Questions and answers about the Nachtlichter project and 2021 results (English)

Authors: Eva C. Weiß, Andreas Hänel, Brita Kuechly, Daniel Fischer, Georg Sulzer, Henning von Brandis, Jacqueline Degen, Johannes A. Schultz, Nona Schulte-Römer, René Curwy, Sabine Frank, Sicco Bauer, Yiğit Öner Altıntaş, Christopher C.M. Kyba

Abstract: The Nachtlichter (“Nighttime lights”) app was developed by a team of academic and citizen scientists during 2019-2023, and used to collect data about outdoor lights. We’ve published an article about the results of our 2021 campaign, and wrote this explainer in a question and answer format for people who are interested in the project, but not interested in reading a scientific publication.

This document has five parts:

- General project questions
- Questions about the 2021 campaign results and publication
- Questions about pollution in general
- Organizational questions
- Summary

General project questions

What was the project about?

Beyond streetlights, there isn't a lot of data about the numbers and kinds of lights used outdoors. Our aim was to collect a huge amount of data from many cities in Germany.

How did the project come about?

In 2019, the German Helmholtz Association asked scientists at Helmholtz centres to come up with citizen science projects, and 3 projects were funded. Nachtlichter is one part of the larger "Nachtlicht-BüHNE" project that was run by the GFZ Helmholtz Centre for Geosciences, the German Space Agency (DLR), and the Helmholtz-Centre for Environmental Research (UFZ). In 2023, the German Federal Ministry of Education and Research (BMBF) invited our group to examine a related science question as part of Science Year 2023 – Our Universe.

What is "Citizen Science"?

Projects that aim to answer scientific questions and that involve the active participation of volunteers are known as citizen science. There are many different kinds of citizen science, with different levels of involvement and required background knowledge. Sometimes groups prefer other terms, such as "participatory science".

What did the participants in your project do?

Our project was "co-designed", which means that participants took part from the start (planning the experiment) to the finish (publishing a scientific paper). A gradually changing group of about a dozen people met regularly from 2019 until now, but several hundred people took part by counting lights during our campaigns.

What counts as outdoor night lighting?

We included any light sources you can see from public areas, including public streetlights, and non-public lighting such as commercial, retail, industrial, and residential lighting (including decorative lighting and illuminated windows). Mobile and vehicle lighting such as car headlights also light the environment, although we counted those only indirectly. In the remainder of this document, all of these possible light sources are referred to as "lights".

Why is it important to collect data about outdoor lights?

We know that outdoor lights consume a lot of energy, and that the light they produce damages the environment. But until now, we didn't know much about how many of each kind of lights are turned on every night in a typical city. Gathering data about what exists in nature is the first step of the scientific method. Here, it will help scientists better understand the light that shines out of cities and smaller communities.

Couldn't you just use data from cities or from satellites?

These days, cities usually know how many streetlights they have, but they don't have databases of signs, architectural lighting, or porch lights. Satellites can see brighter and darker spots in cities, but it is often not clear what kind of source made the light.

Was it possible for people with disabilities to take part, and if so, how did you go about it?

One of the members of our co-design team is hearing impaired, and helped us to consider the needs of people with disabilities throughout the co-design process. While the participants who took part in counting were mainly not known to us directly, we do know that at least one wheelchair user took part. Although blindness prevents people from observing outdoor lights, our team member also invited a blind friend to join her as a companion while counting lights.

How did you handle privacy of personal data?

We made sure to protect the personal data both for our participants, as well as for the people who lived on the streets where we counted. We collected only a name and email address from our participants, and we made sure that each street that was counted had either 0 households, or more than 3.

Who can I contact if I have more questions?

Please send an email to kyba @ gfz.de.

Questions about the 2021 campaign results and publication

What was the goal of the campaign?

In 2021, we wanted to understand how the lights on the ground relate to what satellites see from space, and how the mix of different kinds of lights changes between city centers and less dense areas like residential neighborhoods.

Where did you count the lights?

