

# INTERNATIONAL STANDARD



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

IEC 60904-3:2016

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## CONTENTS

FOREWORD.....	3
1 Scope and object.....	5
2 Normative references .....	5
3 Measurement principles.....	6
4 Reference solar spectral irradiance distribution .....	6
Annex A (informative) Use of SMARTS .....	80
Bibliography.....	81
Figure 1 – Global and direct reference solar spectral irradiance distribution listed in Table 1 .....	79
Table 1 – Reference solar spectral irradiance distribution .....	8
Table A.1 – Input data for generation of reference solar spectral irradiance distribution .....	80

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## INTERNATIONAL ELECTROTECHNICAL COMMISSION

## PHOTOVOLTAIC DEVICES –

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

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

This third edition cancels and replaces the second edition published in 2008. This edition constitutes a technical revision.

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

- a) the direct beam irradiance corresponding to the global irradiance in Table 1 was included;
- b) the term “Global photon irradiance” in Table 1 was changed to “Global photon flux”;
- c) the titles of some clauses have been changed (others have been added) in accordance with the usual structure of IEC standards.

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 standard is based on the following documents.

FDIS	Report on voting
82/1071/FDIS	82/1096/RVD

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

This publication 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 publication will remain unchanged until the stability date indicated on the IEC website under “<http://webstore.iec.ch>” in the data related to the specific publication. At this date, the publication will be

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- withdrawn,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

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## PHOTOVOLTAIC DEVICES –

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

#### 1 Scope and object

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 standard cover testing in both natural and simulated sunlight.

~~This standard is not applicable to solar cells designed for operation in concentrated sunlight or to modules embodying concentrators.~~

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 standard includes such a reference solar spectral irradiance distribution.

This standard also describes basic measurement principles for determining the electrical output of PV devices. The principles given in this standard 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~~ **is** given in this standard ~~is required~~ in order to classify solar simulators according to the spectral performance requirements contained in IEC 60904-9.

#### 2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60891:1987, *Photovoltaic devices – Procedures for temperature and irradiance corrections to measured I-V characteristics of crystalline silicon photovoltaic devices* Amendment 1 (1992)

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

IEC 60904-2, *Photovoltaic devices – Part 2: Requirements for photovoltaic reference solar 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 ~~error~~ introduced in the testing of a 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~~

### 3 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 ~~rated~~ 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 ~~response must~~ 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 response, its performance is significantly affected by the spectral distribution of the incident radiation, which in natural sunlight varies with ~~several~~ 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.

~~If~~ Regardless of whether the irradiance is measured with either a thermopile-type radiometer (that is not spectrally selective) or with a reference solar ~~cell~~ device, the spectral irradiance distribution of the incoming light ~~must~~ shall be known in order to ~~make the necessary corrections to obtain the performance of the PV device under the reference solar spectral distribution defined in this standard as specified in 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 standard.

When the spectral responsivity of the PV device is known as determined according to IEC 60904-8, it is also possible ~~for a user or array designer, using the spectral response of the cells, to use IEC 60904-7 to compute within a reasonable tolerance the performance of a the performance of that PV device when exposed to light of any other known spectral irradiance distribution. The methodology for this calculation can be found in IEC 60904-7.~~

### 4 Reference solar spectral irradiance distribution

The reference solar spectral distributions AM1.5 ~~is~~ are given in Table 1 and Figure 1. These are

- global distribution (direct + diffuse) of sunlight, corresponding to an integrated irradiance of  $1\,000\text{ W}\cdot\text{m}^{-2}$  incident on a sun-facing plane surface tilted at  $37^\circ$  to the horizontal, and
- the direct distribution of sunlight, 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<sub>2</sub> 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: ~~1013,25 hPa~~ 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. Emery<sup>1</sup>, 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 (~~0,9974~~ 0,997 08) in order to get an integrated irradiance of 1 000 W·m<sup>-2</sup> 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 W·m<sup>-2</sup> in the wavelength range 0 to infinity.

