INVENTORY OF SOLAR RADIATION/SOLAR ENERGY SYSTEMS ESTIMATORS, MODELS, SITE-SPECIFIC DATA, AND PUBLICATIONS

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SOLAR SYSTEM POTENTIAL AND PERFORMANCE

- **Solar Estimator**
  http://www.findsolar.com/index.php?page=rightforme

  Estimates of PV price, savings, and system size. The results are based on many assumptions and the limited user data. An actual site assessment by a qualified solar professional is needed to determine the actual costs and benefits of installing a solar system.

- **PVWatts™**
  http://www.nrel.gov/rredc/pvwatts/
  http://rredc.nrel.gov/solar/calculators/PVWATTS/version1/
  http://rredc.nrel.gov/solar/calculators/PVWATTS/version2/

  Estimates the electrical energy produced by grid-connected photovoltaic systems.

- **Solar Advisor Model**
  http://www.nrel.gov/analysis/sam

  Allows users to investigate the impacts of variations in physical, cost, and financial parameters. Figures of merit related to the cost and performance of these systems include system output, peak and annual system efficiency, levelized cost of electricity, system capital, and operating and maintenance costs.

- **HOMER**
  https://analysis.nrel.gov/homer/

  Simplifies the task of evaluating design options for off-grid and grid-connected power systems.

- **Hybrid Power System Simulation Model**
  http://www.ceere.org/rerl/rerl_hybridpower.html

  Simulates the performance of various hybrid renewable energy systems. These hybrid systems may include three types of electrical loads, multiple wind turbines of different types, photovoltaics, multiple diesel generators, battery storage, and four types of power conversion devices.

- **In My Backyard**
  http://www.nrel.gov/eis/imby/

  Estimates the electricity that can be produced with a solar photovoltaic (PV) array or wind turbine at a home or business. Homeowners, businesses, and researchers use IMBY to develop quick estimates of renewable energy production at locations throughout the continental United States, Hawaii, and northern Mexico.

  IMBY uses a map-based interface to allow users to choose the exact location of a PV array or wind turbine. Based on the location, system size, and other variables, IMBY estimates the electricity production that can be expected from the system.

- **PVFORM: Predicting Array Performance**
  Contact Daryl Myers (daryl.myers@nrel.gov; 303-384-6768).

  Simulates hourly performance for a standalone or grid-interactive photovoltaic system for a one-year period and then summarizes the results into a statistical summary. Each hourly simulation accounts for the type of PV system being simulated, the incoming solar radiation, the temperature of the PV system, and other ambient weather conditions.

- **ViPOR**
  http://analysis.nrel.gov/vipor/

  Provides an optimization model for designing village electrification systems. Given a map of a village and some information about load sizes and equipment costs, ViPOR decides which houses should be powered by isolated power systems (such as solar home systems) and which should be included in a centralized distribution grid. The distribution grid is optimally designed with consideration of local terrain.

- **RetScreen Renewable Energy Modeling Package**
  http://www.retscreen.net/ang/home.php

  Offers a decision-support tool developed with the contribution of numerous experts from government, industry, and academia. The software, provided free of charge, can be used worldwide to evaluate the energy production and savings, costs, emission reductions, financial viability, and risk for various types of renewable energy and energy-efficient technologies. Also see the free renewable project e-textbook at http://www.retscreen.net/ang/12.php.

BROADBAND SOLAR RADIATION MODELS

- **Clear sky hourly data (maximium envelope)**
  Bird Clear Sky model: http://rredc.nrel.gov/solar/models/clearsky/

  Hourly estimates clear sky direct beam, hemispherical diffuse, and total hemispherical solar radiation for horizontal planes.

- **All Sky With Simple Cloud Cover Modifier**
  Bird, REST2, Iqbal C Cloud Modified: REST2, IQBAL Param
  Contact Daryl Myers (daryl.myers@nrel.gov; 303-384-6768).

  Hourly estimates all-sky hemispherical diffuse solar radiation for horizontal planes; requires hourly cloud cover in 10ths for site.

- **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.

- **Radiation on a tilted surface**
  Perez 1990 Anisotropic Tilt Conversion model
  Contact Daryl Myers (daryl.myers@nrel.gov; 303-384-6768).

