The Design Reference Year

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Abstract

Design Reference Years are used as climatic input data for computer calculations -simulations - mainly of solar energy systems, and of building energy consumption, energy conservation, indoor climate and comfort.

They can be seen as a new generation of such data collections already known as Test Reference Years in Europe or Typical Meteorological Year or WYEC in US. The advantages of DRY's, compared to existing TRY's are:

- more correct monthly mean values and standard deviations for many parameters
- some new parameters not available in the existing TRY's
- new types of parameters, eg 5 minute values for direct normal radiation, or forecast information to be used with simulation of "intelligent" energy management systems.

This paper describes the news in the Design Reference Years. It is the outcome of a cooperation in IEA Solar Heating and Cooling Programme task 9, Solar Radiation and Pyranometry.

Two reports will be published within this year, one as a guide for producers of DRY, another as a model for national DRY users guides.

1. Introduction

A Design Reference Year (DRY) contains hourly climate data for a specific location, arranged as hourly sets of simultaneous climate parameters.

The basic requirements for a DRY (as for a TRY) are that it corresponds to an average year, both regarding monthly or seasonal mean values, and occurrence and persistence of warm, cold, sunny or overcast periods. It can be said in three requirements:

I true frequencies, i.e. as near as possible true mean values over a longer period, e.g. a month, and a natural distribution of higher and lower values for single days;

II true sequences, i.e. the weather situations must have a duration and follow each other like often-recorded courses for the location;

III true correlation between different parameters, i.e. temperature, solar radiation, cloud cover, wind etc.

Although the requirement of I) could be fulfilled by the generation of a synthetic year, from available mean values, standard deviations, etc., so far II) and III) could not be satisfied in this way, because many of the relations between individual parameters cannot yet be described mathematically.

Originally, the aim of the working group was to generate DRY's purely synthetic, that is

derived from statistical parameters, mean values, standard deviations, cross - and auto correlations etc.
This has not been possible to realize, because no methods was found which permit the generation of a DRY with many parameters. Two or three parameters are possible, but not many parameters.

Instead those methods used for generation of the CEC TRY's [1,2] has been used, followed by an adjustment procedure, which modify mean values and distributions of the most important parameters to values corresponding to the multiyear period from which the DRY is generated.

Ratto and Festa [3] have produced a large survey over "Solar Radiation Statistical Properties". It also contains analyses of selection methods for Test Reference Years. Ratto and Festa have also made proposals for improvements in such selection procedures.

There are however several acceptable selection methods, and the final quality of a DRY is to large extent determined by the quality control of the single climate parameters, before the selection, and before the adjustment, and in the resulting DRY.

2. Process

The production process shows three steps:

- A selection process, where the "best" periods, normally months, are selected from available machine-readable climatic data for the location. Preferably 10 years of data, or more, should be at hand.

- An adjustment process, where the selected "best" months are given the desired long term average values and distributions, and

- processes where needed but unavailable parameters are derived from existing data.

The selection process preceeds the adjustment process, the generation of other data, however, is to some degree interwoven in the selection or the adjustment.

Before the selection process can start two important initial steps must be taken:

- Selection of sites for which DRY should be created, and

- a careful check of the daily values of those parameters used in the selection process.

After the selection process hourly values used in the adjustment procedure must be checked especially regarding extreme values.

3. Selection of sites for Design Reference Years

A number of criteria must be considered for selection of sites for DRY. Desirable are:

A site with high activity economically and regarding construction. Town, or airport near to town.

Meteorological data available with an acceptable quality and for 10 years or more. The most recent period available should be used. Preferably hourly data, however, tri-hourly (synoptic) data can be used.

Sufficient data available, including global radiation, and diffuse radiation, sunshine duration or cloud cover and types to enable a generation of global, diffuse and direct normal radiation.
Use of stations with at least measured hourly global radiation is strongly recommended. Generation of hourly radiation data from sunshine duration or cloud cover is possible, but should be avoided for this purpose.

Sites shall be selected considering the orography (mountains, distance to oceans), population centers, distance to other DRY locations, and national climatological descriptions, and also, and that is normally the most important question, where measured climate data of good quality are available for many years.

After the successful production of a DRY, two limitations should be remembered:

- The DRY should not be considered as a climatological description of a specific town or a region. A DRY is merely a tool for calculations (simulations) with computer programmes.

- Within each region for which a DRY is valid there might be difference in climate, but generally the deviations from the locations for which DRY has been generated will be small compared with the deviations from year to year. Very particular orographic conditions (e.g. mountains), for a given location, make the DRY for that region less representative.

