

Development of a Benchmarking Tool for Solar Energy Resource Datasets. A Guide for Non-Expert Users to Determine the most Appropriate Use of Solar Energy Resource Information

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DEVELOPMENT OF A BENCHMARKING TOOL FOR SOLAR ENERGY RESOURCE DATASETS

A GUIDE FOR NON-EXPERT USERS TO DETERMINE THE MOST APPROPRIATE USE OF SOLAR ENERGY RESOURCE INFORMATION

SUPPORTING DOCUMENTATION

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http://www.ises.org



United Nations Environment Programme برنامج الأمم المتحدة للبيئة . 取合同环境规划署

PROGRAMME DES NATIONS UNIES POUR L'ENVIRONNEMENT · PROGRAMA DE LAS NACIONES UNIDAS PARA EL MEDIO AMBIENTE ПРОГРАММА ОРГАНИЗАЦИИ ОБЪЕДИНЕННЫХ НАЦИЙ ПО ОКРУЖАЮЩЕЙ СРЕДЕ UPPORTING DOCUMENTATION

International Solar Energy Society

DEVELOPMENT OF A BENCHMARKING TOOL FOR SOLAR ENERGY RESOURCE DATASETS

A GUIDE FOR NON-EXPERT USERS TO DETERMINE THE MOST APPROPRIATE USE OF SOLAR ENERGY RESOURCE INFORMATION

UNEP-ISES

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BACKGROUND

Knowledge of solar energy resources is essential for the planning and operation of solar energy systems. Different organizations provide several autonomous solar data covering various spatial and temporal periods with several different resolutions [1]. Understanding the quality of the datasets underlying assessments of solar energy resources requires a level of technical knowledge that only few Solar and Wind Energy Resource Assessment (SWERA) users posses. Solar data sets differ in spatial and temporal resolution, time period covered, and methodology used. Some of these datasets are available for free, while some are not, and they all may provide varying results. As a result, most users cannot verify the suitability of a given solar dataset or map based on the purpose of their assessment. This can lead users to abandon their search or make non-appropriate use of the information. A simple guide tool can help alleviate this problem, if it is developed through open and inclusive expert consultation. The results of this exercise provide guidance in data qualification and the selection of data sources for specific applications and give a better indication of the suitability of the available data sources. Therefore, aiming at developing better guidance about the energy application of solar resource information a user-friendly tool, or "guide" has been designed to help experts and non-experts make an educated decision as to which solar data sets are appropriate for use depending on the type of solar application. The tool has been developed in a joint effort between UNEP and the International Solar Energy Society (ISES) and in cooperation with principal experts in the solar radiation field (IEA/SHC Task36 [2], MESoR [3], and networks of active consultancies). The guide basically consists of two tables and relates information from each to help a user identify appropriate datasets for specific applications. The first table is a description of the data sources. The second table consists of recommendations of minimum requirements in the characteristics of the data depending on different applications.

The final result is accessible through the UNEP Energy Branch (<u>http://www.unep.fr/energy/</u>) as well as the ISES website (<u>http://www.ises.org</u>). Links are also provided from the UNEP SWERA web site, which is a natural point of inquiry for solar resource data and information worldwide (<u>http://swera.unep.net</u>) and the MESOR web site (<u>http://www.mesor.org</u>). If a solar dataset provider is interested in adding datasets to the guide, they should contact UNEP by filling in the application form on the UNEP website.

DESCRIPTION OF THE GUIDE

The online friendly-user guide helps expert and non-expert users to decide which solar resource data sets are the most appropriate depending on a type of application that the user is interested in. Figure 1 depicts how the tool works. The programme relates information back to two information tables: one related to a compilation of a selection of existing satellite based solar datasets and their metadata and the other defines specific requirements a data set should meet for specific solar application.





