



BSI Standards Publication

Photovoltaic devices

Part 3: Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data (IEC 60904-3:2019)

National foreword

This British Standard is the UK implementation of EN IEC 60904-3:2019. It is identical to IEC 60904-3:2019. It supersedes BS EN 60904-3:2016, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee GEL/82, Photovoltaic Energy Systems.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Compliance with a British Standard cannot confer immunity from legal obligations.

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Amendments/corrigenda issued since publication

Date	Text affected
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English Version

Photovoltaic devices - Part 3: Measurement principles for
terrestrial photovoltaic (PV) solar devices with reference spectral
irradiance data
(IEC 60904-3:2019)

Dispositifs photovoltaïques - Partie 3: Principes de mesure
des dispositifs solaires photovoltaïques (PV) à usage
terrestre incluant les données de l'éclairement spectral de
référence
(IEC 60904-3:2019)

Photovoltaische Einrichtungen - Teil 3: Messgrundsätze für
terrestrische photovoltaische (PV)-Einrichtungen mit
Angaben über die spektrale Strahlungsverteilung
(IEC 60904-3:2019)

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Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CENELEC member.

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European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

European foreword

The text of document 82/1342/CDV, future edition 4 of IEC 60904-3, prepared by IEC/TC 82 "Solar photovoltaic energy systems" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN IEC 60904-3:2019.

The following dates are fixed:

- latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2020-01-05
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2022-07-05

This document supersedes EN 60904-3:2016.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC shall not be held responsible for identifying any or all such patent rights.

Endorsement notice

The text of the International Standard IEC 60904-3:2019 was approved by CENELEC as a European Standard without any modification.

Annex ZA

(normative)

Normative references to international publications with their corresponding European publications

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE 1 Where an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu.

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 60891	-	Photovoltaic devices - Procedures for temperature and irradiance corrections to measured I-V characteristics	EN 60891	-
IEC 60904-1	-	Photovoltaic devices - Part 1: Measurement of photovoltaic current-voltage characteristics	EN 60904-1	-
IEC 60904-2	-	Photovoltaic devices - Part 2: Requirements for photovoltaic reference devices	EN 60904-2	-
IEC 60904-5	-	Photovoltaic devices - Part 5: Determination of the equivalent cell temperature (ECT) of photovoltaic (PV) devices by the open-circuit voltage method	EN 60904-5	-
IEC 60904-7	-	Photovoltaic devices - Part 7: Computation of the spectral mismatch correction for measurements of photovoltaic devices	EN 60904-7	-
IEC 60904-8	-	Photovoltaic devices - Part 8: Measurement of spectral responsivity of a photovoltaic (PV) device	EN 60904-8	-
IEC 60904-9	-	Photovoltaic devices - Part 9: Solar simulator performance requirements	EN 60904-9	-
IEC 61853-4	-		EN IEC 61853-4	-

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

PHOTOVOLTAIC DEVICES –

**Part 3: Measurement principles for terrestrial photovoltaic (PV)
solar devices with reference spectral irradiance data**

FOREWORD

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International Standard IEC 60904-3 has been prepared by IEC technical committee 82: Solar photovoltaic energy systems.

This fourth edition cancels and replaces the third edition published in 2016. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) all spectral data were recalculated due to some minor calculation and rounding errors in the third edition; the global spectral irradiance returned to exactly the data of the second edition;
- b) the angular distribution of the irradiance was clarified.

This publication contains an attached file in the form of an Excel spreadsheet. This file is intended to be used as a complement and does not form an integral part of the publication.

The text of this International Standard is based on the following documents:

CDV	Report on voting
82/1342/CDV	82/1425/RVC

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of the IEC 60904 series, published under the general title *Photovoltaic devices*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

PHOTOVOLTAIC DEVICES –

Part 3: Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data

1 Scope

This part of IEC 60904 applies to the following photovoltaic devices for terrestrial applications:

- solar cells with or without a protective cover;
- sub-assemblies of solar cells;
- modules; and
- systems.

NOTE The term “test specimen” is used to denote any of these devices.

The principles contained in this document cover testing in both natural and simulated sunlight.

Photovoltaic conversion is spectrally selective due to the nature of the semiconductor materials used in PV solar cells and modules. To compare the relative performance of different PV devices and materials a reference standard solar spectral distribution is necessary. This document includes such a reference solar spectral irradiance distribution.

This document also describes basic measurement principles for determining the electrical output of PV devices. The principles given in this document are designed to relate the performance rating of PV devices to a common reference terrestrial solar spectral irradiance distribution.

The reference terrestrial solar spectral irradiance distribution is given in this document in order to classify solar simulators according to the spectral performance requirements contained in IEC 60904-9.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60891, *Photovoltaic devices – Procedures for temperature and irradiance corrections to measured I-V characteristics*

IEC 60904-1, *Photovoltaic devices – Part 1: Measurement of photovoltaic current-voltage characteristics*

IEC 60904-2, *Photovoltaic devices – Part 2: Requirements for photovoltaic reference devices*

IEC 60904-5, *Photovoltaic devices – Part 5: Determination of the equivalent cell temperature (ECT) of photovoltaic (PV) devices by the open-circuit voltage method*

IEC 60904-7, *Photovoltaic devices – Part 7: Computation of the spectral mismatch correction for measurements of photovoltaic devices*

IEC 60904-8, *Photovoltaic devices – Part 8: Measurement of spectral responsivity of a photovoltaic (PV) device*

IEC 60904-9, *Photovoltaic devices – Part 9: Solar simulator performance requirements*

IEC 61853-4, *Photovoltaic (PV) module performance testing and energy rating - Part 4: Standard reference climatic profiles*

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

4 Measurement principles

In current practice the photovoltaic performance of a solar cell or module is determined by exposing it at a known temperature to stable sunlight, natural or simulated, and measuring its current-voltage (I-V) characteristic curve while measuring the magnitude of both the incident irradiance and the PV device temperature. Detailed I-V curve measurement procedures are included in IEC 60904-1. The measured performances can then be corrected to standard test conditions (STC) or other desired conditions of irradiance and temperature according to IEC 60891. The corrected power output at the maximum power voltage and STC is commonly referred to as the rated power.

