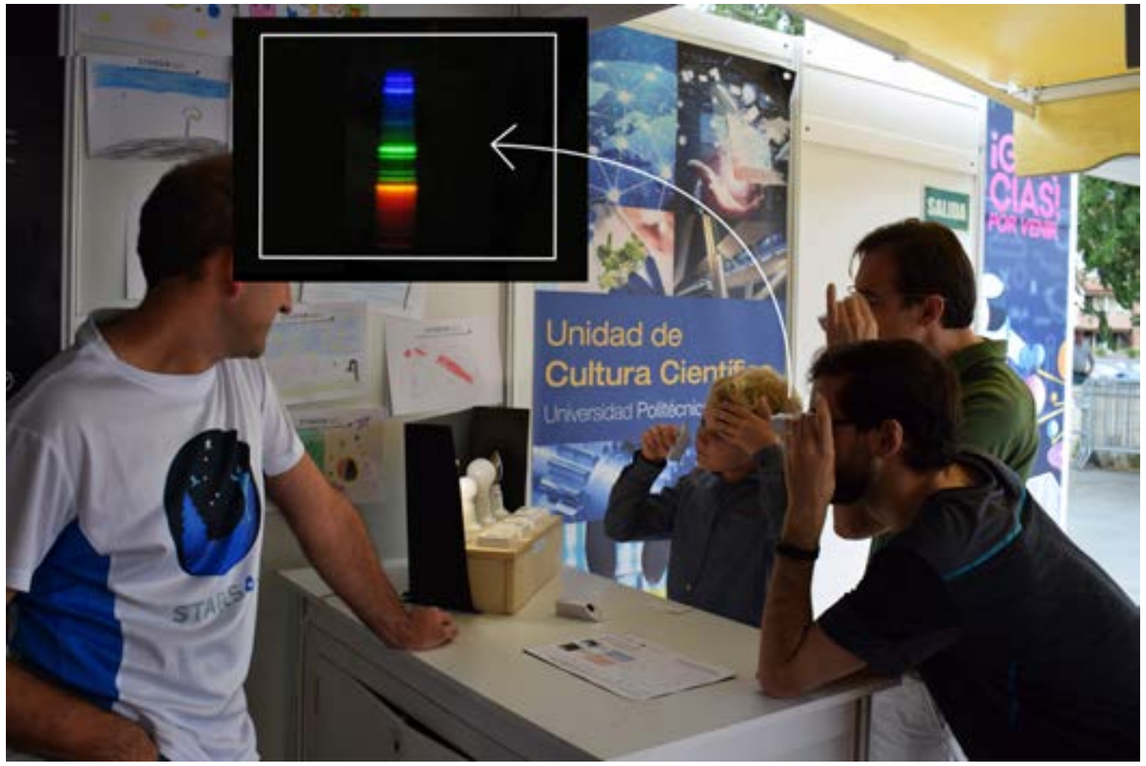
Make a list that includes at least 5 bulbs that you have installed in your home or in your school. **Write down the place where they are installed, their power, their colour temperature and indicate how you could improve the lighting in these places.**

Your answer:

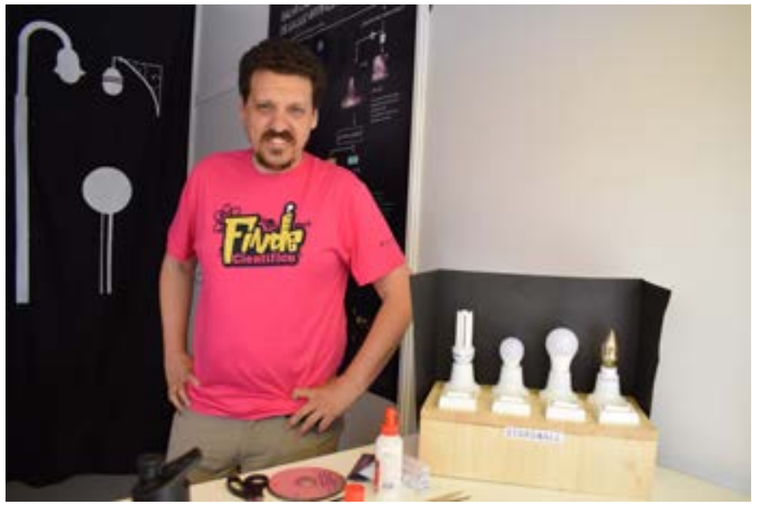
Light bulb	Place	Power	Colour temperature	How would you improve it?
1				
2				
3				
4				
5				