At the time of publication of this standard 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 ~~WG-2~~ control.

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

<sup>1</sup> 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)	Spectral irradiance (W·m <sup>-2</sup> ·nm <sup>-1</sup> )	Spectral photon irradiance (m <sup>-2</sup> ·s <sup>-1</sup> ·nm <sup>-1</sup> )	Cumulative integrated irradiance (W·m <sup>-2</sup> )	Wave-length (nm)	Spectral irradiance (W·m <sup>-2</sup> ·nm <sup>-1</sup> )	Spectral photon irradiance (m <sup>-2</sup> ·s <sup>-1</sup> ·nm <sup>-1</sup> )	Cumulative integrated irradiance (W·m <sup>-2</sup> )
280,0	4,72E-23	6,649E-05	0,00E+00	302,5	0,0043	6,505E+15	0,01
280,5	1,23E-21	1,733E-03	3,19E-22	303,0	0,0071	1,079E+16	0,01
281,0	5,67E-21	8,025E-03	2,04E-21	303,5	0,0090	1,368E+16	0,01
281,5	1,56E-19	2,213E-01	4,25E-20	304,0	0,0094	1,445E+16	0,02
282,0	1,19E-18	1,691E+00	3,79E-19	304,5	0,0119	1,827E+16	0,02
282,5	4,53E-18	6,443E+00	1,81E-18	305,0	0,0164	2,520E+16	0,03
283,0	1,84E-17	2,621E+01	7,54E-18	305,5	0,0187	2,870E+16	0,04
283,5	3,53E-17	5,032E+01	2,10E-17	306,0	0,0185	2,853E+16	0,05
284,0	7,25E-16	1,036E+03	2,11E-16	306,5	0,0210	3,247E+16	0,06
284,5	2,48E-15	3,550E+03	1,01E-15	307,0	0,0278	4,291E+16	0,07
285,0	7,99E-15	1,146E+04	3,63E-15	307,5	0,0355	5,500E+16	0,09
285,5	4,25E-14	6,107E+04	1,62E-14	308,0	0,0377	5,850E+16	0,11
286,0	1,36E-13	1,964E+05	6,10E-14	308,5	0,0413	6,415E+16	0,13
286,5	8,36E-13	1,205E+06	3,04E-13	309,0	0,0404	6,287E+16	0,15
287,0	2,73E-12	3,942E+06	1,20E-12	309,5	0,0433	6,728E+16	0,17
287,5	1,09E-11	1,573E+07	4,60E-12	310,0	0,0508	7,926E+16	0,19
288,0	6,22E-11	9,011E+07	2,29E-11	310,5	0,0653	1,021E+17	0,22
288,5	1,71E-10	2,485E+08	8,12E-11	311,0	0,0827	1,294E+17	0,26
289,0	5,61E-10	8,162E+08	2,64E-10	311,5	0,0838	1,315E+17	0,30
289,5	2,07E-09	3,015E+09	9,22E-10	312,0	0,0931	1,462E+17	0,34
290,0	6,00E-09	8,758E+09	2,94E-09	312,5	0,0987	1,553E+17	0,39
290,5	1,37E-08	2,010E+10	7,87E-09	313,0	0,1070	1,686E+17	0,44
291,0	3,50E-08	5,120E+10	2,00E-08	313,5	0,1073	1,693E+17	0,49
291,5	1,09E-07	1,597E+11	5,60E-08	314,0	0,1193	1,886E+17	0,55
292,0	2,68E-07	3,932E+11	1,50E-07	314,5	0,1302	2,062E+17	0,61
292,5	4,26E-07	6,267E+11	3,23E-07	315,0	0,1359	2,154E+17	0,68
293,0	8,62E-07	1,272E+12	6,45E-07	315,5	0,1180	1,875E+17	0,74
293,5	2,26E-06	3,345E+12	1,43E-06	316,0	0,1231	1,959E+17	0,80
294,0	4,16E-06	6,160E+12	3,03E-06	316,5	0,1499	2,389E+17	0,87
294,5	6,57E-06	9,743E+12	5,72E-06	317,0	0,1711	2,730E+17	0,95
295,0	1,23E-05	1,820E+13	1,04E-05	317,5	0,1819	2,908E+17	1,04
295,5	2,77E-05	4,127E+13	2,04E-05	318,0	0,1754	2,808E+17	1,13
296,0	4,78E-05	7,117E+13	3,93E-05	318,5	0,1854	2,972E+17	1,22
296,5	7,11E-05	1,062E+14	6,90E-05	319,0	0,2041	3,278E+17	1,32
297,0	9,65E-05	1,443E+14	1,11E-04	319,5	0,1953	3,142E+17	1,42
297,5	1,86E-04	2,779E+14	1,81E-04	320,0	0,2047	3,297E+17	1,52
298,0	2,89E-04	4,336E+14	3,00E-04	320,5	0,2445	3,945E+17	1,63
298,5	3,57E-04	5,362E+14	4,62E-04	321,0	0,2495	4,032E+17	1,75
299,0	4,91E-04	7,386E+14	6,73E-04	321,5	0,2377	3,848E+17	1,88
299,5	8,58E-04	1,294E+15	1,01E-03	322,0	0,2214	3,589E+17	1,99
300,0	0,0010	1,537E+15	0,00	322,5	0,2165	3,514E+17	2,10
300,5	0,0012	1,878E+15	0,00	323,0	0,2116	3,441E+17	2,21
301,0	0,0019	2,916E+15	0,00	323,5	0,2479	4,037E+17	2,32
301,5	0,0027	4,073E+15	0,00	324,0	0,2746	4,478E+17	2,45
302,0	0,0029	4,428E+15	0,01	324,5	0,2824	4,613E+17	2,59