Incident irradiance can be measured by means of a PV reference device (whose spectral responsivity shall be known) or, if measuring under natural sunlight, by means of a thermopile-type irradiance detector (pyranometer). If a PV reference device is used, it shall satisfy the requirements specified in IEC 60904-2. Temperature determination of the PV device under test shall be made according to IEC 60904-1 or IEC 60904-5.

Since a solar cell has a wavelength-dependent responsivity, its performance is significantly affected by the spectral distribution of the incident radiation, which in natural sunlight varies with factors such as location, weather, time of year, time of day, orientation of the receiving surface, etc., and with a simulator varies with its type and conditions of use according to IEC 60904-9. Regardless of whether the irradiance is measured with either a thermopile-type radiometer (that is not spectrally selective) or with a reference solar device, the spectral irradiance distribution of the incoming light shall be known in order to use IEC 60904-7 to calculate the spectral mismatch between the measured performance and the predicted performance under the global or direct reference solar spectral distribution defined in this document. When performing measurements according to the standard test conditions, the spectral mismatch between the PV device under test and the thermopile is usually much larger than the spectral mismatch between the PV reference device and the PV device under test.

When the spectral responsivity of the PV device is known as determined according to IEC 60904-8, it is also possible to use IEC 60904-7 to compute the performance of that PV device when exposed to light of any known spectral irradiance distribution.

5 Reference solar spectral and angular irradiance distribution

The reference solar spectral distributions are given in Table 1 and Figure 1.

The reference angular distribution is defined for both, the direct and the global spectral distribution, so that the complete radiation hits the solar device perpendicularly under normal incidence. Other, more realistic geometrical and ambient conditions for different climate zones are defined in IEC 61853-4.

The calculation of the spectral distributions was done using the following geometrical and environmental input parameters:

- global distribution (direct + diffuse + albedo) of sunlight (AM1.5 spectrum), corresponding to an integrated irradiance of $1\,000\text{ W}\cdot\text{m}^{-2}$ incident on a sun-facing plane surface tilted at 37° to the horizontal, and
- the direct distribution of sunlight (AM1.5d spectrum), corresponding to an integrated irradiance of $900\text{ W}\cdot\text{m}^{-2}$ incident on a sun-facing plane surface perpendicular to the incident sunlight,

considering the wavelength-dependent albedo of a light bare soil, under the following atmospheric conditions:

- U.S. standard atmosphere with CO_2 concentration increased to current level (370 ppm), a rural aerosol model, and no pollution;
- precipitable water: 1,416 4 cm;
- ozone content: 0,343 8 atm-cm (or 343,8 DU);
- turbidity (aerosol optical depth): 0,084 at 500 nm;
- pressure: 101,325 kPa (i.e. sea level).

Data contained in Table 1 have been generated using the solar spectral model SMARTS, Version 2.9.2. A general description of this model and its suitability to reproduce actual solar spectral irradiance distributions can be found in “Proposed Reference Irradiance Spectra for Solar Energy Systems Testing” by C. A. Gueymard, C. Myers and K. Emery¹, and in the references therein. Table 1 can be obtained using the data contained in Annex A as an input to the model SMARTS Version 2.9.2. The resulting output spectral irradiance values have to be multiplied by a normalization factor (0,997 1) in order to get an integrated irradiance of $1\,000\text{ W}\cdot\text{m}^{-2}$ in the wavelength range 0 to infinity for the global irradiance. This same scaling factor is applied to the direct spectrum giving an integrated irradiance of $900\text{ W}\cdot\text{m}^{-2}$ in the wavelength range 0 to infinity.

At the time of publication of this document the SMARTS Version 2.9.2 spectral model code is available, free of charge, subject to the author's license agreement, at <http://www.nrel.gov/rredc/smarts>. A copy of the model, not for distribution purposes, is kept under IEC TC 82 control.

The contents of Table 1 are included in an attached file in the form of an Excel spreadsheet.

¹ C. A. Gueymard, C. Myers and K. Emery, “Proposed Reference Irradiance Spectra for Solar Energy Systems Testing”, *Solar Energy*, Vol 73, No. 6, pp. 443-467, 2002.

