HTW Berlin weather data with a temporal resolution of 1 Hz

1 Introduction

Since 2010, weather data has been recorded in high temporal resolution on the roof of the Berlin University of Applied Sciences (HTW) at the Wilhelminenhof campus. Until 2017, the data were stored as 1-minute averages. In 2017, the weather station was rebuilt, and the functional range of the irradiance measurement was extended. Since 2017, the data are measured and stored with a temporal resolution of 1 Hz.

The following documentation describes the data set published here and the steps taken to prepare the data. The raw data can be visualized and downloaded from the weather station website: https://wetter.htw-berlin.de/

2 Metrology

The measurement technology of the weather station is presented in the appendix and its characteristics and designation in the data set are shown. The entire measurement technology was recalibrated before the relaunch in 2017.

Special attention was paid to the measurement of the solar irradiance. Here, redundant measurements are made with different sensors. The designations could lead to confusion when looking at the data set for the first time and are therefore listed here in Table 1. For further details see appendix and homepage.

Table 1 List of sensors

Orientation	Tilt angle	Name in data set
	SP-Light2	
Horizontal	0°	EGH_SPL1
South (180°)	35°	EGS_SPL2
	CMP11	
Horizontal	0°	EGH_CMP1
South (180°)	35°	EGS_CMP2
South-West (225°)	15°	EGSW_CMP3
	SMP21	
Horizontal, global	0°	EGH_SMP4
Horizontal, diffuse	0°	DIF_SMP5
South (180°), global	35°	EGS_SMP2
West (270°), global	35°	EGW_SMP3
East (90°), global	35°	EGO_SMP1

3 Methodology for preparation

Despite high availability and data quality, the data require a certain amount of processing. The methodology for processing is presented below. The processing is oriented towards the best possible processing of the irradiance data.

3.1 Adjusting the timestamp

The time changeover to daylight saving time makes a correction of the data necessary. The recorded data is not only shifted by one hour as expected, but the time stamp jumps several times during the time change to daylight saving time. Thus, the time stamp jumps once correctly from 2:00 to 3:00. However, the time stamp jumps again from 4:00 to 5:00. Due to the double jump, on the one hand the time stamp in the raw data record is incorrect, on the other hand the resulting measurement gaps must be filled.

An ideal time stamp in UTC+1 is created for the correction. Subsequently, the resulting measurement gaps are replaced by the correct data. Now the data set of the entire daylight-saving time is shifted forward by one hour. Here, one hour is missing in March, which is replaced by a copy of the data of the previous hour.

The time changeover to wintertime in October takes place only once and does not have to be corrected.

3.2 Fill measurement gaps

In addition to the measurement gaps caused by the time change, however, there are also measurement gaps in the raw data that occur due to errors in the recording. It has happened in 2017, 2018 and 2019 that the data logger was not available for one or more days, so that isolated measurement data are missing. Especially with the second-by-second data, however, it also happens from time to time that the data logger does not record any values for individual time steps. These large and small measurement gaps are corrected in two different ways. For measurement gaps that last longer than one hour, the data are either replaced by previously measured data within the day, or by previously measured data of a previous day.

If the measurement gaps are smaller than one-hour, linear interpolation is performed between the measured values.

Table 2 shows the number of unrecorded time steps.

Table 2 Number of measurement gaps

	2017	2018	2019	2020
Number of measurement gaps in second-by-second data	257526	144167	159839	655
Regarding the year	0,82%	0,46%	0,51%	0,00%
number of measurement gaps in minute-by-minute data	3008	766	799	0
Regarding the year	0,57%	0,15%	0,15%	0,00%

The raw data of the year 2017 are most incomplete. The data logger is down for several days.

In 2018 and 2019, the data logger also failed completely for more than one day. Because of this, the raw data had many measurement gaps that needed to be cleaned up. In 2020, the data logger did not fail. The only measurement errors are second-by-second errors that were corrected by interpolation.