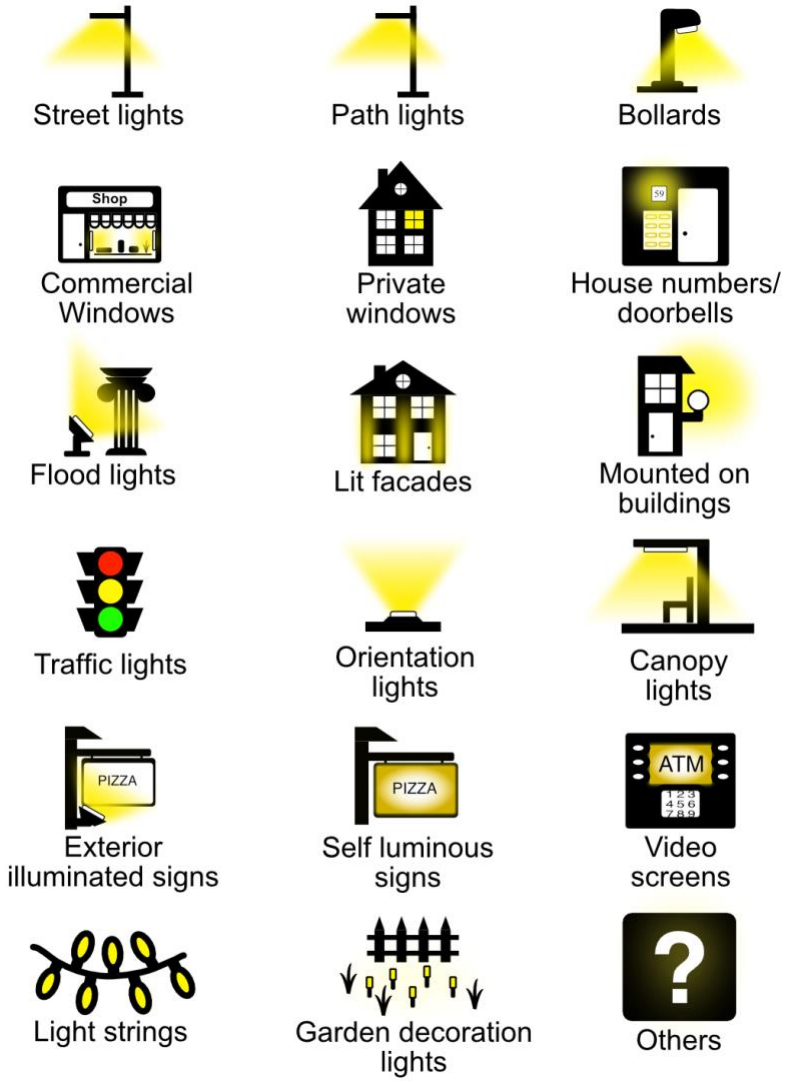
We had to count every light in really large areas (0.15 km^2 or larger), so we found local people willing to organize campaigns. Together with them, we picked an area to count, and marked out all of the streets and paths along which the participants should walk. Counts were completed in 26 communities in Germany and 8 international locations, covering a total area of more than 22 km^2.

How many lights did you count?

In total, 258 participants walked a distance of 600 km in about 500 hours, and counted 234,044 lights. Some streets had their lights counted multiple times, either to understand the difference between our counters, or to test how lights turn off as the night goes on.

What kinds of lights did you count?

We tried to count every single light source that could be seen from public spaces. We sorted lights into 18 different categories (see image on next page).



What are your most important results?