Wave-length (nm)	Spectral irradiance (W·m <sup>-2</sup> ·nm <sup>-1</sup> )	Spectral photon irradiance (m <sup>-2</sup> ·s <sup>-1</sup> ·nm <sup>-1</sup> )	Cumulative integrated irradiance (W·m <sup>-2</sup> )
325,0	0,2781	4,550E+17	2,73
325,5	0,3234	5,299E+17	2,88
326,0	0,3801	6,238E+17	3,06
326,5	0,4060	6,674E+17	3,25
327,0	0,3969	6,534E+17	3,45
327,5	0,3835	6,323E+17	3,65
328,0	0,3501	5,781E+17	3,83
328,5	0,3706	6,128E+17	4,01
329,0	0,4211	6,975E+17	4,21
329,5	0,4674	7,753E+17	4,43
330,0	0,4700	7,808E+17	4,67
330,5	0,4268	7,100E+17	4,89
331,0	0,4015	6,689E+17	5,10
331,5	0,4168	6,956E+17	5,30
332,0	0,4350	7,270E+17	5,52
332,5	0,4379	7,330E+17	5,74
333,0	0,4282	7,178E+17	5,95
333,5	0,4061	6,817E+17	6,16
334,0	0,4138	6,957E+17	6,37
334,5	0,4438	7,473E+17	6,58
335,0	0,4625	7,800E+17	6,81
335,5	0,4518	7,631E+17	7,03
336,0	0,4140	7,002E+17	7,25
336,5	0,3810	6,455E+17	7,46
337,0	0,3727	6,323E+17	7,64
337,5	0,3993	6,785E+17	7,83
338,0	0,4329	7,365E+17	8,04
338,5	0,4539	7,735E+17	8,26
339,0	0,4622	7,888E+17	8,49
339,5	0,4731	8,085E+17	8,72
340,0	0,5003	8,564E+17	8,97
340,5	0,4993	8,558E+17	9,22
341,0	0,4700	8,068E+17	9,46
341,5	0,4680	8,045E+17	9,69
342,0	0,4879	8,400E+17	9,93
342,5	0,5062	8,728E+17	10,18
343,0	0,5134	8,865E+17	10,44
343,5	0,4847	8,381E+17	10,69
344,0	0,4172	7,225E+17	10,91
344,5	0,4019	6,970E+17	11,12
345,0	0,4576	7,948E+17	11,33
345,5	0,4879	8,486E+17	11,57
346,0	0,4764	8,298E+17	11,81
346,5	0,4852	8,463E+17	12,05
347,0	0,4926	8,605E+17	12,29
347,5	0,4754	8,316E+17	12,54
348,0	0,4737	8,299E+17	12,77