  Estimates diffuse on tilted surfaces from any two of global horizontal, direct beam, and diffuse horizontal data (typically measured confirguration).

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**
  http://rredc.nrel.gov/solar/codesandalgorithms/spa/

  Calculates the solar position with very low uncertainty based on location, date, and time inputs for the years -2000–6000.

- **Solar Position and Intensity**
  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

- **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.

- **Solar Power Prospector**
  http://maps.nrel.gov/node/10

  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.

- **1991–2005 Hourly and Statistically Summarized Data**
  http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/

  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) via FTP
  - Typical Meteorological Year (TMY3) files
    - State and site name
    - USAF number
  - NSRDB_StationsMeta.csv (CSV, 112 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/

  Provide 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**
  http://www.eere.energy.gov/buildings/energyplus/cfm/weather_data.cfm

  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)

- **Satellite Based Estimates of Surface Solar Radiation**
  http://www.soils.wisc.edu/wimnext/sun.html

  Estimates are provided in 500-wh/m^2 resolution in terms of energy (MegaJoule) units for months without snow.

MEASURED DATA SOURCES

- **World Meteorological Organization Committee on Measurements and Observation Guide to Meteorological and Weather Observations (WMO Publication No. 8) Seventh Edition**
  http://www.wmo.int/pages/prog/www/IMOP/publications/CIMO-Guide/CIMO%20Guide%207th%20Edition,%202008/CIMO_Guide-7th_Edition-2008.pdf

  Includes WMO methods of observation for temperature, pressure, humidity, radiation, and surface winds as well as sections on data sampling, quality, and testing and calibration.

- **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 from 1995 to 2001.

- **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 1991–2005.

- **Solar Energy Measurement Research and Training Sites Data Set**
  http://rredc.nrel.gov/solar/old_data/semrts/

  Offers solar resource data for five 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**
  http://www.ncdc.noaa.gov/oa/ncdc.html

  Offers the world's largest active archive of weather data.

- **NOAA Regional Climate Centers**
  http://www.ncdc.noaa.gov/oa/climate/regionalclimatecenters.html

  Provides detailed climate data for regions throughout the United States.

- **NOAA Surface Radiation Research Branch**
  http://www.srrb.noaa.gov/

  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 located on or near a 10-meter-tall tower. The measurements are packaged into "observations" every 5 minutes and include:

  - Air temperature measured at 1.5 meters 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/

- **World Radiation Data Centre**
  http://wrdc-mgo.nrel.gov/
  http://wrdc.mgo.rssi.ru/wrdccgi/dataview.exe?datadir0001/wrdc/data_type.html

  Serves as a central depository for solar radiation data collected at more than 1,000 sites throughout the world.

- **Atmospheric Radiation Measurement Program**
  http://www.arm.gov/

  Collects a wealth of climate-related data for sites throughout the world.

GEOGRAPHICAL INFORMATION SYSTEMS GEOSPATIAL TOOLKITS
http://www.nrel.gov/applying_technologies/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.

Download Toolkits

Country	File	Last Updated
Afghanistan - Funding provided by USAID	(EXE 40.6 MB) http://www.nrel.gov/applying_technologies/afghanistan/gst/data/setup_gst_homer_afghanistan_lite.exe	July 6, 2007
Afghanistan (Enhanced) - Funding provided by USAID	(EXE 59.4 MB) http://www.nrel.gov/applying_technologies/afghanistan/gst/data/setup_gst_homer_afghanistan.exe	July 6, 2007
Bangladesh - Funding provided by UNEP	(EXE 18.7 MB) http://www.nrel.gov/analysis/downloads/setup_bangladesh.exe	Sept. 26, 2005
Brazil - Funding provided by UNEP and INPE	(EXE 47.0 MB) http://www.nrel.gov/analysis/downloads/setup_brazil.exe	Oct. 11, 2005
El Salvador - Funding provided by UNEP	(EXE 24.8 MB) http://www.nrel.gov/analysis/downloads/setup_el_salvador.exe	Sept. 26, 2005
Ghana - Funding provided by UNEP	(EXE 13.1 MB) http://www.nrel.gov/analysis/downloads/setup_ghana.exe	Dec. 12, 2005
Guatemala - Funding provided by UNEP	(EXE 32.6 MB) http://www.nrel.gov/analysis/downloads/setup_guatemala.exe	Sept. 26, 2005
Hebei, China - Funding provided by EPA, UNEP, and USDOE	(EXE 15.5 MB) http://www.nrel.gov/analysis/downloads/setup_hebei.exe	Feb. 10, 2006
Honduras - Funding provided by UNEP	(EXE 72.2 MB) http://www.nrel.gov/analysis/downloads/setup_honduras.exe	Sept. 27, 2005