How to Use it

- 1. The user selects either
 - i. Location (by country or region) AND solar data set (see Datasets in Table I)
 - OR
 - ii. Location AND type of application (see classification of applications in Table II);
 - iii. Location only
 - OR
 - iv. Dataset only
 - . OR
 - v. Type of application only

- 2. The interface interconnects Table I and II with the inputs given by the user
- 3. A list of relevant data sets is provided each listing the type of applications that the data set can be used for. The requirements for each application type are provided.
- 4. The data set information also includes notes on whether any of the requirements are not met completely for a specific application as well as notes on the applications specification where applicable, referring the user to examine the criteria requirements listed for each application.

Select a region or country	*
Data Set (Providing Organisation) :	
Select a dataset	*
Type of Application :	

Figure 2: The search menu presents the user with three different search functions.

The guide lists only datasets as a result of the search.



Figure 3: The results of the search show the relevant datasets, and include the search criteria entered.

By clicking on "*Show*", the user can view the metadata of the data sets, the appropriate application types and notes on the application requirements (see figure 4).

Solemi

Dataset : Solemi

Providing Organisation : DLR

Geographical Coverage : Europe, Africa, Middle East

Validation Information :

Peer-reviewed or third party-validated ?:	yes
Validation Type ^(a)	benchmarked
Database has been benchmarked according to IEA Task 36 and/or \ensuremath{MESoR} :	yes
Validation information available publication articles, preferably peer-reviewed & third-party (primary) authored, using IEA Task 36 benchmarks :	Mesor-Reports; Benchmarked within MESoR

Source of data and further information :

Source : geostationary satellites

Availability : for sale

Web Sites : http://www.solemi.com

Remarks : one year free via MESOR

Other applications this dataset is suitable for :

Commisioning / System Acceptance	(show results: Application requirements / Dataset values)
Due Diligence	(show results: Application requirements / Dataset values)
Feasibility	(show results: Application requirements / Dataset values)
Pre feasibility	(show results: Application requirements / Dataset values)
Site Selection	(show results: Application requirements / Dataset values)
CSP	(show results: Application requirements / Dataset values)
Daylighting	(show results: Application requirements / Dataset values)
PV Large systems	(show results: Application requirements / Dataset values)
PV Medium sized systems	(show results: Application requirements / Dataset values)
PV offgrid systems	(show results: Application requirements / Dataset values)

Figure 4: By clicking on "Show" all the information available about the dataset will be displayed, including the applications types and additional notes on requirements, (note all the information presented is not displayed in the above screen shot). Foot notes to the metadata are also provided by scrolling the numbers.

By clicking on "show results: Application requirements/Dataset values", under the application types listed under "Other applications this dataset can be used for", the user can view a comparison table showing the minimum requirements recommended for these applications and how the dataset fulfills these requirements .

	Application Requirement	Dataset value	Correct/not sufficient
atial resolution	10 km	3 km	¥
mporal resolution	hourly	hourly	×
ne coverage	10 years	1999-2011	¥
diation components	GHI+DNI	GHI, DHI, DNI	¥
w bias ⁽¹⁾	yes	yes	¥
w root mean square error	no	yes	¥
quency distribution trics	yes	yes	¥
rrent Data Available / Near al Time Data ⁽³⁾	yes/yes	n/a / n/a ⁽⁴⁾	Requirement highly recommended to be
lidation information ailable	yes	no	fulfilled:dataset still NOT validated

Figure 5: The comparison table shows the minimum requirements recommended for the applications and how the dataset fulfills these requirements. Notes are included as well, below the list of applications, when for instance a dataset does not meet all the requirements for a specific application or certain clarification is required about the application, for examples by scrolling over the (*) next to the red cross, a notice is given that this requirement is high recommended but not fulfilled.

Close

STRUCTURE OF THE GUIDE

Two tables form the basis for the guide:

- Table I is a compilation of solar data sources and provides metadata about each data source (see Annex I).
- Table II relates this metadata to a number of different solar applications, such as investment planning for different types and sizes of solar systems, operation of systems, policy analysis and/or scientific inquiries (see Annex II).

Both tables are interconnected; therefore Table II provides recommendations for the minimum data characteristics that should be fulfilled for each application, in terms of the metadata provided in Table I. The criteria are based on expert consultations and on existing knowledge of solar resource data and state of the art of the solar benchmarking [MESoR, IEA/SHC Task36].