4. New parameters in the Design Reference Years

Toni Püntener made a questionnaire and produced a survey over data needed for different types of applications. Fig 1. shows the results.

Besides the parameters known from existing TRY's or TMY's some new parameters has been included in the model format for DRY. Fig 2, 3 and 4 shows the recommended format.

About some of the new parameters:

Illuminance

Illuminance is given in the same way as irradiance, as global illuminance on horizontal, diffuse illuminance on horizontal, and direct normal illuminance.

As illuminance is not normally available as measured data for those sites where the other parameters in the DRY are collected, the values are derived from the irradiance values and using solar zenith angle and clearness index, turbidity or other parameters.

Cloud cover

Cloud observations are processed to two parameters only: Total cloud cover, as N in the SYNOP - weather data, and an "Equivalent opaque cloud amount" in which high, partly transparent clouds are reduced with a factor 0,5, or with individual factors for the most common transparent cloud types for the location.

If cloud observations are not available for the location a computed value should be derived from the global radiation, at least for solar zenith angles < 80 degree, or from hourly sunshine. This cloud cover will be strongly related to the clouds in the vicinity of the position of the sun. That is permissible because the accuracy demands are normally low for the cloud data used in various application programmes, eg. for distribution of diffuse irradiance from the sky.

If cloud cover is to be used for generation of longwave irradiance from the sky, especially during the night hours the accuracy demands are higher stressed and real observations are desirable.

Cloud amounts are normally observed and recorded either in oktas or tenths. To get a common format independent of the original recordings, a scale 0-80 is used, giving also room for fractions of tenths or octas in the computed values "Equivalent opaque cloud amount".

Longwave downward irradiance

Longwave downward irradiance is important during night hours. During daytime it is normally masked by the shortwave diffuse radiation. It is normally not available as a easured value. It is therefore computed

Figure 1. Data demands for Design Reference Year for various applications.

Application Parameter	ACT	PAS	INC	BEN	BEC	ILL	PV	STS	POL	new DRY ?
(Year), month, day, hour	h	h	h	h	h	h	h	d	h	h
Dry bulb temperature	h	h	h	h	h		h	d	3	h
Daily max and min dbt		12	12							12
Ground temp.		d	d	d	d			d		
Vertical temp. profile,									3	?
or inversions										
Global irradiance	h	h	h	h	h	h	h	h		h
Direct and diffuse irrad.	m	h	h	h	h	h	h	h		m
Longwawe rad. or sky temp.	h	h	h	h	h			h		h
Spectral distribution							?		?	
or color temp.						h	h			h
Illuminance									3	
Turbidity		h	h							h
Total cloud amount		h	h	h	h					
Cloud type, 3 or 4 layers		3	3	3	(3)	3				
Cloud amount, lowest layer		(3)	3	(3)		3				
Equ. opaque cloud amount										
Dewpoint or wet bulb temp.										h
or rel. humidity		h	h	h	h					
Entalpi					h					
Wind speed and direction	h	h	h	h	h				h	h
Pressure			(h)		(h)					3
Surface conditions, snow		(d)	(d)	(d)	(d)					d
Weather type		3	3	3					3	3
Precipitation									d	
Visibility									3	
Forecasts, per 12 or 24 hour					d					d or 12

Applications:

ACTive Solar, PASsive Solar system
INdoor (thermal) Climate,
Building Energy calc. No cooling
Building Energy calc. with Cooling
ILLuminance, PhotoVoltaics
Seasonal Thermal Storages,
POLlution

Time interval:

h	hourly
(h)	hourly, less important data
3	synoptic data sufficient
12	12 - hour values
d	daily values
m	interval < 1 h eg 5 min, or variance each hour.

Figure 2. Design Reference Year Format, Tentative — Revised 1991-7-3

1. record, all hours, 100 characters

Pos		Freq.	Format	Col.
1.	Station name or number	h	A5	1-5
2.	Time indicator for rad. measurement	h	A1	6
3.	Dry bulb temperature, 0.1 deg C	h	I4	7-10
4.	Dew point temperature, 0.1 deg C	h	I4	11-14
5.	Global irradiance W/m^2	h	I4	15-18
6.	Diffuse irradiance W/m^2	h	I4	19-22
7.	Direct normal irradiance W/m^2	h	I4	23-26
8.	Downward longwawe irradiance W/m^2	h	I4	27-30
9-11.	Illuminance, global, diffuse and direct normal, lux	h	3I5	31-45
12.	Total cloud amount 0-80, observed	h	I2	46-47
13.	Equivalent opaque cloud amount 0-80	3 h or h	I2	48-49
14.	Sunshine duration, minutes	h	I3	50-52
15.	Wind direction, deka-deg	h	I2	53-54
16.	Wind speed 0,1 m/s	h	I3	55-57
17.	Indicator for special data	h	I2	58-59
18-29.	Special data		4I4,I2	60-91
30-31.	(Year), month, day	h	3I2	92-97
33.	Hour, local standard time, 01-24	h	I2	98-99
34.	Continuation, 0 or 1	h	I1	100

