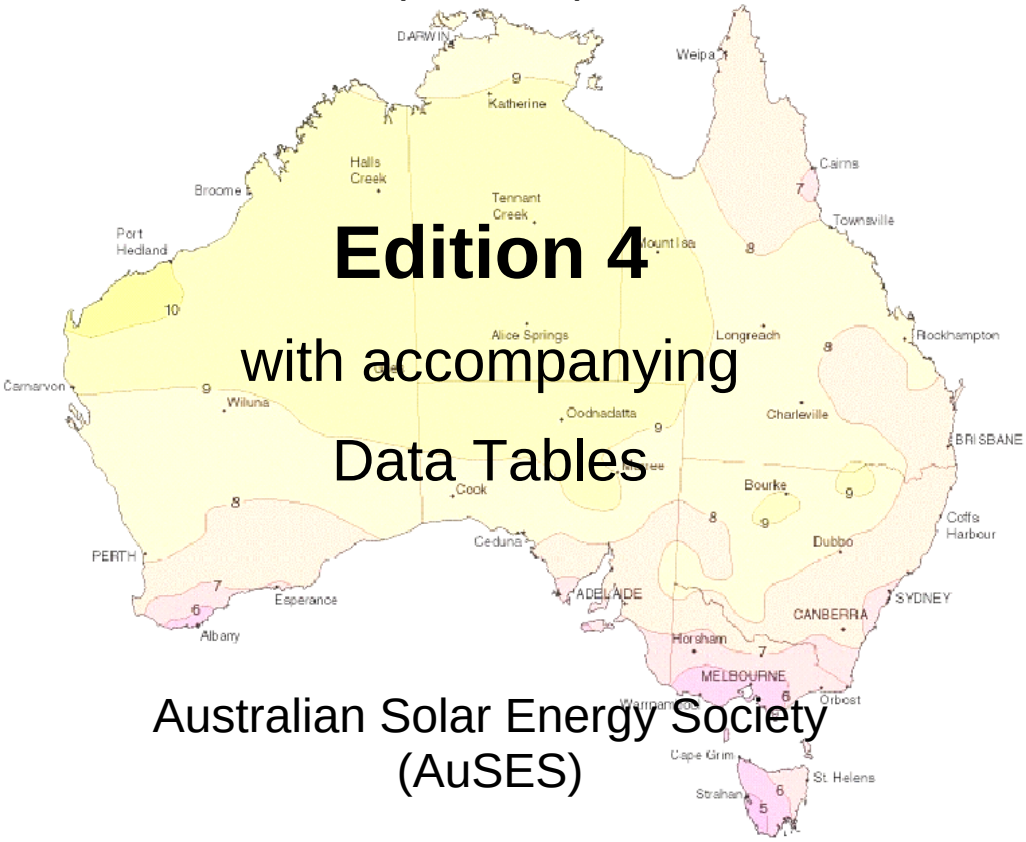
Australian Solar Radiation Data Handbook

(ASRDH)



Edition 4

with accompanying

Data Tables

Australian Solar Energy Society
(AuSES)

April 2006

Australian Government funding through the Australian Greenhouse Office in the Department of Environment and Heritage supported this project.

ENERGY PARTNERS

Energy Partners (a Division of Energy Strategies Pty Ltd, ABN 60 085 841 416)
Level 1, Manuka Arcade, 20 Franklin Street (PO Box 4170), Manuka ACT 2603, Australia
Phone: (02) 6260 6173, Fax: (02) 6260 6555
Email: energy.partners@exemplary.com.au, Web: www.exemplary.com.au

