

Standard Meteorological & Simulation Weather File Formats

Comprehensive Scientific & Engineering Reference Manual • Ver 2026-8

Executive Overview & Purpose

Building energy simulation, photovoltaic (PV) performance modeling, daylighting calculation, and HVAC equipment sizing rely on time-series meteorological datasets representing Typical Meteorological Years (TMY) or Multi-Decadal Historical/Extreme periods.

This document serves as an authoritative technical reference manual detailing the six primary standard weather file formats supported by the platform:

- **EnergyPlus Weather Format (.epw):** Whole-building physics simulation and hourly load analysis.
- **Typical Meteorological Year 3 & Extended CSV (.csv / TMY3 / TMYx):** NREL 68-column standard with data quality flags.
- **NREL System Advisor Model CSV (.csv / SAM):** Streamlined 15-variable format for solar PV, battery, and CSP dispatch.
- **EnergyPlus Design Day Definitions (.ddy):** ASHRAE 99.6% heating and 0.4% cooling extreme conditions for peak HVAC equipment sizing.
- **Daysim / Radiance Daylighting Weather Format (.wea):** Mid-hour solar irradiance format for dynamic daylight autonomy (sDA / ASE).
- **Legacy NREL Typical Meteorological Year Formats (.tm2 / .tmy / TMY2):** Fixed-width 126-byte ASCII format for legacy simulation codebases.

Summary of Supported Meteorological Formats

Format Identifier	Ext	Governing Authority	Primary Discipline	Key Software Compatibility
EnergyPlus Weather	.epw	U.S. DOE / NREL	Whole-Building Energy	EnergyPlus, OpenStudio, IES VE, Ladybug, eQUEST
TMY3 / TMYx CSV	.csv	NREL (TP-581-43156)	Solar & Data Science	PVsyst, HelioScope, NREL SAM, Excel, Python
NREL SAM Solar	.csv	NREL SAM Engine	Solar PV & Renewables	NREL SAM, PySAM, PV Array Engines
ASHRAE Design Days	.ddy	ASHRAE TC 4.2	Peak HVAC Sizing	Carrier HAP, Trane TRACE 3D, EnergyPlus, OpenStudio
Daysim Daylighting	.wea	Fraunhofer ISE / Daysim	Daylight Autonomy & Glare	Daysim, Radiance, DIVA, ClimateStudio, Honeybee
Legacy TMY2	.tm2	NREL (SP-463-7668)	Legacy Building Engines	eQUEST, DOE-2.1E, TRNSYS 16/17, Carrier HAP v5

1. Meteorological Data Provenance & Observational Backbone

The weather records in this repository are constructed from multi-decadal, quality-controlled observational surface networks, satellite solar measurements, and atmospheric reanalysis models.

Provenance Layer	Source Institutions & Networks	Data Coverage & Quality Control Standards
Tier 1: Surface Backbone	- WMO Global Telecommunication System (GTS) - NOAA / NCEI Integrated Surface Database (ISD)	Over 15,800+ global land-based stations reporting hourly calibrated dry-bulb temperature, dew point, barometric pressure, wind vector, and celestial sky cover.
Tier 2: Solar Reanalysis	- ECMWF ERA5 Global Atmospheric Reanalysis - Copernicus Regional Reanalysis (CERRA)	Rigorous radiative transfer models assimilating geostationary satellite imagery to synthesize Direct Normal (DNI), Diffuse Horizontal (DHI), and Global Horizontal (GHI) solar irradiance.
Tier 3: National Authorities	- USA: NOAA / NCEI Climate Normals, NREL, CEC - Canada: Environment Canada (CWEC) & NRC - Europe: Deutscher Wetterdienst (DWD), ISO 15927-4 - Australia: Bureau of Meteorology (BoM), CSIRO - International: INMET, CMA, NIWA, SMN, IMS	Harmonized national station standards and statutory building code baseline datasets.