A list of measurement gaps >1 h can be found in the appendix under Documentation of the measurement gaps

3.3 Correct irradiance values

At night, insufficient calibration and other environmental influences may cause the irradiance sensors to measure values that are not zero. For all values where the zenith angle is greater than 90°, irradiance values are set equal to zero to correct this error.

Another error is the calculation of the direct irradiance by the global and diffuse irradiance. When the sun rises or sets and only illuminates the horizon the total irradiance consists only of a diffuse irradiance component.

If, for example, in the morning and evening hours the diffuse irradiance sensor measures a lower irradiance than the sensor that measures the global horizontal irradiance, the calculation incorrectly assumes that direct irradiance is present. However, this is not the case in the morning and evening hours. To avoid these conversion errors, the horizontal global irradiance is set equal to the diffuse irradiance in the evening and morning hours when the sun elevation is below 2.5°.

3.4 Limiting the diffuse irradiance to the global irradiance

Similar measurement errors can also occur when measuring the diffuse irradiance. The diffuse irradiance is sometimes measured too large by the sensor, for example if unwanted reflections hit the sensor. The diffuse irradiance values are compared with the measured global irradiance values. If the diffuse irradiance values are too large, they are limited to the measured global irradiance. The diffuse irradiance values can never be greater than the measured global irradiance.

4 Visualization

In this chapter the measured weather data are visualized and discussed.

4.1 Annual energy totals

Figure 1 below shows the measured average annual energy sums of the global irradiance sensors and compares them with the long-term average. The long-term mean value is taken from freely available data of the German Weather Service (DWD). To ensure the best possible comparability, the weather station Lindenberg in Brandenburg was used for the comparison [9].

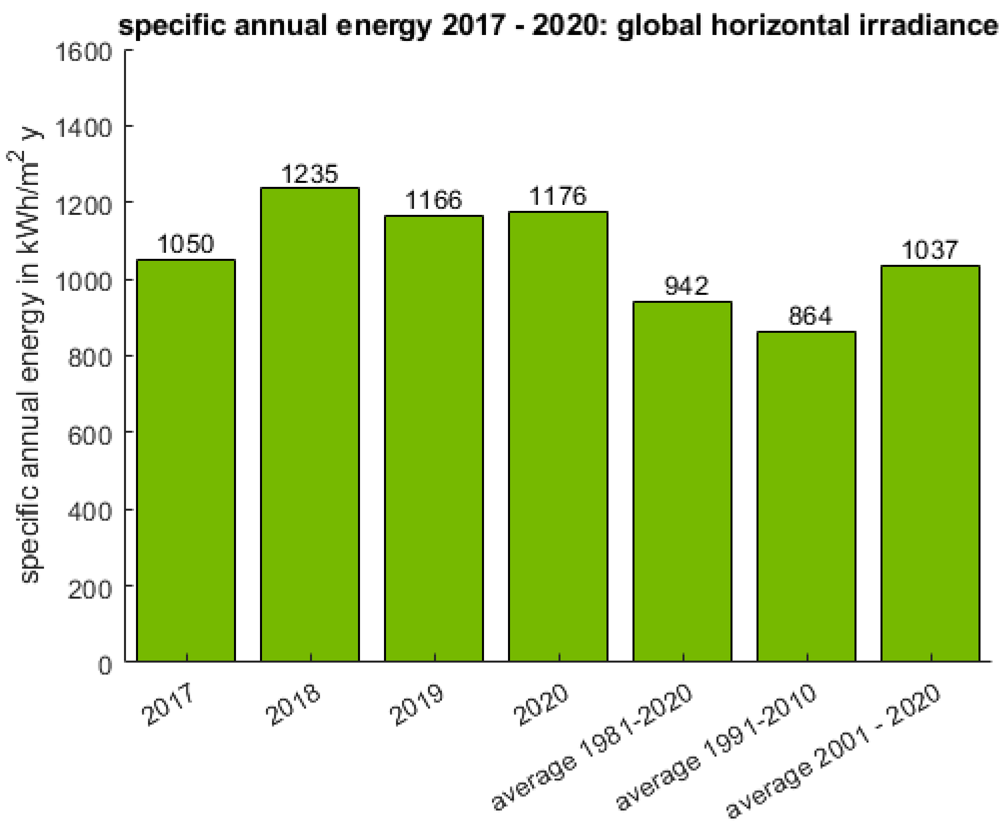

Figure 1 Comparison of annual energy sums measured at the HTW Berlin with the SMP21 with the long-term average of the annual energy sum at the DWD site Lindenberg (Brandenburg).