ACTIVITY 3: BUILD YOUR OWN HOME SPECTROGRAPH

Build your own homemade spectrograph following the instructions below and use it to take 5 photographs of different light sources.



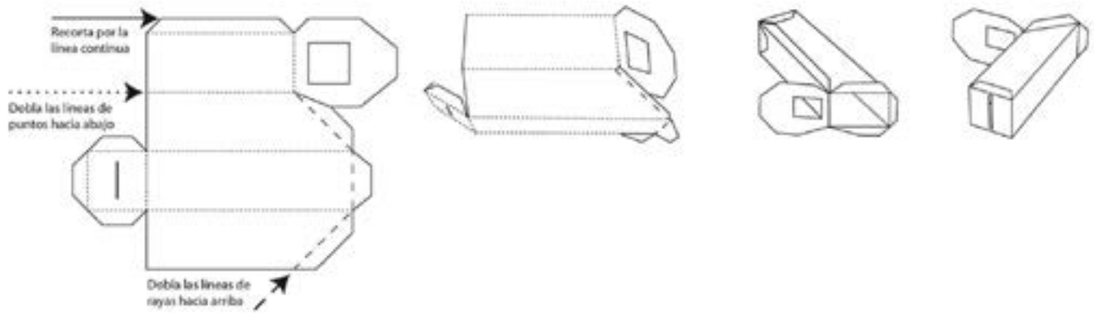
Using the homemade spectrograph



Types of bulbs

Instructions:

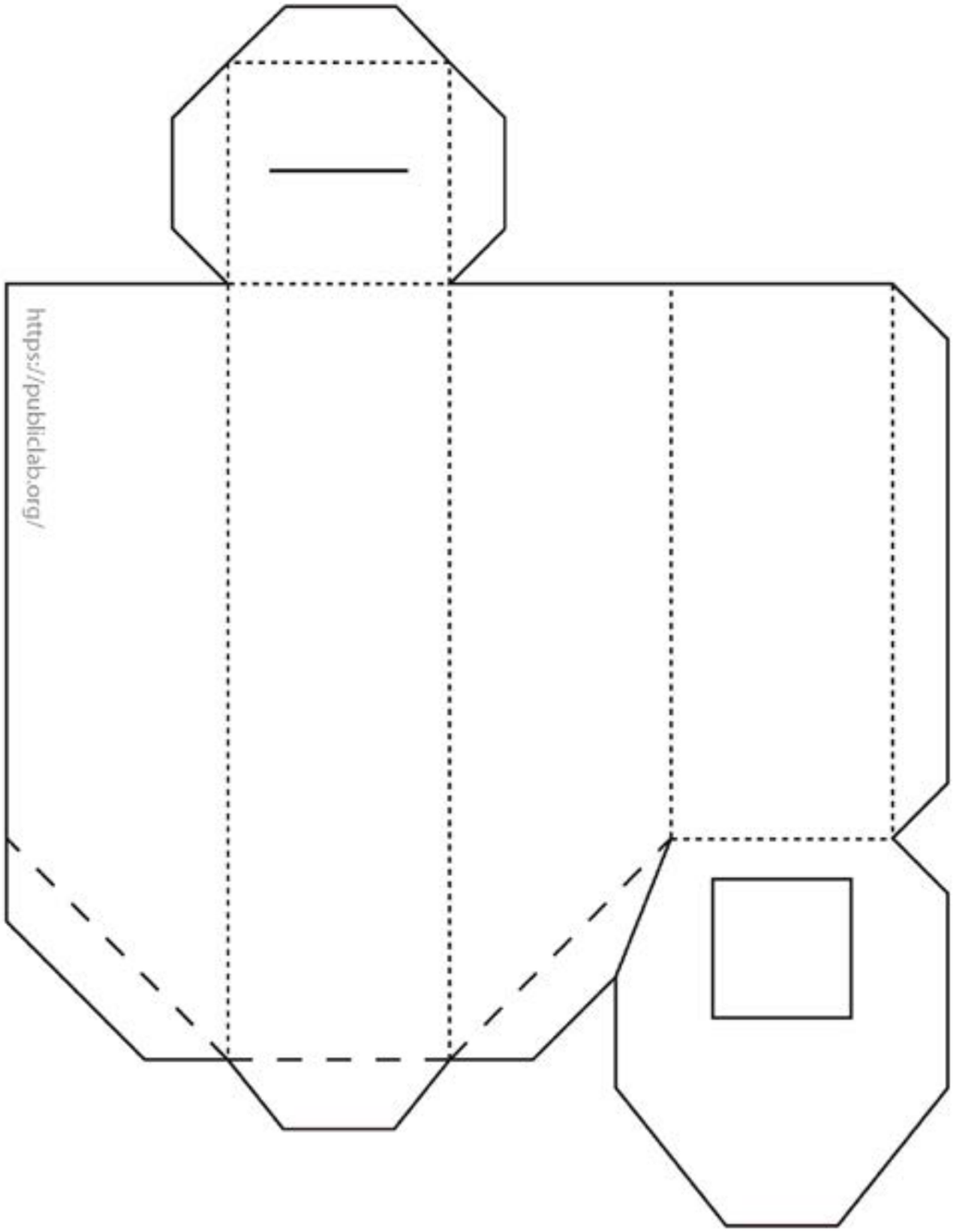
1 Cut along the continuous line, both the outline of the figure and the window. Open the slit carefully using a sharp knife. Fold the dotted lines down and the dashed lines up to form a prism. Glue all tabs except those at the base of the window.



2 It is necessary to include a diffraction grating to make it work. You can make one by cutting a CD and removing the reflective layer. It is important to place the network with the grooves vertically so that they are parallel to the slit.

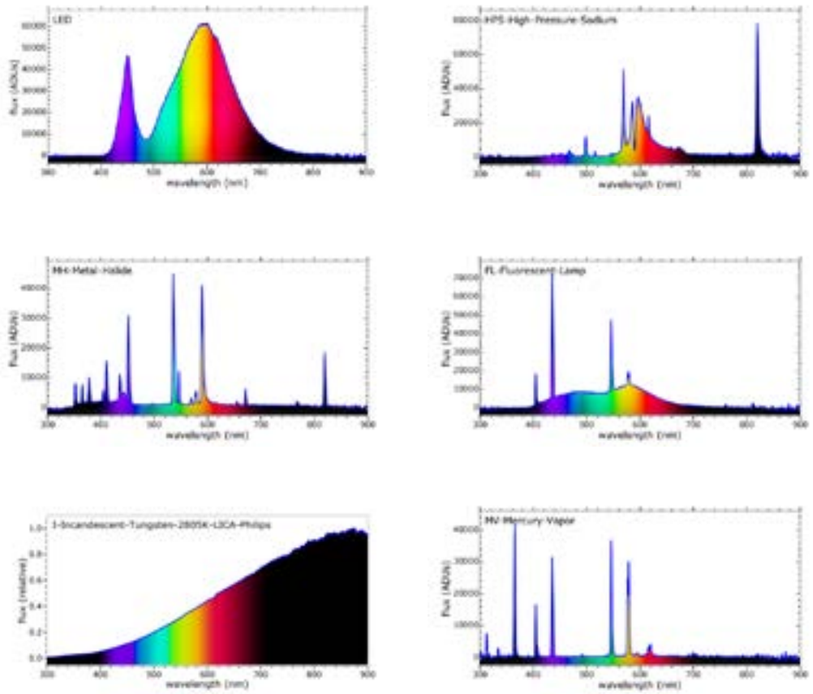
3 The spectra can be observed directly with the naked eye, but you can take photographs as well using a camera.The one on your cell phone or your laptop should do the trick!