Figure 3. Special data, pos 17-29, tentative, example

Parameters:	Indicator	For hour
Synoptic data: e.g. pressure PPPP, weather WW, W1 and W2 Precipitation RRR, snowcover E	1	1,4,7 -- 22
Max. and min. temp. TXTXTX, TNTNTN plus synoptic data	3	7 and 19
Forecast for h 13 and h 19	5	9
for day + 1, h 1,7,13 and 19	6	11
for day + 2, h 1,7,13 and 19	7	12
for day + 3, h 1,7,13 and 19	8	15
for day + 4 and + 5, daily mean	9	17
Vertical temperature or stability	10	?

This group of data must be tailored to utilize locally available data as good as possible.

Figure 4. 2. record, for day hours only. 50 characters

Pos		Format	Col.
1.	Direct normal radiation, computed highest clear sky intensity for the hour, W/m²	I5,1X	1-6
2-13.	Computed 5 min. intensity, % of 1	12I3	7-42
14-16.	Month, day, hour	1X,3I2	43-49
17.	Continuation (here always 0)	I1	50

from dbt, humidity, cloud amount, types and height of various cloud layers. [4]. If cloud data are not available for night hours the cloud data must be extrapolated from the last evening hour or the first morning hour, or interpolated between them.

Forecasts

Forecasts can be used for the simulation of "intelligent" energy managements systems, preferably with short time horizons, 1-3 days.

Such forecasts should contain dry bulb temperature, windspeed and cloud amount. In regions, where air condition is frequently used, also a humidity parameter should be included in the forecast. The forecast data should be given as numerical values, and as they are delivered today from the National Meteorological Services.

Because the form of presentation has changed much in recent years, and the time horizon for the routine prognoses has grown to five days it might well happen that forecasts from 10 years old months does not fulfill the requirements, or cover five days.

An experienced meteorologist should be asked to create "forecasts" based on the then available parameters, and corresponding to todays forms.

Short time variations

Hourly values of climatic data are sufficient for todays common applications, but for active solar systems. For active solar systems with lightweight absorbers and suitable control systems, increased average efficiency are computed in simulations, as well as measured in reality, if short time - interval values of radiation are available.

Analyses by Skartveit and Olseth [5,6] has shown that especially for direct radiation there is a clear bimodality in cloudy weather - the sun is either visible or obscured - and this bimodality is practically the same for instantaneous values, through 30 sec averages, 2 min or 5 min averages. Average over more than 5 min reduces the bimodality. Although this 5 min limit might possibly be site - dependant we have chosen 5 min values of direct radiation as a sufficient short time interval.

Short time interval values are not normally available as measured data. They are computed using a model by Skartveit and Olseth, using the variation in hourly direct normal radiation.

Only direct normal radiation is given as 5 min values. The diffuse radiation can be considered constant, or interpolated between hourly values.

5. Participants

The participants in this group has been Lars Dahlgren, Swedish Meteorological and Hydrogogical Institute, R. Festa and C.F. Ratto, University of Genova, A. Skartveit and J.A. Olseth, University of Bergen, B. Aune, The Norwegian Meteorological Institute, Toni W. Püntener and K. Mathis, EMPA, Zürich, and H. Lund, Technical University of Denmark.

Besides the directly participating scientists valuable contributions has been delivered by Eugene Maxwell, SERI, Richard Perez, State University of New York, Frits Kasten and Gerhard Czeplak, MOH, German Weather Service, and other participant in the task 9 work.

6. Expected results

The products from this work will be:

i. Some "Demonstration Design Years", most likely for Bergen, Stockholm, Zurich, Ispra, Copenhagen and a US-station.

   It is not yet clear how many of these DDY will in fact also be the Design Reference Year, DRY, for the location. Some of the DDY's might be labelled "Tentative, for experimental use only".

ii. A "Design Reference Years Producers Manual" with the knowhow, computer programs and other information needed by those local producers, hopefully national authorities, who will produce and market DRY's for a country.

iii. A "Design Reference Years Users Manual" which can be used as a model, or not used, by the same local authorities who will produce DRY's. Local manuals should be in local language.

References:

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