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Multi-year and reference year weather data for building energy labelling in north Italy climates

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ABSTRACT

Representative weather information is essential for a reliable building energy performance evaluation. Even if detailed energy analyses can be carried out considering the multi-year weather data, generally a single reference year is adopted. Thus, this artificial year has to correctly approximate the typical multi-year conditions. In this work, we investigate the representativeness of the method described in the technical standard EN ISO 15927-4:2005 for the development of reference years. Energy performance of a set of different simplified buildings is simulated for 5 north Italy locations using TRNSYS. The energy needs computed using the reference year are compared to those of a multi-year simulation. The annual variability of energy results for the studied thermal zones is investigated, paying attention to its effects on the building envelope energy ratings according to a proposed classification. Also, those configurations more influenced by the annual weather changes are identified by means of statistical indexes. The analyses demonstrate that the representativeness of the reference year results can vary significantly in the considered locations—and, consequently, the accuracy in building energy assessment and classification can be reduced, especially for some building envelope configurations.

1. Introduction

In many building design applications, the use of simplified calculation methods for the evaluation of the energy consumption cannot provide results detailed enough for advanced investigations. For instance, these approaches are not suitable to achieve both high energy efficiency and adequate visual and thermal comfort for the occupants. Consequently, the recourse to the detailed building energy simulation (BES) tools by professionals is becoming more and more frequent. The higher capability in calculating detailed outputs requires more complex and detailed inputs [1]. As regards the weather data, the datasets of monthly mean values used in simplified methods, such as those of dry bulb temperature, solar radiation and relative humidity in the Italian standard UNI 10349:1994 [2], are not sufficient for detailed simulation tools, which generally require at least an hourly discretization of the weather data inputs. The problem of the development of weather data for BES has been widely investigated in the literature and Barnaby and Crawley discussed and presented the main aspects, contexts and issues related to their definition [3].

We can distinguish three kinds of data for dynamic simulation [4]:

- multi-year weather data;
- typical or reference years;
- representative days.

The multi-year weather data are the best solution in trend and sensitivity analyses of building performance to the variability of the weather conditions, especially if aimed at a design robust to climatic changes [5]. Typical weather data years are simply a single year of hourly data representative of the profiles recorded in a multi-year dataset. The representative days are hourly data for some average days descriptive of the typical climatic conditions (e.g., summer conditions). Simulations with typical years (or representative days) instead of multi-year weather data lead to less information but they are less time-consuming and results are easier to manage [6,7]. They are also preferred to mitigate the effects of missing or wrong data in the collected series. Eventually, typical years are also necessary for assessing the building energy

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Nomenclature

Symbols

α	solar absorptance (–)
Δ	parameter deviation with respect to the reference values computed by means of TRY_{EN}
θ	temperature (K)
λ	thermal conductivity ($W\,m^{-1}\,K^{-1}$)
ρ	density ($kg\,m^{-3}$)
Φ	cumulative distribution function of variable daily means within the whole historic series of the calendar months (–)
A	surface (m^2)
CDD	cooling degree days (K d)
c	specific heat ($J\,kg^{-1}\,K^{-1}$)
EP	energy performance of the building envelope (GJ)
F	cumulative distribution function of variable daily means within the whole days of the calendar month of a specific year (–)
F_S	Finkelstein–Schafer statistics (–)
HDD	heating degree days (K d)
H	solar radiation ($MJ\,m^{-2}$)
h	heat transfer surface coefficient ($W\,m^{-2}\,K^{-1}$)
I	solar irradiance ($W\,m^{-2}$)
IQR	interquartile range
J	rank order of variable daily means within the month of a specific year (–)
K	rank order of variable daily means for a calendar month within all years of the series (–)
k	areal heat capacitance of an envelope components ($kJ\,m^{-2}\,K^{-1}$)
m	specific calendar month analyzed in the TRY_{EN} calculation procedure (–)
N	total number of days for a specific calendar month within the whole historic series (–)
n	number of days for a specific calendar month (–)
p	weather variable used in the TRY_{EN} calculation procedure (–)
$Q_{1/3}$	first or third quartile
R	thermal resistance ($m^2\,K\,W^{-1}$)
R_R	maximum energy performance for new construction in a specific climate zone ($GJ\,yr^{-1}$)
R_S	national or regional average of building stock heating demand ($GJ\,yr^{-1}$)
RH	relative humidity (%)
s	thickness (m)
SHGC	solar heat gain coefficient (–)
TRY	test reference year (–)
t	time shift of the envelope components (h)
U	thermal transmittance ($W\,m^{-2}\,K^{-1}$)
Y	periodic thermal transmittance of an envelope component ($W\,m^{-2}\,K^{-1}$)
y	select year of the historical series

Subscripts

EN	calculation procedure of European standard EN ISO 15927-4:2005
e	external surface of the envelope or external environment
env	area weighted average of a variable
fr	referred to window frame
gl	referred to window glazing plane
hor	horizontal surface
i	internal surface of the envelope
se	envelope external surface
sol–air	referred to sol–air temperature
sky	referred to sky dome
win	referred to window

performance under standard weather reference conditions, which are expected to be representative of the multi-year series in a given location. Some previous studies observed that the variability of buildings annual energy uses are less than 10 % in the multi-year period—between 4 % and 6 % for U.S. climates [8,9] or 4.6 % for Hong Kong [10]. Although the previous studies are valid only for the climatic context and buildings analyzed, they indicate that a single reference year can generally be used to express the typical energy performance.

The reference years have been defined in different ways in the last decades. One of the first definitions was given for 60 American localities [11]: the test reference year TRY was an actual year selected using a process where years in the period 1948–1975 with extremely high or low mean dry bulb temperatures were progressively eliminated until only one year remained. Crawley [12] recommends using the typical meteorological years (TMY), the European test reference years [3] or other typical years built according to similar procedures instead of the original TRY of 1976. In these cases the reference year is an artificial year composed of 12 months selected as the most representative in the multi-year series. One of the first definitions of the typical year was given by Hall et al. [13]. According to Lund [14–16] and Lund and Eidorff [17], they have to be characterized by:

- true frequencies (i.e., the reference year should be a good approximation of the mean values derived from a long period of measurements);
- true sequences (i.e., the weather situations must follow each other in a similar manner to the recorded data);
- true correlations (i.e., the weather data are cross-correlated variables).

The last feature is probably one of the most important [18].

In the literature many approaches are available and there is not a single procedure accepted for the construction of a reference year [19]. Each method starts from the calculation of some statistics of the weather variables (e.g., mean dry bulb temperature, daily solar radiation) for the selection of the representative month from the collected data [13]. The relative importance of the different variables is given by weighting factors, whose selection should be made considering the final use of the reference year, for instance distinguishing sizing from energy assessment [20]. Most of the approaches are based on the Finkelstein–Schafer statistic [21], with the exception of the method by Festa and Ratto [22], which implements the Kolmogorov–Smirnov statistic. Among the methods there is no agreement on the number of weather parameters to use. For instance, as observed by Argiriou et al. [23], nine weather parameters were considered in the SANDIA method [13], while seven were considered in the "Danish method" [17,24] and five were considered in the method by Festa and Ratto [22]. Moreover, there is no general agreement on the weighting factors for the weather variables and some authors remarked that they should be based also on the type of building analyzed [25].

Different methods and groups of weighting factors for the determination of the reference year were compared by many authors, considering the average results of the multi-year series as benchmark. Weather statistics, solar fraction of thermal solar systems,