homemade spectrograph model:

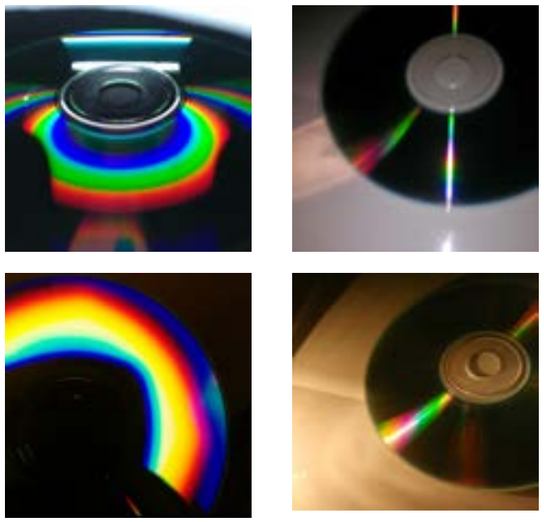


ACTIVITY 4

Depending on the technology of the bulbs, their spectra will be different. Compare your results with the theoretical spectra below to determine what type of bulb you have used.



Examples of the light spectrum of different light sources on the surface of a CD, obtained with a smartphone camera:



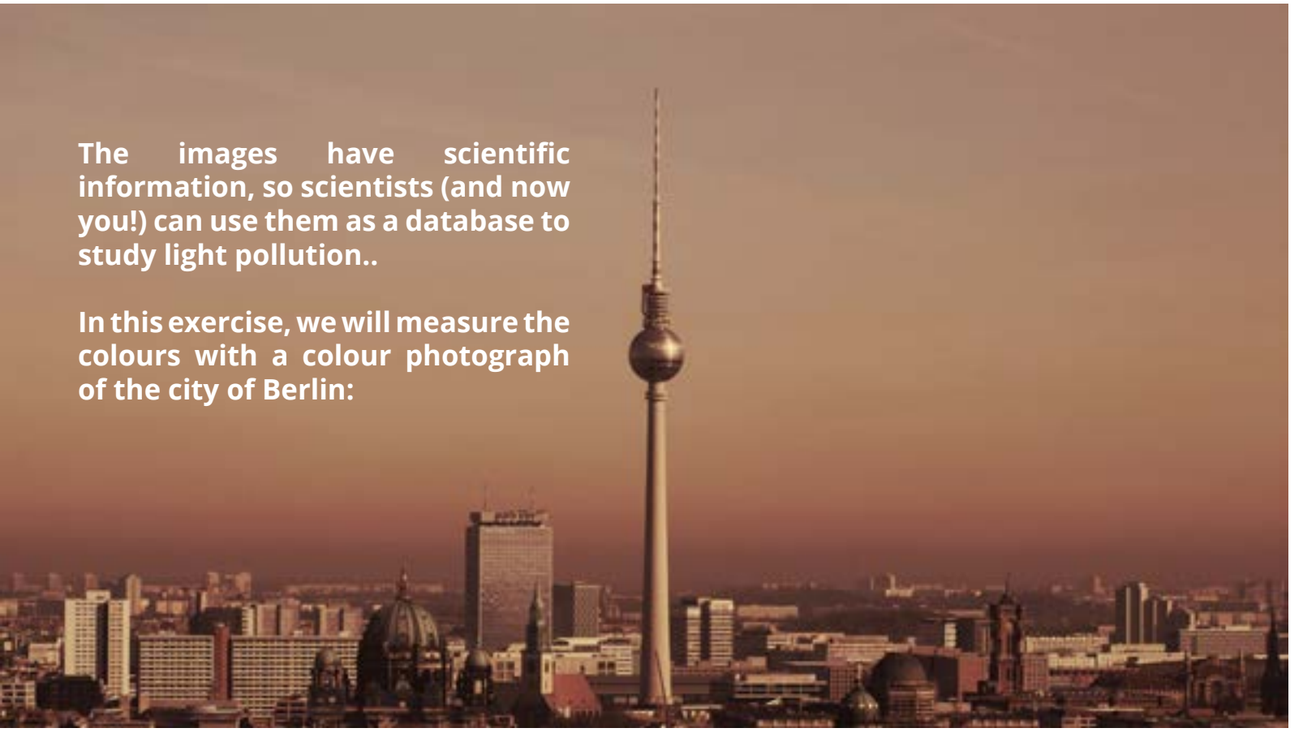
Sunlight

LED

FLuorescent

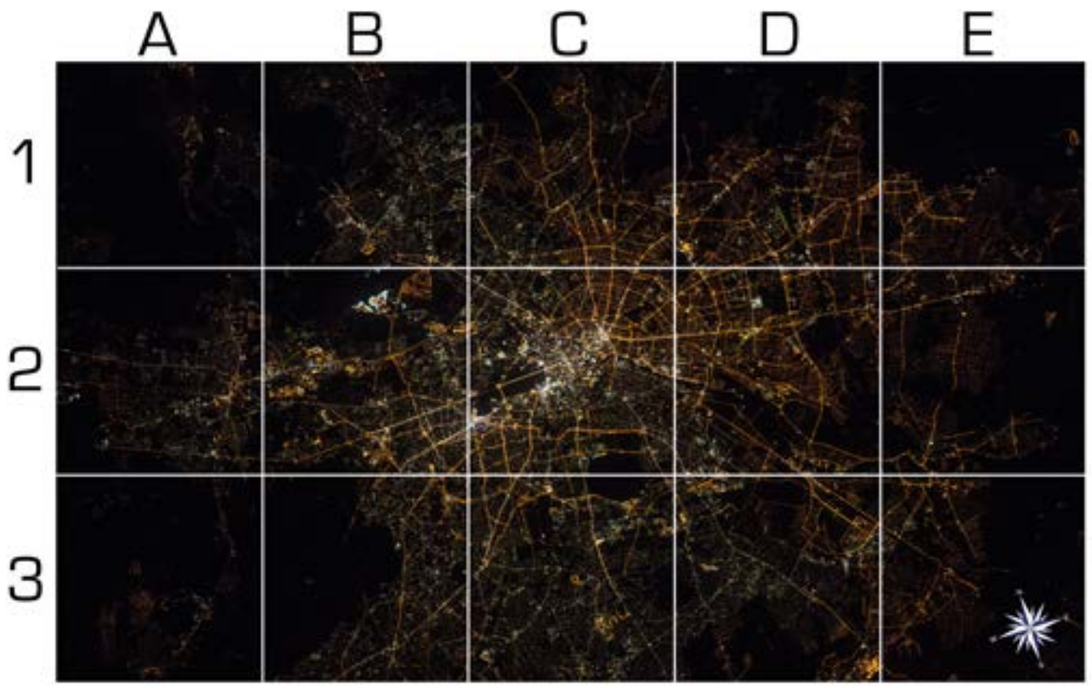
Conventional Bulb

ACTIVITY 5



The images have scientific information, so scientists (and now you!) can use them as a database to study light pollution..

In this exercise, we will measure the colours with a colour photograph of the city of Berlin:



Open this image with an image editing program (you can choose a very simple one, for example Paint). Choose the point you think best represents the color of the lighting in each area and mark it with the colour picker.