Australian Solar Radiation Data Handbook (ASRDH) - Edition 4

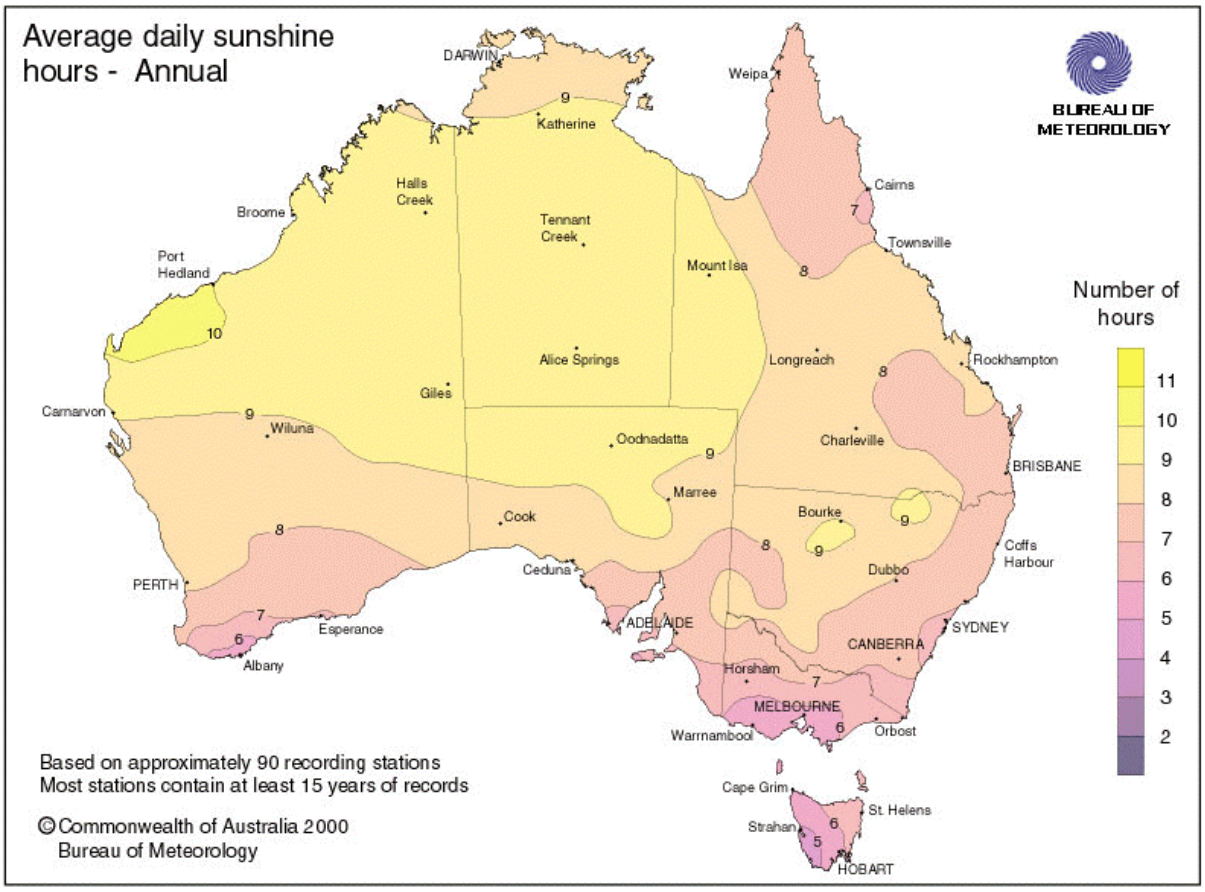
MAIN REPORT

On the Creation of a Revised and Fully Updated Edition

Published by the Australian and New Zealand Solar Energy Society (ANZSES), April 2006

Compiled by Energy Partners in association with Adelaide Applied Algebra

ISBN 0 642 19121 2 Hardcopy



Cover

The image on the front cover was obtained from the Bureau of Meteorology and was adapted from the original (pictured above) for aesthetic purposes. This image displays the annual average daily sunshine hours across Australia, collected over a 15 year period. For further information please refer to the Bureau of Meteorology website (http://www.bom.gov.au).

TABLE OF CONTENTS

1. INTRODUCTION

1.1 Purpose of the Handbook

The purpose of this handbook is to provide suitable data for teachers, researchers, users and designers of various types of solar systems for many locations around Australia.

This 2004 edition of the Australian Solar Radiation Data Handbook updates the 1995 Australian Solar Radiation Data Handbook by Lee *et. al.* (1995), that previously updated work by Frick *et. al.* (1988). The form of the handbook is in response to a user survey conducted in 1993 and again in 2003.