The specific annual energies in the years 2017 - 2020 are considerably higher than the long-term average in the period from 1981 - 2020. From 2018 - 2020, the specific annual energy is about 26.6% higher than the long-term average. The year 2018 stands out here especially due to a high specific irradiance. According to the Helmholtz Centre for Environmental Research, the summer and autumn of 2018 was the drier than all available droughts since the beginning of the "Drought Monitor" in 1951 [10]. This is also reflected in the irradiance data.

In the following Figure 2 specific annual energies measured at HTW Berlin are compared with the specific annual energies from the DWD data set.

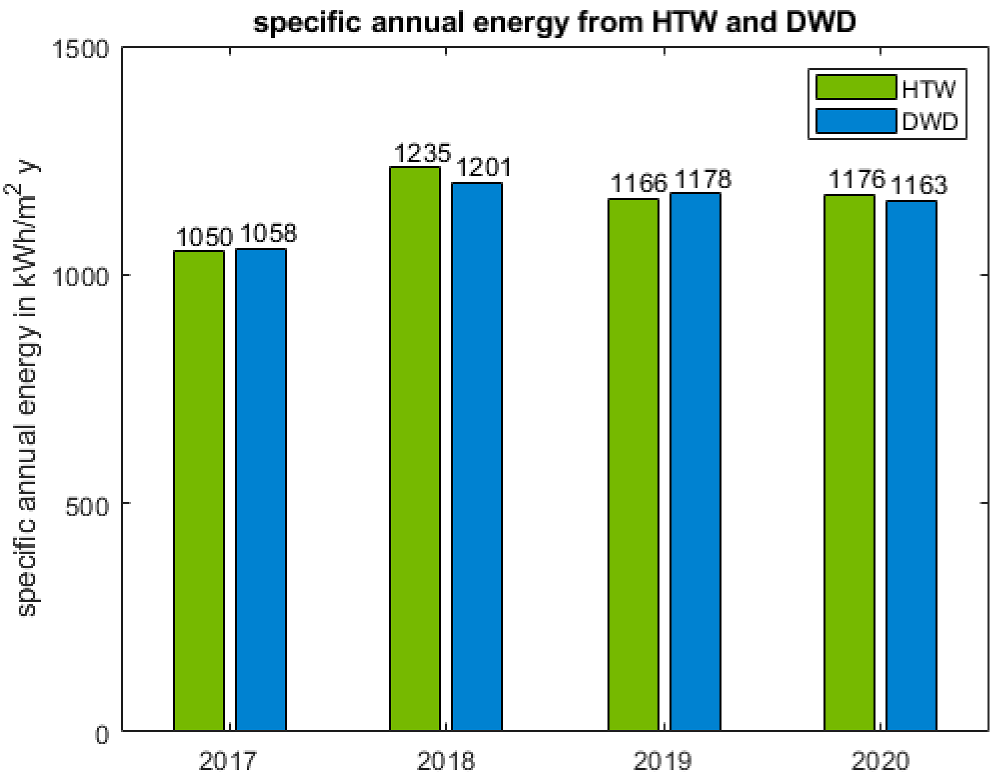

Figure 2 Comparison of the measurement of specific annual energy: HTW Berlin (measured with the SMP21) and DWD site Lindenberg (Brandenburg).

The measured specific energy sums differ only slightly from each other. The largest difference is found in the data of the year 2018. This measurement deviation may indicate local weather differences or may be caused by the correction of missing values.

Table 3 below lists the measured values for the specific annual energy of the other orientations.

Table 3 Specific annual energies at tother orientations measured with SMP21.

