INVENTORY OF SOLAR RADIATION/SOLAR ENERGY SYSTEMS ESTIMATORS, MODELS, SITE-SPECIFIC DATA, AND PUBLICATIONS (updated in 2016)

Updated by the
Resource Assessment and Forecasting group
National Renewable Energy Laboratory
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SOLAR SYSTEM POTENTIAL AND PERFORMANCE

- **PVWatts®**
  http://pvwatts.nrel.gov/
  Estimates the energy production and cost of energy of grid-connected photovoltaic (PV) energy systems throughout the world. It allows homeowners, small building owners, installers and manufacturers to easily develop estimates of the performance of potential PV installations.

- **System Advisor Model (SAM)**
  https://sam.nrel.gov/
  The System Advisor Model (SAM) is a performance and financial model designed to facilitate decision making for people involved in the renewable energy industry. SAM makes performance predictions and cost of energy estimates for grid-connected power projects based on installation and operating costs and system design parameters that you specify as inputs to the model. Projects can be either on the customer side of the utility meter, buying and selling electricity at retail rates, or on the utility side of the meter, selling electricity at a price negotiated through a power purchase agreement (PPA).

- **HOMER®**
  http://homerenergy.com/
  Simplifies the task of evaluating design options for off-grid and grid-connected power systems.

- **RetScreen**
  http://www.nrcan.gc.ca/energy/software-tools/7465
  A clean energy management software system for energy efficiency, renewable energy and cogeneration project feasibility analysis as well as ongoing energy performance analysis.

BROADBANDSOLAR RADIATION MODELS

- **Clear sky hourly data (maximum envelope)**
  Bird Clear Skymodel: http://rredc.nrel.gov/solar/models/clearsky
  Hourly estimates clear sky direct beam, hemispherical diffuse, and total hemispherical solar radiation for horizontal planes.

- **Direct Beam From Global Horizontal Data**
  Maxwell DISC model: http://rredc.nrel.gov/solar/models/DISC
  Estimates direct beam irradiance from user-supplied hourly average measured global horizontal data.

SPECTRAL SOLAR MODELS

- **Bird Simple Spectral Model**
  http://rredc.nrel.gov/solar/models/spectral
  Computes clear sky spectral direct beam, hemispherical diffuse, and hemispherical total irradiances on tilted or horizontal planes.

- **Simple Model of the Atmospheric Radiative Transfer of Sunshine (SMARTS)**
  http://www.nrel.gov/rredc/smarts
  Computes clear sky spectral irradiances for a set of user-specified atmospheric conditions.

SOLAR POSITION AND GEOMETRY CALCULATIONS

- **Solar Position Algorithm (SPA)** http://www.nrel.gov/midc/spa
  Calculates the solar position with very low uncertainty based on location, date, and time inputs for the years -2000 to 6000.

- **Solar and Moon Position Algorithm (SAMPA) http://www.nrel.gov/midc/sampa**
  Calculates the Sun and Moon position with very low uncertainty based on location, date, and time inputs for the years -2000–6000. This algorithm can be used for solar eclipse monitoring and estimating the influence on solar irradiance.

- **Solar Position and Intensity (SOLPOS)**
  http://rredc.nrel.gov/solar/codesandalgorithms/solpos
  Calculates the solar position and intensity based on location, date, and time inputs for the years 1950–2050.

SOLAR RESOURCE DATA COLLECTIONS

- **Gridded National Solar Radiation Database (NSRDB)**
  https://nsrdb.nrel.gov/
  The current version of the NSRDB is the Physical Solar Model (PSM), and it offers users the latest available data. PSM comprises 30-minute solar and meteorological data for approximately 1.4 million 0.038 degree latitude by 0.038 degree longitude surface pixels (nominally 4 km^2). Previous versions of NSRDB also reside in this webpage.

- **NASA Surface Solar Energy**
  http://eosweb.larc.nasa.gov/sse/
  Includes more than 200 satellite-derived meteorology and solar energy parameters, monthly averages from 22 years of data, data tables for particular locations, color plots on both global and regional scales, and global solar energy data for 1,195 ground sites.
  Allows users to download solar resource information via an interactive Google-based map interface. This is meant to be a simple tool that gives access to recent year data files in TMY or CSV format.

- **1961–1990 Hourly and Statistically Summarized Data**
  http://rredc.nrel.gov/solar/old_data/nsrdb/1961-1990/
  Includes:
    - Daily statistics files (Note: These files are monthly averages of daily totals)
    - Hourly data files
    - Solar Radiation Data Manual for Buildings
      - 30-year (1961–1990) average of solar radiation and illuminance for each month
    - Solar Radiation Data Manual for Flat-Plate and Concentrating Collectors
      - Averages of solar radiation for each of the 360 months during 1961–1990
      - 30-year (1961–1990) average of solar radiation for each month
      - Atlas for The Solar Radiation Data Manual For Flat-Plate and Concentrating Collectors
    - Typical Meteorological Year (TMY2) files.