Table 1 – Reference solar spectral irradiance distribution

Wave-length nm	Global spectral irradiance $\text{W} \cdot \text{m}^{-2} \cdot \text{nm}^{-1}$	Global photon flux $\text{m}^{-2} \cdot \text{s}^{-1} \cdot \text{nm}^{-1}$	Cumulative global integrated irradiance $\text{W} \cdot \text{m}^{-2}$	Direct spectral irradiance $\text{W} \cdot \text{m}^{-2} \cdot \text{nm}^{-1}$	Direct photon flux $\text{m}^{-2} \cdot \text{s}^{-1} \cdot \text{nm}^{-1}$	Cumulative direct integrated irradiance $\text{W} \cdot \text{m}^{-2}$
280,0	4,72E-23	6,649E-05	0,00E+00	2,529E-26	3,564E-08	0,000E00
280,5	1,23E-21	1,733E-03	3,19E-22	1,089E-24	1,537E-06	2,785E-25
281,0	5,67E-21	8,025E-03	2,04E-21	6,108E-24	8,640E-06	2,077E-24
281,5	1,56E-19	2,213E-01	4,25E-20	2,740E-22	3,883E-04	7,210E-23
282,0	1,19E-18	1,691E+00	3,79E-19	2,826E-21	4,012E-03	8,472E-22
282,5	4,53E-18	6,443E+00	1,81E-18	1,323E-20	1,882E-02	4,862E-21
283,0	1,84E-17	2,621E+01	7,54E-18	6,745E-20	9,609E-02	2,503E-20
283,5	3,53E-17	5,032E+01	2,10E-17	1,457E-19	2,080E-01	7,832E-20
284,0	7,25E-16	1,036E+03	2,11E-16	4,969E-18	7,105E00	1,357E-18
284,5	2,48E-15	3,550E+03	1,01E-15	2,156E-17	3,088E01	7,990E-18
285,0	7,99E-15	1,146E+04	3,63E-15	8,974E-17	1,287E02	3,581E-17
285,5	4,25E-14	6,107E+04	1,62E-14	6,424E-16	9,232E02	2,188E-16
286,0	1,36E-13	1,964E+05	6,10E-14	2,343E-15	3,374E03	9,653E-16
286,5	8,36E-13	1,205E+06	3,04E-13	1,840E-14	2,654E04	6,152E-15
287,0	2,73E-12	3,942E+06	1,20E-12	7,234E-14	1,045E05	2,884E-14
287,5	1,09E-11	1,573E+07	4,60E-12	3,651E-13	5,284E05	1,382E-13
288,0	6,22E-11	9,011E+07	2,29E-11	2,798E-12	4,056E06	9,290E-13
288,5	1,71E-10	2,485E+08	8,12E-11	9,039E-12	1,313E07	3,888E-12
289,0	5,61E-10	8,162E+08	2,64E-10	3,488E-11	5,074E07	1,487E-11
289,5	2,07E-09	3,015E+09	9,22E-10	1,532E-10	2,233E08	6,189E-11
290,0	6,00E-09	8,758E+09	2,94E-09	5,130E-10	7,490E08	2,285E-10
290,5	1,37E-08	2,010E+10	7,87E-09	1,326E-09	1,940E09	6,883E-10
291,0	3,50E-08	5,120E+10	2,00E-08	3,885E-09	5,691E09	1,991E-09
291,5	1,09E-07	1,597E+11	5,60E-08	1,438E-08	2,111E10	6,558E-09
292,0	2,68E-07	3,932E+11	1,50E-07	4,067E-08	5,978E10	2,032E-08
292,5	4,26E-07	6,267E+11	3,23E-07	7,021E-08	1,034E11	4,804E-08
293,0	8,62E-07	1,272E+12	6,45E-07	1,571E-07	2,318E11	1,049E-07
293,5	2,26E-06	3,345E+12	1,43E-06	4,696E-07	6,938E11	2,616E-07
294,0	4,16E-06	6,160E+12	3,03E-06	9,428E-07	1,395E12	6,147E-07
294,5	6,57E-06	9,743E+12	5,72E-06	1,592E-06	2,360E12	1,248E-06
295,0	1,23E-05	1,820E+13	1,04E-05	3,215E-06	4,775E12	2,450E-06
295,5	2,77E-05	4,127E+13	2,04E-05	7,997E-06	1,190E13	5,253E-06
296,0	4,78E-05	7,117E+13	3,93E-05	1,469E-05	2,190E13	1,093E-05
296,5	7,11E-05	1,062E+14	6,90E-05	2,324E-05	3,469E13	2,041E-05
297,0	9,65E-05	1,443E+14	1,11E-04	3,309E-05	4,947E13	3,449E-05
297,5	1,86E-04	2,779E+14	1,81E-04	6,772E-05	1,014E14	5,970E-05
298,0	2,89E-04	4,336E+14	3,00E-04	1,109E-04	1,664E14	1,044E-04
298,5	3,57E-04	5,362E+14	4,62E-04	1,423E-04	2,138E14	1,677E-04
299,0	4,91E-04	7,386E+14	6,73E-04	2,026E-04	3,050E14	2,539E-04
299,5	8,58E-04	1,294E+15	1,01E-03	3,728E-04	5,620E14	3,978E-04