	2017	2018	2019	2020
specific annual energy (kWh/m^2): South	1198	1462	1363	1374
specific annual energy (kWh/m^2): West	938	1158	1107	1129
specific annual energy (kWh/m^2) : East	1021	1169	1087	1097

With an orientation of the sensor to the south, an additional yield can be achieved compared to a flat orientation. The Tilt angle gains of the individual years are listed in the following Table 4.

Table 4 Tilt angle gains south

	2017	2018	2019	2020	⌀
Tilt angle gains (south) in %	14	18	17	17	16,5

With an orientation to the south and an elevation of 35°, an average additional yield of 16.5% could be achieved.

4.2 Monthly energy totals

The Figure 3 shows the monthly energy totals for 2017, 2018, 2019 and 2020.

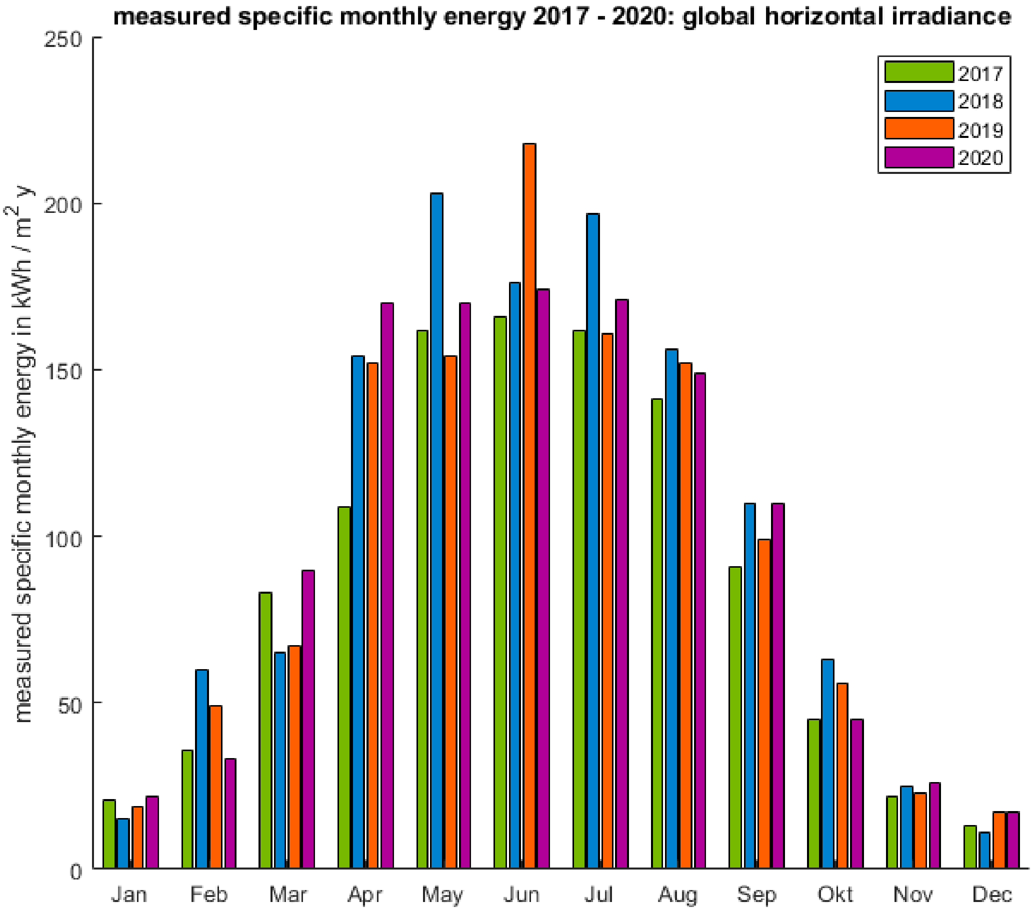

Figure 3 Comparison of the specific monthly energy measured at HTW Berlin with the SMP21 for the years 2017 to 2020.

The sunniest months vary from year to year. For example, while June was clearly the sunniest month in 2019, the distribution in 2020 is much broader. The months of April, May, June, and July have almost the same global irradiance.