TABLE I – SOLAR DATA SETS

Table 1 gathers a selected number of the existing satellite-based solar radiation datasets as a practical sample of information and at the same time provides the features of each dataset. Table 1 does not intend to include all existing data sets, however it is open to be expanded on by the suggestions of providers, additional datasets and the respective metadata can be inserted by filling in the application form on the UNEP website. For each dataset the following information is provided:

- 1. Organisation providing the data
- 2. Geographical coverage
- 3. Source of data: geostationary satellites, or a combination of geostationary satellites and ground stations
- Spatial resolution: the minimum distance between two adjacent features or the minimum size of a feature that can be detected by a remote sensing system (units in km)
- 5. Temporal resolution: refers to the frequency with which images of a given geographic location can be acquired (15 min, 30 min, hourly, daily, monthly, annual....).
- 6. Time coverage. Period of time the data have been acquired (including start and end periods)
- 7. Component: The solar radiation components contained in the dataset, i.e. GHI, DNI, TPI, DFI, PAR, Diffuse, Global in-plane, Global Inclined
- 8. Peer reviewed or third party validated: indication of validation information available
- 9. Database has been benchmarked according to IEA Task 36 and/or MESoR benchmarks: refers to the validation information available.
- 10. Validation information available: Published articles, preferably peer-reviewed & thirdparty (primary) authored, providing RMSE & MBE results with documented methodology, and using IEA/SHC Task 36 [2] and/or MESoR [1] benchmarks

- 11. Validation Type: none provided/not available, conference paper, peer reviewed paper or third party authored peer reviewed using IEA/SHC Task 36 and/or MESoR benchmarks¹
- Low Mean Bias Error (MBE): Low difference between an estimator's expectation and the true value of the solar parameter being estimated. Considered Low when: <5% GHI; <10% DNI²
- 13. Low root mean square error (RMSE): The root mean square error measures the differences between values predicted by a model and the values actually observed. Considered Low when: <120W/sqm hourly GHI; <160W/sqm hourly DNI
- 14. Frequency distribution metrics, eg KSI, OVER, available? If yes, values and link should be provided
- 15. Current data available / Near real time data: Yes, no or N/A
- 16. Availability: Free data set or for sale
- 17. Website: Where available
- 18. Remarks: any additional/relevant notes on the datasets

The information for spatial resolution, temporal coverage, time coverage and solar radiation component, as well as the validation information are the key eliminating criteria that are related back the minimal requirements of the various application types. While the tool compares all the information about the dataset with the requirements for an application, information provided on these five criteria are decisive for determining if a data set can be used for a specific application. Moreover, two of the listed requirements ("Use of multiple independent data source" and "On Site Measurements") contain information useful for the user in order to understand the requirements of each application; however, they are not listed in the characteristics of the datasets. Therefore these requirements not considered by the tool as minimum requirements, but rather as part of a detailed description of characteristics a dataset could have for a specific application.

¹ Peer reviewed papers by third party author would imply higher quality work than a conference paper, but this is not necessarily always the case. Validation references not available for all datasets

² For points 12-14: When short-term, locally specific solar radiation measurements are available; these can be used to reduce the uncertainty of the satellite modelled estimates for that particular location. Doing so combines the precision of the ground measurements and the long term coverage from the satellite models. There are several methodologies to combine the short-term with the long-term data to obtain a more accurate estimate of the long-term solar resource at the site, ranging from the simple so-called ratio method (taking the model/measurement ratio over their short-term common period and applying this ratio as a model correction over the long term) to more sophisticated methods adjusting the model's underlying parameters (e.g., its turbidity settings) to better match observations, and to optimally combining multiple modelled data sets and ground measurements. These procedures have been shown to be effective as long as the satellite model to be corrected has a sound physical basis and is self-consistent over the long term (i.e., has been validated in a sufficient number of locations to properly account for long term trends and year-to-year variability).

