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The new Italian climatic data and their effect in the calculation of the energy performance of buildings

Giovanni Murano[a]*, Vincenzo Corrado[a], Domenico Dirutigliano[a]

[a]Department of Energy, Politecnico di Torino, C.so Duca degli Abruzzi 24, Torino 10129, Italy

Abstract

Reference climatic data have been available since the early 90s in order to ensure uniformity of assessment and repeatability of energy performance calculations: they include monthly means of meteorological elements, as reported in national standards. Other climatic data were provided by ENEA for the period 1995-1999. More recently, new test reference years, representing the basis of UNI 10349 update, were made available by CTI. Some discrepancies between the old and the new sets of data appear.
For some reference NZEBs, this paper presents the analysis of the effects of the climatic data on the calculation of energy performance of buildings.

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Keywords: energy performance assessment; simplified energy model; climatic data.

1. Introduction

The Directive 2010/31/UE [1] promotes the improvement of the energy performance of buildings within the European Union, taking into account outdoor climatic and local conditions, as well as indoor climate requirements and cost-effectiveness. It requires that after 31 December 2018, new buildings occupied and owned by public authorities must be nearly zero-energy buildings, and from 31 December 2020, all new buildings must be nearly zero energy buildings. In this context, the great importance of reliable climate data is recognized.

Weather data play an important role in the estimated energy savings, as they are important inputs required to simulate the thermal behavior of buildings and can have a significant impact on the output of the simulation. Weather data can influence the building performance in several ways: for example, dry bulb temperature and solar radiation

* Corresponding author. Tel.: +39-011-090-4543; fax: +39-011-090-6329.
E-mail address: giovanni.murano@polito.it

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influence the heating and cooling loads while relative humidity affects the latent load of the building and sizing of HVAC equipment.

The weather plays a significant role as it directly influences the thermal loads and thus energy performance of buildings. The weather conditions influence the energy balance of buildings for:

- Solar heat gains derived from opaque and glazed walls;
- Temperature difference (ΔT) induced transmission through the envelope and ventilation enthalpy flow (sensible part);
- Air infiltration induced by pressure difference caused by stack effect (ΔT induced) and by wind effect;
- Convective surface heat transfer (wind, ΔT);
- Radiative surface heat transfer (equivalent black body sky temperature);
- Ventilation enthalpy flow (latent part) due to outdoor-indoor moisture content difference.

Given the spatial variability of the climate, the energy performance requirements of NZEBs provided by the national legislation [2] are different for climatic zones. The energy performance for new buildings, or buildings to be renovated, is based on the reference U-values and other parameters as prescribed by the law. In Italy, since 1994, the buildings have been designed using the national standard UNI 10349 [3] that reports monthly means of single meteorological elements (temperature of air, water vapor pressure, reference wind speed, global solar irradiation, direct solar irradiation, diffuse solar irradiation). The Standard provides conventional climatic data needed for design and verification of both buildings and heating and cooling thermal systems. The data utilized to compile it date back to the period 1951–1970, they are determined by stations for the acquisition of climate data equipped with low accuracy sensors or even lacking at all as far as solar radiation is concerned [4]; consequently, it was necessary to update this database by means of models. Furthermore, the data acquired during this period do not respect the rules and the advice on good practices for meteorological measurements and observations elaborated by the Meteorological Instruments and Methods of Observation WMO [5] as required by the new standards developed by ISO and CEN [6].

In 2016, a new version of the standard UNI 10349 divided into three parts has been published. The standard UNI 10349-1:2016 [7] contains monthly average data calculated from test reference years developed by CTI for 110 Italian locations. Therefore, at national level, there are two different official archives that are mutually consistent for determination of building energy performance in the context of the EPBD. The first is the standard UNI 10349-1:2016 [7] that reports climate monthly average data as used in the steady state method given in EN ISO 13790 [11], the second is the archive of the test reference years with hourly values used in dynamic simulation procedures. The paper investigates the effect of different climate datasets on the results of energy performance assessment, focusing on the comparison between old data sets and new data sets rather than on the effect of the type of numerical model (e.g. dynamic, stead-state). Firstly, a climate analysis was conducted on all Italian localities using different climatic sources as regards temperature, wind velocity, humidity, and solar radiation monthly-averaged data. Secondly, a test on a reference residential building NZEB located in all Italian localities was performed to evaluate the effect of the differences between the analyzed databases on the results of energy performance calculated in accordance with the quasi-steady-state method [12]. Finally, a test on the same building located in seven Italian localities, Catania, Palermo, Bari, Ancona, Roma, Milano and Torino was performed to evaluate the effect of Test Reference Year difference on the results of dynamic energy simulations using Design Builder with Energy Plus code.