4.3 Weekly energy totals

In Figure 4 below, the specific weekly energies for the years 2017, 2018, 2019 and 2020 are plotted. Especially the year 2020 stands out due to the very even distribution of energy in summer.

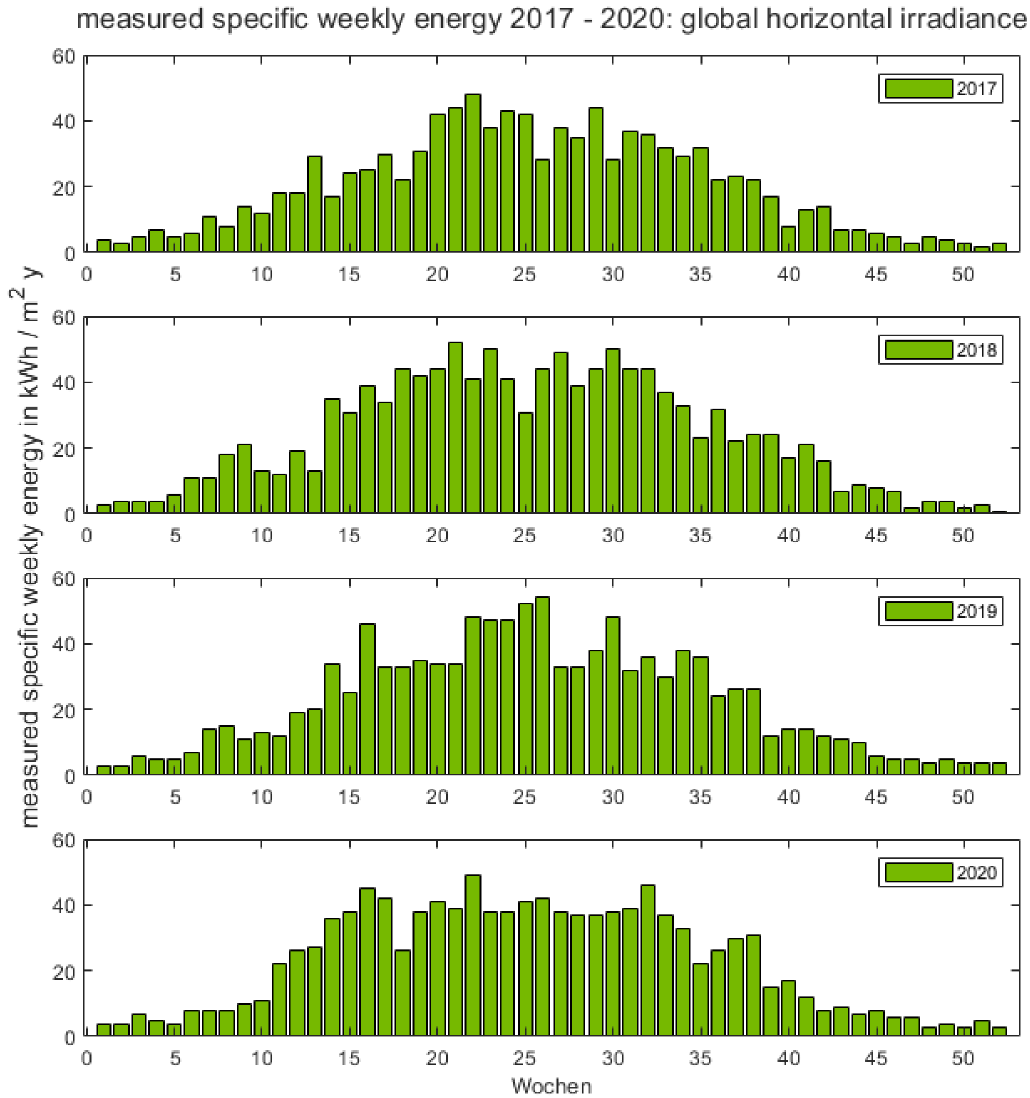

Figure 4 Comparison of the specific weekly energy measured at HTW Berlin with the SMP21 for the years 2017 to 2020.