Wave-length (nm)	Spectral irradiance (W·m <sup>-2</sup> ·nm <sup>-1</sup> )	Spectral photon irradiance (m <sup>-2</sup> ·s <sup>-1</sup> ·nm <sup>-1</sup> )	Cumulative integrated irradiance (W·m <sup>-2</sup> )
348,5	0,4820	8,455E+17	13,01
349,0	0,4643	8,157E+17	13,25
349,5	0,4767	8,386E+17	13,48
350,0	0,5264	9,276E+17	13,73
350,5	0,5658	9,983E+17	14,01
351,0	0,5501	9,720E+17	14,29
351,5	0,5287	9,355E+17	14,56
352,0	0,5164	9,151E+17	14,82
352,5	0,4882	8,663E+17	15,07
353,0	0,5189	9,221E+17	15,32
353,5	0,5706	1,015E+18	15,59
354,0	0,6032	1,075E+18	15,89
354,5	0,6098	1,088E+18	16,19
355,0	0,6096	1,089E+18	16,49
355,5	0,5886	1,053E+18	16,79
356,0	0,5523	9,897E+17	17,08
356,5	0,5179	9,295E+17	17,35
357,0	0,4654	8,184E+17	17,59
357,5	0,4608	8,293E+17	17,82
358,0	0,4288	7,728E+17	18,04
358,5	0,3981	7,185E+17	18,25
359,0	0,4682	8,461E+17	18,46
359,5	0,5639	1,020E+18	18,72
360,0	0,5964	1,081E+18	19,01
360,5	0,5637	1,023E+18	19,30
361,0	0,5187	9,427E+17	19,57
361,5	0,5081	9,246E+17	19,83
362,0	0,5327	9,707E+17	20,09
362,5	0,5834	1,065E+18	20,37
363,0	0,6002	1,097E+18	20,66
363,5	0,5837	1,068E+18	20,96
364,0	0,6045	1,108E+18	21,26
364,5	0,5988	1,099E+18	21,56
365,0	0,6218	1,142E+18	21,86
365,5	0,6843	1,259E+18	22,19
366,0	0,7332	1,351E+18	22,54
366,5	0,7344	1,355E+18	22,91
367,0	0,7208	1,332E+18	23,28
367,5	0,7071	1,308E+18	23,63
368,0	0,6657	1,233E+18	23,98
368,5	0,6612	1,227E+18	24,31
369,0	0,6911	1,284E+18	24,65
369,5	0,7425	1,381E+18	25,00
370,0	0,7529	1,402E+18	25,38
370,5	0,6806	1,269E+18	25,74
371,0	0,6914	1,291E+18	26,08
371,5	0,7184	1,344E+18	26,43

