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ScienceDirect

Energy Procedia 101 (2016) 200 – 207

Energy Procedia

71st Conference of the Italian Thermal Machines Engineering Association, ATI2016, 14-16 September 2016, Turin, Italy

Verification of the new Ministerial Decree about minimum requirements for the energy performance of buildings

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Abstract

The Italian Ministerial Decree 26/06/2015 specifies the requirements of nearly zero-energy buildings (nZEBs) and demands that the energy performance of the new building is compared with that of a *reference* or *target building*, which has the same location, function, size, but reference insulation level and technical systems efficiencies.
The research aims both to investigate the technical feasibility of design solutions complying with the legislative requirements and to verify the *reference building* approach. The analysis is applied to a residential building in three Italian climatic zones. The calculations are conducted by means of quasi-steady (UNI/TS 11300) and dynamic (*Energy Plus*) methods.

Peer-review under responsibility of the Scientific Committee of ATI 2016.

Keywords: nearly zero-energy building; energy performance requirements; quasi-steady state calculation method; dynamic numerical simulation

1. Introduction

The Italian Ministerial Decree 26/06/2015 on the "*Application of the energy performance calculation methods and establishment of prescriptions and minimum requirements of buildings*" [1] (MD) entered into force in October 2015. It implements the national law no. 90/2013 [2] which transposes the Directive 2010/31/EU (EPBD recast) [3] in Italy, by modifying and integrating the legislative decree no. 192/2005. The MD sets the methodology for calculating the energy performance of buildings and establishes the minimum energy performance requirements of

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Peer-review under responsibility of the Scientific Committee of ATI 2016.
doi:10.1016/j.egypro.2016.11.026

buildings and building units. It introduces new prescriptions, both for new buildings and for the energy refurbishment and renovation of existing buildings. It also specifies the requirements of nearly zero-energy buildings (nZEBs) that will be applied to new buildings and major renovations from 1st January 2019 for the public buildings and from 1st January 2021 for all the other buildings. As defined by the EPBD recast, a nearly zero-energy building is "*a building that has a very high energy performance [...]. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby*" [3].

In compliance with the decree, during the design phase many parameters must be checked, ranging from the features of single components to energy performance (EP) indicators regarding the whole building. In the latter case, the building energy performance requirements are based on the comparison between the building and a *reference* (or *target*) *building*, which has the same location, function, size, but with parameters replaced by reference values.

The research aims to investigate the applicability of the MD for the verification of the nZEBs energy performance requirements, pointing out its limits and strengths. This is a topic widespread in the research community: many international studies deal with analysis of legislative documents with several goals, e.g. to verify impacts of requirements on technology progress, to investigate issues of harmonization, to identify methodologies for requirements definition. In this context, Papamanolis [4] studied the impact of the implementation of the new legislation on the progress of renewable energy applications in buildings in Greece. Rodríguez-Soria et al. [5] compared the requirements of residential buildings by various countries of the European Union and the USA, and discussed the causes of the divergences and their degrees of disparity. Szalay et al. [6] set up a method suitable for developing building energy regulation threshold values, certification schemes or benchmarking values.

In the present article, the following aspects related to the MD are discussed: (a) technical feasibility of the design solutions that comply with the legislative requirements set up for nZEBs, (b) issues concerning the *reference building* approach, (c) robustness of calculation methods in assessing low-energy buildings. To this purpose, the EP is assessed by the method prescribed by the MD (UNI/TS 11300) and by dynamic simulation (*Energy Plus*).

The case study is a new residential nZEB located in three Italian cities (Milan, Rome and Palermo). The analysis focuses on different configurations of technical systems while a fixed package of solutions regarding the envelope has been assumed. All the energy services installed in the building are taken into account. Some high efficiency technical system variants are simulated, including technologies using renewable energy sources.

Nomenclature

A	area [m^2]	H	overall heat transfer coefficient [W/K]
COP	coefficient of performance [-]	H'	mean overall heat transfer coefficient [W m^{-2}K^{-1}]
E	energy [kWh]	V	volume [m^3]
EER	energy efficiency ratio [-]	W	power [W]
EP	energy performance [kWh m^{-2}]	Y_{ie}	periodic thermal transmittance [W m^{-2}K^{-1}]
F, f	factor [-]	η	efficiency [-]
g	total solar energy transmittance [-]		

Subscripts

A	adjacent	g	ground, gross	sh	shading
adj	adjusted	gl	glazing, global	sol	solar
C	space cooling	gn	generation (subsystem)	sum	summer
c	control (subsystem)	H	space heating	T, tr	thermal transmission
coll	collectors	nd	need (energy)	tot	total
D	direct (external)	nren	non-renewable	U	unconditioned (space)
d	distribution (subsystem)	ob	obstacles	u	utilisation (subsystem)
e	emission (subsystem)	P	primary (energy)	V	ventilation
env	envelope	p	projected	W	domestic hot water
F	frame	rc	heat recovery	w	window
f	floor	ren	renewable	wl	wall (external)