2. EnergyPlus Weather Format (.epw)

- **Standard Authority:** U.S. Department of Energy (DOE) / NREL / EnergyPlus Development Team.
- **File Structure:** Plain-text ASCII comma-delimited layout, consisting of exactly 8 header lines followed by 8,760 hourly data records.
- **Time Alignment:** End-of-hour timestamping (Hour 1 = 00:00:01 to 01:00:00). Irradiance values represent accumulated energy over the preceding hour (Wh/m²).

2.1 Header Block Specification (Lines 1 to 8)

Line	Header Keyword	Field Structure & Syntax	Example Record
1	LOCATION	City, State, Country, Source, Station ID, Lat, Lon, TZ, Elev (m)	LOCATION,Denver Centennial CO,CO,USA,TMY3,724666,39.57,-104.85,-7.0,1793.0
2	DESIGN CONDITIONS	Condition Count, Source/Standard, ASHRAE Fundamentals Values	DESIGN CONDITIONS,1,Climate Design Data 2009 ASHRAE Handbook,...
3	TYPICAL/EXTREME PERIODS	Period Count, Name 1, Type 1, Start Date 1, End Date 1, ...	TYPICAL/EXTREME PERIODS,6,Summer Max Temp,Extreme,7/8,7/14,...
4	GROUND TEMPERATURES	Depth Count, Depth 1 (m), Soil Properties, 12 Monthly Means (°C)	GROUND TEMPERATURES,3,0.5,,1.2,2.3,5.4,9.8,14.5,19.2,22.1,21.0,16.8,11.2,5.6,2.1,...
5	HOLIDAYS/DAYLIGHT SAVINGS	Leap Year (Yes/No), Daylight Savings Start, End, Holiday Count	HOLIDAYS/DAYLIGHT SAVINGS,No,0,0,0
6	COMMENTS 1	Observation period, station history, source notes	COMMENTS 1,NCEI ISD/ERA5 - Period of Record 2011-2025
7	COMMENTS 2	Processing notes, ground temperature modeling details	COMMENTS 2,Calculated undisturbed earth temperatures
8	DATA PERIODS	Period Count (1), Records/Hour (1), Name, Start Day, Start Date, End Date	DATA PERIODS,1,1,Data,Sunday,1/1,12/31

2.2 Hourly Data Record Fields (Lines 9 to 8,768)

Each hourly line contains 35 comma-delimited fields arranged in the following sequence:

Index	Field Name	Physical Variable	SI Units	Valid Range (Missing)	Engineering Description
1	Year	Observation Year	YYYY	1900 to 2099	Source historical year for typical month selection
2	Month	Month of Year	1 to 12	1 to 12	1 = January, 12 = December
3	Day	Day of Month	1 to 31	1 to 31	Calendar day
4	Hour	Hour of Day	1 to 24	1 to 24	End-of-hour notation (Hour 1 = 00:00 to 01:00)
5	Minute	Minute of Hour	0 to 59	0 to 59	Standard hourly files use 60 (or 00)
6	Flags	Source & Uncertainty	text	String (?9?9...)	2 characters per element describing data source
7	DryBulb	Dry-Bulb Temperature	°C	-70.0 to +70.0 (99.9)	Ambient air temperature in ventilated shelter
8	DewPoint	Dew-Point Temperature	°C	-70.0 to +70.0 (99.9)	Saturation temperature for ambient vapor pressure
9	RelHum	Relative Humidity	%	0 to 100 (999)	Vapor pressure ratio relative to saturation
10	AtmPressure	Atmospheric Pressure	Pa	30000 to 120000 (999999)	Local barometric pressure at station elevation
11	ExtHorizRad	Extraterrestrial Horiz Rad	Wh/m ²	≥ 0 (9999)	Solar radiation at top of atmosphere on horizontal
12	ExtDirNormRad	Extraterrestrial Direct Normal	Wh/m ²	≥ 0 (9999)	Solar radiation at top of atmosphere normal to beam
13	HorizIR	Downwelling Infrared Rad	Wh/m ²	0 to 800 (9999)	Atmospheric longwave thermal radiation (4-100 µm)
14	GHI	Global Horizontal Radiation	Wh/m ²	0 to 1400 (9999)	Total broad-spectrum solar on horizontal plane
15	DNI	Direct Normal Radiation	Wh/m ²	0 to 1200 (9999)	Collimated direct beam normal to the sun
16	DHI	Diffuse Horizontal Radiation	Wh/m ²	0 to 800 (9999)	Sky-scattered solar received on horizontal surface
17	GlobalHorizIllum	Global Horiz Illuminance	lux	≥ 0 (999999)	Total visible daylight (380-780 nm) on horizontal
18	DirNormIllum	Direct Normal Illuminance	lux	≥ 0 (999999)	Visible direct beam daylight normal to the sun
19	DiffHorizIllum	Diffuse Horiz Illuminance	lux	≥ 0 (999999)	Visible daylight from sky dome excluding sun
20	ZenithLum	Zenith Luminance	Cd/m ²	≥ 0 (9999)	Luminous intensity per unit area at zenith
21	WindDir	Wind Direction	deg (°)	0 to 360 (999)	0° = North, 90° = East, 180° = South, 270° = West
22	WindSpeed	Wind Speed	m/s	0 to 100 (999)	Measured wind speed at standard 10m mast height
23	TotSkyCover	Total Sky Cover	tenths	0 to 10 (99)	Fraction of celestial dome covered by clouds
24	OpaqSkyCover	Opaque Sky Cover	tenths	0 to 10 (99)	Cloud fraction completely obscuring the sun/stars
25	Visibility	Horizontal Visibility	km	≥ 0 (9999)	Maximum distance prominent objects can be seen

Index	Field Name	Physical Variable	SI Units	Valid Range (Missing)	Engineering Description
26	CeilingHt	Cloud Ceiling Height	m	≥ 0 (99999)	Cloud base height covering >50% of the sky
27	PresWeathObs	Present Weather Obs	code	0 or 9	0 = Weather observation present, 9 = Missing
28	PresWeathCodes	Present Weather Codes	code	9-digit int	Encoded WMO weather events (fog, rain, snow)
29	PrecipWater	Precipitable Water	mm	≥ 0 (999)	Condensed depth of atmospheric water vapor
30	AOD	Aerosol Optical Depth	unitless	≥ 0 (0.999)	Particulate atmospheric extinction coefficient
31	SnowDepth	Snow Depth	cm	≥ 0 (999)	Ground surface snow accumulation depth
32	DaysSinceSnow	Days Since Last Snow	days	≥ 0 (99)	Elapsed days since measurable snowfall
33	Albedo	Ground Surface Albedo	unitless	0.0 to 1.0 (999)	Ratio of reflected to incident global solar
34	LiqPrecipDepth	Liquid Precip Depth	mm	≥ 0 (999)	Liquid equivalent precipitation in preceding hour
35	LiqPrecipQuantity	Liquid Precip Quantity	hr	≥ 0 (99)	Duration of precipitation during the hour

3. Typical Meteorological Year 3 & Extended CSV (.csv / TMY3 / TMYx)

- **Standard Authority:** NREL Technical Report NREL/TP-581-43156 (Wilcox and Marion) / White Box Technologies.
- **Format Structure:** Standard Comma-Separated Values (.csv) consisting of 2 header lines and 8,760 hourly data rows.
- **Header Structure:** Line 1: USAF/WBAN ID, Station Name, State/Province, Time Zone, Latitude, Longitude, Elevation (m)
Line 2: 68 standard field descriptors with measurement units.
- **Quality Flags:** Each physical variable is paired with a Source Flag (1-character data origin code) and Uncertainty Flag (1-digit uncertainty index 1-9).