Country	File	Last Updated
Mexico (Oaxaca) - Funding provided by USAID and USDOE	(EXE 58.9 MB) http://www.nrel.gov/analysis/downloads/setup_oaxaca.exe	Sept. 26, 2005
Nicaragua - Funding provided by UNEP	(EXE 40.5 MB) http://www.nrel.gov/analysis/downloads/setup_nicaragua.exe	Sept. 26, 2005
Pakistan - Funding provided by USAID	(EXE 14.8 MB) http://www.nrel.gov/applying_technologies/pakistan/gst/data/setup_gst_homer_pakistan_lite.exe	July 6, 2007
Pakistan (Enhanced) - Funding provided by USAID	(EXE 34.8 MB) http://www.nrel.gov/applying_technologies/pakistan/gst/data/setup_gst_homer_pakistan.exe	July 6, 2007
Sri Lanka – Funding provided by USAID and UNEP	(EXE 15.8 MB) http://www.nrel.gov/analysis/downloads/setup_sri_lanka.exe	Sept. 26, 2005
Sri Lanka (Enhanced) - Funding provided by USAID	(EXE 34.1 MB) http://www.nrel.gov/analysis/downloads/setup_gst_homer.exe	Dec. 1, 2005

Please download the Getting Started Guide at http://analysis.nrel.gov/swera3/getting_started.doc to learn the software.

SOLAR MAPS

- **United States Solar Atlas – Dynamic Map**
  http://mapserve2.nrel.gov/website/L48NEWPVWATTS/viewer.htm

  Accesses monthly average PVWatts Version 2 – Dynamic Maps solar resource information for any given location in the United States

- **PVWatts Version 2 – Dynamic Map**
  http://mapserve2.nrel.gov/website/PVWATTSLITE/viewer.htm

  Calculates electrical energy produced by a grid-connected photovoltaic system.

- **Map of U.S. Solar Measurement Station Locations - Dynamic Map**
  http://mapserve2.nrel.gov/website/Measurements/Viewer.htm

  Shows the spatial distribution of measurement stations across the U.S.

- **PV Solar Radiation (Flat Plate, Facing South, Latitude Tilt) – Static Maps**
  http://www.nrel.gov/gis/solar.html

  Offers maps (.jpeg images ranging in size from 260 kb to 273 kb) that provide monthly average daily total solar resource information on grid cells of approximately 40 km by 40 km.

- **Direct Normal Solar Radiation (Two-Axis Tracking Concentrator) –Static Maps**
  http://www.nrel.gov/gis/solar.html

  Offers maps (.jpeg images ranging in size from 268 kb to299 kb) that provide monthly average daily total solar resource information on grid cells of approximately 40 km by 40 km.

- **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 of 36- and 12-km resolution)

- **University of Wisconsin daily Satellite Estimates Solar Radiation (MAPS AND DATA)**
  http://www.soils.wisc.edu/wimnext/sun.html

  Provides daily solar energy amounts estimated using data in the visible portion of the spectrum, which come from the Geostationary Operational Environmental Satellites (GOES). Simple physical models of radiative transfer for the clear and cloudy atmosphere are used with these data to evaluate whether a particular location is cloudy or clear and, if cloudy, to what extent clouds have depleted the solar beam. Usually, about eight to twelve individual GOES images are used during the course of a day to make estimates of the solar energy at the satellite image times. These instantaneous estimates are later summed to produce the daily solar energy totals.

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 the 1961–1990 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.

NREL PUBLIC DOMAIN PUBLICATIONS SEARCH SITE
http://nrelpubs.nrel.gov/Webtop/ws/nich/www/public/SearchForm