This Handbook is different from the so-called *Spencer Tables* - *Spencer* (1978) - that use completely clear skies to calculate irradiation levels. The *Spencer Tables* provide, however, equivalent information for architectural surfaces for the specific case of a cloudless sky. The data used for this Handbook are all statistical mean values that account for the reduction (particularly in beam radiation) caused by actual cloud conditions.

1.2 Further copies

Further copies of this Handbook have been lodged in State or Territory libraries. Electronic copies and an accompanying software version is available from the Australian and New Zealand Solar Energy Society (ANZSES), details of which can be found at www.anzses.org.

1.3 Definition of Terms

The definition of terms adopted in this edition of the Handbook conforms to those used in the International Standard (ISO/DIS 9488, 1999) which was first circulated as a draft by Standards Australia in 1995 which proposed a different nomenclature and has now been accepted. The significant differences noted in the draft are:

What this Handbook calls "global irradiation" the ISO/DIS calls "hemispherical irradiation".

What this Handbook calls separately "diffuse" and "reflected irradiation" on a tilted surface, the ISO/DIS calls "diffuse irradiation".

What this Handbook calls "total irradiation" the ISO/DIS calls "global irradiation".

The ISO/DIS defines "total irradiation" as the incident radiation of all wavelengths, including the infrared radiation from the atmosphere and surrounding surfaces.

The ISO/DIS defines "solar azimuth" as being different from "geographical azimuth" in that it measures counter-clockwise from north in the southern hemisphere.

(Solar) radiation - A generic term covering all forms of radiant energy falling on the surface of the earth and originating from the sun. (Sometimes *insolation* is used with this meaning). The far infrared "sky radiation" is not included.

(Solar) irradiation - The sum of the energy falling on a surface in a given time-period, originating from the sun, measured in MJ/m^2.

(Solar) irradiance - The power or instantaneous rate of energy received by a surface, originating from the sun, measured in W/m^2. In practice, the irradiance is usually measured by the average rate of accumulation of energy over one hour, for each hour of the day.

Global irradiance/irradiation - The power/energy received in the direct beam from the sun and that diffused by the hemisphere of the sky, onto a horizontal surface. Also referred to as the hemispherical solar irradiance on a horizontal plane, measured in W/m^2.

Diffuse irradiance/irradiation - That portion of the power/energy received by a surface, not necessarily horizontal, from as much of the hemisphere of the sky as is exposed to the surface, and not including the radiation in direct beam from the sun.

Direct beam irradiance/irradiation - The power/energy falling in a direct line from the orb of the sun, without dispersion or reflection, onto a surface. For a horizontal surface, it is taken as the difference between the measured global and diffuse radiation.

Reflected irradiance/irradiation - The power/energy reflected from the surface of the earth which may fall onto a surface inclined to the horizontal. For these tables, it is calculated for an albedo of 0.2 corresponding approximately to the albedo of green vegetation and scrubland and assumes the best available anisotropic model (see Appendix A).

Total irradiance/irradiation - The sum of direct beam, diffuse and reflected power/energy falling on an inclined surface. For a horizontal surface, it is the same as the global.

Extraterrestrial irradiance/irradiation - The total power/energy falling on a surface of the earth, which is conceived as a perfect spheroid without atmosphere. It is a function of the date and apparent time. It assumes a constant direct irradiance from the mean sun to be 1367 W/m^2, as given by the World Radiation Centre. The earth's orbit is slightly elliptical so the actual intensity varies between about 1412 W/m^2 in December and about 1322 W/m^2 in mid-year. This is important when comparing similar latitudes in the northern and southern hemispheres but, as this parameter was only used to spatially apportion measured global and diffuse irradiation values in this Handbook, using the annual mean value as a constant was sufficiently accurate.

Clearness Index - The ratio between the global and the extraterrestrial irradiance at a given instant.

Solar heat gain factor - The solar irradiance transmitted through an unshaded standard clear glass window 3 mm thick, including that portion of the absorbed radiation that is transferred indoors (refer to Appendix A for a detailed discussion on varying conditions).

Azimuth (of a vector) - The angle between true north and the projection of the vector onto a horizontal plane, measured clockwise.

Azimuth of a plane - The azimuth of the normal to the plane.