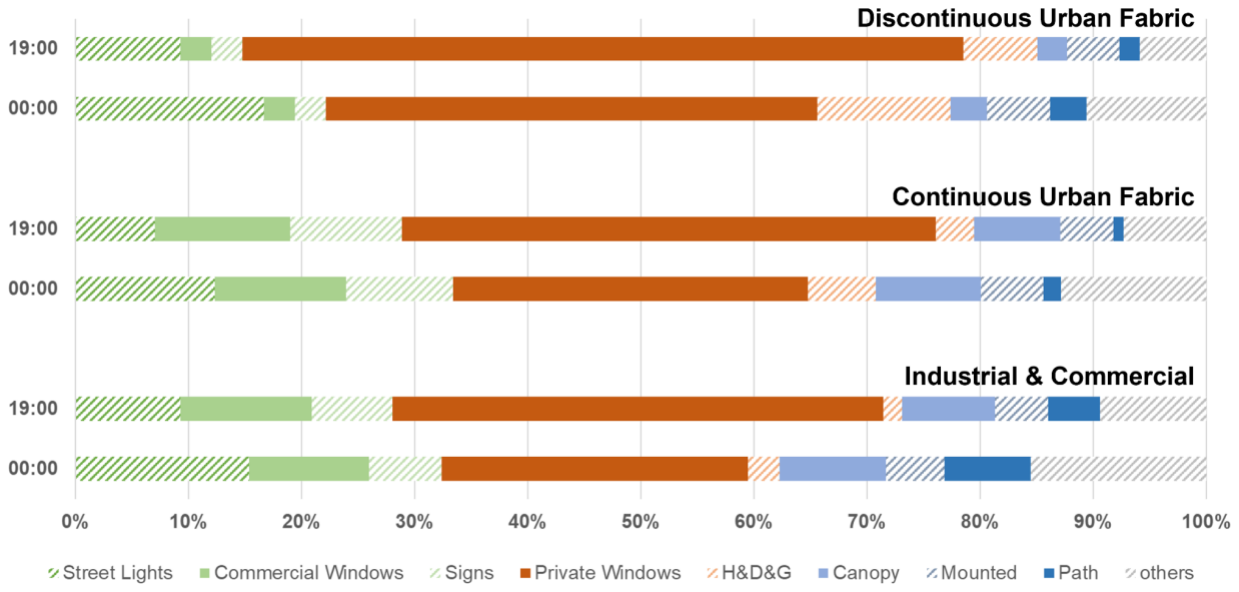
We measured how the kinds of lights that are present change as you go from more urban to less urban places. We also found a “translation” factor to convert satellite brightness measurements (in $nWcm^{-2}sr^{-1}$, see below) into the more easily understandable unit lights/km^2. These two results are described in more detail in later questions.

How does your study compare to previous research on outdoor lights?

No one has ever counted lights on this scale before, but some researchers have looked into how much light comes from streetlights compared to other sources. These earlier studies generally found that streetlights are a major source of light in rural areas, but that other types of lights make up the majority of emissions in urban areas. Our results are in agreement with this, but provide much more detail about these other types of lights.

In what way do the lights in city centers differ from smaller places?

We found that in dense areas, for every streetlight there is an illuminated sign and a shop window. Settled areas that are less dense have far fewer signs, and private windows are the most common light source everywhere (even if they aren't the brightest). The graphic below is from the paper, and shows the fraction of different types of lights in three areas ranging from low density residential areas (top) to commercial city center areas (bottom), for two different times of night.

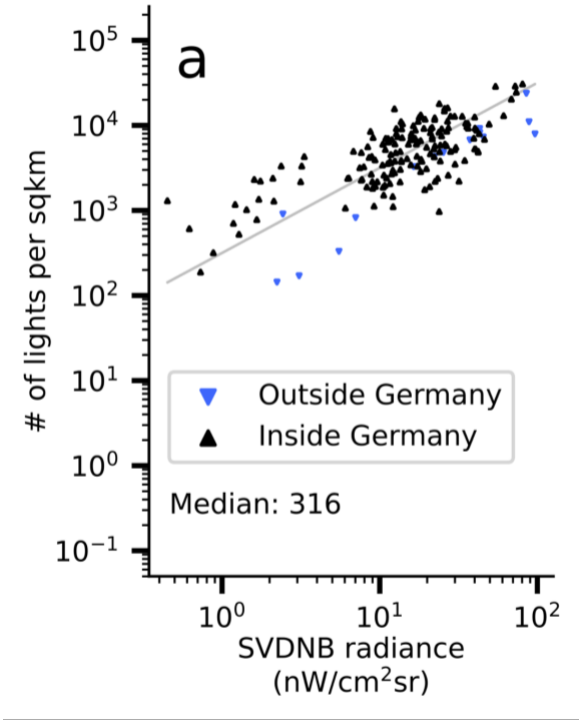


What did you learn about the different kinds of lights?

We found out that about half of streetlights in Germany are "fully shielded" (only shine their light downward), and that pathway lights are more likely to shine in all directions than streetlights. Street lights tend to be more warmly colored than most other kinds of lights (including pathway lights), and "canopy lights" are the whitest lighting group. About one quarter of bollards (lights on small poles) were rated as being "bright", which means they are probably glaring.

How do your results compare to satellite images?