Wave-length (nm)	Spectral irradiance ( $\text{W}\cdot\text{m}^{-2}\cdot\text{nm}^{-1}$ )	Spectral photon irradiance ( $\text{m}^{-2}\cdot\text{s}^{-1}\cdot\text{nm}^{-1}$ )	Cumulative integrated irradiance ( $\text{W}\cdot\text{m}^{-2}$ )
372,0	0,6725	1,259E+18	26,78
372,5	0,6407	1,201E+18	27,11
373,0	0,6171	1,159E+18	27,42
373,5	0,5562	1,046E+18	27,72
374,0	0,5548	1,045E+18	27,99
374,5	0,5507	1,038E+18	28,27
375,0	0,5876	1,109E+18	28,55
375,5	0,6497	1,228E+18	28,86
376,0	0,6728	1,274E+18	29,19
376,5	0,6620	1,255E+18	29,53
377,0	0,7102	1,348E+18	29,87
377,5	0,7922	1,506E+18	30,25
378,0	0,8535	1,624E+18	30,66
378,5	0,8318	1,585E+18	31,08
379,0	0,7417	1,415E+18	31,47
379,5	0,6649	1,270E+18	31,82
380,0	0,6987	1,337E+18	32,17
380,5	0,7486	1,434E+18	32,53
381,0	0,7616	1,461E+18	32,90
381,5	0,6864	1,318E+18	33,27
382,0	0,5851	1,125E+18	33,58
382,5	0,5061	9,746E+17	33,86
383,0	0,4537	8,747E+17	34,10
383,5	0,4392	8,479E+17	34,32
384,0	0,5082	9,824E+17	34,56
384,5	0,6118	1,184E+18	34,84
385,0	0,6716	1,302E+18	35,16
385,5	0,6418	1,245E+18	35,49
386,0	0,6192	1,203E+18	35,80
386,5	0,6438	1,253E+18	36,12
387,0	0,6496	1,265E+18	36,44
387,5	0,6402	1,249E+18	36,76
388,0	0,6340	1,238E+18	37,08
388,5	0,6295	1,231E+18	37,40
389,0	0,6834	1,338E+18	37,73
389,5	0,7575	1,485E+18	38,09
390,0	0,7947	1,560E+18	38,47
390,5	0,8014	1,575E+18	38,87
391,0	0,8489	1,671E+18	39,29
391,5	0,8609	1,697E+18	39,71
392,0	0,7926	1,564E+18	40,13
392,5	0,6606	1,305E+18	40,49
393,0	0,4784	9,464E+17	40,77
393,5	0,3804	7,536E+17	40,99
394,0	0,4942	9,803E+17	41,21
394,5	0,6819	1,354E+18	41,50
395,0	0,8054	1,601E+18	41,87

Wave-length (nm)	Spectral irradiance ( $\text{W}\cdot\text{m}^{-2}\cdot\text{nm}^{-1}$ )	Spectral photon irradiance ( $\text{m}^{-2}\cdot\text{s}^{-1}\cdot\text{nm}^{-1}$ )	Cumulative integrated irradiance ( $\text{W}\cdot\text{m}^{-2}$ )
395,5	0,8579	1,708E+18	42,29
396,0	0,7544	1,504E+18	42,69
396,5	0,5486	1,095E+18	43,02
397,0	0,4250	8,493E+17	43,26
397,5	0,6276	1,256E+18	43,52
398,0	0,8500	1,703E+18	43,89
398,5	1,0040	2,014E+18	44,36
399,0	1,0662	2,142E+18	44,88
399,5	1,0989	2,210E+18	45,42
400,0	1,1109	2,237E+18	45,97
401,0	1,1569	2,335E+18	47,10
402,0	1,2026	2,434E+18	48,28
403,0	1,1579	2,349E+18	49,46
404,0	1,1767	2,393E+18	50,63
405,0	1,1478	2,340E+18	51,79
406,0	1,1194	2,288E+18	52,93
407,0	1,0994	2,253E+18	54,04
408,0	1,1481	2,358E+18	55,16
409,0	1,2263	2,525E+18	56,35
410,0	1,0455	2,158E+18	57,48
411,0	1,1704	2,422E+18	58,59
412,0	1,2442	2,580E+18	59,80
413,0	1,1936	2,482E+18	61,02
414,0	1,1808	2,461E+18	62,20
415,0	1,2222	2,553E+18	63,41
416,0	1,2587	2,636E+18	64,65
417,0	1,2276	2,577E+18	65,89
418,0	1,1743	2,471E+18	67,09
419,0	1,2222	2,578E+18	68,29
420,0	1,1199	2,368E+18	69,46
421,0	1,2720	2,696E+18	70,66
422,0	1,2547	2,665E+18	71,92
423,0	1,2149	2,587E+18	73,15
424,0	1,2082	2,579E+18	74,36
425,0	1,2452	2,664E+18	75,59
426,0	1,2100	2,595E+18	76,82
427,0	1,1690	2,513E+18	78,01
428,0	1,1805	2,543E+18	79,18
429,0	1,0931	2,361E+18	80,32
430,0	0,8721	1,888E+18	81,30
431,0	0,7916	1,718E+18	82,13
432,0	1,3169	2,864E+18	83,19
433,0	1,2252	2,671E+18	84,46
434,0	1,1319	2,473E+18	85,64
435,0	1,2416	2,719E+18	86,83
436,0	1,3619	2,989E+18	88,13
437,0	1,3903	3,058E+18	89,50

