# Practice of public lighting in proposed German Star Parks

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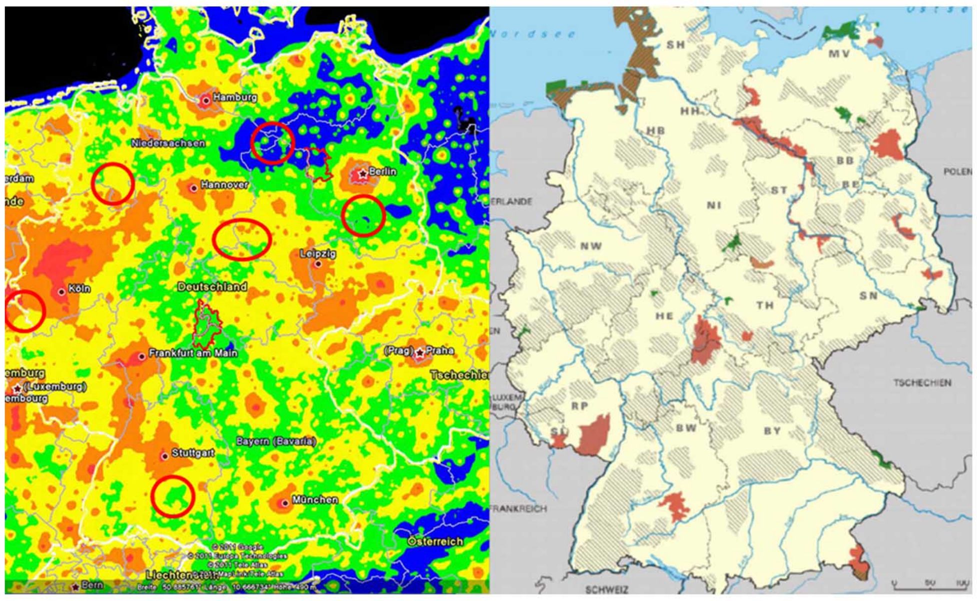
## Identification of possible Star Parks in Germany

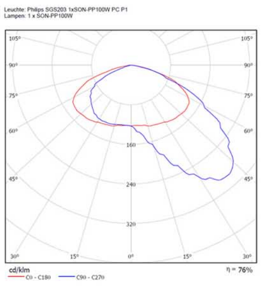
Though Germany is densely populated and highly industrial, there are still regions where natural darkness and nearly natural dark skies can be discovered. Often these are already protected areas (the different degrees of national parks, biosphere reserves or nature parks).

Recognition as protected dark areas (IDA Dark Sky Reserves or Parks, Starlight touristic destinations) should help to preserve these dark areas for natural dark environments and skies as the upper sphere of a protected region.
The process for applications as IDA Dark Sky Places was started in the Nature Park Westhavelland (Brandenburg) and the Biosphere Reserve Rhön (Hessen, Bayern, Thüringen).

The main method to quantify and possibly change the lighting habits is an inventory of lighting within star parks. With this data it is possible to determine how much light is emitted totally and how much is emitted towards the sky. This will help to find solutions to limit and reduce light pollution. Dominant artificial light sources with the easiest access to data are public road lighting. Other sources (like commercial or sports lights) are absent or used only part-time in smaller villages. In the few larger cities these sources might have higher contributions but we estimate them to be not more than 20% and neglect them due to the large uncertainty.



Map of the sky brightness (left, Cinzano et al. 2000) with areas where sky brightness was measured and protected areas (right, BfN) in Germany (Westhavelland west of Berlin, Rhön in the center)



A luminaire with well known light distribution

Examples of further luminaires used in the proposed star parks

## Lighting inventory

### Types of the fixtures

A classification of the lighting fixtures is necessary to determine the upward luminous flux.

1. Identification of model and manufacturer.
With this information photometric data for light distribution (EULUMDAT) were searched and with the help of the lighting planning software DIALUX the **upward light ratio** (ULR) was calculated.
The uncertainty in the photometric data is, that sometimes simply no values are given for the upper hemisphere of the luminaire though it still emits there light. In some cases it was also uncertain at what inclination angle the luminaire was installed.

2. Search for similar models
Many models were so old that no photometric data could be found. We then looked for similar models, assuming that they have similar light distributions and derived the ULR from these with the above method.
The uncertainty of the determined ULR value is less reliable

3. Estimation
In many cases it was difficult to find similar models with photometric data. In these cases, we estimated the ULR just from the appearance of the luminaire. This method is certainly the least accurate.