Solar zenith angle - The angle between the normal to a horizontal plane and the solar beam. Also referred to as the angular distance of the sun from the vertical (Θz)

Inclination of a plane - The angle between the normal to the plane and the vertical.

Mean Solar Time (MST) - This is Universal Time (UT or "Greenwich Mean Time") adjusted to a local longitude. It is the time recorded for all radiation measurements.

Local Time - This is the standard clock time (ignoring daylight saving) for the location. All recorded radiation measurements are adjusted to local time. The radiation values tabulated in this Handbook are centred around the one hour local time period shown in the Table.

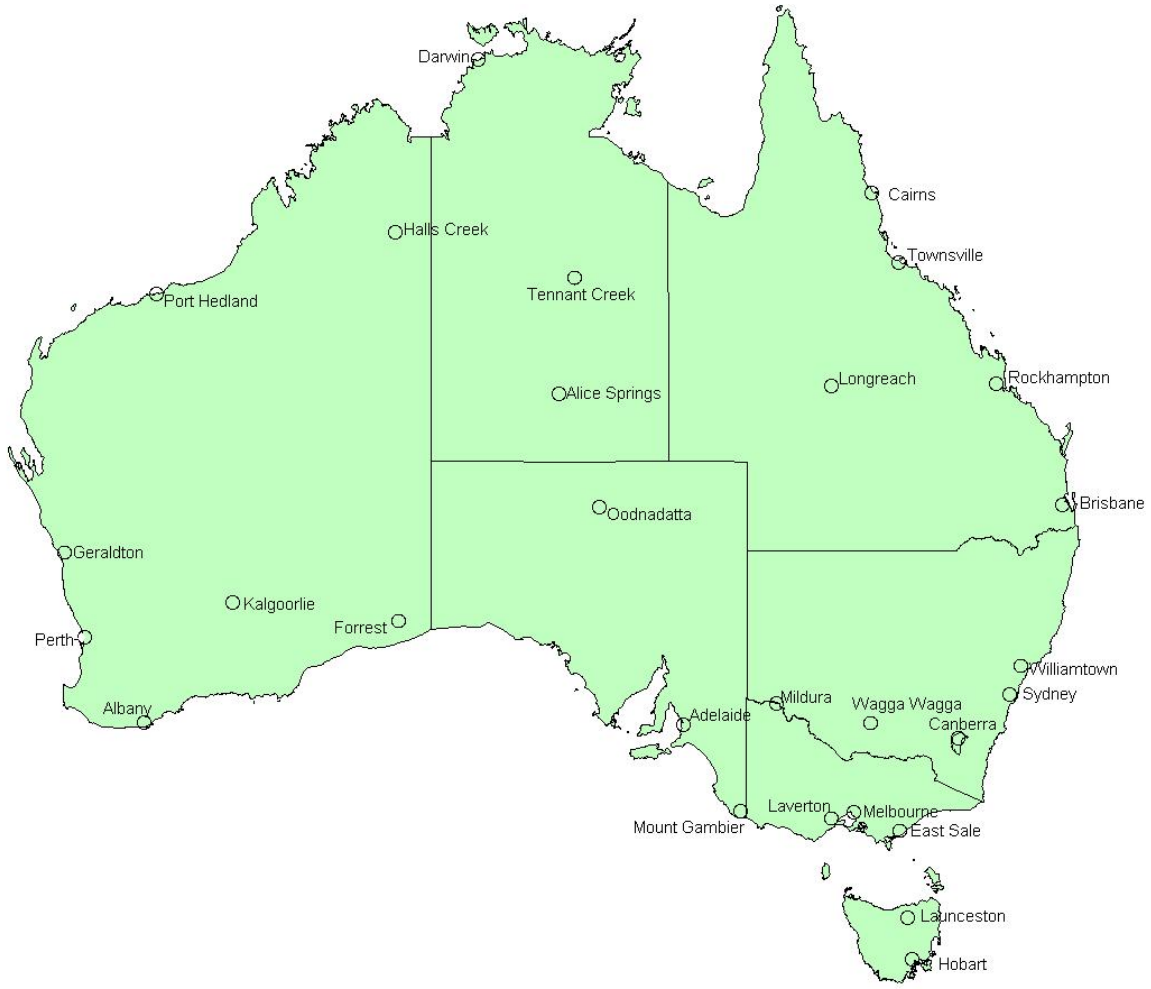
1.4 Sources of Data

All data tabulated in this Handbook are drawn from the Australian Climatic Data Bank (ACDB). The ACDB is available from ACADS-BSG, 16 High Street, Glen Iris, Victoria, Australia, Tel +61 3 885 6586. Additional information on the data can be obtained from the National Climate Centre, 700 Collins Street, Melbourne, Victoria, Australia, Tel + 61 3 669 4000. A full description of the ACDB and its construction can be found in Delsante (1989).