Satellites measure the “radiance” (“brightness”) of Earth at night in a unit that is unfamiliar to most people, including most scientists: Watts (or nanowatt, nW) per square meter per steradian ($Wm^{-2}sr^{-1}$). We therefore wanted to convert the observations of a satellite instrument called "VIIRS DNB" from $nWcm^{-2}sr^{-1}$ into the more comprehensible unit “lights per square kilometer”. We found that a conversion factor of about 220 applies in Germany, but that it may be smaller outside Germany. The following graph is taken from our publication. The vertical axis shows how many lights we counted per square kilometer in each area, and the horizontal axis shows the brightness measured by the satellite. The line shows the average relationship between the two quantities.



How many lights are on in all of Germany at midnight?

Based on the number above, we estimate that at midnight there are about 2.5 million lights still shining in Berlin, and 78 million in all of Germany. That’s roughly one light per person, at a time when most people in Germany are asleep!

How did you deal with the fact that not everyone counted lights at the same time?

By counting some streets multiple times, we found that some kinds of lights (especially private windows and signs) tend to turn off as the night goes on. We made a mathematical model of this, and used it with the observation to estimate how many lights would still have been counted if the observation was made at midnight.

If the data was taken by untrained citizen scientists, how do you know that it is trustworthy?

All of our participants completed an online training that took about 20 minutes, to make sure that everyone counted in the same way. We also compared the numbers counted by different people on the same streets, and we compared our streetlight counts to city databases. We found that while the counts don't match perfectly, they are close enough that we can be confident in our results.

Are the statistics reliable?

The estimate of the numbers of lights in Germany are based on the assumption that the rest of Germany is similar to the 26 communities in which we counted. We know that this is not true for the entire area of the country. For example, industrial parks are surely different. But most of the lit area of Germany is made up of cities, and our sampling includes areas ranging from city centers to small villages.

Do you have policy recommendations based on the results?

In our work, we focused on the measurements, and not on what should be done about light pollution. However, some of our participants plan on sharing these results with their local governments, and we hope that you might too! One result has clear policy implications: while streetlights are frequent and bright, they are far from the only source of light pollution, especially in cities. There are a lot of private and commercial lights out there!

Do the results also apply outside of Germany?

The relation between satellite brightness and lights per km^2 seems to be different outside of Germany. However, for rough estimates, our results are still very useful. It is likely that throughout the world the fraction of commercial lighting increases in urban areas, but the exact fraction of signs compared to streetlights is probably different in different countries. Another open question is whether different fractions of lights are turned off late at night in different countries.

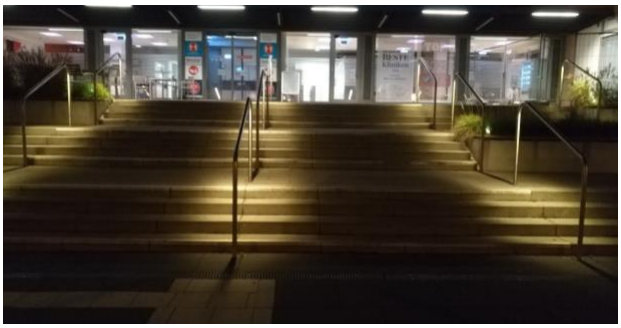
Questions about light pollution in general

Why is light pollution a problem?

The night is a natural environment, and is therefore a home to a lot of animals that are adapted to live there. When artificial light is added to the environment it changes relationships between species, and can also affect the physiology of plants, animals, and even microorganisms. Producing the light also costs money and uses electricity that could be better spent more usefully.

What is the difference between “good” and “bad” lights?

The best lights are those that fit well to their environment. They are not overly bright or glaring, and they shine the light to useful areas. The worst lights are the opposite: they are glaring and shine in directions that don’t provide benefit to people. The two staircase examples below illustrate the two extremes.



In what ways can light pollution be reduced?

First of all, you should check whether additional light is needed at all! Sometimes an additional light is not necessary, and sometimes alternatives such as reflective markings are sufficient. Lights that are essential should only shine at the times and places where the light is needed. For example, a light used for the entryway to a private home could use a timer or motion sensor to turn on only when it is needed, and should shine downward onto the walkway, not across the street into the neighbor’s windows.

What can I personally do about light pollution?

Both homeowners and business owners should ensure that the light does not shine beyond their property. We recommend avoiding decorative lighting in the garden and on the balcony to protect wildlife. Make sure that your lights are not too bright compared to their surroundings and use timers, switches or motion detectors to turn lights off when they are no longer needed. Advertising lighting should be dimmer in rural areas than in urban environments, for example. A lot of people aren't aware of the negative impacts of light, so talking with them and sharing resources can help to increase awareness.