Type of lamp and power rating, times of switch-off and the geo-referenced positions of the fixtures were mainly provided by the cities and the agencies that installed the lighting. When not available, we determined the positions using a smartphone with GPS and mapping software.

### Luminous efficiency

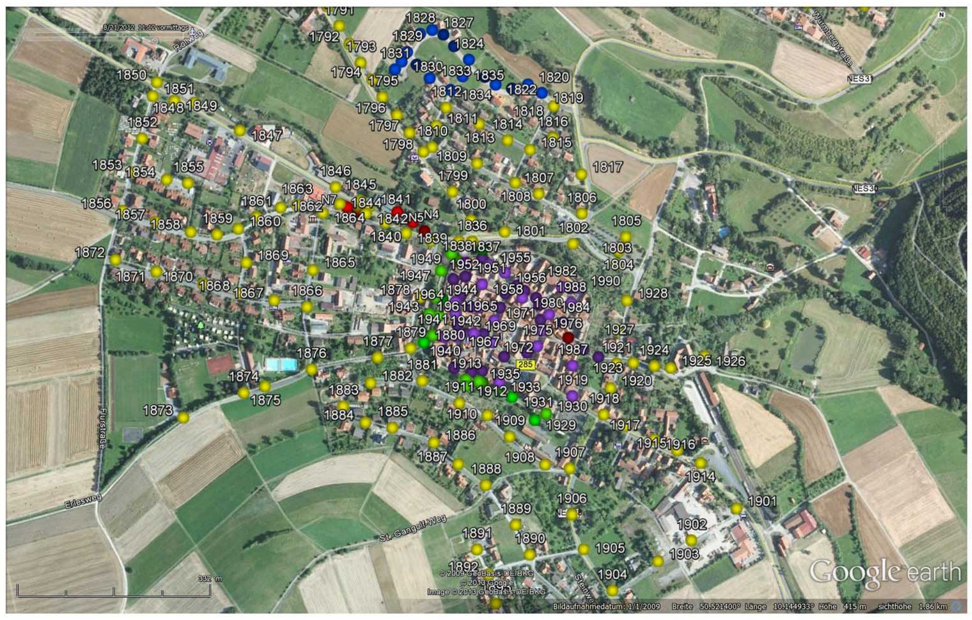
Typical values for the luminous efficiency were used (taken from Osram), in practice the flux is certainly lower (due to aging, dirt etc.).

| Lamp type | Power [W] | Luminous Flux [lm] |
|---|---|---|
| Mercury high pressure | 80 | 4000 |
| Mercury high pressure | 125 | 6000 |
| (Compact) fluorescent tubes | 18 | 1100 |
| (Compact) fluorescent tubes | 38 | 3350 |
| Sodium high pressure | 50 | 3600 |
| Sodium high pressure | 70 | 5600/5900 |
| Sodium high pressure | 100 | 10000 |
| Sodium high pressure | 150 | 15000 |
| HID | 90 | 10000 |
| LED | 34 | 1800 |

### Data of the classified luminaires
(not the whole parks)

| | Westhavelland | Rhön |
|---|---|---|
| **Inhabitants** | 31.651 | 35.114 |
| **Number luminaires** | 4998 | 5213 |
| **Electric power [kW]** | 416 | 394 |
| **Total light power [Mlm]** | 32 | 28 |
| **Upward light ration [%]** | 6 | 8 |
| **Luminaires with ULR<1% [%]** | 26 | 20 |

Lighting inventory Fladungen/Rhön

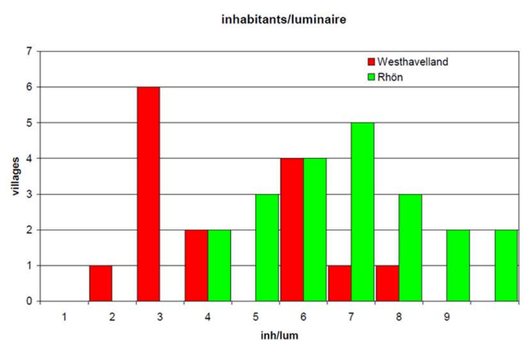


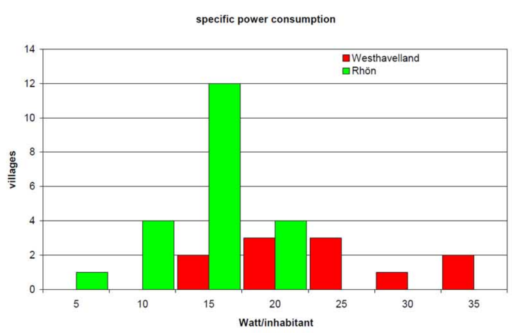
Villages in the Rhön as seen from the Kreuzberg