4.4 Diffuse and direct irradiance

The following Figure 5 shows the share of direct and diffuse irradiance in the specific annual energy. The direct irradiance share is listed above the columns.

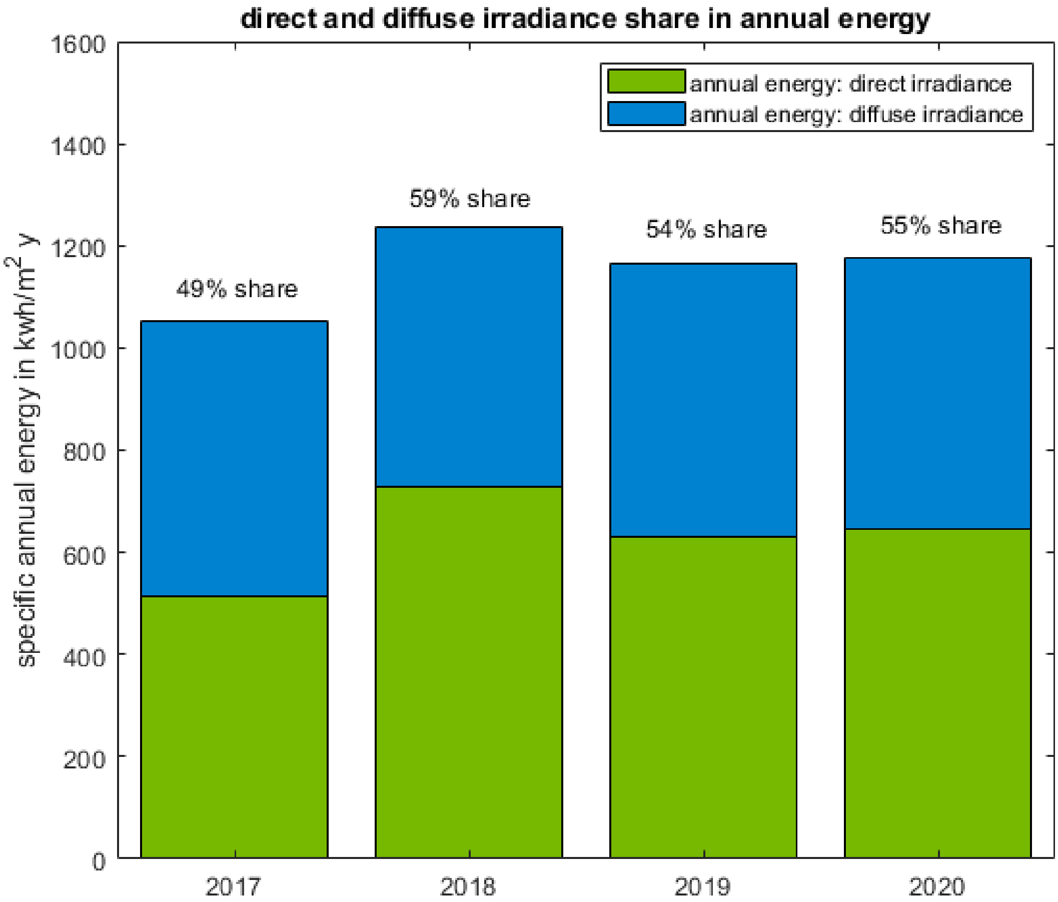

Figure 5 Shares of direct and diffuse irradiance of the global irradiance measured at the HTW Berlin with the SMP21.

The direct irradiance share also indicates that the year 2018 was particularly dry. The direct irradiance share of the specific annual energy is positively influenced by low cloud formation.

5 Sources

[1] OTT HydroMet Corp., „SP Lite2 Silizium-Pyranometer“, 2021. https://www.kippzonen.de/Product/469/SP-Lite2-Silizium-Pyranometer (last opened June 16, 2021).