TABLE II REQUIREMENTS FOR SOLAR ENERGY APPLICATIONS:

The second table (Table II) takes the same metadata but relates it to a number of different solar energy applications, such as investment planning for different types and sizes of systems, operation of systems, policy analysis and science. For each application Table II provides a recommendation of the minimum characteristic to be fulfilled, e.g. in terms of spatial and temporal resolutions, for a data set to be suitable for this specific application. The following is a list of the different application including examples/descriptions of each:

- Investment Decision
 - Site selection: e.g. search for sites with best resources within a given area, comparison of different sites for project development. The search usually requires a map with long term average of the available solar resource
 - **Pre feasibility**: e.g. First assessment of a project feasibility, rough assessment of investment cost, plant performance, operational cost. The initial assessment can be done with annual average values.
 - Feasibility: e.g. Study of plant feasibility, assessment of investment and operational cost. Simulation of plant performance and energy yield, assessment of electricity or heat cost. Feasibility studies are more detailed in the simulation of the power plant and therefore require more detailed data.
- **Design and construction**: Designing of solar energy system is usually done simulating the system. The different components (Number of panels or collectors, interconnections, field layout, inverter, storage size, etc.) are modified until optimal plant performance is achieved. The detail of the simulation depends on the type of the system, larger systems usually call for a more detailed simulation. The level of detailed simulation determines the necessary detail in the solar radiation data. The following are typical examples of different applications presented in the exercise:
 - PV off-grid systems
 - PV Small systems
 - PV medium sized systems
 - PV Large Systems
 - Tracking/Concentrating PV
 - Solar Hot Water
 - Solar cooling
 - o CSP
 - Daylighting
 - Solar Process Heat
- **Due diligence**: A review process by an independent expert of the project development documents used to acquire project financing. The needs are therefore the same as in the design phase.
- **Commissioning**: The commissioning phase requires solar data for the validation of the performance of the solar components.
- Operation
 - Performance monitoring (does the system work correctly?): The operation of solar energy systems needs current data to monitor the performance, e.g. are all strings working correctly in a PV-system or does the inverter work with the expected efficiency?
 - Performance improvement (how to improve system performance): Records of plant performance and solar data can be used to model the actual system performance and find improvements in operation or system layout.

• **Forecasting**: Can be used to optimize performance within the electricity grid by reducing necessary back up power, optimize the use of storage or market participation in the energy markets.

• Energy policy

- Potential assessment: Assessment of the technical and economical potential of an energy technology is the first step in the market introduction. This assessment shows if it is worthwhile to introduce a technology into a market and which share of the market it can reach. Long term average values are needed for the assessment.
- **Design of support instruments, e.g. levels of tariffs, incentives**: It is usually the aim of a support instrument to make investments successful. Incentives therefore have to be at a level which gives the investors a reasonable return on investment. The amount of the incentive depends on the locally available resource. A too low incentive will not level the investment, a too high incentive will waste funding and give the investors an unnecessary high return.
- **Policy monitoring**: Monitoring and evaluation of policies also needs resource data to level monitoring data of a particular time frame to the long term averages.
- **Climate policy**: Solar radiation is one of the main parameters within climate modeling.
 - Climate models
 - Impact assessment models
 - Climate monitoring
- **Science/technology**: The application of solar radiation data within science and technology is a very wide field. The named applications are just a few but common ones.
 - Energy system analysis (Systems, components)
 - System simulations
 - Grid integration studies

EXPERT CONSULTATION

To support the validity of the information presented a consultation with solar resource experts has been undertaken to expand and up-date the metadata presented in the Table I as well as to review the requirements presented in Table II.

ACCESS

The tool is accessible from the UNEP Energy Branch and ISES web sites, and links are available from the SWERA and MESOR web sites.

AUTHORS AND ACKNOWLEDGMENTS

Prof. Richard Perez of the State University of New York at Albany, Carsten Hoyer-Klick of the German Aerospace Centre, Dr. David Renné of the United States National Renewable Energy Laboratory (NREL), Dr. Magda Moner-Girona and Daniel Puig from UNEP, and Jennifer McIntosh from ISES have worked together to define the nature and scope of the tool and develop the main elements of the tables and tools.