3.1 Standard 68-Column Specification Table

Col #	Column Header	Variable Description	Engineering Units	Data Type / Flags
1	Date (MM/DD/YYYY)	Observation Date	MM/DD/YYYY	Date String
2	Time (HH:MM)	Observation Time (End-of-Hour)	HH:MM	Time String (01:00-24:00)
3	ETR (W/m ²)	Extraterrestrial Horizontal Radiation	W/m ²	Integer (Wh/m ²)
4	ETRN (W/m ²)	Extraterrestrial Direct Normal Radiation	W/m ²	Integer (Wh/m ²)
5 - 7	GHI / Source / Uncert	Global Horizontal Irradiance	W/m ²	Float / 1-Char Code / 1-Digit Index
8 - 10	DNI / Source / Uncert	Direct Normal Irradiance	W/m ²	Float / 1-Char Code / 1-Digit Index
11 - 13	DHI / Source / Uncert	Diffuse Horizontal Irradiance	W/m ²	Float / 1-Char Code / 1-Digit Index
14 - 16	GH illum / Source / Uncert	Global Horizontal Illuminance	lux	Float / 1-Char Code / 1-Digit Index
17 - 19	DN illum / Source / Uncert	Direct Normal Illuminance	lux	Float / 1-Char Code / 1-Digit Index
20 - 22	DH illum / Source / Uncert	Diffuse Horizontal Illuminance	lux	Float / 1-Char Code / 1-Digit Index
23 - 25	Zenith lum / Source / Uncert	Zenith Luminance	cd/m ²	Float / 1-Char Code / 1-Digit Index
26 - 28	TotSkyCvr / Source / Uncert	Total Sky Cover (0 to 10)	tenths	Integer / 1-Char Code / 1-Digit Index
29 - 31	OpaqSkyCvr / Source / Uncert	Opaque Sky Cover (0 to 10)	tenths	Integer / 1-Char Code / 1-Digit Index
32 - 34	Dry-bulb / Source / Uncert	Ambient Dry-Bulb Temperature	°C	Float / 1-Char Code / 1-Digit Index

Col #	Column Header	Variable Description	Engineering Units	Data Type / Flags
35 - 37	Dew-point / Source / Uncert	Ambient Dew-Point Temperature	°C	Float / 1-Char Code / 1-Digit Index
38 - 40	RHum / Source / Uncert	Relative Humidity	%	Integer / 1-Char Code / 1-Digit Index
41 - 43	Pressure / Source / Uncert	Barometric Atmospheric Pressure	mbar (hPa)	Float / 1-Char Code / 1-Digit Index
44 - 46	Wdir / Source / Uncert	Wind Direction (0° - 360°)	degrees	Integer / 1-Char Code / 1-Digit Index
47 - 49	Wspd / Source / Uncert	Wind Speed at 10m Mast	m/s	Float / 1-Char Code / 1-Digit Index
50 - 52	Visibility / Source / Uncert	Horizontal Visibility	km	Float / 1-Char Code / 1-Digit Index
53 - 55	CeilHgt / Source / Uncert	Cloud Ceiling Base Height	m	Integer / 1-Char Code / 1-Digit Index
56 - 58	Pwat / Source / Uncert	Precipitable Water Vapor	cm	Float / 1-Char Code / 1-Digit Index
59 - 61	AOD / Source / Uncert	Aerosol Optical Depth (Broadband)	unitless	Float / 1-Char Code / 1-Digit Index
62 - 64	Alb / Source / Uncert	Ground Surface Albedo (0.0-1.0)	unitless	Float / 1-Char Code / 1-Digit Index
65 - 67	LRadProc / Source / Uncert	Downwelling Infrared Radiation	Wh/m²	Integer / 1-Char Code / 1-Digit Index
68	LRadProc uncert	Liquid/Infrared Uncertainty Band	code (1-9)	Single Digit Quality Flag

4. NREL System Advisor Model CSV (.csv / SAM)

- **Standard Authority:** National Renewable Energy Laboratory (NREL) SAM Development Team.
- **Engineering Focus:** Photovoltaic (PV), battery storage, concentrating solar power (CSP), and solar thermal simulation without building envelope overhead.
- **Format Layout:** 2 metadata header rows + 1 column descriptor row + 8,760 hourly data rows.

