

## **Letter of Transmittal**

12/6/2022

Don Leu, Mayor of West Unity  
West Unity Village Clerk's Office  
224 W Jackson St  
West Unity, OH

Dear Mr. Leu:

In this report, we would like to talk about the light pollution in West Unity and how we can better the village in not wasting so much light into our bright night sky. In doing this we recommend different kinds of light bulbs, dimmers and light covers. Our goal is to make it so that we can see our night sky more clearly and let the stars provide us with a better picture, and to also protect our wildlife from unnecessary light. We hope that you give this idea a chance and implement our thoughts into action so we can better our planet!

Sincerely,

Claire Hutchinson, Caleb Macklin, Hayden Meyer, Jaden Bowers, Jeremy Kennedy, Nathan Brubaker

## **Light Pollution**

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## **Abstract**

Light pollution is the excessive and inappropriate use of artificial outdoor night light. This issue is affecting energy costs, public health, and the ability to observe the night sky. About 1/3rd of public light in the United States is wasted, costing taxpayers about \$2.2 billion a year. This is primarily caused by using inefficient bulbs, improper shielding, and over-illumination. Public health is also affected by light pollution, primarily by disrupting the circadian rhythm, the process that regulates the melatonin hormone. Disruption of melatonin results in many adverse health effects, some of which include sleep deprivation, headaches, and anxiety. The ability to observe deep-sky objects, such as the Milky Way and Andromeda galaxies, has been negatively affected by light pollution. The inability to observe a night-sky, free of light pollution, has dissuaded many people from the study of space, leaving only a niche group of people with interest.

To solve these problems, it is recommended that the public lighting infrastructure is updated. The first improvement that could be made would be to swap out the current HPS bulbs on street posts with efficient LED bulbs, preferably with bulbs with warmer colors, to reduce running costs by up to 75%. The next improvement to make would be to add light shields to reduce light trespass. The final improvement would be to adjust the luminous intensity of the posts to a point that effectively covers the intended area of illumination. Together, these changes would reduce running expenses by a significant amount, eliminate light trespass causing the adverse health effects, and reencourage people to study the night-sky.

## **Introduction**

Light pollution is the “excessive or inappropriate use of artificial outdoor light”. This issue is affecting energy costs, public health, and the ability to observe the night sky. It is estimated that about “1/3rd” of all light in the United States is wasted, which equates to about “\$2.2 billion”, according to the International Dark Sky Association. Artificial night light interrupts our internal clocks and disrupts the production of melatonin, which causes many health problems. Light pollution affects the ability to see the Milky Way and other deep sky objects as artificial light drowns their natural light.

I propose that the West Unity municipality invest in sustainable upgrades to its streetlamp infrastructure to reduce light pollution. This minor investment will save a significant amount of taxpayer's money in the long run while also reducing the negative health effects incurred and increasing night sky visibility.

### **Energy Costs**

A significant amount of light is wasted each year, “1/3” of it in the United States. This translates to about “\$2.2 billion” wasted in energy costs, money that could be better spent elsewhere. The reasons behind such a large portion of light being wasted are due to excessive luminosity, the types of light bulbs used, and improper shielding of light. Many outdoor lights’ brightness is set to illuminate more than what is intended, contributing to energy waste. Currently, high-pressure sodium (HPS) lights are the most common bulb used for outdoor lighting, but they are quite energy inefficient compared to a light emitting diode (LED) bulb, which uses up to “75%” less energy than an HPS bulb. Many street posts do not have proper shields on top of them to prevent light leakage, which contributes to nearly “30%” of the wasted energy.

### **Types of Bulbs**

#### **High-Pressure Sodium (HPS)**



High-Pressure Sodium, or HPS bulbs, are relatively energy efficient, producing between 80 to 140 lumens per watt and having a lifespan of around 24,000 hours. They are composed of an aluminum oxide ceramic arc tube that contains xenon, mercury, and sodium. HPS bulbs operate by sending a pulse of energy through the arc tube by way of an ignitor built into the electrical ballast, igniting the xenon gas. As the xenon rises in temperature, it heats the mercury first to the point of vaporization and then ignition. As the arc tube continues to heat, the sodium vaporizes and ignites, producing the distinct orange glow we know so well.

One downside to the HPS bulbs is the hazardous elements they contain within. Mercury can be extremely harmful or even fatal if ingested or inhaled, and sodium is exceptionally volatile, having the potential to explode when introduced to air. This makes proper disposal of used bulbs paramount once they have reached the end of their life cycle.