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- Prof. Dr. A. David Pozo Vázquez, University of Jaen, Spain
- Dr. Enio B. Pereira, INPE, Brazil
- Dr. Lourdes Ramírez, CENER, Spain

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[1] "Management and Exploitation of Solar Resource Knowledge", C. Hoyer et al., EuroSun 2008
[2] Task 36 under the International Energy Agency's 'Implementing Agreement' –

http://www.iea-shc.org/task36/index.html

[3] European Commission-funded MESOR 'Management and exploitation of solar resource knowledge' - <u>http://www.mesor.org/</u>

[4] "Developing a Guide for Non-Experts to Determine the Most Appropriate Use of Solar Energy Resource Information", C. Hoyer et al., EuroSun 2010

ANNEXES

ANNEX I: TABLE I SOLAR DATASETS (EXTRACT ONLY) – SEE THE FULL TABLE I ON WEBSITE

SXRAM39	"DNI available only on a monthly basis; DNI bias exceeds 10% poleward of 60 degrees	Model based on histogram of 1985- 1991 RTNEPH data; not updated by NREL	* DNI only for Brazil	** only selected sites are hourly		few sites availalble in annual resolution	***one year free via MESOR	spattal resolution changes in 2005 to 0.025°, on request 15 or 30 min values are		***one year free via MESOR	DNI must be calculated from horizontal direct DHI			increased bias in winter due to prevalence of snow		* 8 weeks delayed
ejiedeW	eosweb.larc.n asa.gov/sse	swera.unep.or g	swera.unep.or g	swera.unep.or g	swera.unep.or g	swera.unep.or g	<u>www.solemi.c</u> <u>om</u>	www.energie meteorologie. de	http://www.so da- is.com/eng/he lp/index.html	http://www.so <u>da-</u> is.com/eng/he lo/index.html	http://www.sat	<u>ttp://ttp.ncdc.n</u> oaa.gov/pub/d ata/nsrdb- solar	<u>www.solarany</u> where.com		http://re.jrc.ec. europa.eu/pvg is/	
y tilidelie vA	free	free	Free	free	Free	free	for sale ^{xxx}	for sale ^{xxx}	for sale 1985- 1989 free	for sale ^{xxx}	free	free	for sale	free	free	free
Current data available / Near real time data	Q	2	No	e	N	е	еu	yes	2	yes	е Ц	e	yes	оц	e	yes*
Frequency distribution OVER, available? XSI, available?	2	e	Yes	n/a	Yes	n/a	yes	yes	N/A	yes	yes	yes	yes	N/A	N/A	N/A
DMI) (S) Myed th for hourly Wyewn for hourly square error (< 125 Low root mean	e/u	n/a	Yes	yes	Yes	yes	yes	yes	NIA	yes	yes	yes	yes	yes*	AIA	N/A
Low Bias (<5% for GHI and <10% for DUI) (2)	'səų	yes	Yes	yes	Yes	yes	yes	yes	VIA	yes	yes	yes	yes	yes"	yes	yes
(r) eqvT no≇sbileV	bench marked	NA	peer reviewed	conference paper	peer reviewed	peer reviewed	bench marked	bench marked	Peer reviewed	bench marked	bench marked	Peer reviewed	peer reviewed	٩N	bench marked	NA