The main symbols and nomenclature used in the text are provided below.

Nomenclature

$EP_{C,nd}$	Thermal performance for cooling	[kWh/m^2]
$EP_{H,nd}$	Thermal performance for heating	[kWh/m^2]
$g_{gl,n}$	Total solar energy transmittance for normal incidence	[-]
H_{tot}	Global solar radiation on a horizontal surface	[MJ/m^2]
κ_i	Internal areal heat capacity	[kJ/(m^2·K)]
t	Temperature	[°C]
U	Thermal transmittance	[W/(m^2·K)]
U_W	Thermal transmittance of window	[W/(m^2·K)]
x	Ratio of the mass of water vapour to the mass of dry air with which the water vapour is associated	[g/kg]

2. Climatic Data

Detailed and reliable climatic data are important for technicians to properly face very common energy issues like evaluating the energy performance of buildings (for example for the preparation of energy performance certificates for buildings) or for the design of renewable energy systems [2]. For this reason, a comparative analysis of three official databases has been carried out with the aim to highlight the main differences.

The national standard UNI 10349-1 [7] reports the monthly means of the following climate data: external air temperature; incident solar irradiation on a horizontal surface; wind speed; water vapor pressure of external air.

The EnergyPlus weather data for the Italian cities, available today, refer to two sources: the International Weather for Energy Calculation (IWEC), typical weather files © 2001 ASHRAE, and the Italian Climatic data collection "Gianni De Giorgio" (IGDG), based on recorded data from 1951-70 period.

In 2016 CTI has drawn national Typical Meteorological Year (NTMY) for all locations [11], they can be used for the detailed simulation and include the following data: hourly external air temperature, direct normal solar irradiance and diffuse solar irradiance on a horizontal surface; wind speed; relative humidity of external air.

UNI 10349-1 [7] and NTMY are mutually consistent. In fact, the average climate data of UNI 10349-1 are calculated from the national Typical Meteorological Year [8].

Therefore, while the previous standard UNI 10349:1994 [3] shows average data calculated over the long term, the new standard UNI 10349-1:2016 contains data that are been calculated from test reference year processed according EN ISO15927-4 [16]. Figs. 1-3, show, for all Italian locations, a comparison of the total global solar radiation on a horizontal surface for the full year, average annual temperature, and humidity by mass for the full year, respectively. Each point represents an Italian locality while, the dashed line represents the perfect correspondence between the data sources analyzed. The Figs take into account the following sources a) UNI 10349:1994 [3], b) database ENEA (1995-1999) [12] and c) files EPW (IWEC, IGDG) [13].