Wave-length (nm)	Spectral irradiance ( $\text{W}\cdot\text{m}^{-2}\cdot\text{nm}^{-1}$ )	Spectral photon irradiance ( $\text{m}^{-2}\cdot\text{s}^{-1}\cdot\text{nm}^{-1}$ )	Cumulative integrated irradiance ( $\text{W}\cdot\text{m}^{-2}$ )
438,0	1,2203	2,691E+18	90,81
439,0	1,1741	2,595E+18	92,01
440,0	1,3460	2,981E+18	93,27
441,0	1,3274	2,947E+18	94,60
442,0	1,4209	3,161E+18	95,98
443,0	1,4411	3,214E+18	97,41
444,0	1,4043	3,139E+18	98,83
445,0	1,4577	3,265E+18	100,26
446,0	1,3070	2,934E+18	101,64
447,0	1,4860	3,344E+18	103,04
448,0	1,5037	3,391E+18	104,53
449,0	1,5001	3,391E+18	106,04
450,0	1,5550	3,523E+18	107,56
451,0	1,6126	3,661E+18	109,15
452,0	1,5437	3,513E+18	110,73
453,0	1,4256	3,251E+18	112,21
454,0	1,5291	3,495E+18	113,69
455,0	1,5180	3,477E+18	115,21
456,0	1,5678	3,599E+18	116,75
457,0	1,5808	3,637E+18	118,33
458,0	1,5469	3,567E+18	119,89
459,0	1,5346	3,546E+18	121,43
460,0	1,5247	3,531E+18	122,96
461,0	1,5781	3,682E+18	124,51
462,0	1,5926	3,705E+18	126,10
463,0	1,5985	3,726E+18	127,70
464,0	1,5499	3,620E+18	129,27
465,0	1,5305	3,583E+18	130,81
466,0	1,5628	3,666E+18	132,36
467,0	1,4930	3,510E+18	133,88
468,0	1,5574	3,669E+18	135,41
469,0	1,5637	3,692E+18	136,97
470,0	1,5033	3,557E+18	138,50
471,0	1,5287	3,624E+18	140,02
472,0	1,6079	3,821E+18	141,59
473,0	1,5454	3,680E+18	143,16
474,0	1,5626	3,728E+18	144,72
475,0	1,6138	3,859E+18	146,31
476,0	1,5586	3,735E+18	147,89
477,0	1,5678	3,765E+18	149,46
478,0	1,6183	3,894E+18	151,05
479,0	1,5870	3,827E+18	152,65
480,0	1,6134	3,899E+18	154,25
481,0	1,6130	3,906E+18	155,87
482,0	1,6189	3,928E+18	157,48
483,0	1,5991	3,888E+18	159,09
484,0	1,5688	3,822E+18	160,67