Acronyms and abbreviations

BIO	biomass	H	space heating	MV	mechanical ventilation
C	space cooling	HDD	heating degree days	NV	natural ventilation
DHW	domestic hot water	HP	heat pump	nZEB	nearly zero-energy building
EP	energy performance	MD	Ministerial Decree	PV	photovoltaic
EPBD	Energy Performance of Buildings Directive				

2. Energy performance requirements of nZEBs

The MD requires for new buildings to verify the following parameters concerning the building envelope:

- the mean overall heat transfer coefficient by thermal transmission (H'_T), calculated as:

$$H'_T = \frac{H_{tr,adj}}{\sum_k A_k} \quad (1)$$

where, $H_{tr,adj}$ is the overall heat transfer coefficient by thermal transmission of the building envelope calculated in accordance with EN ISO 13789 [7], and A_k is the area of the opaque or transparent envelope component k.
The maximum allowable value of H'_T is fixed by the MD 26/06/2015 in function of the climatic zone and of the compactness ratio of the building (A_{env}/V_g), as shown in Table 1.

Table 1. Maximum allowable value of the mean overall heat transfer coefficient by thermal transmission (H'_T) [W m^{-2}K^{-1}] [1].

Compactness ratio (A_{env}/V_g) [m^{-1}]	Italian climatic zone				
	Zone A and B (≤900 HDD)	Zone C (900< HDD ≤1400)	Zone D (1400< HDD ≤2100)	Zone E (2100< HDD ≤3000)	Zone F (HDD >3000)
$A_{env}/V_g < 0.4$	0.80	0.80	0.80	0.75	0.70
$0.4 \leq A_{env}/V_g < 0.7$	0.63	0.60	0.58	0.55	0.53
$A_{env}/V_g \geq 0.7$	0.58	0.55	0.53	0.50	0.48

- the summer solar effective collecting area of the building ($A_{sol,sum}$), calculated as:

$$A_{sol,sum} = \sum_k F_{sh,ob,k} \cdot g_{gl,sh,k} \cdot (1 - F_F)_k \cdot A_{w,p,k} \cdot F_{sol,sum,k} \quad (2)$$

where, for each transparent envelope component k: $F_{sh,ob,k}$ is the shading reduction factor for external obstacles, $g_{gl+sh,k}$ is the total solar energy transmittance of the transparent part of the element in presence of a shading device, $F_{F,k}$ is the frame area fraction, $A_{w,p,k}$ is the overall projected area of the glazed element, and $F_{sol,sum,k}$ is the correction factor for the incident solar radiation, which is determined as the ratio between the solar irradiation of July, in the same site and orientation, and the mean annual solar irradiation in Rome on a horizontal plane.
According to the decree, the maximum allowable value of the summer solar effective collecting area related to the building conditioned net floor area ($A_{sol,sum}/A_f$) is 0.03 for the residential use and 0.04 for all the other uses.

The decree requires that opaque vertical external walls, except walls at North, North-West and North-East, must have surface mass not lower than 230 kg·m^{-2} or periodic thermal transmittance (Y_{ie}) not higher than 0.10 W·m^{-2}K^{-1}. In addition, Y_{ie} of horizontal or tilted external walls must be not higher than 0.18 W·m^{-2}K^{-1}.

The performance parameters concerning the whole building and its systems are the energy performance (EP) and the mean global seasonal efficiency of the thermal systems (η). In particular, the following variables must be determined for the building under design:

- $EP_{H,nd}$ and $EP_{C,nd}$ are the annual energy needs of the building for space heating and space cooling, respectively, divided by the building conditioned net floor area,
- $EP_{gl,tot}$ is the global total annual primary energy of the building divided the conditioned net floor area, where "*global*" means all the building services, "*total*" includes both renewable and non-renewable energy sources,
- η_H, η_C, η_W are the mean global seasonal efficiencies of the heating system, of the cooling system and of the domestic hot water system, respectively.

The limit values of the above listed parameters are not established *a priori* by the MD, but they are determined for a notional building, named *reference* or *target building*. The *reference building* has the same location, building function, size of the building under analysis, but with parameters of the thermal envelope and of the technical systems replaced by reference values. The reference parameters are provided by the MD and consist of:

- thermal transmittance of the envelope components and of components between units or attached buildings,
- total solar energy transmittance of windows in presence of a shading device,
- heat utilization and heat generation subsystems efficiencies of space heating, space cooling and DHW systems,
- specific electricity need for mechanical ventilation in function of the air flow.

As concerns the first two bullet points, limits starting from 2019/2021 are applied in case of nZEBs.