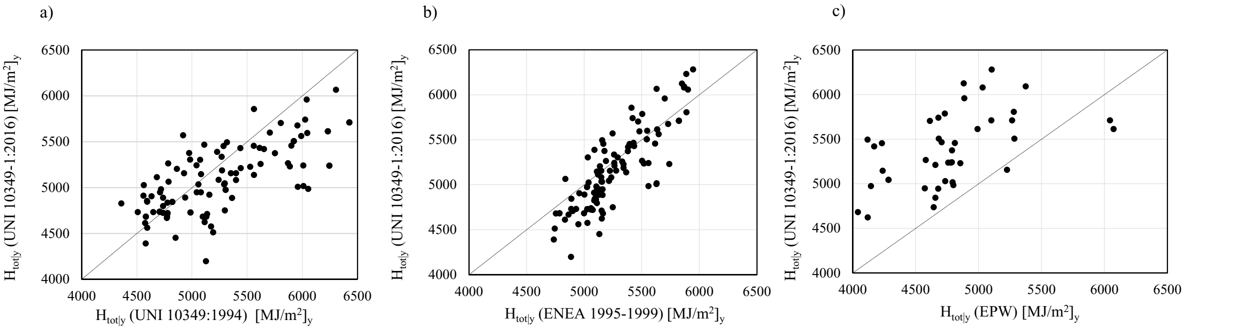

Fig. 1. Total annual global solar radiation. (a) UNI 10349:1994 vs. UNI 10349-1:2016 (b) Archive ENEA 1995 – 1999 vs. UNI 10349-1:2016 (c) files EPW vs. UNI 10349-1:2016.

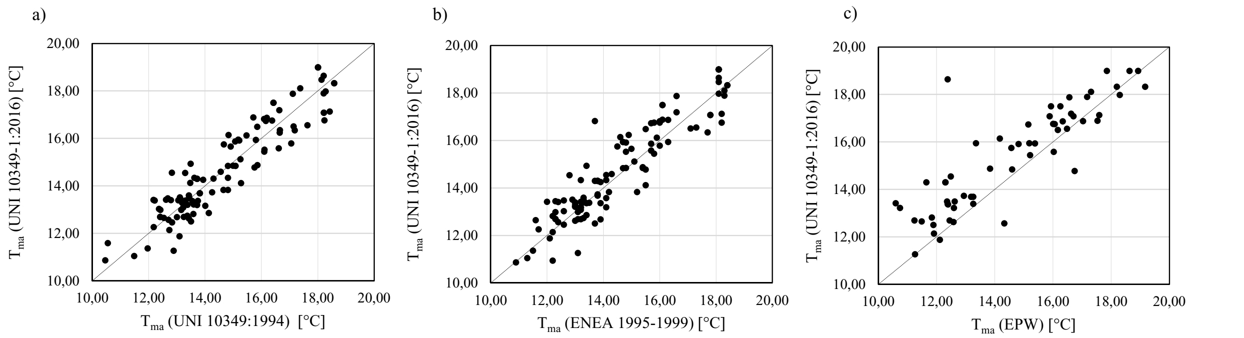

Fig. 2. Average annual temperature (a) UNI 10349-1:2016 vs. UNI 10349:1994 (b) UNI 10349-1:2016 vs. Archive ENEA 1995 - 1999 (c) UNI 10349-1:2016 vs. files EPW

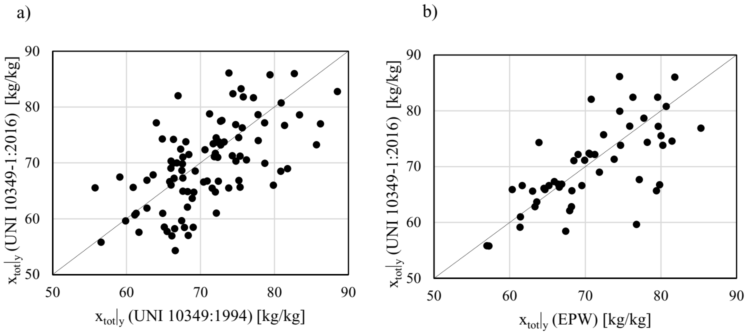

Fig. 3. Humidity by mass for the full year (a) UNI 10349-1:2016 vs. UNI 10349:1994 (b) UNI 10349-1:2016 vs. files EPW

More in detail, Tables 1-3 show the deviation (minimum and maximum) between the data of UNI 10349:1-2016 [3] and UNI 10349:1994 [7]. The analyzed climatic parameters are average monthly temperature (Table 1), average monthly global solar radiation (Table 2) and average humidity by mass (Table 3). The number of locations examined varies for each climate zone based on the locations available in the standards. For the Climatic Zone F only two locations (Cuneo and Belluno) are available.

Table 1. Deviation of the average monthly temperature. UNI 10349-1:2016 vs. UNI 10349:1994.