Wave-length (nm)	Spectral irradiance ( $\text{W}\cdot\text{m}^{-2}\cdot\text{nm}^{-1}$ )	Spectral photon irradiance ( $\text{m}^{-2}\cdot\text{s}^{-1}\cdot\text{nm}^{-1}$ )	Cumulative integrated irradiance ( $\text{W}\cdot\text{m}^{-2}$ )
485,0	1,5638	3,818E+18	162,24
486,0	1,2679	3,102E+18	163,66
487,0	1,4200	3,481E+18	165,00
488,0	1,5368	3,775E+18	166,48
489,0	1,4477	3,564E+18	167,97
490,0	1,6177	3,990E+18	169,50
491,0	1,5550	3,843E+18	171,09
492,0	1,4826	3,672E+18	172,61
493,0	1,5857	3,935E+18	174,14
494,0	1,5480	3,850E+18	175,71
495,0	1,6437	4,096E+18	177,31
496,0	1,5631	3,903E+18	178,91
497,0	1,5898	3,977E+18	180,49
498,0	1,5464	3,877E+18	182,05
499,0	1,5462	3,884E+18	183,60
500,0	1,5406	3,878E+18	185,14
501,0	1,4935	3,767E+18	186,66
502,0	1,4923	3,771E+18	188,15
503,0	1,5608	3,952E+18	189,68
504,0	1,4545	3,690E+18	191,19
505,0	1,5590	3,963E+18	192,69
506,0	1,6217	4,131E+18	194,28
507,0	1,5515	3,960E+18	195,87
508,0	1,5121	3,867E+18	197,40
509,0	1,5847	4,060E+18	198,95
510,0	1,5436	3,963E+18	200,52
511,0	1,5723	4,045E+18	202,07
512,0	1,6139	4,160E+18	203,67
513,0	1,5162	3,916E+18	205,23
514,0	1,4842	3,840E+18	206,73
515,0	1,5270	3,959E+18	208,24
516,0	1,5410	4,003E+18	209,77
517,0	1,2557	3,268E+18	211,17
518,0	1,4361	3,745E+18	212,52
519,0	1,3917	3,636E+18	213,93
520,0	1,5192	3,977E+18	215,38
521,0	1,5301	4,013E+18	216,91
522,0	1,5644	4,111E+18	218,46
523,0	1,4746	3,882E+18	219,98
524,0	1,5859	4,183E+18	221,51
525,0	1,5735	4,159E+18	223,09
526,0	1,5297	4,050E+18	224,64
527,0	1,3378	3,549E+18	226,07
528,0	1,5312	4,070E+18	227,51
529,0	1,6024	4,267E+18	229,07
530,0	1,5401	4,109E+18	230,64
531,0	1,6245	4,342E+18	232,23

Wave-length (nm)	Spectral irradiance ( $\text{W}\cdot\text{m}^{-2}\cdot\text{nm}^{-1}$ )	Spectral photon irradiance ( $\text{m}^{-2}\cdot\text{s}^{-1}\cdot\text{nm}^{-1}$ )	Cumulative integrated irradiance ( $\text{W}\cdot\text{m}^{-2}$ )
532,0	1,5952	4,272E+18	233,84
533,0	1,4245	3,822E+18	235,35
534,0	1,5258	4,102E+18	236,82
535,0	1,5490	4,172E+18	238,36
536,0	1,6152	4,358E+18	239,94
537,0	1,4946	4,040E+18	241,50
538,0	1,5692	4,250E+18	243,03
539,0	1,5307	4,153E+18	244,58
540,0	1,4782	4,018E+18	246,08
541,0	1,4210	3,870E+18	247,53
542,0	1,5466	4,220E+18	249,02
543,0	1,5212	4,158E+18	250,55
544,0	1,5746	4,312E+18	252,10
545,0	1,5390	4,222E+18	253,65
546,0	1,5247	4,191E+18	255,19
547,0	1,5445	4,253E+18	256,72
548,0	1,5005	4,139E+18	258,24
549,0	1,5475	4,277E+18	259,77
550,0	1,5354	4,251E+18	261,31
551,0	1,5337	4,254E+18	262,84
552,0	1,5651	4,349E+18	264,39
553,0	1,5206	4,233E+18	265,94
554,0	1,5504	4,324E+18	267,47
555,0	1,5589	4,355E+18	269,03
556,0	1,5321	4,288E+18	270,57
557,0	1,4945	4,100E+18	272,08
558,0	1,5266	4,288E+18	273,59
559,0	1,4441	4,064E+18	275,08
560,0	1,4697	4,143E+18	276,54
561,0	1,5550	4,391E+18	278,05
562,0	1,4804	4,188E+18	279,57
563,0	1,5363	4,354E+18	281,08
564,0	1,5062	4,276E+18	282,60
565,0	1,5157	4,311E+18	284,11
566,0	1,4332	4,084E+18	285,58
567,0	1,5276	4,360E+18	287,06
568,0	1,5136	4,328E+18	288,58
569,0	1,4764	4,229E+18	290,08
570,0	1,4773	4,239E+18	291,55
571,0	1,4289	4,107E+18	293,01
572,0	1,5090	4,345E+18	294,48
573,0	1,5154	4,371E+18	295,99
574,0	1,5075	4,356E+18	297,50
575,0	1,4734	4,265E+18	298,99
576,0	1,4612	4,237E+18	300,46
577,0	1,4979	4,351E+18	301,94
578,0	1,4518	4,224E+18	303,41