- **1991–2010 Update Hourly and Statistically Summarized Data**
  http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2010/
  Includes:

    - Hourly solar data and statistical summaries
      Individual site-years by:
      - State and site name
      - USAF number
    - All available solar data and statistical files in compressed site files (gzip compression)
      - State and site name
      - USAF number
    - Typical Meteorological Year (TMY3) files
    - NSRDB_StationsMeta.csv (CSV, 104 KB) Metadata file containing site USAF number, class, station name, coordinates, etc.
      - NSRDB_StationsMetaMeta.doc (Word Document, 32 KB) Documentation for NSRDB_StationsMeta.csv.

- **Typical Meteorological Year Data Sets**
  http://rredc.nrel.gov/solar/old_data/nsrdb/1961-1990/tmy2
  http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3
  Provides hourly values of solar radiation and meteorological elements for U.S. sites and territories for a 1-year period during 1961–1990 or 1991–2005.

- **EnergyPlus Weather Data**
  https://energyplus.net/Offers weather data, arranged by World Meteorological Organization region and country, for more than 1,300 locations throughout the world.

- **Near Real-Time Surface Solar Resource Forecast**
  (Northwest and Western US 36-km and 12-km resolution)
  http://www.atmos.washington.edu/mm5rt/
  (next to last element in 36- and 12-km surface block)
  http://www.atmos.washington.edu/mm5rt/naminit.html
  (last element in 36- and 12-km “surface” block for each 36- and 12-km resolution)

- **Solar and Wind Energy Resource Assessment (SWERA)**
  http://maps.nrel.gov/swera
  The Solar and Wind Energy Resource Assessment tool provides easy access to high-quality renewable energy resource information and data to users around the world.

- **Solar Data Warehouse**
  http://www.solardatawarehouse.com/
  The Solar Data Warehouse accesses climate data from more than 30 measurement networks across the United States and proves hourly and daily data from more than 3,000 stations.

- **DLR ISIS**
  http://www.pa.op.dlr.de/ISIS/
  The Deutsches Zentrum für Luft-und Raumfahrt (DLR) irradiance at the surface derived from ISCCP cloud data (DLR-ISIS) data set gives an overview of the available TSI worldwide based on radiative transfer model results using cloud properties and cloud amount data supplied from the ISCCP.

- **HelioClim**
  www.helioclim.org/radiation/index.html
  The Deutsches Zentrum für Luft-und Raumfahrt (DLR) irradiance at the surface derived from ISCCP cloud data (DLR-ISIS) data set gives an overview of the available TSI worldwide based on radiative transfer model results using cloud properties and cloud amount data supplied from the ISCCP

- **Clean Power Research—SolarAnywere**
  www.cleanpower.com/SolarAnywhere
  SolarAnywhere is a Web-based service that provides hourly estimates of the solar irradiance based on satellite images and atmospheric data using algorithms developed and maintained by Dr. Richard Perez and the State University of New York at Albany (Perez et al. 2002).

MEASURED DATA SOURCES

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- **Cooperative Networks for Renewable Resource Measurements (CONFRRM) Solar Energy Resource Data**
  http://rredc.nrel.gov/solar/new_data/confrrm/
  Provides solar radiation and wind measurement data for select U.S. locations.

- **Historically Black Colleges and Universities Solar Radiation Monitoring Network**
  http://rredc.nrel.gov/solar/old_data/hbcu/
  Provides five-minute measurements of solar irradiance for six stations in the southeastern United States from 1985 to 1996.

- **Lawrence Berkeley National Laboratory Reduced Circumsolar Radiation Database**
  http://rredc.nrel.gov/solar/old_data/circumsolar/
  Provides detailed intensity profiles of the solar and circumsolar region, direct normal radiation data, and total hemispherical solar radiation data for 11 U.S. locations from 1976 to 1981.

- **Measurement and Instrumentation Data Center**
  http://www.nrel.gov/midc/
  Offers near real-time solar irradiance and meteorological data for several U.S. locations.

- **National Aeronautics and Space Administration Remote Sensing Validation Data**
  http://rredc.nrel.gov/solar/new_data/Saudi_Arabia/
  Offers solar radiation data from a network of 12 stations in Saudi Arabia since 1995.