Are there groups that work to protect the night?

There are several German and international organizations that work directly on protection of the night, including the Hessisches Netzwerk gegen Lichtverschmutzung, Paten der Nacht, DarkSky International, and Natur braucht Nacht. A number of other organizations include protecting night in their activities, including the Vereinigung der Sternfreunde, NABU, and BUND.

Does light have an effect on safety?

From place to place across the planet and within a country or even a single city, there are extremely large differences in the relative amount of automobile collisions and crime. If the amount of ambient light has any effect on either of these in one direction or the other, the size of the effect is so small that it is difficult to measure. Large and well conducted research studies tend to show either negligibly small or else no measurable effect from changes in illumination.

Are there laws that require light use in Germany?

Roadway vehicles (e.g. cars, bicycles) are required to have and use lights during twilight and night (Straßenverkehrs-Ordnung § 17). Certain marked crosswalks are required to be illuminated. Employers must guarantee their employees a safe working environment, and depending on the situation, this may imply a need for suitable outdoor workplace lighting during working periods. Other than these, there are no other legal requirements for lighting in Germany. Most Autobahns and highways are unlit, and cities have no legal obligation to light streets.

Which rules limit light use in Germany?

The Federal Immission Control Act (Bundesimmissionschutzgesetz § 22) places limits on how much light can shine into residences, and forbids the use of searchlights during migratory bird seasons. The Federal Nature Conservation Act has a requirement (Bundesnaturschutzgesetz § 41a) that wild plants and animals be protected from light, which is passed but not yet in effect. State level laws also apply, for example the Hessian Nature Conservation Act requires avoiding shining light into natural areas, turning lights off late at night, and avoiding parts of the spectra that attract insects (Hessisches Naturschutzgesetz § 4, § 35).

Are there places that have measurably reduced light pollution?

Many communities have successfully reduced the amount of light emission and skyglow in their areas, without compromising safety. For example, the region near Mont-Mégantic in Canada reduced sky brightness by 30-50% with targeted replacement of polluting lights, and Tucson, Arizona reduced its public street lighting network emission from 445 million lumens to 142 million lumens.

Are there communities that turn off streetlights late at night?

Many communities in Europe, including hundreds in Germany, turn their streetlights off late at night. The largest German city currently doing this in Germany is Gütersloh, which has a population over 100,000. In France, about one in three communities now turns the streetlights off late at night when pedestrians are rarely present.

Images showing the view of the city of Preussisch-Oldendorf before (above) and after (below) the shutoff of the public lighting.

Organizational questions

Who took part in the project?

Our regular planning meetings typically had about a dozen German-speaking citizen scientists, although the full group was a bit larger than that, and changed over time. Several hundred people participated in data taking, mainly in Germany, but also in a few international places.

Who wrote these questions and answers?

Our co-design team created the questions together. The answers were written mainly by Christopher Kyba, and then machine translated into German and discussed and edited by co-design team members.

How was your work financed?

Our first campaign was funded during 2019-2022 primarily by the Helmholtz Association Initiative and Networking Fund under grant CS-0003. Our second campaign was funded during 2022-2024 primarily by the German Ministry of Education and Research (BMBF) as part of Research Year 2023 – Our Universe. The participation of the citizen scientists was voluntary, they were not financially compensated for their contributions.

Is it still possible to take part?

The app is still online, and is currently supported by DarkSky Ireland, so you can try it out if you like. However, our group is not planning on analyzing any future data taken with the app, so we are not asking people to take data on our behalf at this time.

Why does research take so long?

In general, analyzing scientific results takes quite a bit of time, because you need to develop analysis methods, and double check that everything you have done is correct. In our case, working with citizen scientists slows the process down somewhat further, because the co-design team had limited time, and we aimed for everyone involved to understand all of the steps. By both direct and indirect effects, COVID-19 slowed down the process.

Did you make your data and computer codes public?

We did. If you are interested in looking at them, you can access them here.

Summary

Our team is very proud of what we have accomplished over the last several years! In addition to producing new knowledge about outdoor lights and their relationship to satellite data, our co-design team learned a great deal about the scientific method, and more importantly became a community in which a number of new friendships were formed. While our primary goal was the generation of scientific knowledge, we hope that our results will be also useful in political discussions about outdoor light in Germany, and abroad. We are thankful to the funding organizations that we had the opportunity to develop this project as a team.