Wave-length nm	Global spectral irradiance $W \cdot m^{-2} \cdot nm^{-1}$	Global photon flux $m^{-2} \cdot s^{-1} \cdot nm^{-1}$	Cumulative global integrated irradiance $W \cdot m^{-2}$	Direct spectral irradiance $W \cdot m^{-2} \cdot nm^{-1}$	Direct photon flux $m^{-2} \cdot s^{-1} \cdot nm^{-1}$	Cumulative direct integrated irradiance $W \cdot m^{-2}$
300,0	0,0010	1,537E+15	0,00	4,550E-04	6,871E14	0,00
300,5	0,0012	1,878E+15	0,00	5,704E-04	8,629E14	0,00
301,0	0,0019	2,916E+15	0,00	9,166E-04	1,389E15	0,00
301,5	0,0027	4,073E+15	0,00	1,316E-03	1,998E15	0,00
302,0	0,0029	4,428E+15	0,01	1,453E-03	2,209E15	0,00
302,5	0,0043	6,505E+15	0,01	2,185E-03	3,327E15	0,00
303,0	0,0071	1,079E+16	0,01	3,722E-03	5,678E15	0,00
303,5	0,0090	1,368E+16	0,01	4,790E-03	7,319E15	0,01
304,0	0,0094	1,445E+16	0,02	5,083E-03	7,778E15	0,01
304,5	0,0119	1,827E+16	0,02	6,449E-03	9,885E15	0,01
305,0	0,0164	2,520E+16	0,03	8,908E-03	1,368E16	0,02
305,5	0,0187	2,870E+16	0,04	1,016E-02	1,562E16	0,02
306,0	0,0185	2,853E+16	0,05	1,012E-02	1,559E16	0,03
306,5	0,0210	3,247E+16	0,06	1,153E-02	1,780E16	0,03
307,0	0,0278	4,291E+16	0,07	1,520E-02	2,349E16	0,04
307,5	0,0355	5,500E+16	0,09	1,941E-02	3,005E16	0,05
308,0	0,0377	5,850E+16	0,11	2,069E-02	3,208E16	0,06
308,5	0,0413	6,415E+16	0,13	2,268E-02	3,523E16	0,07
309,0	0,0404	6,287E+16	0,15	2,223E-02	3,458E16	0,08
309,5	0,0432	6,728E+16	0,17	2,360E-02	3,677E16	0,09
310,0	0,0508	7,926E+16	0,19	2,775E-02	4,330E16	0,10
310,5	0,0653	1,021E+17	0,22	3,577E-02	5,592E16	0,12
311,0	0,0827	1,294E+17	0,26	4,526E-02	7,086E16	0,14
311,5	0,0838	1,315E+17	0,30	4,602E-02	7,217E16	0,16
312,0	0,0931	1,462E+17	0,34	5,075E-02	7,971E16	0,19
312,5	0,0987	1,553E+17	0,39	5,361E-02	8,434E16	0,21
313,0	0,1070	1,686E+17	0,44	5,815E-02	9,163E16	0,24
313,5	0,1073	1,693E+17	0,49	5,883E-02	9,284E16	0,27
314,0	0,1193	1,886E+17	0,55	6,508E-02	1,029E17	0,30
314,5	0,1302	2,062E+17	0,61	7,027E-02	1,113E17	0,33
315,0	0,1359	2,154E+17	0,68	7,347E-02	1,165E17	0,37
315,5	0,1180	1,875E+17	0,74	6,464E-02	1,027E17	0,40
316,0	0,1231	1,959E+17	0,80	6,689E-02	1,064E17	0,44
316,5	0,1499	2,389E+17	0,87	8,088E-02	1,289E17	0,47
317,0	0,1711	2,730E+17	0,95	9,275E-02	1,480E17	0,52
317,5	0,1819	2,908E+17	1,04	9,942E-02	1,589E17	0,57
318,0	0,1754	2,808E+17	1,13	9,554E-02	1,529E17	0,61
318,5	0,1854	2,972E+17	1,22	9,976E-02	1,599E17	0,66
319,0	0,2041	3,278E+17	1,32	1,094E-01	1,757E17	0,72
319,5	0,1953	3,142E+17	1,42	1,066E-01	1,715E17	0,77
320,0	0,2047	3,297E+17	1,52	1,124E-01	1,811E17	0,82

Wave-length nm	Global spectral irradiance $W \cdot m^{-2} \cdot nm^{-1}$	Global photon flux $m^{-2} \cdot s^{-1} \cdot nm^{-1}$	Cumulative global integrated irradiance $W \cdot m^{-2}$	Direct spectral irradiance $W \cdot m^{-2} \cdot nm^{-1}$	Direct photon flux $m^{-2} \cdot s^{-1} \cdot nm^{-1}$	Cumulative direct integrated irradiance $W \cdot m^{-2}$
320,5	0,2445	3,945E+17	1,63	1,327E-01	2,140E17	0,89
321,0	0,2495	4,032E+17	1,75	1,338E-01	2,161E17	0,95
321,5	0,2377	3,848E+17	1,88	1,278E-01	2,068E17	1,02
322,0	0,2214	3,589E+17	1,99	1,216E-01	1,972E17	1,08
322,5	0,2165	3,514E+17	2,10	1,194E-01	1,938E17	1,14
323,0	0,2116	3,441E+17	2,21	1,159E-01	1,884E17	1,20
323,5	0,2479	4,037E+17	2,32	1,335E-01	2,175E17	1,26
324,0	0,2746	4,478E+17	2,45	1,481E-01	2,415E17	1,33
324,5	0,2824	4,613E+17	2,59	1,542E-01	2,519E17	1,41
325,0	0,2781	4,550E+17	2,73	1,546E-01	2,529E17	1,49
325,5	0,3234	5,299E+17	2,88	1,788E-01	2,930E17	1,57
326,0	0,3801	6,238E+17	3,06	2,081E-01	3,415E17	1,67
326,5	0,4060	6,674E+17	3,25	2,210E-01	3,632E17	1,77
327,0	0,3969	6,534E+17	3,45	2,177E-01	3,584E17	1,88
327,5	0,3835	6,323E+17	3,65	2,122E-01	3,499E17	1,99
328,0	0,3501	5,781E+17	3,83	1,972E-01	3,255E17	2,09
328,5	0,3706	6,128E+17	4,01	2,062E-01	3,409E17	2,19
329,0	0,4211	6,975E+17	4,21	2,323E-01	3,847E17	2,30
329,5	0,4674	7,753E+17	4,43	2,579E-01	4,278E17	2,42
330,0	0,4700	7,808E+17	4,67	2,612E-01	4,338E17	2,55
330,5	0,4268	7,100E+17	4,89	2,403E-01	3,999E17	2,68
331,0	0,4015	6,689E+17	5,10	2,277E-01	3,794E17	2,80
331,5	0,4168	6,956E+17	5,30	2,357E-01	3,933E17	2,91
332,0	0,4350	7,270E+17	5,52	2,444E-01	4,084E17	3,03
332,5	0,4379	7,330E+17	5,74	2,458E-01	4,115E17	3,16
333,0	0,4282	7,178E+17	5,95	2,419E-01	4,055E17	3,28
333,5	0,4061	6,817E+17	6,16	2,320E-01	3,895E17	3,40
334,0	0,4138	6,957E+17	6,37	2,375E-01	3,994E17	3,51
334,5	0,4438	7,473E+17	6,58	2,536E-01	4,270E17	3,64
335,0	0,4625	7,800E+17	6,81	2,640E-01	4,452E17	3,77
335,5	0,4518	7,631E+17	7,03	2,582E-01	4,361E17	3,90
336,0	0,4140	7,002E+17	7,25	2,374E-01	4,016E17	4,02
336,5	0,3810	6,455E+17	7,45	2,203E-01	3,733E17	4,13
337,0	0,3727	6,323E+17	7,64	2,170E-01	3,682E17	4,24
337,5	0,3993	6,785E+17	7,83	2,337E-01	3,970E17	4,36
338,0	0,4329	7,365E+17	8,04	2,525E-01	4,296E17	4,48
338,5	0,4539	7,735E+17	8,26	2,647E-01	4,511E17	4,61
339,0	0,4622	7,888E+17	8,49	2,702E-01	4,611E17	4,74
339,5	0,4731	8,085E+17	8,72	2,777E-01	4,745E17	4,88
340,0	0,5003	8,564E+17	8,97	2,957E-01	5,062E17	5,02
340,5	0,4993	8,558E+17	9,22	2,959E-01	5,072E17	5,17