Validation information available - publication arfoles, party (primary) party (primary) party (primary tet Taek 36 IEA Taek 36 IEA Taek 36	Link to NASA sites; Literature and Conference, Benchmarked within IEA Task 36	SWERA website	MARTINS, Fernando Ramos ; PEREIRA, E. B. ; ABREU, Samuel Luna de . Satellite-Derived	Conference articles, independent review	MARTINS, Fernando Ramos ; PEREIRA, E. B. ; ABREU, Samuel Luna de . Satellite-Derived	Solar Energy Article	Mesor-Reports; Benchmarked within MESoR	Mesor-Reports, Benchmarked within MESoR	Solar Energy Article; Benchmarked within MESoR	Mesor-Reports & Solar Energy, Benchmarked within MESoR	Mesor-Reports, Benchmarked within MESoR	NREL-Report	Solar Energy Article	Ongoing Validation by CanMet	Benchmarked within MESoR	not available at this time
Detebese has been benchmarked according to IEA Task 36 and/or RSAR	yes	QL	аu	QL	по	92	yes	yes	yes	yes	yes	QL	ou	ы	yes	Q
Peer-reviewed or third perty- validated?	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	ou
tn enoqmo O	"ING-IH9	IND-IHD	GHI, DNI, TPI, DFI, PAR	IND-IH9	GHI, DNI, TPI, DFI, PAR	IND-IHD	ING-IH9	IND-IHD	IND-IH9	IND-IH9	eHI-DHI**	IND-IHD	IND-IHD	IND-IH9	GHI, G inclined	GHI, direct horizontal
Time ooverage	1983-2008	1985-1991	1995-2005	1999-2005	1995-2005	2000-2003	1991-2005	1995- present	1985-2005	2004 - present	1996-2000	1998-2007	1998- present	1998-2008	1981-1990 (EU), 1985- 2004 (Africa)	2005-2010
u ognjosa i jejodijaj	Daily	Monthly	Monthly	hourly	Monthly	annual *	hourly	hourly	monthly (DNI), daily (GHI)	1/4 hourly	1/2 hourly	hourly	hourly	hourly	monthly	daily averages
noituloen leitege (kn) na 00 ange vigeo	100 km	40 km	40 km	10 km	10 km	10km	5 km	5 km	30 km	5 km	5 km	10 km	10 km	10 km	Interpolati on of variable density stations	15 km
Source	multiple satellites	US-Airforce cloud cover	satellites	geostationar y satellites	satellites	geostationar y satellites	geostationar y satellites	geostationar y satellites	geostationar y satellites	geostationar y satellites	geostationar y satellites	geostationar y satellites	geostationar y satellites	geostationar y satellites	ground stations, satellite (Africa)	Satellite (MSG)
Geographical coverage	World	Asia (excluding Japan). South	Brazil and South America	Bangladesh , Brazil, China, Fl	Brazil	Ghana, Ethopia, Kenya, Bangladesh	Europe Africa Middle East	Europe Africa	Europe Africa	Europe Africa	Europe	USA northern Mexico	USA northern Mexico	Canada, below 60degrees	Europe, Africa	Europe, Africa
Providing organisation	NASA	NREL	INPE	SUNY	INPE	DLR	DLR	University of Oldenburg	Mines ParisTec	Mines ParisTec	ENTPE	NREL	Clean Power Research	Natural Resouce Canada	EU-JRC	DWD/Meteos at
DATA SET	NASA-SSE	Swera-40k	Swera 40k	Swera-10k	Swera 10k	Swera 10k	Solemi	EnMetSol	Helioclim-1	Helioclim-3	Satel-Light	NSRDB-SUNY	Solar Anywhere	NRC-SUNY	PVGIS	CM-SAF