[2] OTT HydroMet Corp., „CMP11 Pyranometer“, 2021. https://www.kippzonen.de/Product/476/CMP11-Pyranometer (last opened June 16, 2021).

[3] OTT HydroMet Corp., „SMP21 Pyranometer“, 2021. https://www.kippzonen.de/Product/479/SMP21-Pyranometer (last opened June 16, 2021).

[4] OTT HydroMet Corp., „SHP1 Pyrheliometer“, 2021. https://www.kippzonen.com/Product/204/SHP1-Pyrheliometer (last opened June 16, 2021).

[5] Adolf Thies GmbH & Co. KG, „Hygro-Theromogeber compact“, 2021. https://www.thiesclima.com/de/Produkte/Feuchte-Elektrische-Geraete/?art=705 (last opened Aug. 04, 2021).

[6] Adolf Thies GmbH & Co. KG, „Windgeber Classic“, 2021. https://www.thiesclima.com/de/Produkte/Wind-Classic/?art=258 (zugegriffen Aug. 04, 2021).

[7] Adolf Thies GmbH & Co. KG, „Ultraschall Anemometer“. https://www.thiesclima.com/de/Produkte/Wind-Ultraschall-Anemometer/ (last opened Aug. 04, 2021).

[8] Adolf Thies GmbH & Co. KG, „Datenlogger DL16“, 2021. https://www.thiesclima.com/de/Produkte/Sonstige-Geraete-Datenlogger/?art=992 (last opened Aug. 04, 2021).

[9] Deutscher Wetterdienst, „DWD Downloadportal - Tageswerte“, Aug. 13, 2021. https://opendata.dwd.de/climate_environment/CDC/observations_germany/climate/daily/solar/ (last opened Aug. 13, 2021).

[10] Helmholtz-Zentrum für Umweltforschung GmbH - UFZ, „Dürre 2018“, Feb. 08, 2019. https://www.ufz.de/index.php?de=44429 (last opened Aug. 13, 2021).

6 Appendix

6.1 Solar irradiance

Different sensor types with different orientation and inclination are used for the measurement of the different irradiation types. The sensors used and their designation are briefly presented below.

6.1.1 Silicon pyranometer SP-Lite2

In the weather station 2 silicon pyranometers of the type SP-Lite2 of the company Kipp & Zonen are installed. These are silicon pyranometers which are easy to handle and maintain [1].

The silicon pyranometers SP-Lite2 measure the global irradiance in the following directions (the direction specification in degrees uses the definition in DIN 5034-2):

Table 5 Orientation SP-Lite2

Orientation	Tilt angle	Name in Data set
Horizontal	0°	EGH_SPL1
South (180°)	35°	EGS_SPL2

6.1.2 Pyranometer CMP11

In addition to the silicon pyranometers SP-Lite 2, 3 pyranometers of the type CMP11 from the company Kipp & Zonen are installed in the weather station. While the silicon pyranometer SP-Lite 2 has a shorter response time, the pyranometer CMP11 is less susceptible to measurement errors that occur over the years. Furthermore, the pyranometer CMP11 has a better linear measurement behavior between 100 and 1000 W/m2 irradiance [2].

With the pyranometer CMP11 the global irradiance is measured in the following orientations and tilt angles:

Table 6 Orientation CMP11

Orientation	Tilt angle	Name in Data set
Horizontal	0°	EGH_CMP1
South (180°)	35°	EGS_CMP2
South-West (225°)	15°	EGSW_CMP3

6.1.3 Pyranometer SMP21

The pyranometer SMP21 of the company Kipp & Zonen is most frequently installed in the weather station. In contrast to the CMP11 it has a better response behavior. The measuring errors, as well as the linearity do not differ. The pyranometer SMP21 can correct the temperature dependence of the sensor via an integrated temperature sensor [3]. In contrast to the CMP21 pyranometer, a power supply is required for this correction.