Wave-length nm	Global spectral irradiance $W \cdot m^{-2} \cdot nm^{-1}$	Global photon flux $m^{-2} \cdot s^{-1} \cdot nm^{-1}$	Cumulative global integrated irradiance $W \cdot m^{-2}$	Direct spectral irradiance $W \cdot m^{-2} \cdot nm^{-1}$	Direct photon flux $m^{-2} \cdot s^{-1} \cdot nm^{-1}$	Cumulative direct integrated irradiance $W \cdot m^{-2}$
341,0	0,4700	8,068E+17	9,46	2,785E-01	4,781E17	5,31
341,5	0,4680	8,045E+17	9,69	2,777E-01	4,774E17	5,45
342,0	0,4879	8,400E+17	9,93	2,904E-01	4,999E17	5,59
342,5	0,5062	8,728E+17	10,18	3,021E-01	5,208E17	5,74
343,0	0,5134	8,865E+17	10,44	3,077E-01	5,313E17	5,89
343,5	0,4847	8,381E+17	10,69	2,916E-01	5,043E17	6,04
344,0	0,4172	7,225E+17	10,91	2,528E-01	4,378E17	6,18
344,5	0,4019	6,970E+17	11,12	2,437E-01	4,226E17	6,30
345,0	0,4576	7,948E+17	11,33	2,777E-01	4,824E17	6,43
345,5	0,4879	8,486E+17	11,57	2,967E-01	5,161E17	6,58
346,0	0,4764	8,298E+17	11,81	2,905E-01	5,059E17	6,73
346,5	0,4852	8,463E+17	12,05	2,966E-01	5,174E17	6,87
347,0	0,4926	8,605E+17	12,29	3,023E-01	5,281E17	7,02
347,5	0,4754	8,316E+17	12,54	2,927E-01	5,120E17	7,17
348,0	0,4737	8,299E+17	12,77	2,922E-01	5,119E17	7,32
348,5	0,4820	8,455E+17	13,01	2,980E-01	5,228E17	7,46
349,0	0,4643	8,157E+17	13,25	2,878E-01	5,056E17	7,61
349,5	0,4767	8,386E+17	13,48	2,963E-01	5,214E17	7,76
350,0	0,5264	9,276E+17	13,73	3,282E-01	5,782E17	7,91
350,5	0,5658	9,983E+17	14,01	3,537E-01	6,240E17	8,08
351,0	0,5501	9,720E+17	14,29	3,450E-01	6,096E17	8,26
351,5	0,5287	9,355E+17	14,56	3,329E-01	5,891E17	8,43
352,0	0,5164	9,151E+17	14,82	3,258E-01	5,773E17	8,59
352,5	0,4882	8,663E+17	15,07	3,086E-01	5,477E17	8,75
353,0	0,5189	9,221E+17	15,32	3,288E-01	5,843E17	8,91
353,5	0,5706	1,015E+18	15,59	3,625E-01	6,450E17	9,08
354,0	0,6032	1,075E+18	15,89	3,841E-01	6,845E17	9,27
354,5	0,6098	1,088E+18	16,19	3,893E-01	6,947E17	9,46
355,0	0,6096	1,089E+18	16,49	3,903E-01	6,974E17	9,66
355,5	0,5886	1,053E+18	16,79	3,777E-01	6,759E17	9,85
356,0	0,5523	9,897E+17	17,08	3,552E-01	6,366E17	10,03
356,5	0,5179	9,295E+17	17,35	3,340E-01	5,994E17	10,21
357,0	0,4554	8,184E+17	17,59	2,944E-01	5,291E17	10,36
357,5	0,4608	8,293E+17	17,82	2,986E-01	5,374E17	10,51
358,0	0,4288	7,728E+17	18,04	2,785E-01	5,020E17	10,65
358,5	0,3981	7,185E+17	18,25	2,592E-01	4,678E17	10,79
359,0	0,4682	8,461E+17	18,46	3,056E-01	5,523E17	10,93
359,5	0,5639	1,020E+18	18,72	3,691E-01	6,679E17	11,10
360,0	0,5964	1,081E+18	19,01	3,913E-01	7,091E17	11,29
360,5	0,5637	1,023E+18	19,30	3,706E-01	6,725E17	11,48
361,0	0,5187	9,427E+17	19,57	3,418E-01	6,211E17	11,66