ANNEX II: TABLE II APPLICATIONS

delieve eteb tremu⊃ Steb ernit leer reel/	No with the accuracy needed	e	0	Po		yes	DO	yes/no	yes	yes	DO	ou	yes	0 C	yes	yes	yes	No with the accuracy needed	yes	yes	yes	YES	ę	2	No with the accuracy needed	0	PO	yes	No with the accuracy needed	0	Ю	по
iəmənuzsəm ətik nÖ	recommend ed always	2	OL	D		yes	DO	yes	yes	yes	Ы	оц	yes	0	yes	yes	yes	recommend ed always	ou	оц Ц	no	recommend ed always	2	2	recommend ed alwavs	ou Du	QL	yes	recommend ed always	0	0L	DO
Use of multiple independent data source	recommend ed always	ves	yes	yes		yes	DO	yes	yes	yes	DO	0L	yes	0	yes	yes	yes	recommend ed always	0	Q	DO	recommend ed always	yes	yes	recommend ed alwavs	2	ou	yes	recommend ed always	Q	0L	DO
Frequency distribution metrics, e.g., KSI, OVER, available? (1		n/a	DO	0		yes	U0	yes	yes	yes	DO	00	yes	6	yes	yes	yes		less important	less important	less important		n/a	n/a		2	DO	0		yes	yes	yes
Low root mean square error (< 125 Wswm for hourly G Mswm 100 Wswm 1 1 m.ps/W 061 > 160 101 hourly DMI) (1)		n/a	OL	DO		DO	по	ou	ou	по	по	по	ou	ou	DO	Q	ПО		yes	yes	yes		n/a	n/a		ou	ро	no		0	yes	yes
Low Bias (<5% for GHI and <10% for DNI) (1)		ves	yes	yes		yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes		yes	yes	yes		yes	ves		yes	yes	yes		yes	yes	yes
Database has been benchmarked according to IEA Ta 36 and/or MESoR		e	e P	yes		yes	Q	yes	yes	yes	Q	e P	yes	ou	yes	yes	yes						yes	ves		yes	yes	yes		yes	yes	yes
Peer-reviewed or thi Spatsbillev-yhed		ves	yes	yes		yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes		yes	yes	yes		yes	yes		yes	yes	yes		yes	yes	yes
noiteiber reloß stnenopmoo		GHI or DNI	GHI or DNI	DHI or DNI		GHI	GHI incl.	GHI + DNI, in	GHI + DNI, in	GHI + DNI, in	GHI incl.	GHI incl.	DNI	Illuminance	GHI	GHI + DNI	GHI + DNI		IND + IH9	IND + IH9	GHI		BHI	Б		GHI	GHI+DNI	GHI+DNI		GHI+DNI	GHI+DNI	GHI
Minimum time (voverage (years)		6	5	10		10	0	9	10	10	5	Q	10	0	10	10	10		n/a	n/a	n/a		G	10		20	10	20		n/a	n/a	5
leroqmət muminiM noitulozer		annual long-term (map)	annual long-term	hourly		hourly	monthly	hourly	hourly	hourly	monthly	monthly	hourly	hourly	hourly	hourly	hourly		hourly	hourly	hourly		annual long-term (map)	annual long-term (map)		daily	daily	annual		hourly	hourly	hourly
leiteqe muminiM axa (mx) noitulosen aton ataupa yingua aagab		ę	100	10		100	100	10	10	10	100	10	10	100	10	10	10		10	10	10		10	1		25	10	25		10	10	10
	nvestment Decision	Site selection	Pre feasibility	-easibility	Design and construction	PV offgrid systems	PV Small systems	PV Medium sized systems	PV Large systems	Tracking / concentrating PV	Solar hot water	Solar cooling	CSP	Daylighting	Solar Process Heat	Due diligence	Commissioning / System Acceptance	Deration	Performance monitoring (does the system work correct?)	Performance improvement (how to improve system performance)	Forecasting	Energy policy	Potential assessment	Design of support instruments, e.g. levels of tariffs, incentives.	Climate policy	Climate models	Impact assessment models	Climate monitoring	Science	Energy system analysis (Systems, components)	System simulations	Grid integration studies

ANNEX III: SOLAR RESOURCE PARAMETER- SOLAR TECHNOLOGY

Solar Resource Pa	rameter	Solar Technology						
Direct Normal Irradiance-DNI	Principal component of sunshine, directly from the sun	Concentrating solar thermal installations. Installations that track the position of the sun. Concentrating PV						
Diffuse Horizontal Irradiance- DHI	Amount of radiation received per unit area by a surface scattered by molecules and particles in the atmosphere	Building climatology (daylighting)						
Global Horizontal Irradiance-GHI	Total amount of solar radiation (sum of direct, diffuse, and ground-reflected radiation on a horizontal surface)	Photovoltaic installations						
Global Inclined	Total amount of solar radiation on tilted or tracking surfaces	Photovoltaic Solar water heating Passive solar						

ANNEX IV GLOSSARY OF TERMS

Azimuth Angle

Angle between the horizontal direction (of the sun) and a reference direction (usually North, although some solar scientists measure the solar azimuth angle from due South).

Bias Limit

An indication of the average deviation of the predicted, values, from the measured (i.e., true) values. typically expressed as mean bias error (MBE).

$$MBE = \sum_{i=1}^{N} (y_i - x_i) / N$$

where:

 y_i is the ith predicted, or true value x_i is the ith measured value N is the number of observations.