Write down how much your colour is made out of green, red and blue. Make the divisions that are marked on the table. Zone 1A shows you an example.

To get the X value, you need to divide the amount of blue with the amount of green. And to get the Y value, divide the amount of green by the amount of red. Once you have finished, create a graph using the results of columns X and Y.

Colours positioned in the right top corner are the biggest polluters.

zona	color seleccionado	VERDE	ROJO	AZUL	VERDE/ROJO	AZUL/VERDE
1A		85	146	40	0,41	0,58
1B						
1C						
1D						
1E						
2A						
2B						
2C						
2D						
2E						
3A						
3B						
3C						
3D						
3E						

ACTIVITY 6

Discuss the lighting problems you see in the following images. If you would want to reduce the light pollution, how could the lighting be improved in each case?

Your Answer:

LINKS OF INTEREST

CRÉDITOS DE LAS IMÁGENES

Cities at Night Project
https://citiesatnight.org/

Fundación Ibercivis
https://ibercivis.es

Spanish Foundation for Science and Technology
https://www.fecyt.es

Catalog of NASA photographs taken by astronauts aboard the ISS
https://eol.jsc.nasa.gov/

IDA - International Dark-Sky Association
https://www.darksky.org/

Light quality education kit
https://www.noao.edu/education/qltkit-es.php

Definition of Light Pollution
https://www.informea.org/en/terms/light-pollution

High Light Pollution
https://www.lightpollutionmap.info/

Software to change the color temperature of your computer screen
https://justgetflux.com

UCM light pollution projects
https://guaix.ucm.es/darkskies

Imagen de la Actividad 5: Alejandro Sánchez de Miguel et al, "Colour remote sensing of the impact of artificial light at night (I): The potential of the International Space Station and other DSLR-based platforms" Remote Sensing of Environment Volume 224, April 2019, Pages 92-103
https://doi.org/10.1016/j.rse.2019.01.035

Bulb - Imagen de Jonny Lindner en Pixabay
https://pixabay.com/es/photos/bombilla-actuales-la-luz-resplandor-503881/

Teacher - Imagen de Free-Photos en Pixabay
https://pixabay.com/es/photos/persona-mujer-femal-801829/#_=_

Honk Kong - Imagen de David Mark en Pixabay
https://pixabay.com/es/photos/hong-kong-ciudad-urbana-rascacielos-1990268/

Road - Imagen de SplitShire en Pixabay
https://pixabay.com/es/photos/carretera-calle-por-carretera-noche-407093/

Night animals
https://pixabay.com/es/photos/alce-animales-navidad-1793632/

Milky Way - Imagen de Pexels en Pixabay
https://pixabay.com/es/photos/la-astronom%C3%ADa-constelación-oscuro-1866822/

Bear and computer - Imagen de DanFa en Pixabay
https://pixabay.com/es/photos/bear-computer-night-lila-dark-2382779/

Flash - Imagen de Pexels en Pixabay
https://pixabay.com/es/photos/fotograf%C3%ADa-estudio-sesi%C3%B3n-de-fotos-1850469/

Cloudy City - Imagen de carloyuen en Pixabay
https://pixabay.com/es/photos/nubes-hong-kong-noche-niebla-haze-2517653/

TESS fotometer - Producción propia
https://tess.stars4all.eu

Las vegas - Imagen de skeeze en Pixabay
https://pixabay.com/es/photos/las-vegas-tiempo-de-la-noche-599840/

Lamps - Imagen de xegxef en Pixabay - Editada
https://pixabay.com/es/photos/luz-lámpara-electricidad-el-poder-1603766/
Formas de farolas - Producción propia
https://citiesatnight.org/wp-content/uploads/2016/07/Farolas_esp.jpg

Colour Temperature - Producción propia - Bombilla original de geralt en Pixabay
https://pixabay.com/es/illustrations/bombilla-creo-que-idea-solución-2010022/