#### HPS Advantages:

- Energy efficient light production 80-140 lm/W
- 24,000 hour average lifespan.
- Wide availability and relatively inexpensive

#### HPS Disadvantages:

- Requires a ballast for primary ignition and to maintain constant current.
- Contains harmful elements that are necessary for operation.
- Disperses light in all directions rather than being focused on a single area.

### **Light Emitting Diode (LED)**



Light Emitting Diodes, or LEDs, were invented in 1927 by Oleg Losev and work through a process called Electroluminescence. Electroluminescence is a phenomenon where light is emitted from a material in response to an electrical current flowing through it. LEDs found their first practical use in 1962 when they were used as a replacement for incandescent indicator bulbs in various electronic devices. In 2008, the United States Department of Energy launched the “L Prize” competition which sought to encourage the development of LEDs as replacements for 60W incandescent bulbs. The first L Prize was won in August 2011 by Philips Home Lighting of America with their LED bulb that produced light similar to the 60W bulbs available at the time but used 1/5th the power. Modern-day LEDs are extremely energy efficient, producing between 135 to 223 lumens per watt, and have a lifespan of around 35,000 to 50,000 hours.

One downside of LED lights is that because of how they operate, changes in the voltage applied to the bulb could negatively impact its lifespan. Because of this, it may be necessary to implement surge protection for each bulb, increasing the initial cost of the upgrade. Also, because LEDs contain trace amounts of lead and arsenic, which could potentially cause harm to the environment, they must be properly disposed of once their life cycle has been completed.

LED Advantages:

- Extremely energy efficient light production 135-223 lm/W.
- Light can be focused in a general area rather than dispersed in all directions.
- 35,000-50,000 hour lifespan.

LED Disadvantages:

- Upfront cost is more expensive than other options.
- Fluctuating currents could shorten its lifespan.
- Contains trace amounts of harmful elements.

## **Compact Fluorescent Lamp (CFL)**



Compact fluorescent lamps, or CFLs, were first created in the mid-1970s, but it would be another 20 years before the corkscrew design we know so well today would come to market. CFLs work similarly to standard fluorescent tubes, in which a ballast creates a high-voltage arc that is sent through a gas-filled tube which heats and vaporizes the mercury, producing UV light. The phosphors coated on the interior of the tube then convert the UV light into visible light by increasing the wavelength. CFLs can be broken down into two categories, integrated and non-integrated. Integrated CFLs contain an integrated ballast built into the bulb and can be used in standard lighting sockets. Non-integrated CFLs require an external ballast either built into the lighting fixture itself or by way of an adapter.

One of the downsides of CFL bulbs is that in order to get a higher light output, the helical bulb would require a greater surface area. This not only means that the bulb size will need to be increased to produce more light, but it will also require more energy to produce that light. The larger bulb may also make it difficult to use in existing fixtures.

#### CFL Advantages:

- Energy efficient light production 50–70 lm/W.
- 6000–15,000 hour lifespan.
- Wide availability and relatively inexpensive

## CFL Disadvantages:

- A larger bulb is required for higher light output.
- Additional voltage may be required in colder climates to assist in the CFLs' startup.
- Contains harmful elements that are necessary for operation.

## Metal Halide



Metal Halide bulbs, first developed in the 1960s, are another type of bulb we see in streetlights today. Metal Halide bulbs are fairly energy efficient, producing between 65-115 lumens per watt, and have a lifespan of around 20,000 hours. They are composed of a quartz arc tube that's filled with argon gas, mercury, and halide salts. The bulbs operate by sending a pulse of energy through the arc tube by way of an ignitor built into the electrical ballast, igniting the argon gas. As the argon rises in temperature, it heats the mercury first to the point of vaporization and then ignition. As the arc tube continues to heat, the halide salts vaporize and ignite, producing light. The color of light produced by these bulbs depends on the halide salt used in the arc tube. Silver chloride produces white light, silver bromide produces soft yellow light, and silver iodide produces a greenish-yellow light.

One of the downsides of Metal Halide bulbs is that the light they produce is by far whiter than the light produced by most other bulbs. While this is great in areas where color needs to be displayed as true-to-life, this white light can be a significant contributor to light pollution.