Wave-length (nm)	Spectral irradiance ( $\text{W}\cdot\text{m}^{-2}\cdot\text{nm}^{-1}$ )	Spectral photon irradiance ( $\text{m}^{-2}\cdot\text{s}^{-1}\cdot\text{nm}^{-1}$ )	Cumulative integrated irradiance ( $\text{W}\cdot\text{m}^{-2}$ )
579,0	1,4727	4,293E+18	304,87
580,0	1,4976	4,373E+18	306,36
581,0	1,5045	4,400E+18	307,86
582,0	1,5276	4,475E+18	309,38
583,0	1,5434	4,530E+18	310,91
584,0	1,5403	4,528E+18	312,45
585,0	1,5280	4,500E+18	313,99
586,0	1,4910	4,398E+18	315,50
587,0	1,5237	4,502E+18	317,01
588,0	1,4891	4,408E+18	318,51
589,0	1,2857	3,812E+18	319,90
590,0	1,3689	4,000E+18	321,23
591,0	1,4619	4,349E+18	322,64
592,0	1,4312	4,265E+18	324,09
593,0	1,4519	4,334E+18	325,53
594,0	1,4449	4,321E+18	326,98
595,0	1,4267	4,273E+18	328,41
596,0	1,4702	4,411E+18	329,86
597,0	1,4745	4,431E+18	331,33
598,0	1,4565	4,384E+18	332,80
599,0	1,4564	4,392E+18	334,25
600,0	1,4710	4,443E+18	335,72
601,0	1,4537	4,398E+18	337,18
602,0	1,4318	4,339E+18	338,62
603,0	1,4621	4,438E+18	340,07
604,0	1,4878	4,524E+18	341,55
605,0	1,4852	4,523E+18	343,03
606,0	1,4779	4,509E+18	344,51
607,0	1,4868	4,543E+18	346,00
608,0	1,4819	4,536E+18	347,48
609,0	1,4706	4,509E+18	348,96
610,0	1,4643	4,497E+18	350,42
611,0	1,4569	4,481E+18	351,88
612,0	1,4788	4,556E+18	353,35
613,0	1,4579	4,499E+18	354,82
614,0	1,4135	4,369E+18	356,26
615,0	1,4654	4,537E+18	357,70
616,0	1,4269	4,425E+18	359,14
617,0	1,4087	4,375E+18	360,56
618,0	1,4621	4,549E+18	362,00
619,0	1,4690	4,578E+18	363,46
620,0	1,4696	4,587E+18	364,93
621,0	1,4759	4,614E+18	366,40
622,0	1,4228	4,455E+18	367,85
623,0	1,4124	4,430E+18	369,27
624,0	1,4077	4,422E+18	370,68
625,0	1,3985	4,400E+18	372,08