- **National Oceanic and Atmospheric Administration (NOAA) Solar Data**
  http://rredc.nrel.gov/solar/old_data/noaa/
  Provides archived solar radiation information from a network of 39 stations throughout the United States.

- **National Renewable Energy Laboratory Spectral Solar Radiation Database**
  http://rredc.nrel.gov/solar/old_data/spectral/
  Provides spectral solar radiation data for several U.S. sites for 1986–1988.

- **National Solar Radiation Database**
  http://rredc.nrel.gov/solar/old_data/nsrdb/
  Offers hourly solar radiation and meteorological data for sites throughout the United States for 1961–1990 and 1991–2010.

- **Solar Energy Measurement Research and Training Sites Data Set**
  http://rredc.nrel.gov/solar/old_data/semrts/
  Offers solar resource data for four sites across the United States for dates ranging from 1979 to 1984.

- **Solar Spectra**
  http://rredc.nrel.gov/solar/spectra/
  Provides standard spectral irradiance information, descriptions, and data for the United States from a variety of sources.

- **WEST Associates Solar Monitoring Network**
  http://rredc.nrel.gov/solar/old_data/wa/
  Offers solar resource data for 52 stations in six Western U.S. states for 1976–1980.

- **National Climatic Data Center**
  https://www.ncdc.noaa.gov/
  Offers the world's largest active archive of weather data.

- **NOAA Regional Climate Centers**
  http://www.ncdc.noaa.gov/customer-support/partnerships/regional-climate-centers
  Provides detailed climate data for regions throughout the United States.

- **NOAA Surface Radiation Research Branch**
  http://www.esrl.noaa.gov/gmd/
  Monitors surface radiation in the continental United States. Its Web site includes: Integrated Surface Irradiance Study (ISIS) Network.

  http://www.srrb.noaa.gov/isis/index.html
  Surface Radiation (SURFRAD) Network

  http://www.srrb.noaa.gov/surfrad/index.html

- **Texas Solar Radiation Database**
  http://www.me.utexas.edu/~solarlab/tsrdb/tsrdb.html
  Offers solar radiation data for sites throughout Texas.

- **University of Oregon Solar Radiation Monitoring Laboratory**
  http://solardat.uoregon.edu/
  Operates solar radiation monitoring stations throughout the Pacific Northwest.

- **AZMET Arizona Meteorological Network**
  http://ag.arizona.edu/AZMET/
  Offers meteorological data and weather-based information to agricultural and horticultural interests operating in southern and central Arizona. Meteorological data are collected from a network of automated weather stations located in rural and urban production settings. Meteorological data collected by AZMET include temperature (air and soil), humidity, solar radiation, wind (speed and direction), and precipitation.

- **Oklahoma Mesonet**
  http://www.mesonet.org/
  Consists of more than 110 automated stations covering Oklahoma. There is at least one Mesonet station in each of Oklahoma's 77 counties. At each site, the environment is measured by a set of instruments locate donor near a 10-meter-tall tower. The measurements are packaged into "observations" every 5 minutes and include:
    - Air temperature measured at 1.5meters above the ground
    - Relative humidity measured at 1.5 meters above the ground
    - Wind speed and direction measured at 10 meters above the ground
    - Barometric pressure
    - Rainfall
    - Incoming solar radiation
    - Soil temperatures at 10 centimeters below the ground under both the natural sod cover and bare soil.

CLIMATE RESEARCH QUALITY MEASURED SOLAR DATA

- **The NOAA Earth System Research Laboratory**
  http://www.esrl.noaa.gov/
  Develops a number of datasets, experimental forecasts, and climate observations.

- **Baseline Surface Radiation Network (WMO Climate Research Solar Data)**
  http://www.bsrn.awi.de/
  Central archive of the Baseline Surface Radiation Network (BSRN).

- **World Radiation Data Centre**
  http://wrdc-mgo.nrel.gov/
  Serves as a central depository for solar radiation data collected at more than 1,000 sites throughout the world.

  http://wrdc.mgo.rssi.ru/wrdccgi/dataview.exe?datadir0001/wrdc/data_type.html
  Registration Form

- **Atmospheric Radiation Measurement Program**
  http://www.arm.gov/
  Collects a wealth of climate-related data for sites throughout the world.

DATA VISUALIZATION & GEOSPATIAL TOOLS

- **Geospatial Toolkits**
  http://www.nrel.gov/international/geospatial_toolkits.html
  Offers a map-based software application that integrates resource data and GIS for integrated resource assessment. A variety of agencies within countries and global datasets provided country-specific data.