## Metal Halide Advantages:

- Energy efficient light production 65-115 lm/W.
- 20,000-hour average lifespan.
- Excellent for indoor applications where color needs to be displayed true-to-life.

## Metal Halide Disadvantages:

- Requires a ballast for primary ignition and to maintain constant current.
- The light produced is a major contributor to light pollution.
- Disperses light in all directions rather than being focused on a single area.

## Correlated Color Temperature - CCT



As it pertains to light, we use the correlated color temperature, or CCT, to show what hue of light will produce in degrees Kelvin. The Kelvin scale measures the temperature a black body would need to be heated to before it radiates visible light. The visible light produced falls between around 1,000K to 10,000K, with anything measured higher or lower falling respectively into the ultraviolet and infrared ranges. Visible light on the lower end of this spectrum produces a longer wavelength of light that results in a reddish hue, whereas light on the higher end produces a shorter wavelength of light resulting in a bluish hue. Oddly enough, we think of light on the higher end of this spectrum as being “cool” in color and light on the lower end as being “warm,” though naturally, it is the complete opposite. The artificial light sources we use typically fall in the 2000K to 6000K range. For reference, the CCT of light produced by our sun is around 5000K to 6500K depending on its position in the sky and other environmental factors.

## Light Shields

Light shields are a critical component in reducing light pollution. Light shields are contraptions that block light from moving in a certain direction. When implemented, they are placed on top of

street posts to block light from leaking into unwanted areas, and keep light focused on the needed areas. There are different types of light shields, which are either considered partial, half, or full light shields. Partial shields only block a small amount of light, typically not enough to make a noticeable difference compared to before the shield was implemented. Half shields eliminate direct leakage to the sky, but glare still remains. Full shields eliminate leakage to the sky, most glare, and the negative health effects associated with light pollution, therefore providing the best protection to the population.

### **Public Health**

Light pollution is causing a very serious health crisis. It affects our internal “circadian” clocks and disrupts melatonin production. This causes people to suffer from “sleep deprivation, fatigue, headaches, stress, anxiety”, with higher wavelength lights (blue-violet) significantly enhancing these symptoms. The glare produced by excessive light can also distract drivers and can hide potential intruders or attackers from view. Melatonin is a hormone that is released by darkness and blocked by light. It plays a large role in regulating our wake-up and sleep schedule.

### **Wildlife**

Not only does light pollution affect human health, but it also affects other animals and disrupts their ecosystems. Migration patterns, reproduction cycles, and hunting/feeding times are determined by the brightness of the natural sky. Artificial light adds to the night sky, disrupting these patterns and causing a catastrophe. Sea turtles, an endangered species, naturally move toward moonlight during migration, but with excessive artificial light, they get confused and head toward cities, eventually dying off. This instance is only one of many effects of light pollution on the night sky. Songbirds are greatly affected by light pollution as well. To avoid predators, they mostly migrate at night to avoid predators using moonlight to guide them. Light pollution can disorient the birds messing up their natural compass, causing them to veer off course or fly into buildings in bright cities.

### **Circadian Rhythm**

The circadian rhythm is an internally driven clock that runs twenty-four hours a day and aids in the sleep cycle. It also regulates processes such as “hormonal activity, body temperature

rhythm”, and the digestive system. The circadian rhythm works as light enters the eyes, even when the eyelids are shut, it stimulates a signal in the back of the retina and sends the signal to the circadian clock in the brain. In response to the absence of light, the pineal gland produces melatonin, a hormone that induces sleepiness or keeps a person sleeping. Nearby light pollution can enter the retina as someone tries to sleep, disrupting the production of melatonin and preventing them from sleeping, which hosts the adverse health effects of sleep deprivation, headaches, stress, etc., with blue light having the most significant effect out of the color spectrum.

### **Case Study**

This case study observes the differences in two of the most light polluted locations in the world Warsaw, Poland and Fukuoka, Japan. It compares two large cities close in population size. On average Warsaw had an illumination of 22.6lx and Fukuoka had an illumination level of 19.9lx. This indicates that most of the population of the city live in highly light areas. The lighting temperature was found to be 2652 Kelvin in Warsaw and 4084 Kelvin in Fukuoka. 5000K is considered to be as bright as the sky at noon and a cool blue color. Fukuoka, while having a hotter lighting temperature, also has a lower luminance level because of better lighting infrastructure. Fukuoka had only 38.7% of unacceptable light sources that were unshielded or over grouped together while Warsaw had 42.6%. Although Fukuoka uses brighter colored lights they demonstrate how effective light shielding can be for lowering unnecessary illuminance.