Climatic Zone	Deviation [°C]	Number of locations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
A/B	Minimum	8	-0,5	-1,9	-1,7	-1,8	-1,7	-2,4	-3,2	-2,8	-2,3	-1,3	-0,8	-1,2
	Maximum		1,2	1,1	0,5	1,3	1,7	1,6	1,6	1,8	0,5	1,0	0,8	1,8
C	Minimum	16	-1,5	-1,5	-1,8	-1,5	-1,3	-1,6	-2,1	-1,9	-2,9	-2,4	-3,0	-1,2
	Maximum		3,0	0,9	1,8	1,4	2,4	2,2	2,8	2,6	0,8	1,6	2,4	1,7
D	Minimum	29	-1,3	-2,4	-1,5	-1,3	-0,7	-2,1	-1,9	-3,9	-2,9	-2,4	-1,5	-2,5
	Maximum		3,8	3,2	2,3	1,2	2,3	2,0	1,8	1,7	0,8	1,8	1,7	2,1
E	Minimum	45	-2,4	-1,9	-1,5	-2,8	-1,3	-1,5	-3,3	-3,3	-2,7	-2,3	-1,8	-2,6
	Maximum		4,6	2,9	2,9	2,7	2,9	3,8	2,1	1,7	1,2	1,8	1,3	2,7
F	Minimum	2	-2,4	-1,8	-1,3	-1,8	-0,2	0,0	-1,1	-1,3	-2,9	-2,1	-3,3	-2,4
	Maximum		-0,5	-0,4	0,1	-1,5	0,8	0,9	0,2	-0,7	-1,5	-0,6	-0,6	-1,7

Table 2. Deviation of the average monthly global solar radiation. UNI 10349-1:2016 vs. UNI 10349:1994.

Climatic Zone	Deviation [MJ/m^2]	Number of locations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
A/B	Minimum	8	-1,1	-2,1	-2,7	-3,6	-4,1	-5,7	-4,9	-4,5	-4,4	-1,8	-1,0	-1,1
	Maximum		2,3	1,1	0,8	-0,7	-0,1	-0,9	-0,5	-1,1	-1,8	0,7	1,1	0,8
C	Minimum	16	-1,9	-2,8	-3,7	-4,3	-5,4	-4,9	-5,7	-4,2	-4,3	-2,8	-2,0	-1,5
	Maximum		0,5	1,1	-0,2	0,4	2,7	1,4	2,1	4,0	0,6	0,7	1,3	0,7
D	Minimum	29	-2,2	-2,6	-2,7	-3,6	-2,8	-4,2	-5,1	-4,0	-3,9	-3,7	-2,7	-1,9
	Maximum		1,0	1,4	2,0	1,7	3,6	4,7	2,6	3,0	1,7	1,4	1,0	1,5
E	Minimum	45	-1,3	-1,0	-2,4	-4,2	-3,6	-4,4	-5,1	-3,4	-3,8	-2,5	-1,7	-2,1
	Maximum		2,7	2,2	2,2	3,8	3,0	3,9	4,1	3,9	3,0	1,8	1,6	1,4
F	Minimum	2	-0,1	0,5	-0,2	-0,6	-1,0	-0,7	-2,5	-1,4	-0,8	-0,3	-0,6	-0,3
	Maximum		0,4	1,4	2,0	1,5	1,9	2,4	2,1	2,9	2,0	0,5	0,5	-0,2

Table 3. Deviation of the average monthly humidity by mass. UNI 10349-1:2016 vs. UNI 10349:1994.