Col #	Field Name	Variable	Units	SAM Simulation Role
1 - 4	Year, Month, Day, Hour	Timestamp	YYYY, M, D, H	Hourly time indexing
5	GHI	Global Horizontal Irradiance	W/m ²	Total plane of array benchmark
6	DNI	Direct Normal Irradiance	W/m ²	Tracking systems & CSP beam modeling
7	DHI	Diffuse Horizontal Irradiance	W/m ²	Diffuse sky radiation on tilted panels
8	Temperature	Dry-Bulb Ambient Temp	°C	PV cell operating temperature derating
9	Dew Point	Ambient Dew Point	°C	Condensation and night cooling
10	Relative Humidity	Relative Humidity	%	Atmospheric transmission loss
11	Pressure	Atmospheric Pressure	mbar	Air mass & spectral correction factors
12	Wind Speed	Wind Speed (10m mast)	m/s	Convective module back-surface cooling
13	Wind Direction	Wind Direction	degrees	Array structural & thermal boundary layer
14	Albedo	Ground Surface Albedo	0.0 - 1.0	Bifacial PV rear-side gain calculation
15	Snow Depth	Snow Ground Accumulation	cm	Snow coverage & panel soiling loss

5. Peak Heating & Cooling Design Day Definitions (.ddy)

- **Standard Authority:** ASHRAE Technical Committee 4.2 / EnergyPlus Development Team.
- **Primary Application:** Peak heating and cooling HVAC load calculations, central plant equipment sizing, and coil capacity design.
- **Object Structure:** Plaintext EnergyPlus Input Data File (IDF) syntax containing SizingPeriod:DesignDay objects with ASHRAE Clear Sky optical depth parameters.

Design Condition Category	Statistical Threshold	Primary Design Application
Annual 99.6% Heating Dry-Bulb	Extreme Winter Minimum	Peak boiler, furnace, and heat pump heating coil sizing.
Annual 99.0% Heating Dry-Bulb	Standard Winter Minimum	Secondary heating baseline and zone radiator sizing.
Annual 0.4% Cooling DB / MCWB	Extreme Summer Peak DB	Chiller capacity, rooftop unit (RTU) sensible cooling coil sizing.
Annual 1.0% Cooling DB / MCWB	Standard Summer Peak DB	Standard commercial building air handling unit (AHU) sizing.
Annual 0.4% Dehumidification DP/MCDB	Extreme Peak Humidity	Dedicated Outdoor Air Systems (DOAS) and latent coil sizing.
Annual 0.4% Enthalpy / MCDB	Extreme Total Heat Content	Cooling tower, condenser water loop, and evaporative cooler sizing.

6. Daysim / Radiance Daylighting Weather Format (.wea)

- **Standard Authority:** Fraunhofer Institute for Solar Energy Systems (ISE) / Christoph Reinhart (Daysim).
- **Primary Application:** Dynamic Daylight Autonomy (sDA 300/50%), Annual Sunlight Exposure (ASE 1000,250h), and glare probability modeling.
- **File Layout:** Exactly 6 metadata header lines followed by 8,760 hourly solar irradiance rows (Month, Day, Decimal Hour, Direct Beam Irradiance, Diffuse Irradiance).

