2010 Production Modeling Tools [1]

Software Program	Basics			Weather Data Source	Irradiance Model
	Developer	**Cost**	**Web-Based or Application**		
HOMER	HOMER ENERGY, originally developed by NREL	free	application	user provides hourly average global solar radiation on the horizontal surface (kW/m²), monthly average global solar radiation on the horizontal surface (kWh/m²/day), or monthly average clearness index	Hay and Davies model
Polysun	Vela Solaris	Light $159 Pro $489	application	Meteotest	unknown
PV Designer	Solmetric	$400/yr	application	various weather sources including TMY2 and TMY3 data; outside the US, the same weather sources as Energy Plus	Perez et al. model
PV-DesignPro	Maui Solar Energy Software with Sandia	$259	application	TMY2, TMY3 , Meteonorm, Global Solar Irradiation Database	Perez et al. model (default), HDKR model (option)
PV F-Chart	F-Chart Software with University of Wisconsin	$400	application	TMY2, TMY3, weather data can be added	Isotropic Sky model
PV*SOL	Valentin Software	$698 [2]	application	MeteoSyn, Meteonorm, SWERA, PVGIS, NASA SSE	Hay and Davies model
PVsyst	University of Geneva	1st license $984, additional $197	application	TMY2, TMY3, Meteonorm, ISM-EMPA, Helioclim-1 and -3, NASA-SSE, WRDC, PVGIS-ESRA and RETScreen; user can import custom data in a CSV file	Hay and Davies model (default), Perez et al. model (option)
PVWatts v. 1	NREL	free	Web	in the US—TMY2 data; 239 options outside the US—TMY data from the Solar and Wind Energy Resource Assessment Programme, the International Weather for Energy Calculations (V1.1), and the Canadian Weather for Energy Calculations	Perez et al. model
PVWatts v. 2	NREL	free	Web	combination of TMY2 data with monthly weather data from Real-Time Nephanalysis (RTNEPH) database (cloud cover), Canadian Center for Remote Sensing (albedo), National Climatic Data Center (daily maximum dry bulb temperatures) and RDI/FT Energy (1999 residential electric rates)	Perez et al. model
RetScreen	Natural Resources Canada	free	application	combination of weather data collected from 4,720 sites from 20 different sources with data from 1961–1990 & NASA-SSE	Isotropic Sky model
System Advisor Model (SAM)	NREL	free	application	TMY2, TMY3, EPW, Meteronorm	Perez et al. model (default); Isotropic Sky Model, Hay and Davies model, Reindl model (options); total and beam (default), beam and diffuse (option)

Notes:

[1] Some entries in this table adopted from Klise and Stein (2009).   [2] Does not include expert version to be released in 2010.

[3] Shading derate is from SunEye readings. Inverter efficiency derate is from an equipment database.

[4] User enters array operating temperature, reference efficiency, temperature coefficient and array area.

Modeling					
Production-Estimating Model: Module	**Production-Estimating Model: Inverter**	**Simulation Frequency**	**Tilt**	**Orientation**	**Derate Factors**
linear irradiance model with temperature correction	single efficiency derate factor	hourly	manual input	manual input	derate factors not categorized, all losses except for single percentage for inverter efficiency are covered by "miscellaneous losses"
empirical model of module performance, dependent on three MPPT power ratings at different irradiance values and the module temperature coefficient	unknown	hourly	manual input	manual input	soiling, degradation, mismatch, wiring
proprietary model based on nominal power and operating temperature	single-weighted efficiency derate factor	hourly	manual input	manual input	PV module nameplate dc rating, inverter and transformer, mismatch, diodes and connections, dc wiring, ac wiring, soiling, system availability, shading, sun tracking, age [3]
Sandia model	Sandia model	hourly	manual input	manual input	wiring, MPPT efficiency, array current derate factor, array voltage derate factor
function of efficiency and temperature	power tracking and power conversion efficiency factors	hourly	manual input	manual input	inverter conversion efficiency and power tracking efficiency
modeled using V and irradiance at STC, module efficiency curve and an incident angle modifier; linear or dynamic temperature model options	inverter profile and efficiency curve generated from measured data	hourly	manual input	manual input	mismatch, diodes, module quality, soiling, wiring, deviation from standard spectrum, module height above ground
Shockley's one-diode model for crystalline silicon; modified one-diode model for thin film	inverter profile and efficiency curve generated from measured data	hourly	manual input	manual input	field thermal loss, standard NOCT factor, Ohmic losses, module quality, mismatch, soiling (annual or monthly), IAM losses
simplified PVFORM	single efficiency derate factor	hourly	manual input	manual input	PV module nameplate dc rating, inverter and transformer, mismatch, diodes and connections, dc wiring, ac wiring, soiling, system availability, shading, sun tracking, age
simplified PVFORM	single efficiency derate factor	monthly	manual input	manual input	PV module nameplate dc rating, inverter and transformer, mismatch, diodes and connections, dc wiring, ac wiring, soiling, system availability, shading, sun tracking, age
Evan's average efficiency model	single efficiency derate factor	monthly	manual input	manual input	inverter efficiency, miscellaneous losses
Sandia model, CEC model, PVWatts model	single efficiency derate factor, Sandia Model for grid-connected inverters	hourly	manual input	manual input	mismatch, diodes and connections, dc wiring, soiling, sun tracking, ac wiring, transformer