The data bank sets consist of hourly records over numbers of years of climatic variables, including solar radiation. Measurements of global solar radiation are available for 22 locations, and of these, 16 locations have additional simultaneously measured diffuse solar radiation. A further 67 locations contain solar radiation data estimated from cloud cover records.

The column 'Data Type' in Table 1 shows the type of the radiation data for each collection site. This includes climate data post 1986. Table 2 lists the old data sets used to generate the 1995 2nd edition. Appendix H provides a detailed breakdown of the type of the radiation data for each collection site including satellite-derived data. A computer program ASRDH94 was written to undertake calculations and data manipulation required for producing tables. This has been updated into a computer program called ASRDHv04. Data for the isorad map comes direct from the Bureau of Meteorology. This revision did not involve updating ASDRH Table 1 parameters (Climatic averages) and remains as published in the 1995 2nd Edition. In future work we hope to include this as an update.

1.4.1 Map showing data collection sites



1.4.2 Data collection sites

Table 1. Data collection sites used in 2004 Handbook with various details

State Terr	Location	Elevation	Data type	Radiation data start date to May 2004	No. of days	% of days with estimated data only
NSW ACT	Canberra City	571 m	G&D	Mar 1976	10,301	24.2%
	Sydney RO	4 m	G&D	Aug 1983	7,604	29.4%
	Wagga Wagga AMO	224 m	G&D	July 1968	13,111	13.1%
	Williamtown AMO	12 m	G	Dec 1968	12,960	28.8%
QLD	Brisbane AMO	6 m	G&D	Jan 1983	7,805	22.2%
	Cairns AMO	3 m	EST	Oct 1990	4,962	28.9%
	Longreach	195 m	G	July 1968	13,093	23.9%
	Rockhampton AMO	8 m	G&D	Feb 1973	11,437	11.6%
	Townsville	4 m	EST	Mar 1971	12,128	21.7%
SA NT	Adelaide AMO	11 m	G&D	Jan 1983	7,816	16.2%
	Alice Springs AMO	547 m	G&D	July 1968	13,112	4.1%
	Darwin AMO	35 m	G	Oct 1968	13,021	9.8%
	Mt Gambier AMO	63 m	G&D	July 1968	13,108	5.2%
	Oodnadatta AMO	113 m	G	May 1969	12,798	42.5%
	Tennant Creek	375 m	EST	Oct 1990	4,962	6.1%
VIC TAS	East Sale AMO	14 m	EST	Oct 1990	4,962	51.8%
	Hobart RO	8 m	G&D	Oct 1967	13,367	18.3%
	Launceston AMO	171 m	EST	Oct 1990	4,962	51.9%
	Laverton AMO	14 m	G&D	Feb 1968	13,258	17.1%
	Melbourne HO	123 m	G&D	Jan 1967	13,660	25.6%
	Mildura AMO	53 m	G&D	Jan 1969	12,929	3.0%
WA	Albany AMO	71 m	G&D	June 1968	13,143	27.0%
	Forrest AMO	157 m	G	Nov 1969	12,623	29.6%
	Geraldton AMO	35 m	G&D	June 1968	13,124	6.5%
	Halls Creek AMO	423 m	G	May 1969	12,809	22.0%
	Kalgoorlie	360 m	EST	Feb 1979	9,240	4.9%
	Perth RO	11 m	G&D	Feb 1973	11,437	17.5%
	Port Hedland	8 m	G&D	Sep 1968	13,048	22.8%

Legend for Data Sources (listed in descending order of accuracy):

AMO indicates that the station is an Airport Meteorological Office

HO indicates that the station is Head Office of the Bureau of Meteorology, 150 Lonsdale Street, Melbourne

RO indicates that the station is Regional Office

G&D Locations using both global and diffuse measurements

G Locations using global radiation measurements only, with the diffuse radiation estimated.