Climatic Zone	Deviation [g/kg]	Number of locations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
A/B	Minimum	8	-1,4	-1,3	-2,1	-1,5	-1,4	-2,1	-4,8	-3,9	-2,4	-1,2	-1,1	-0,7
	Maximum		1,2	1,5	1,4	1,3	1,3	1,3	4,1	2,0	3,9	3,9	1,4	2,7
C	Minimum	16	-1,5	-0,9	-1,1	-3,0	-2,1	-3,3	-4,4	-3,2	-2,6	-1,2	-2,1	-2,0
	Maximum		1,6	1,1	1,8	2,4	2,7	5,4	3,3	2,1	1,1	2,2	2,1	1,5
D	Minimum	29	-1,4	-1,8	-0,8	-0,9	-2,7	-4,0	-4,9	-3,1	-3,3	-2,9	-2,9	-3,1
	Maximum		1,3	0,6	1,5	1,6	4,9	4,0	3,0	2,3	1,8	2,6	1,8	0,6
E	Minimum	45	-1,4	-2,6	-2,4	-2,7	-2,6	-4,3	-4,0	-4,1	-5,1	-2,2	-2,1	-2,1
	Maximum		1,7	1,1	2,0	1,2	2,4	3,2	2,7	3,4	1,4	1,9	1,4	1,1
F	Minimum	2	-0,5	-0,5	-0,6	-1,0	-0,3	-0,1	-1,0	0,5	-0,6	-0,7	-1,3	-0,7
	Maximum		-0,5	-0,2	-0,2	-0,5	0,0	1,8	1,1	0,6	-0,4	-0,6	-0,2	-0,7

3. Case study

The case study is a two-floor residential building. As it regards the geometrical, technological and construction characteristics, it can be considered as representative of a new NZEB, specifically a single-family house in Italy. The conditioned space has a compactness ratio (envelope surface-to-heated volume) equal to 0,72 $m^{-1.}$ The conditioned floor area is equal to 161 m^2. The volume of conditioned zones is 429 m^3. As regards the envelope system, it was selected an externally insulated massive envelope technology that changes for each climate zone as to satisfy the minimum requirements defined by M.D. 26/06/2015 [2]. The absorption coefficient for solar radiation of the opaque part is equal to 0,6. All windows have double or triple glazing with a thickness variable as a function of climatic zone and the thermal transmittance U_w of the entire opening (glasses and frame) is variable. It is provided the use of curtain (outside white venetian blinds) for all orientations except for the North side. More details are given in the Table 4 that shows data determined with the standards EN ISO 6946 [9], EN ISO 13786[10] and EN ISO 13790 [11] and in table 5 that reports the main geometric characteristics of the building.

Table 4. Thermo-physical properties of the case study envelope

		Zone A/B HDD≤ 900	Zone C 900<HDD≤ 1400	Zone D 1400<HDD≤ 2100	Zone E 2100<HDD≤ 3000	Zone F HDD>3000
Walls	U [W/m^{2}K]	0,43	0,34	0,29	0,26	0,24
	κ_i [kJ/(m^{2}K)]	50,10	49,78	49,58	49,48	49,43
Roof	U [W/m^{2}K]	0,35	0,33	0,26	0,22	0,20
	κ_i [kJ/(m^{2}K)]	69,51	69,49	69,42	69,36	69,34
Ground floor	U [W/m^{2}K]	0,44	0,38	0,29	0,26	0,24
	κ_i [kJ/(m^{2}K)]	65,39	65,44	65,50	65,51	65,52
Windows	U_W [W/m^{2}K]	3,00	2,20	1,80	1,40	1,10
	$g_{gl,n}$ [-]	0,67	0,67	0,67	0,67	0,67

The U-values are considered including the effect of thermal bridges

Table 5. Main geometric characteristics of the building (internal measures)

	South oriented [m^2]	East oriented [m^2]	North oriented [m^2]	West oriented [m^2]	Horizontal [m^2]
Transparent envelope	6,16	6,80	9,20	3,40	-
Vertical opaque envelope outwards	17,06	42,21	42,12	44,80	-
Vertical opaque envelope towards unheated spaces	23,22	-	-	-	-
Vertical opaque envelope to unheated attic	5,73	9,69	-	7,96	-
Ceiling to unheated attic	-	-	-	-	64,66
Ground floor	-	-	-	-	77,48
Roof slab					13,44
Total	69,82	49,01	51,32	48,20	

4. Calculation models

To quantify the effect of the new Italian climatic data [7] in the calculation of the energy performance of buildings, two calculation approaches were used in this study: quasi-steady-state calculation method and dynamic simulation.