2010 Production Modeling Tools

Software Program	Modeling			Output Data
	Technologies	Tracking	Shading	
HOMER	not technology specific[4]	single axis (horizontal, daily adjustment), single axis (horizontal, weekly adjustment), single axis (horizontal monthly adjustment), single axis (horizontal, continuous adjustment), single axis (vertical, continuous adjustment), dual axis	not considered independently, could be incorporated into single derate factor	hourly ac production data
Polysun	cSi, aSi, CdTe, CIS, CIGS, HIT, µc-Si, Ribbon (EFG)	single axis, dual axis	horizon profile may be defined or imported	unknown
PV Designer	cSi, aSi, CdTe, CIS	n/a	sub-module level shading, computed based on distance-weighted interpolation of readings taken from Solmetric SunEye	hourly ac energy production; daily and monthly ac energy production displayed graphically on screen
PV-DesignPro	cSi, aSi, CdTe, CIS, CPV, mj-CPV	single axis (horizontal axis EW), single axis (horizontal axis NS), single axis (vertical axis), single axis (NS axis parallel to Earth's axis), dual axis	horizon profile user-defined	hourly data available for meteorological data, PV array behavior (cell temp, module efficiency), energy production and more
PV F-Chart	not technology specific[4]	flat-plate array, single-axis tracking (adjustable tilt/azimuth), dual-axis tracking, concentrating parabolic collector	not considered, could be incorporated into other derate factors	monthly average hourly values of ac energy
PV*SOL	cSi, aSi, CdTe, CIS, HIT, µc-Si, Ribbon	single axis (vertical), dual axis	horizon profile user-defined or imported from shade survey tool, 3D modeling environment in Expert version	hourly energy production in one-week segments
PVsyst	cSi, HIT, CdTe, aSi, CIS, µc-Si	single axis (horizontal axis EW), single axis (vertical axis), single axis (tilted axis), dual axis, dual axis (frame NS), dual axis (frame EW), tracking sun shields; ability to define parameters such as collector width, shade spacing and rotation limits	horizon profile can be user-defined or imported from a shade survey tool, 3D modeling environment, based on array configuration	hourly data available for meteorological data, PV array behavior (cell temp, wiring losses, etc.), energy production
PVWatts v. 1	cSi	single axis, dual axis	single derate factor	hourly ac energy production
PVWatts v. 2	cSi	single axis, dual axis	single derate factor	n/a
RetScreen	cSi, aSi, CdTe, CIS, spherical-Si	single axis, dual axis, azimuth	n/a	n/a
System Advisor Model (SAM)	cSi, aSi, CdTe, CIS, CPV, HIT	single axis (tilted NS axis), dual axis	12-month by 24-hour shade profile can be imported	hourly data available for meteorological data, PV array behavior (cell temp, wiring losses, etc.), energy production

Notes:

[4] User enters array operating temperature, reference efficiency, temperature coefficient and array area.   n/a = not available

Details			Component Database			
Financial Analyses	**Ability to Export Data to Excel**	**Optimization**	**Module**	**Inverter**	**Update Method and Frequency**	**User Support & Documentation**
cash-flow analysis considering energy costs, operating costs and calculation of LCOE	exported as a text file	sensitivity analysis and optimization capability	n/a	n/a	n/a	user manual provided with software
financial analysis including O&M costs, incentives, projected electricity costs, inflation and interest rates	yes	n/a	yes	yes	automatically checks for updates	user manual provided with software
n/a	yes	n/a	yes	yes	component data complied from PVXchange database, updated approximately monthly	user manual provided with software
basic cash-flow analysis	yes	parametric analysis	yes	yes	updates supplied periodically on the Maui Solar Software site; you can add modules and inverters	online help file, training videos
lifecycle cost calculations including electricity purchased from utility, electricity sold to utility, O&M costs, rebates, tax credits, depreciation; cash-flow analysis	can be copied and pasted into Excel	parametric analysis	n/a	n/a	n/a	user manual provided with software
economic efficiency and cash-flow analysis	yes	tilt, inter-row spacing, inverter loading	yes	yes	updates to the database are supplied by manufacturers; the program can be set to check for updates at start up	limited help file available with program; training available
considers energy costs, feed-in tariffs and system financing	yes	tilt, orientation, inter-row spacing, inverter loading	yes	yes	updated approximately once a year, usually with the release of a software update; you can define additional components or import individual component files received from other sources	detailed help file available with program, FAQ on Web site, no user manual
basic calculation of energy value	8,760 report is output as text that can be pasted into an Excel file	n/a	n/a	n/a	n/a	online documentation and support available
basic calculation of energy value	n/a	n/a	n/a	n/a	n/a	limited help file provided available with program, additional online documentation and support available
detailed cash-flow analysis, sensitivity and risk analysis	program is Excel based	n/a	yes	n/a	manufacturer must contact RetScreen	online manual, detailed help file, online training courses
detailed cash-flow analysis for residential, commercial and utility scale projects; focused on the US market; sensitivity and statistical analysis tools	yes	numerous production and financial optimization tools, parametric analysis	yes	yes	CEC module model (NREL maintains a library of CEC-approved modules), SAM can sync with the most recent library, additional modules can be added by contacting NREL; library of inverter coefficients is updated regularly as the CEC inverter database is updated	extensive user manual, detailed help file, online user group, email support