EST Locations using only estimated data from cloud cover records

Table 2. Data collection sites used in 1995 Handbook with various details

State Terr	Location	Data type	Latitude	Longitude	Elevation	Australian Climatic Data Base period avail
NSW ACT	Canberra City	G&D	35°19'S	149°12'E	571 m	Nov 1983 - May 1987
	Sydney RO	G&D	33°56'S	151°10'E	4 m	Aug 1983 - May 1987
	Wagga Wagga AMO	G&D	35°15'S	147°28'E	224 m	Aug 1968 - Apr 1980
	Williamtown AMO	G	35°48'S	151°50'E	12 m	Dec 1968 - Mar 1980
QLD	Brisbane AMO	G&D	27°25'S	153°05'E	6 m	1983 - 1986
	Cairns AMO	EST	16°54'S	145°48'E	3 m	1978 - 1987
	Longreach	G	23°26'8	144°16'E	195 m	Aug 1968 - March 1980
	Rockhampton AMO	G&D	23°23'S	150°29'E	8 m	Feb 1973 - Jan 1979
	Townsville	EST	19°18'S	146°48'E	4 m	1980 - 1987
SA NT	Adelaide AMO	G&D	34°58'S	138°32'E	11 m	1983 - May 1987
	Alice Springs AMO	G&D	23°49'S	133°54'E	547 m	July 1968 - March 1980
	Darwin AMO	G	12°25'S	130°52'E	35 m	Oct 1968 - March 1980
	Mt Gambier AMO	G&D	37°45'S	140°47'E	63 m	Aug 1968 - July 1979
	Oodnadatta AMO	G	27°34'S	135°25'E	113 m	1969 - 1979
	Tennant Creek	EST	19°36'S	134°06'E	375 m	1978 - 1987
VIC TAS	East Sale AMO	EST	38°06'S	147°06'E	14 m	1978 - 1987
	Hobart RO	G&D	42°50'S	147°30'E	8 m	1968 - April 1980
	Launceston AMO	EST	41°36'S	147°12'E	171 m	1978 - 1987
	Laverton AMO	G&D	37°53'S	144°45'E	14 m	1968 - 1979
	Melbourne HO	G&D	37°50'S	144°58'E	123 m	1967 - March 1980
	Mildura AMO	G&D	34°15'S	142°05'E	53 m	1969 - Oct 1979
WA	Albany AMO	G&D	34°57'S	117°48'E	71 m	1968 - 1979 (exc. 1971)
	Forrest AMO	G	30°50'S	128°07'E	157 m	Dec 1969 - March 1980
	Geraldton AMO	G&D	28°48'S	114°4TE	35 m	July 1968 - March 1980
	Halls Creek AMO	G	18°14'S	127°40'E	423 m	May 1969 - March 1978
	Kalgoorlie	EST	30°47'S	121°30'E	360 m	1978 - 1987
	Perth RO	G&D	31°56'S	115°58'E	11 m	Oct 1972 - Apr 1980
	Port Hedland	G&D	20°23'S	118°37'E	8 m	Oct 1968 - Mar 1980

Legend for Data Sources (listed in descending order of accuracy):

AMO indicates that the station is an Airport Meteorological Office

HO indicates that the station is Head Office of the Bureau of Meteorology, 150 Lonsdale Street, Melbourne

RO indicates that the station is Regional Office

G&D Locations using both global and diffuse measurements

G Locations using global radiation measurements only, with the diffuse radiation estimated.