The quasi-steady-state calculation method, specified in the technical specification UNI/TS 11300-1:2014 [16] and based on the standard EN ISO 13790 [14] to determine the net energy need for space heating and cooling, evaluates the steady state balance of heat losses (transmission and ventilation) and heat gains (solar and internal) in average monthly conditions. The dynamic effects on the net heating and cooling energy needs are taken into account by introducing dynamic parameters, such as the utilization factors, that accounts for the mismatch between transmission plus ventilation heat losses and solar plus internal heat gains; and an adjustment of the set point temperature for intermittent heating/cooling or set-back [15].

The dynamic simulation was conducted by means of *EnergyPlus* (version 8.3). It is a modular building energy analysis and thermal load simulation program, developed by the DOE research labs (DOE, US Army Construction Engineering Research Lab, Illinois Univ., LBNL, Ocklaoma Univ.,Gard Analytics) [13]. The building thermal zone calculation method of *EnergyPlus* is an air heat balance solution method, based on the assumptions that, by default, the temperature of the air in the thermal zone and of each surface are uniform, the long and short-wave irradiation is uniform, the surface irradiation is diffusive and the heat conduction through the surface is one-dimensional. The geometrical model of the building was developed in *DesignBuilder* (version 4.7.0.027) which presents a simplified interface for *EnergyPlus* simulation.

The simulations with quasi-steady-state calculation method were run for all the Italian locations using data from UNI 10349:1994 [3] and UNI 10349-1:2016 [7]. Other simulations, realized with *EnergyPlus,* were run for seven Italian locations, characterized by different weather conditions: Catania, Palermo, Bari, Ancona, Roma Milano and Torino.The hourly weather data of the locations, got from U.S. DOE [13] and CTI NTMY [11] (Italian Thermo-technical Committee), were used in the dynamic simulation.

5. Results

The results of quasi-steady-state calculation method show important deviations between the results of UNI/TS 11300-1:2014 [16] using the climatic data of the UNI 10349:1994 [3] and UNI 10349-1:2016 [7] respectively. The analysis takes into account changes both in terms of energy consumption for heating and cooling.

Fig. 4 shows, for all Italian locations of the standard, a comparison of energy performance in the heating (a) and cooling (b) season, respectively. Each point represents an Italian locality.

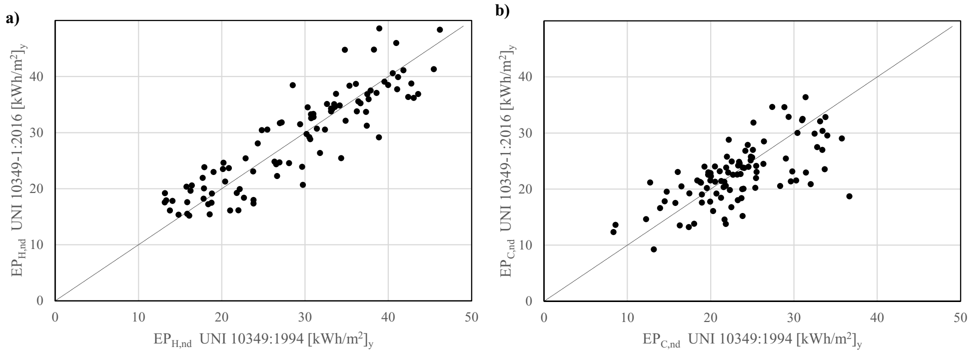

Fig. 4. Energy performance in the heating (a) and cooling (b) season. Comparison between UNI 10349-1:2016 and UNI 10349:1994

In Table 6 are reported, for each climate zone, the percentage rate of variation (minimum and maximum, determined on all set of localities available in the standards) between the energy performance calculated using the climatic data of the technical national standards UNI 10349:1994 and UNI 10349-1:2016, respectively. The comparison shows that the differences found between data reach 65,93% for cooling (PN) and 45,30 % (CA) for heating.