## Characteristic numbers for public lighting

### Density of luminaires [persons/luminaire]

The density of luminaires varies between **2 and 10 persons/luminaire**. It is typically lower in less populated regions and in the Nature Park Westhavelland.



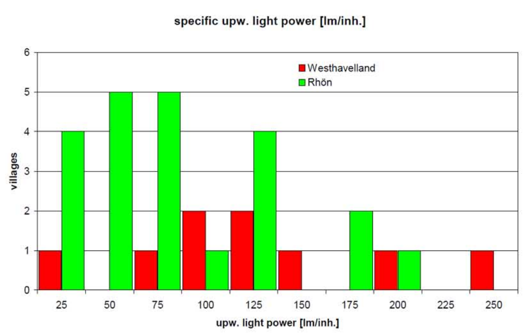




### Specific power consumption [Watt/person]

The power consumption varies between **5 and 35 Watt/person**. Smaller villages have higher power consumption than larger ones and in Westhavelland tends to be higher up to a factor of 2.

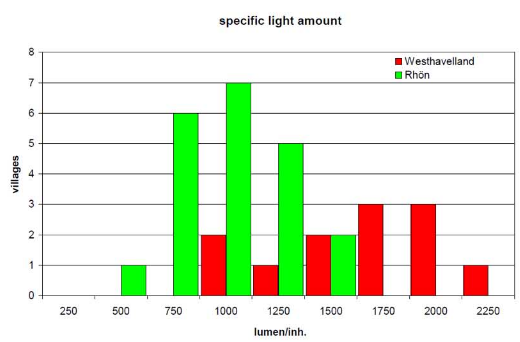
### Specific upward light power [lumen_upw./person]

The mean direct upward light power is **68 lm/person**. There seems to be no significant difference between the two proposed star parks.




### Specific light power consumption [lumen/person]

In analogy to the electric power consumption we use the light power consumption. This varies between **300 and 2200 lumen/person**, with a mean of about 1000 lm/pers., being higher in the Westhavelland.
For comparison: Puschnig et al. (2013) gave 622 lm/inh. for Vienna, Narisada & Schreuder (2004, p. 735) values between 500 and 1600 lm/inh. for Dutch cities. Luginbuhl et al (2009) derived a value of 2610 lm/inh. for Flagstaff including all light sources, of which 43% are due to roadway lighting (corresponding to 1126 lm/inh.).




## Discussion

Though mean values of the derived characteristic numbers in Westhavelland and Rhön are similar, the individual numbers have differences. This is due to the fact, that the numbers in Westhavelland are mainly influenced by the city of Rathenow which has 63% of the population of the Nature Park. Higher power consumption and luminous flux, but lower upward flux could be caused by more modern lighting.

**References:**

Luginbuhl, C.B., Lockwood, G.W., Davis, D.R., Pick, K., Selders, J. (2009): From the Ground UP I: Light Pollution Sources in Flagstaff, Arizona, Publ. Astron. Soc. Pacific 121, 185-203
Narisada, K., Schreuder, D. (2004): Light Pollution Handbook, Springer, Dordrecht
Puschnig, J., Posch, T., Uttenthaler, S. (2013): Night sky photometry and spectroscopy performed at the Vienna University Observatory, http://arxiv.org/abs/1304.7716

## Proposed limits for street lighting in Star Parks

The direct upward luminous flux should be as low as possible, preferably the ULR should be = 0.

Similar to the electric energy consumption we propose a light energy consumption which respects the time when light flux is switched off or reduced. 500 lm/inh. seems to be a feasible power value. Typical burning times in Germany are 4000 h, switch off between 0 and 5 o'clock reduces this time to about 2800 h, which would give a characteristic value of about **1.500.000 lm*h/inh.(or 1.5 Mlmh/inh.)** as a possible limit for the illumination in a star park.