Line #	Header Keyword	Syntax & Description
1	place	Station geographic identifier (City, State/Country)
2	latitude	Station latitude in decimal degrees (North positive)
3	longitude	Station longitude in decimal degrees (East positive / West negative)
4	time_zone	Standard time zone meridian offset (degrees West of UTC, e.g. 105 for MST)
5	site_elevation	Elevation above sea level in meters
6	weather_data_file_units	Integer unit convention code (1 = W/m ² irradiance)
7 - 8766	Hourly Records	Month Day DecimalHour DirectNormalRad DiffuseHorizontalRad

7. Legacy NREL TMY2 ASCII File (.tm2 / .tmy)

- **Standard Authority:** National Renewable Energy Laboratory (NREL Report NREL/SP-463-7668).
- **Primary Application:** Legacy DOE-2.1E, eQUEST, Carrier HAP (v5), and TRNSYS simulation compatibility.
- **File Layout:** 1 header line followed by 8,760 hourly fixed-width records. Each record consists of exactly 126 ASCII characters without commas.

Character Position	Field Descriptor	Data Type & Format	Engineering Units
001 - 005	WBAN Station Number	5-digit integer	Station identifier
006 - 007	Year (2-digit)	Integer (e.g. 85 = 1985)	Observation year
008 - 009	Month	Integer (01 - 12)	Calendar month
010 - 011	Day	Integer (01 - 31)	Calendar day
012 - 013	Hour	Integer (01 - 24)	End-of-hour timestamp
014 - 017	Extraterrestrial Horizontal Rad	Integer	Wh/m ²
018 - 021	Extraterrestrial Direct Normal	Integer	Wh/m ²
022 - 025	Global Horizontal Radiation	Integer + 2-char flag	Wh/m ²
028 - 031	Direct Normal Radiation	Integer + 2-char flag	Wh/m ²
034 - 037	Diffuse Horizontal Radiation	Integer + 2-char flag	Wh/m ²
068 - 071	Dry-Bulb Temperature	Integer in tenths °C	0.1 °C (e.g. -125 = -12.5°C)
074 - 077	Dew-Point Temperature	Integer in tenths °C	0.1 °C
080 - 082	Relative Humidity	Integer (0 - 100)	%
085 - 088	Atmospheric Pressure	Integer in millibars	mbar (hPa)
091 - 093	Wind Direction	Integer (0 - 360)	degrees
096 - 098	Wind Speed	Integer in tenths m/s	0.1 m/s (e.g. 54 = 5.4 m/s)

8. Simulation Software Compatibility Matrix

The matrix below outlines the direct integration and native file format compatibility across major commercial engineering simulation software packages:

Discipline / Category	Target Software Package	Direct File Format	Ingestion Method & Usage Notes
Whole-Building Energy	EnergyPlus	EPW, DDY	Native simulation engine weather file via WeatherConverter or direct IDF object.
Whole-Building Energy	OpenStudio	EPW, DDY	Direct drag-and-drop into OpenStudio Application or Ruby SDK workflow.
Whole-Building Energy	IES Virtual Environment	EPW	Direct import into ApLocate for dynamic thermal and airflow modeling.
Whole-Building Energy	eQUEST / DOE-2	TMY2, EPW	Converted via eQUEST weather utility into .bin binary simulation format.
Solar PV & Storage	PVsyst	TMY3 (CSV), EPW	Imported into Meteo database for plane-of-array and shading simulation.
Solar PV & Storage	NREL SAM / PySAM	SAM (CSV), EPW	Direct load into location selection or programmatic API simulation pipeline.
Solar PV & Storage	HelioScope	TMY3 (CSV)	Upload custom weather file for commercial rooftop and utility-scale solar.
HVAC Equipment Sizing	Carrier HAP	DDY, EPW, TMY2	Design day import for peak coil sizing and 8,760-hour hourly energy analysis.
HVAC Equipment Sizing	Trane TRACE 3D Plus	EPW, DDY	Imported via BIM/IDF weather manager for central plant and zone sizing.
Daylighting & Glare	Daysim / Radiance	WEA	Direct native input for annual dynamic daylight autonomy (sDA / ASE) runs.
Daylighting & Glare	ClimateStudio / Honeybee	EPW, WEA	Direct Grasshopper / Rhino integration for daylight and thermal comfort simulation.
Legacy & Research	TRNSYS	TMY2, EPW	Modular transient system simulation for advanced thermal and renewable energy research.