Table 7 summarizes the results of the simulation analysis conducted by means of EnergyPlus using the Typical Meteorological Year CTI (NTMY) and the TMY of DOE and provides the annual energy need in terms of heating and cooling. $EP_{C,nd}$ calculated with the CTI NTMY is always higher than that calculated with DOE TMY. For the cooling season the differences are between 40,11% and about 200%. The latest value refers to Bari where the altitudes of the weather stations have the maximum difference. Instead, the $EP_{H,nd}$ are always higher with DOE.

Table 6. Percentage deviations between the results of the state steady calculations (UNI/TS 11300-1:2014) using the climatic data of UNI 10349:1994 and of UNI 10349-1:2016

Climatic Zone	HDD	Deviation sign	Number of locations	Locality with $EP_{H,nd}$ highest deviation			Locality with $EP_{C,nd}$ highest deviation		
				Locality	$EP_{H,nd}$	$EP_{C,nd}$	Locality	$EP_{C,nd}$	$EP_{H,nd}$
A/B	HDD≤ 900	Negative	8	KR	-24,64%	11,82%	AG	-49,05%	20,57%
		Positive		SR	34,16%	-3,27%	PA	19,78%	-5,71%
C	900<HDD≤ 1400	Negative	16	IM	-26,77%	5,93%	CS	-34,90%	16,46%
		Positive		CA	45,30%	-22,45%	LT	29,69%	-10,19%
D	1400<HDD≤ 2100	Negative	29	FI	-30,54%	26,52%	NU	-36,41%	22,58%
		Positive		AP	34,64%	-16,42%	FI	26,52%	-30,54%
E	2100<HDD≤ 3000	Negative	45	VI	-25,98%	14,13%	TN	-37,00%	28,59%
		Positive		TN	28,59%	-37,00%	PN	65,93%	-9,80%
F	HDD>3000	Negative	2	CN	7,05%	19,04%	BL	-30,13%	24,65%
		Positive		BL	24,65%	-30,13%	CN	19,04%	7,05%

Table 7. Results of the simulation conducted by means of EnergyPlus using the Typical Meteorological Year CTI (NTMY) and the TMY of DOE

Climatic Zones	Locations	Geographic coordinates DOE Lon.	Lat.	Elev.	Geographic coordinates NTMY Lon.	Lat.	Elev.	$EP_{C,nd}$ [kWh/m²]$_y$ DOE	NTMY	$\Delta EP_{C,nd}$ [%]	$EP_{H,nd}$ [kWh/m²]$_y$ DOE	NTMY	$\Delta EP_{H,nd}$ [%]
B	Catania	15,05	37,47	17	15,07	37,50	7	9,28	14,46	55,87%	10,79	5,59	-48,18%
	Palermo	13,10	38,18	21	13,34	38,11	14	10,64	17,76	66,88%	5,34	4,72	-11,64%
C	Bari	16,75	41,13	49	16,85	41,12	5	9,16	15,85	73,12%	15,77	13,86	-12,07%
	Bari	16,93	40,77	350	16,85	41,12	5	5,30	15,85	199,08%	23,98	13,86	-42,19%
D	Ancona	13,37	43,62	10	13,51	43,60	16	8,71	17,05	95,87%	22,92	15,83	-30,93%
	Roma	12,50	41,95	24	12,48	41,91	20	12,91	20,06	55,43%	13,56	9,92	-26,83%
E	Milano	9,27	45,45	104	9,18	45,48	122	13,00	18,21	40,11%	27,61	18,69	-32,33%
	Torino	7,65	45,22	287	7,68	45,08	239	10,10	15,97	58,10%	29,23	24,53	-16,09%

6. Conclusion

The outdoor climatic data are an important factor in the assessments of the energy performance of buildings: they affect both the heat transfer through the building envelope, and the size and the efficiency of HVAC systems and of thermal and photovoltaic solar systems.

In order to evaluate the buildings that have a very low amount of energy covered to a very significant extent by energy from renewable sources (NZEB), detailed models under dynamic conditions and reliable and accurate climatic data are necessary. The analysis has showed that the sources of climate data currently available lead to results in terms of energy performance of a nearly zero-energy building that, in some cases, can be very different from each other. Nevertheless, in Italy as intended by the national legislation, the design of NZEBs will take place with the use of the national standard UNI 10349-1:2016.

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