### **Night Sky**

Light pollution has severely degraded the ability to observe the Milky Way band and deep sky objects. The ability to observe stars, galaxies, and other deep sky objects are measured in Bortle classes, with a class 1 sky having full visibility of the night sky and a class 9 sky being completely obstructed by light pollution. Naturally, the Bortle class of the sky is determined by sunlight and moonlight, but as of recently in Earth’s history, artificial light greatly determines the Bortle class of the sky. Astronomers are most impacted by this, but casual stargazers are also affected. People who may want to study the night sky may be dissuaded by the light pollution present in the sky.

## **Conclusion**

Light pollution is a financial and public health crisis. It leads to high energy costs, causes sleep deprivation and other adverse health effects, negatively affects animal ecosystems, and impairs the ability to view a natural night sky. Implementing a solution to this problem benefits all. Installing warm-colored LED bulbs on street posts, installing full light shields on top of them, and lowering the brightness to non-excessive levels would solve all mentioned problems.

## **Recommendations**

To solve the problems of energy costs, public health, and night-sky viewing associated with light pollution, it is recommended that the public lighting infrastructure is updated with efficient technology.

The first improvement that could be made to the infrastructure would be to swap out the current HPS bulbs on street posts with efficient LED bulbs, preferably with bulbs with warmer colors. It takes 200 watts to power the frequently used HPS bulbs, while an LED bulb only needs 54 watts to output a light at the same luminosity. This means, based on Ohio Edison's 5.46 ¢ per kWh, running an LED bulb at 54 watts will cost \$12.92 per bulb, per year, compared to running a 200 watt HPS light, which will cost \$47.86 per bulb, per year. This represents about 73% in savings per year if LED bulbs are used for street lighting. In addition to these savings, LED bulbs typically last for 50,000 hours, compared to 24,000 hours for HPS bulbs, reducing upfront costs, in addition to running costs.

The next improvement to make would be to add light shields to reduce light trespass. Light shields will help contain light in the needed area, and will give the ability to properly fine-tune the luminosity of the street posts, possibly reducing electricity expenses even further, which would be the final improvement that could be made.

Together, these changes would reduce running expenses by a significant amount, eliminate light trespass causing the adverse health effects, and reencourage people to study the night-sky.

## Glossary

### B

#### **Bortle scale**

a scale made up of nine classes describing the night sky's level of visibility, with class 1 representing full visibility and class 9 representing complete obstruction via light pollution

### C

#### **Circadian Rhythm**

a sleep and waking cycle every 24 hours

#### **Color Rendering Index (CTI)**

measurement of a light's appearance of color

#### **Compact Fluorescent Lamp (CFL)**

a bright, highly efficient lightbulb fitted into the size of a standard incandescent light bulb

#### **Correlated Color Temperature (CCT)**

the appearance of a light source's light color measured in Kelvin (K)

### E

#### **Electroluminescence (EL)**

light emitted from material caused by the movement of an electrical current or field

### F

#### **Fluorescence**

the visible or invisible radiation emitted by certain substances as a result of incident radiation of a shorter wavelength, such as X-rays or ultraviolet light

### G

#### **Galaxy**

a collective group of star systems and other interstellar objects orbiting a supermassive black hole

## **H**

### **High-Pressure Sodium (HPS)**

method of lighting used in high-intensity light bulbs by combining gasses and metals in a glass tube; commonly found in street lights

## **I**

### **Incandescent**

traditional form of emitting light via heating

## **K**

### **Kelvin (K)**

unit to measure the absolute temperature

## **L**

### **Light Emitting Diode (LED)**

a semiconductor device that emits light when current flows through it

## **Lumen**

SI unit of luminous flux, equal to the amount of light emitted per second in a unit solid angle of one steradian from a uniform source of one candela