Road - Imagen de StockSnap en Pixabay - Editada
https://pixabay.com/es/photos/calle-por-carretera-flechas-2619708/

París - Imagen de Kevin Phillips en Pixabay
https://pixabay.com/es/photos/torre-eiffel-francia-puesta-de-sol-951517/

Streetlight - Imagen de Samuele Schirò en Pixabay
https://pixabay.com/es/photos/noche-árbol-farola-cielo-930963/

Analyze Light Pollution - Lucía García | Comic: Rainer Stock
https://stars4all.eu/wp-content/uploads/2018/12/correcta-iluminación-nocturna.jpg

Astronaut Samantha Cristoforetti - ESA
www.esa.int/ESA_Multimedia/Images/2016/03/ESA_astronaut_Samantha_Cristoforetti_in_the_Cupola

Madrid from the ISS - JSC Earth Science & Remote Sensing Unit. NASA Johnson Space Center
https://eol.jsc.nasa.gov/SearchPhotos/photo.pl?mission=ISS038&roll=E&frame=41064

Milan from the ISS 2012 - JSC Earth Science & Remote Sensing Unit. NASA Johnson Space Center
https://www.iau.org/static/archives/images/screen/iau1510b.jpg

Milan from the ISS 2015 - JSC Earth Science & Remote Sensing Unit. NASA Johnson Space Center
https://www.iau.org/static/archives/images/screen/iau1510a.jpg

Screenshot of Lost at Night - Lucía García (Includes images from NASA)

Comparison of European cities - Lucía García (Includes images from NASA)

Lantern 1 - Goumbik en Pixabay
https://pixabay.com/es/photos/linterna-oscuro-lámpara-noche-2938031/

Lantern 2 - fancycrave1 en Pixabay
https://pixabay.com/es/photos/la-pared-lámpara-grunge-interior-823611/

Lantern 3 - Free-Photos en Pixabay
https://pixabay.com/es/photos/lámparas-linternas-diseño-colgando-918495/

Lantern 4 - JerzyGorecki en Pixabay
https://pixabay.com/es/photos/crepúsculo-lámpara-de-repuesto-2291361/

Lantern 5 - leovalente en Pixabay
https://pixabay.com/photos/lights-pole-street-lamp-posts-340483/

Types of light bulbs - Lucía García

Spectroscope - Lucía García

Paper spectroscope - Publiclab.org
https://publiclab.org/sites/default/files/8.5x11mini-spec3.8.pdf

Luz intrusa - Editada
https://pixabay.com/es/photos/vivir-dormitorio-arquitectura-3104077/

Luz poco uniforme
https://pixabay.com/es/photos/persona-perro-urbana-farola-niño-498197/

Deslumbramiento
https://pixabay.com/es/photos/retrato-flash-tiene-usted-niña-1243972/

Aglomeración
https://pixabay.com/es/photos/los-libros-la-colección-de-2596809/

Espectros de distintas bombillas - Carlos Tapia (UCM)
http://www.carlostapia.es/lamparas/lamps.html

Berlín - JSC Earth Science & Remote Sensing Unit. NASA Johnson Space Center
https://eol.jsc.nasa.gov/SearchPhotos/photo.pl?mission=ISS035&roll=E&frame=17365

Península contraportada - JSC Earth Science & Remote Sensing Unit. NASA Johnson Space Center
https://eol.jsc.nasa.gov/SearchPhotos/photo.pl?mission=ISS040&roll=E&frame=81320

Berlín
https://pixabay.com/nl/photos/berlin-tv-toren-skyline-alex-4001319/

Night Landscape
https://pixabay.com/es/photos/por-carretera-de-la-ciudad-403752/

Estudiante
https://pixabay.com/es/photos/chica-joven-estudiante-sentado-3718526/

DIDACTIC UNIT CITIES AT NIGHT

CITIZEN SCIENCE PROJECT TO LOCATE LIGHT POLLUTION SOURCES

https://citiesatnight.org