Wave-length nm	Global spectral irradiance $W \cdot m^{-2} \cdot nm^{-1}$	Global photon flux $m^{-2} \cdot s^{-1} \cdot nm^{-1}$	Cumulative global integrated irradiance $W \cdot m^{-2}$	Direct spectral irradiance $W \cdot m^{-2} \cdot nm^{-1}$	Direct photon flux $m^{-2} \cdot s^{-1} \cdot nm^{-1}$	Cumulative direct integrated irradiance $W \cdot m^{-2}$
361,5	0,5081	9,246E+17	19,83	3,355E-01	6,105E17	11,83
362,0	0,5327	9,707E+17	20,09	3,525E-01	6,423E17	12,00
362,5	0,5834	1,065E+18	20,37	3,869E-01	7,061E17	12,18
363,0	0,6002	1,097E+18	20,66	3,989E-01	7,289E17	12,38
363,5	0,5837	1,068E+18	20,96	3,888E-01	7,115E17	12,58
364,0	0,6045	1,108E+18	21,26	4,035E-01	7,395E17	12,78
364,5	0,5988	1,099E+18	21,56	4,006E-01	7,351E17	12,98
365,0	0,6218	1,142E+18	21,86	4,169E-01	7,660E17	13,18
365,5	0,6843	1,259E+18	22,19	4,598E-01	8,459E17	13,40
366,0	0,7332	1,351E+18	22,54	4,936E-01	9,095E17	13,64
366,5	0,7344	1,355E+18	22,91	4,955E-01	9,142E17	13,89
367,0	0,7208	1,332E+18	23,28	4,873E-01	9,002E17	14,13
367,5	0,7071	1,308E+18	23,63	4,790E-01	8,862E17	14,37
368,0	0,6657	1,233E+18	23,98	4,519E-01	8,371E17	14,61
368,5	0,6612	1,227E+18	24,31	4,498E-01	8,343E17	14,83
369,0	0,6911	1,284E+18	24,65	4,711E-01	8,750E17	15,06
369,5	0,7425	1,381E+18	25,00	5,071E-01	9,432E17	15,31
370,0	0,7529	1,402E+18	25,38	5,152E-01	9,595E17	15,56
370,5	0,6806	1,269E+18	25,74	4,666E-01	8,703E17	15,81
371,0	0,6914	1,291E+18	26,08	4,749E-01	8,869E17	16,04
371,5	0,7184	1,344E+18	26,43	4,944E-01	9,247E17	16,28
372,0	0,6725	1,259E+18	26,78	4,637E-01	8,684E17	16,52
372,5	0,6407	1,201E+18	27,11	4,426E-01	8,300E17	16,75
373,0	0,6171	1,159E+18	27,42	4,271E-01	8,019E17	16,97
373,5	0,5562	1,046E+18	27,72	3,857E-01	7,252E17	17,17
374,0	0,5548	1,045E+18	27,99	3,854E-01	7,256E17	17,36
374,5	0,5507	1,038E+18	28,27	3,832E-01	7,225E17	17,56
375,0	0,5876	1,109E+18	28,55	4,097E-01	7,734E17	17,75
375,5	0,6497	1,228E+18	28,86	4,538E-01	8,578E17	17,97
376,0	0,6728	1,274E+18	29,19	4,708E-01	8,912E17	18,20
376,5	0,6620	1,255E+18	29,53	4,640E-01	8,795E17	18,44
377,0	0,7102	1,348E+18	29,87	4,987E-01	9,464E17	18,68
377,5	0,7922	1,506E+18	30,25	5,573E-01	1,059E18	18,94
378,0	0,8535	1,624E+18	30,66	6,014E-01	1,144E18	19,23
378,5	0,8318	1,585E+18	31,08	5,872E-01	1,119E18	19,53
379,0	0,7417	1,415E+18	31,47	5,246E-01	1,001E18	19,80
379,5	0,6649	1,270E+18	31,82	4,712E-01	9,002E17	20,05
380,0	0,6987	1,337E+18	32,17	4,961E-01	9,489E17	20,30
380,5	0,7486	1,434E+18	32,53	5,324E-01	1,020E18	20,55
381,0	0,7616	1,461E+18	32,90	5,427E-01	1,041E18	20,82
381,5	0,6864	1,318E+18	33,27	4,899E-01	9,409E17	21,08