DHI or Diffuse Sky Radiation

Diffuse Horizontal Irradiance is the amount of radiation received per unit area by a surface (not subject to any shade or shadow) that does not arrive on a direct path from the sun, but has been scattered by molecules and particles in the atmosphere and comes equally from all directions. In the absence of atmosphere, there should be almost no diffuse sky radiation. High values are produced by an unclear atmosphere or reflections from clouds.

DNI

Direct Normal Irradiance is the amount of solar radiation from the direction of the sun received per unit area by a surface that is always held perpendicular (or normal) to the rays that come in a straight line from the direction of the sun at its current position in the sky. Typically, you can maximize the amount of irradiance annually received by a surface by keeping it normal to incoming radiation. This quantity is of particular interest to concentrating solar thermal installations and installations that track the position of the sun.

GHI

Global Horizontal Irradiance is the total amount of solar radiation received from above by a horizontal surface the sum of direct, diffuse, and ground-reflected radiation because ground reflected radiation is usually insignificant compared to direct and diffuse includes both Direct Normal Irradiance (DNI) and Diffuse Horizontal Irradiance (DIF). This value is of particular interest to photovoltaic installations.

Irradiance

Rate at which radiant energy arrives at a specific area of surface during a specific time interval. This is known as radiant flux density. A typical unit is W/m².

Root Mean Square Error

Square root of the mean square error, which makes it a more easily interpreted statistic since it shares the same units as the quantity being graphed. The mean squared error is the resulting value from measuring the distance between every data point and a simulated curve, squaring each distance, and taking the average of all the squared distance values.

ANNEX V: UNEP & ISES

<u>UNEP</u>

The United Nations Environment Programme (UNEP) is an intergovernmental agency created in 1972 to provide governments with technical assistance in the area of natural resource management. It serves both developed and developing country governments, with a clear focus on the latter. Most of its work is funded by developed countries, often from development aid budgets.

UNEP's work is organised around six priority areas – climate change, disasters and conflicts, ecosystem management, environmental governance, harmful substances and resource efficiency. As a part of its efforts to curb climate change, UNEP promotes the deployment of solar and wind energy technologies. This includes assessments of solar and wind energy technology potentials.

To date UNEP has initiated several assessments of solar and wind energy potentials – by matching the needs expressed by developing countries with the resources made available by certain developed countries. In addition, UNEP works with bilateral donors and recipient countries to integrate the findings of related bilateral aid projects into a more robust consolidated output.

More recently UNEP is helping develop training courses on solar and wind energy resource assessment, and facilitating closer cooperation between selected developing and developed country centres of excellence in this area. As a complement to this work, UNEP will convene selected experts in solar energy resource assessment to develop a benchmarking tool for use by non-experts.

About ISES

Since 1954, the International Solar Energy Society (ISES) has been actively engaged in advancing the science, technology, policy and education needed for the efficient use of renewable energy and its practical applications. As a UN accredited non-profit and non-governmental organisation (NGO), ISES represents scientists, technical experts, industry delegates and related professionals all committed to advancing renewable energy solutions to global climate change and world poverty. The ISES vision is simple and urgent: Rapid Transition to a Renewable Energy World.

The ISES mission is to provide current, scientifically credible renewable energy and energy efficiency information and networking opportunities to the global communities of scientists, educators, practitioners, industries, policy makers, and to the general public. The underlying core values of ISES are sustainable development, scientific methodology and participative decision making. Based on these values, ISES aims to achieve its vision and mission through scientific, popular and policy publications and through conferences, strategic alliances and projects globally.

ISES project activities address issues that affect global climate change and the advancement of renewable energies – by bringing together local and international perspectives, by encouraging the transfer of information and good practices, by promoting interaction and learning. The Society helps raise awareness, promote good policy, stimulate industry, improve quality and development and generally promote the wider use of renewable energy sources.

The Society's long history and extensive technical and scientific expertise provided by its members are what distinguish ISES as a unique and innovative organization.