- **System Advisory Model (SAM)**
  https://sam.nrel.gov/
  SAM makes performance predictions and cost of energy estimates for grid-connected power projects based on installation and operating costs and system design parameters that you specify as inputs to the model. Projects can be either on the customer side of the utility meter, buying and selling electricity at retail rates, or on the utility side of the meter, selling electricity at a price negotiated through a power purchase agreement (PPA).

- **Global RE Opportunity**
  http://maps.nrel.gov/global_re_opportunity
  The Global RE Opportunity Tool enables quick, intuitive analysis and visualization of the technical potential, economic opportunity, and market size for a variety of solar technologies ranging from residential rooftop systems to utility-scale installations.

- **Solar Data**
  http://www.nrel.gov/gis/data_solar.html
  10-kilometer, 40-kilometer, National Solar Radiation Data Base TMY3 station, and Baseline Measurement data to be used in a geographic information system (GIS).

- **Solar Maps**
  http://www.nrel.gov/gis/solar.html and http://www.nrel.gov/gis/mapsearch/
  NREL's Geospatial Data Science Team develops maps for various renewable resources and for specific projects. As a benefit to the public, a majority of static maps are offered and Google Map (KML/KMZ) files.

- **Near real time Surface Solar Resource Forecast**
  http://www.atmos.washington.edu/mm5rt/
  Northwest and Western US 36-km and 12-km resolution model forecasts (next to last element in 36-and12-km surface block).
  http://www.atmos.washington.edu/mm5rt/naminit.html
  (last element in 36-and 12-km “surface” block for each of 36-and 12-km resolution)

- **University of Wisconsin**
  http://www.aos.wisc.edu/education/undergrad/facilities.html
  Links to weather and climate data.

SOLAR RESOURCE PUBLICATIONS

- **Calibration of a Solar Absolute Cavity Radiometer with Traceability to the World Radiometric Reference**
  http://www.nrel.gov/rredc/pdfs/20619.pdf
  Explains a method to establish traceability of absolute cavity radiometers.

- **Quality Assessment with QC_TND**
  http://rredc.nrel.gov/solar/pubs/qc_tnd/
  Provides a quality-control method for global or total, direct, and diffuse solar radiation data.

- **Quality Assessment with SERI_QC**
  http://rredc.nrel.gov/solar/pubs/seri_qc/
  Provides a quality-control method for global horizontal, diffuse horizontal and direct normal solar radiation data.

- **A Quasi-Physical Model for Converting Hourly Global Horizontal to Direct Normal Insolation**
  http://www.nrel.gov/rredc/pdfs/3087.pdf
  Describes a physically based model for converting global horizontal insolation data to direct normal insolation data.

- **Shining On**
  http://rredc.nrel.gov/solar/pubs/shining/
  Provides a primer on solar radiation and solar radiation data.

- **Simple Solar Spectral Model for Direct and Diffuse Irradiance on Horizontal and Tilted Planes at the Earth's Surface for Cloudless Atmospheres**
  http://rredc.nrel.gov/solar/pubs/spectral/model/
  Describes a simple model for direct and diffuse spectral irradiance on horizontal and tilted surfaces at the earth's surface for clear days.

- **Simplified Clear Sky Model for Direct and Diffuse Insolation on Horizontal Surfaces**
  http://www.nrel.gov/rredc/pdfs/761.pdf
  Compares several broadband insolation models and presents a simple clear sky model for direct and diffuse insolation.

- **Solar Radiation Data Manual for Buildings**
  http://rredc.nrel.gov/solar/pubs/bluebook/
  Provides solar radiation and illuminance values for a horizontal window and four vertical windows (facing north, east, south, and west) for 239 stations in the United States and its territories.

- **Solar Radiation Data Manual for Flat-Plate and Concentrating Collectors**
  http://rredc.nrel.gov/solar/pubs/redbook/
  Provides solar radiation values for common flat-plate and concentrating collectors for 239 stations in the United States and its territories.

- **Standard Broadband Format Manual**
  http://rredc.nrel.gov/solar/pubs/SBF/
  Describes a tape archival format appropriate for use with research-level solar radiation data.

- **User's Manual for TMY2s**
  http://rredc.nrel.gov/solar/pubs/tmy2/
  Describes typical meteorological year (TMY) data sets derived from the1961–1990 National Solar Radiation Data Base.

- **WEST Associates Online Manual**
  http://rredc.nrel.gov/solar/pubs/wa/
  Provides solar data for 52 stations in Arizona, California, Colorado, Nevada, New Mexico, and Wyoming for 1976–1980.

RReDC PUBLICATIONS SITE (by year)
http://www.nrel.gov/rredc/publications.html

NREL PUBLIC DOMAIN PUBLICATIONS SITE
http://www.nrel.gov/research/publications.html