Wave-length nm	Global spectral irradiance $W \cdot m^{-2} \cdot nm^{-1}$	Global photon flux $m^{-2} \cdot s^{-1} \cdot nm^{-1}$	Cumulative global integrated irradiance $W \cdot m^{-2}$	Direct spectral irradiance $W \cdot m^{-2} \cdot nm^{-1}$	Direct photon flux $m^{-2} \cdot s^{-1} \cdot nm^{-1}$	Cumulative direct integrated irradiance $W \cdot m^{-2}$
382,0	0,5851	1,125E+18	33,58	4,184E-01	8,045E17	21,31
382,5	0,5061	9,746E+17	33,86	3,626E-01	6,981E17	21,50
383,0	0,4537	8,747E+17	34,10	3,255E-01	6,276E17	21,67
383,5	0,4392	8,479E+17	34,32	3,157E-01	6,094E17	21,83
384,0	0,5082	9,824E+17	34,56	3,658E-01	7,072E17	22,00
384,5	0,6118	1,184E+18	34,84	4,411E-01	8,538E17	22,21
385,0	0,6716	1,302E+18	35,16	4,850E-01	9,399E17	22,44
385,5	0,6418	1,245E+18	35,49	4,641E-01	9,007E17	22,67
386,0	0,6192	1,203E+18	35,80	4,485E-01	8,716E17	22,90
386,5	0,6438	1,253E+18	36,12	4,671E-01	9,089E17	23,13
387,0	0,6496	1,265E+18	36,44	4,721E-01	9,196E17	23,37
387,5	0,6402	1,249E+18	36,76	4,660E-01	9,089E17	23,60
388,0	0,6340	1,238E+18	37,08	4,622E-01	9,027E17	23,83
388,5	0,6295	1,231E+18	37,40	4,596E-01	8,989E17	24,06
389,0	0,6834	1,338E+18	37,73	4,998E-01	9,786E17	24,30
389,5	0,7575	1,485E+18	38,09	5,548E-01	1,088E18	24,57
390,0	0,7947	1,560E+18	38,47	5,829E-01	1,144E18	24,85
390,5	0,8014	1,575E+18	38,87	5,887E-01	1,157E18	25,14
391,0	0,8489	1,671E+18	39,29	6,245E-01	1,229E18	25,45
391,5	0,8609	1,697E+18	39,71	6,343E-01	1,250E18	25,76
392,0	0,7926	1,564E+18	40,13	5,849E-01	1,154E18	26,07
392,5	0,6606	1,305E+18	40,49	4,882E-01	9,646E17	26,34
393,0	0,4784	9,464E+17	40,77	3,540E-01	7,003E17	26,55
393,5	0,3804	7,536E+17	40,99	2,819E-01	5,584E17	26,71
394,0	0,4942	9,803E+17	41,21	3,667E-01	7,274E17	26,87
394,5	0,6819	1,354E+18	41,50	5,066E-01	1,006E18	27,09
395,0	0,8054	1,601E+18	41,87	5,992E-01	1,192E18	27,36
395,5	0,8579	1,708E+18	42,29	6,392E-01	1,273E18	27,67
396,0	0,7544	1,504E+18	42,69	5,628E-01	1,122E18	27,97
396,5	0,5486	1,095E+18	43,02	4,098E-01	8,180E17	28,22
397,0	0,4250	8,493E+17	43,26	3,179E-01	6,353E17	28,40
397,5	0,6276	1,256E+18	43,52	4,701E-01	9,408E17	28,59
398,0	0,8500	1,703E+18	43,89	6,376E-01	1,277E18	28,87
398,5	1,0040	2,014E+18	44,36	7,540E-01	1,513E18	29,22
399,0	1,0662	2,142E+18	44,88	8,017E-01	1,610E18	29,61
399,5	1,0989	2,210E+18	45,42	8,274E-01	1,664E18	30,02
400,0	1,1109	2,237E+18	45,97	8,375E-01	1,686E18	30,43
401,0	1,1569	2,335E+18	47,10	8,744E-01	1,765E18	31,29
402,0	1,2026	2,434E+18	48,28	9,112E-01	1,844E18	32,18
403,0	1,1579	2,349E+18	49,46	8,796E-01	1,784E18	33,08
404,0	1,1767	2,393E+18	50,63	8,959E-01	1,822E18	33,96

Wave-length nm	Global spectral irradiance $W \cdot m^{-2} \cdot nm^{-1}$	Global photon flux $m^{-2} \cdot s^{-1} \cdot nm^{-1}$	Cumulative global integrated irradiance $W \cdot m^{-2}$	Direct spectral irradiance $W \cdot m^{-2} \cdot nm^{-1}$	Direct photon flux $m^{-2} \cdot s^{-1} \cdot nm^{-1}$	Cumulative direct integrated irradiance $W \cdot m^{-2}$
405,0	1,1478	2,340E+18	51,79	8,759E-01	1,786E18	34,85
406,0	1,1194	2,288E+18	52,93	8,563E-01	1,750E18	35,72
407,0	1,0994	2,253E+18	54,04	8,430E-01	1,727E18	36,57
408,0	1,1481	2,358E+18	55,16	8,823E-01	1,812E18	37,43
409,0	1,2263	2,525E+18	56,35	9,444E-01	1,944E18	38,34
410,0	1,0455	2,158E+18	57,48	8,068E-01	1,665E18	39,22
411,0	1,1704	2,422E+18	58,59	9,051E-01	1,873E18	40,07
412,0	1,2442	2,580E+18	59,80	9,641E-01	1,999E18	41,01
413,0	1,1936	2,482E+18	61,02	9,268E-01	1,927E18	41,95
414,0	1,1808	2,461E+18	62,20	9,187E-01	1,915E18	42,88
415,0	1,2222	2,553E+18	63,41	9,529E-01	1,991E18	43,81
416,0	1,2587	2,636E+18	64,65	9,834E-01	2,059E18	44,78
417,0	1,2276	2,577E+18	65,89	9,611E-01	2,018E18	45,75
418,0	1,1743	2,471E+18	67,09	9,212E-01	1,939E18	46,69
419,0	1,2222	2,578E+18	68,29	9,607E-01	2,026E18	47,63
420,0	1,1199	2,368E+18	69,46	8,821E-01	1,865E18	48,56
421,0	1,2720	2,696E+18	70,66	1,004E00	2,127E18	49,50
422,0	1,2547	2,665E+18	71,92	9,921E-01	2,108E18	50,50
423,0	1,2149	2,587E+18	73,15	9,625E-01	2,050E18	51,47
424,0	1,2082	2,579E+18	74,36	9,590E-01	2,047E18	52,43
425,0	1,2452	2,664E+18	75,59	9,902E-01	2,119E18	53,41
426,0	1,2100	2,595E+18	76,82	9,639E-01	2,067E18	54,39
427,0	1,1690	2,513E+18	78,01	9,328E-01	2,005E18	55,33
428,0	1,1805	2,543E+18	79,18	9,435E-01	2,033E18	56,27
429,0	1,0931	2,361E+18	80,32	8,751E-01	1,890E18	57,18
430,0	0,8721	1,888E+18	81,30	6,993E-01	1,514E18	57,97
431,0	0,7916	1,718E+18	82,13	6,359E-01	1,380E18	58,64
432,0	1,3169	2,864E+18	83,19	1,060E00	2,305E18	59,48
433,0	1,2252	2,671E+18	84,46	9,876E-01	2,153E18	60,51
434,0	1,1319	2,473E+18	85,64	9,139E-01	1,997E18	61,46
435,0	1,2416	2,719E+18	86,83	1,004E00	2,199E18	62,42
436,0	1,3619	2,989E+18	88,13	1,103E00	2,421E18	63,47
437,0	1,3903	3,058E+18	89,50	1,127E00	2,480E18	64,59
438,0	1,2203	2,691E+18	90,81	9,908E-01	2,185E18	65,65
439,0	1,1741	2,595E+18	92,01	9,548E-01	2,110E18	66,62
440,0	1,3460	2,981E+18	93,27	1,096E00	2,428E18	67,64
441,0	1,3274	2,947E+18	94,60	1,083E00	2,404E18	68,73
442,0	1,4209	3,161E+18	95,98	1,161E00	2,582E18	69,85
443,0	1,4411	3,214E+18	97,41	1,179E00	2,629E18	71,02
444,0	1,4043	3,139E+18	98,83	1,150E00	2,571E18	72,19
445,0	1,4577	3,265E+18	100,26	1,196E00	2,679E18	73,36