## **Lx**

measurement of light illumination

## **W**

### **Watt**

a unit of measurement of electrical energy used

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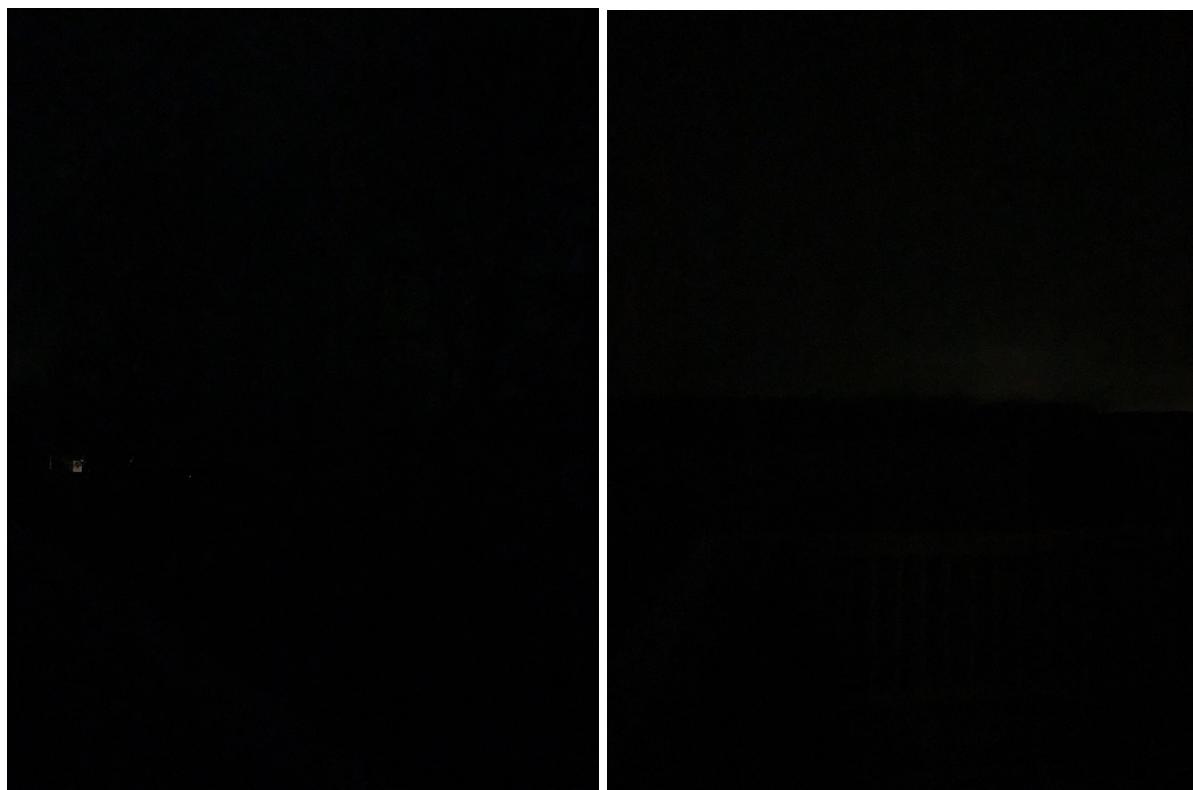
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## Illustrations



Four types of lighting are depicted in the picture. The first is without any covering, which causes the most pollution. The second has a partial shield, but it only mitigates some of the light pollution. The third has a half shield, which eliminates direct light leakage, but could still be improved on. The last has a full shield and is the best to use due to eliminating direct light leakage and most of the glare.



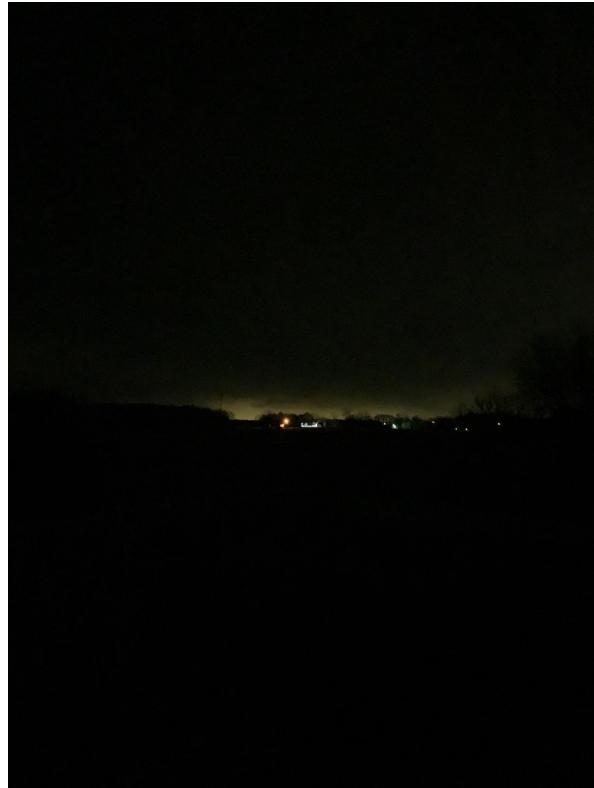
Two pictures outside of Wauseon, Ohio, taken around 12am. These were taken on a county road outside of town. There is not much light pollution, considering the pictures were taken fairly close to town.