EST Locations using only estimated data from cloud cover records

2. TABLES, GRAPHS AND MAPS

2.1 List of tables for each data collection site

Table 3. List of Tables prepared for each data collection site

Table 1	Climatic averages (taken from 2nd Edition)
Table 2	Average clearness index
Table 3.1	Average global hourly irradiance (W/m^2) and daily irradiation (MJ/m^2) on a horizontal plane for each month
Table 3.2	Average diffuse hourly irradiance (W/m^2) and daily irradiation (MJ/m^2) on a horizontal plane for each month
Table 3.3	Average direct beam hourly irradiance (W/m^2) and daily irradiation (MJ/m^2) on a horizontal plane for each month
Table 3.4	Percentage of days when daily global irradiation on a horizontal plane is at least as large as the value given for each month
Table 3.5	Percentage of daily global irradiation on a horizontal plane at least as large as the value given for each month
Table 3.6	Percentage of days when daily direct beam irradiation on a horizontal plane is at least as large as the value given for each month
Table 3.7	Percentage of daily direct beam irradiation on a horizontal plane is at least as large as the value given for each month
Table 3.8	Average number of hours per day in which the global and direct irradiance on a horizontal plane exceeds the specified values (W/m^2)
Table 4.1 (… 4.4)	Average total hourly irradiance (W/m^2) and daily irradiation (MJ/m^2) on a north (… west) facing vertical plane for each month
Table 4.5	Average total hourly irradiance (W/m^2) and daily irradiation (MJ/m^2) on a north facing plane inclined at latitude angle for each month
Table 4.6	Average total hourly irradiance (W/m) and daily irradiation (MJ/m) on a north-south axis tracking plane by hour for each month
Table 4.7	Average direct beam hourly irradiance (W/m^2) and daily irradiation (MJ/m^2) on a north-south axis tracking plane by hour for each month
Table 4.8	Average total hourly irradiance (W/m^2) and daily irradiation (MJ/m^2) on a sun tracking plane for each month
Table 4.9	Average direct beam hourly irradiance (W/m^2) and daily irradiation (MJ/m^2) on a sun tracking plane for each month
Table 4.10	Average total hourly irradiance (W/m^2) and daily irradiation (MJ/m^2) on an east-west axis tracking plane for each month
Table 4.11	Average direct beam hourly irradiance (W/m^2) and daily irradiation (MJ/m^2) on an east-west axis tracking plane for each month
Table 5.1 (… 5.12)	Average daily total irradiation (MJ/m^2) on an inclined plane during January (… December)
Table 5.13	Average annual daily total irradiation (MJ/m^2) on an inclined plane
Table 6.1 (… 6.4)	Average hourly (W/m) and daily (MJ/m) solar heat gain factor through a north (… west) facing window for each month
Table 7.1 (… 7.8)	Proportional occurrence (%) of sequence of days for which the daily global irradiation is less than 2.5 (… 20) (MJ/m^2)

2.2 Electronic Versions of ASRDH Tables

Electronic tables in Rich Text Format (RTF) are included as standard with the ASRDH. Equivalent tables in more readily accessible formats (eg, CSV) are able to be generated by using AUSOLRAD with the default values for shading and ground reflectance (albedo).

2.3 List of graphs for each data collection site

Each site has a single graph that contains the information on a monthly mean basis:

(a) Global irradiation
(b) Direct beam irradiation on the horizontal
(c) Beam irradiation, normal to the beam
(d) Total irradiation on a north facing plane tilted to the latitude angle
(e) Total irradiation on a north facing plane tilted to the latitude angle plus 23.5°
(f) Total irradiation on a north facing plane tilted to the latitude angle less 23.5°
(g) Total irradiation on a north facing vertical plane

2.4 List of Isorad (Contour) Maps

The Bureau of Meteorology has produced Australian isorad contour maps for irradiation intensity on a horizontal plane. One such map showing the 'Annual mean daily global irradiation (MJ/m^2)' is presented in Appendix J. Additional isorad maps can be viewed in Appendix K. These include:

Annual mean daily global irradiation (MJ/m^2)
Mean daily irradiation in December (MJ/m^2)
Mean daily irradiation in March (MJ/m^2)
Mean daily irradiation in June (MJ/m^2)
Mean daily irradiation in September (MJ/m^2)

These have been produced as thematic maps for each of the eight capital cities and surrounding hinterlands. The maps are derived from satellite-measured data for each Australian capital city and its hinterland (within one degree of latitude and longitude from the city centre). They follow work completed by Nunez (1990). Refer to Appendix K for the maps themselves. Each of the eight capital cities has five different isorad (contour) maps.