Wave-length nm	Global spectral irradiance $W \cdot m^{-2} \cdot nm^{-1}$	Global photon flux $m^{-2} \cdot s^{-1} \cdot nm^{-1}$	Cumulative global integrated irradiance $W \cdot m^{-2}$	Direct spectral irradiance $W \cdot m^{-2} \cdot nm^{-1}$	Direct photon flux $m^{-2} \cdot s^{-1} \cdot nm^{-1}$	Cumulative direct integrated irradiance $W \cdot m^{-2}$
446,0	1,3070	2,934E+18	101,64	1,073E00	2,410E18	74,50
447,0	1,4860	3,344E+18	103,04	1,222E00	2,750E18	75,64
448,0	1,5037	3,391E+18	104,53	1,239E00	2,793E18	76,87
449,0	1,5001	3,391E+18	106,04	1,237E00	2,797E18	78,11
450,0	1,5550	3,523E+18	107,56	1,284E00	2,909E18	79,37
451,0	1,6126	3,661E+18	109,15	1,334E00	3,028E18	80,68
452,0	1,5437	3,513E+18	110,73	1,278E00	2,909E18	81,99
453,0	1,4256	3,251E+18	112,21	1,182E00	2,695E18	83,22
454,0	1,5291	3,495E+18	113,69	1,269E00	2,901E18	84,44
455,0	1,5180	3,477E+18	115,21	1,262E00	2,890E18	85,71
456,0	1,5678	3,599E+18	116,75	1,305E00	2,996E18	86,99
457,0	1,5808	3,637E+18	118,33	1,317E00	3,031E18	88,30
458,0	1,5469	3,567E+18	119,89	1,291E00	2,976E18	89,61
459,0	1,5346	3,546E+18	121,43	1,282E00	2,963E18	90,90
460,0	1,5247	3,531E+18	122,96	1,275E00	2,953E18	92,17
461,0	1,5781	3,662E+18	124,51	1,322E00	3,067E18	93,47
462,0	1,5929	3,705E+18	126,10	1,335E00	3,106E18	94,80
463,0	1,5985	3,726E+18	127,70	1,341E00	3,126E18	96,14
464,0	1,5499	3,620E+18	129,27	1,302E00	3,041E18	97,46
465,0	1,5305	3,583E+18	130,81	1,287E00	3,012E18	98,76
466,0	1,5628	3,666E+18	132,36	1,315E00	3,085E18	100,06
467,0	1,4930	3,510E+18	133,88	1,258E00	2,957E18	101,34
468,0	1,5574	3,669E+18	135,41	1,314E00	3,096E18	102,63
469,0	1,5637	3,692E+18	136,97	1,321E00	3,119E18	103,95
470,0	1,5033	3,557E+18	138,50	1,271E00	3,008E18	105,24
471,0	1,5287	3,624E+18	140,02	1,294E00	3,067E18	106,52
472,0	1,6079	3,821E+18	141,59	1,362E00	3,237E18	107,85
473,0	1,5454	3,680E+18	143,16	1,311E00	3,121E18	109,19
474,0	1,5626	3,728E+18	144,72	1,327E00	3,165E18	110,51
475,0	1,6138	3,859E+18	146,31	1,372E00	3,280E18	111,86
476,0	1,5586	3,735E+18	147,89	1,326E00	3,177E18	113,21
477,0	1,5678	3,765E+18	149,46	1,335E00	3,206E18	114,54
478,0	1,6183	3,894E+18	151,05	1,380E00	3,320E18	115,89
479,0	1,5870	3,827E+18	152,65	1,355E00	3,267E18	117,26
480,0	1,6134	3,899E+18	154,25	1,378E00	3,331E18	118,63
481,0	1,6130	3,906E+18	155,87	1,380E00	3,340E18	120,01
482,0	1,6189	3,928E+18	157,48	1,386E00	3,363E18	121,39
483,0	1,5991	3,888E+18	159,09	1,370E00	3,332E18	122,77
484,0	1,5688	3,822E+18	160,67	1,345E00	3,278E18	124,13
485,0	1,5638	3,818E+18	162,24	1,342E00	3,276E18	125,47
486,0	1,2679	3,102E+18	163,66	1,089E00	2,663E18	126,68