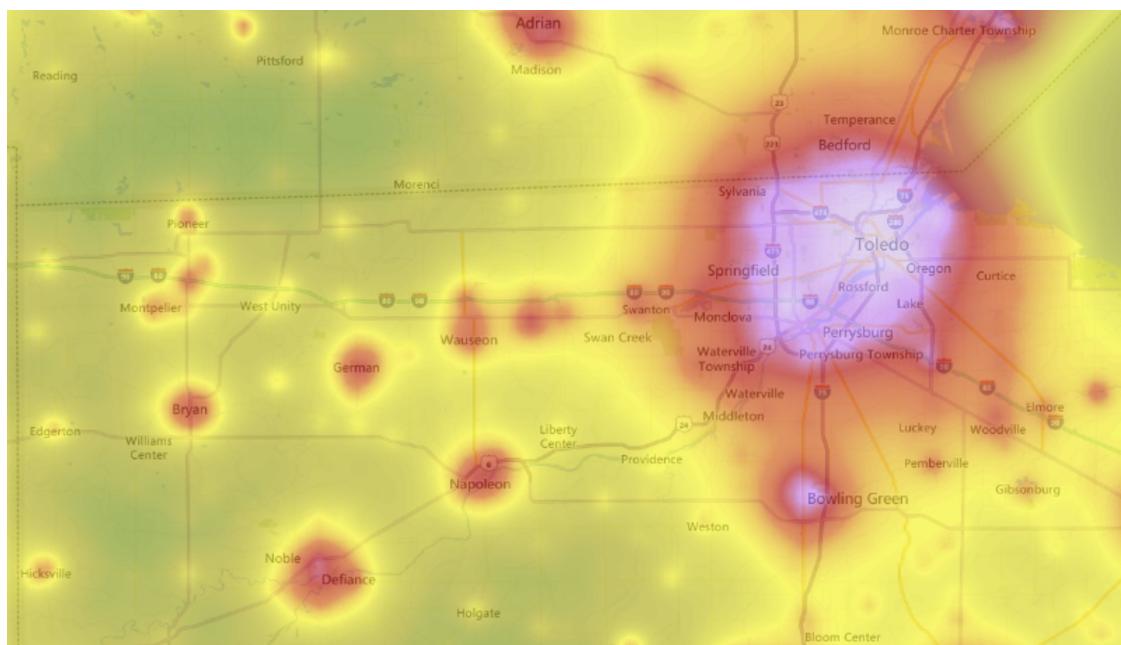
Two pictures in Edon, Ohio, taken around 4am. These were taken in a neighborhood in town. The most light around was the street lamps. Even then, there weren't too many lamps and they didn't produce very much light.



Two pictures in Montpelier, Ohio, taken around 3am. Like the photos of Edon, these were taken in a neighborhood in town. However, the street is lit up with strong street lamps, making the area very bright.



One picture in Wauseon, Ohio, taken around 12am. The light is not coming from Wauseon, instead coming from the Nature Fresh Farms greenhouse in Delta, Ohio. The greenhouse is 9 miles away from the location where the pictures were taken, yet can be clearly seen at night.



One picture of a light map, taken from the website <https://www.lightpollutionmap.info>. Green indicates little to no light pollution, yellow indicates some, red indicates a lot, and white indicates an extreme amount. The city of Toledo is the biggest source of light pollution by a longshot, distantly followed by Bowling Green. Other places depicted with red include Defiance, Napoleon, Wauseon, and Bryan. All of these places are considered cities due to their population. West Unity, Liberty Center, and Holgate are depicted in yellow and are considered villages.



This illustration depicts the comparison between a night sky with light pollution (left) and a night sky without light pollution due to a power outage (right). The Milky Way galaxy band can be clearly seen without light pollution, but is impossible to see without light pollution.

*astrobackyard.com*



“Milky Way over Parque Nacional del Teide” – Mehmet Ergün