The pyranometer SMP21 measures the global irradiance as well as the diffuse irradiance in the following orientations and titl angles:

Table 7 Orientation SMP21

Orientation	Tilt angle	Name in data set
Horizontal, global	0°	EGH_SMP4
Horizontal, diffuse	0°	DIF_SMP5
South (180°), global	35°	EGS_SMP2
West (270°), global	35°	EGW_SMP3
East (90°), global	35°	EGO_SMP1

6.1.4 Pyrheliometer SHP1

The HTW weather station also has a pyrheliometer of the type SHP1 from the company Kipp & Zonen, which measures the direct normal irradiance [4]. In the data set, the direct normal irradiance is designated "DIR_SHP1".

6.2 Temperature and humidity

Furthermore, the air temperature and humidity are measured at the HTW weather station. The measurement is carried out via a hygro-thermo sensor from the company Adolf Thies GmbH & Co KG [5]. The air humidity is measured via a capacitive humidity measuring element and the temperature via a PT100 resistor.

6.3 Wind velocity and wind orientation

The wind direction is recorded by a wind direction sensor from Adolf Thies GmbH & Co KG [6].

The wind speed is measured on the one hand via a cup cross anemometer and on the other hand via a 3D ultrasonic anemometer. Both measuring devices are made by the company Adolf Thies GmbH & Co KG [6] [7]. A 3D anemometer offers the advantage that the wind speed is resolved into the individual dimensions in x, y, z. The wind speed is then calculated via the wind direction. The wind speed then results from a vectorial addition of the individual wind speeds.

6.4 Barometer

The air pressure is also recorded at the HTW weather station. This is done via a baro transducer module, which is part of the data logger DL16 used [8].

6.5 Data logger DL16

The data logger of the weather station is a DL 16 of the company Adolf Thies GmbH and Co KG [8]. This has an internal ring memory for 24 h and is connected via a web server to a database for long-term storage of the time series.

6.6 Documentation of the measurement gaps

The following tables show the large measurement gaps that were replaced by previously measured values. The remaining measurement gaps were interpolated.

6.6.1 2017

Measurement gaps minute-by-minute data

Table 8 Measurement gaps minute-by-minute data 2017

timestamps begin of gap	timestamps end of gap
19.04.2017 03:21	19.04.2017 23:00

Measurement gaps second-by-second data

Table 9 Measurement gaps second-by-second data 2017

timestamps begin of gap	timestamps end of gap
20.03.2017 3:05:32	20.03.2017 09:39:00
23.03.2017 17:37:04	23.03.2017 20:37:40
25.03.2017 14:15:29	25.03.2017 15:19:54
26.03.2017 03:10:56	26.03.2017 11:30:00
29.03.2017 19:29:27	29.03.2017 21:29:58
19.04.2017 03:20:14	19.04.2017 23:00:00
27.06.2017 11:53:31	27.06.2017 14:15:00

6.6.2 2018

Measurement gaps minute-by-minute data

Table 10 Measurement gaps minute-by-minute data 2018

timestamps begin of gap	timestamps end of gap
25.03.2018 4:00	25.03.2018 5:00
03.09.2018 13:14	04.09.2018 0:59

Measurement gaps second-by-second data

Table 11 Measurement gaps second-by-second data 2018

timestamps begin of gap	timestamps end of gap
25.03.2018 4:00:00	25.03.2018 5:00:00
03.09.2018 13:13:06	04.09.2018 22:29:59
05.09.2018 07:54:41	05.09.2018 22:59:59

6.6.3 2019

Measurement gaps minute-by-minute data

Table 12 Measurement gaps minute-by-minute data 2019

timestamps begin of gap	timestamps end of gap
07.02.2019 7:27	07.02.2019 9:30
08.02.2019 4:23	08.02.2019 8:19

Measurement gaps second-by-second data

Table 13 Measurement gaps second-by-second data 2019

timestamps begin of gap	timestamps end of gap
30.01.2019 01:46:58	31.01.2019 00:00:00
05.02.2019 20:12:03	06.02.2019 00:00:00
06.02.2019 09:20:19	06.02.2019 13:05:00

6.6.4 2020

Measurement gaps minute-by-minute data

No significant measurement gap present.

Measurement gaps second-by-second data

No significant measurement gap present.