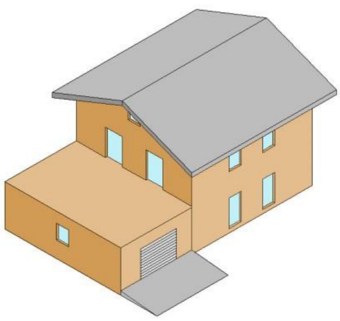
According to the legislative decree no. 28/2011 [8] on the renewable energy sources (RES), 50% of energy demand for DHW and 50% of the sum of energy demands for DHW, space heating and space cooling must be covered by RES (from 1st January 2017). In addition, the minimum electrical power of a system fed by RES (like a PV system), calculated in function of the building footprint area on ground, is prescribed.

3. Case study description and energy performance assessment

3.1. Description of the building and its variants

The case study is a nZEB under design, a two-storey single-family house, supposed located in Milan (2404 HDD), Rome (1415 HDD) and Palermo (751 HDD). A picture of the building, the main geometric data and the thermo-physical parameters variants of the envelope components by climatic zone are reported in Table 2.

Table 2. Picture and main data of the building.

	Geometric data		Thermo-physical data of the envelope components*			
			Parameters	Location		
				Milan	Rome	Palermo
	A_f [m^2]	161	U_{wl} [W m^{-2}K^{-1}]	0.22	0.22	0.37
	V_g [m^3]	651	$Y_{ie,wl}$ [W m^{-2}K^{-1}]	0.04	0.04	0.08
	V [m^3]	429	$U_{f,attic}$ [W m^{-2}K^{-1}]	0.20	0.24	0.40
	A_{env}/V_g [m^{-1}]	0.72	U_g [W m^{-2}K^{-1}]	0.16	0.18	0.37
	A_w [m^2]	25.6	U_w [W m^{-2}K^{-1}]	1.43	2.23	3.11
	A_w/A_f [-]	0.16	g_{gl+sh} [-]	0.20	0.17	0. 17

* The solar shading devices are not installed on the windows at North. $Y_{ie,wl}$ complies with the prescription (see Section 2).

Two heat generation system variants have been considered: (1) a biomass boiler for space heating and DHW *plus* a split air conditioner system for space cooling, (2) an air-to-water heat pump for space heating, space cooling and DHW. The heat emission subsystem consists of radiant heating panels in the former case and of fan-coils in the latter case. The features of the technical subsystems are listed in Table 3. For each system, both natural ventilation and controlled mechanical ventilation have been modelled in accordance with UNI/TS 11300-1 using the input data provided in Table 3. In case of mechanical ventilation, a heat recovery system is provided during the heating season, while mechanical ventilation is inoperative during the cooling season. All system variants include a thermal solar system for DHW and a PV system of 2 kW and 4 kW peak power (complying with the prescription of the legislative decree no. 28/2011 [8]), in the variants of biomass and of heat pump respectively. The PV covers part of the electricity demand (i.e. system auxiliaries, heat pump and fan).

Table 3. Technical subsystem features of the system variants.

Thermal system variants	Energy services*													
	Space heating				Space cooling				Domestic hot water				Ventilation**	
	$\eta_{H,e}$ [-]	$\eta_{H,c}$ [-]	$\eta_{H,d}$ [-]	$\eta_{H,gn}$ *or* COP [-]	$\eta_{C,e}$ [-]	$\eta_{C,c}$ [-]	$\eta_{C,d}$ [-]	EER [-]	$\eta_{W,e}$ [-]	$\eta_{W,d}$ [-]	$\eta_{W,gn}$ *or* COP [-]	$A_{sol,coll}$ [m^2]	$\eta_{V,rc}$ [-]	$W_{V,fan}$ [W]
BIO+NV	0.99	0.99	0.97	0.75	0.97	0.98	1.00	2.50	1.00	0.99	0.75	3	-	-
BIO+MV	0.99	0.99	0.97	0.75	0.97	0.98	1.00	2.50	1.00	0.99	0.75	3	0.8	112
HP+NV	0.96	0.995	0.97	3.00	0.98	0.98	0.98	2.50	1.00	0.99	3.00	3	-	-
HP+MV	0.96	0.995	0.97	3.00	0.98	0.98	0.98	2.50	1.00	0.99	3.00	3	0.8	112

* Mean seasonal values of the efficiencies, except *COP* and *EER* that are declared at full load and reference temperatures of air/water.
** The external air flow in case of mechanical ventilation is 0.08 $m^3 \cdot s^{-1}$.

3.2. Definition of the reference building

A *reference building* has been defined for each case study variant. It is characterized by the same parameters of the design building except those specified in the MD for a nZEB and listed in Table 4.

According to the MD, the *U*-values of the *reference building* include the thermal bridges effect. In case of walls and floors attached to unconditioned spaces, the *U*-value is the ratio of the *U*-value for components facing outdoors to the heat transfer correction factor, as derived from UNI/TS 11300-1 in the form of pre-calculated values.

The utilization subsystems (u) include heat emission, control, distribution. The decree specifies that the efficiency of utilization and generation subsystems (Table 4) includes the effect of auxiliary electricity consumption.

Table 4. Main data of the *reference building* variants.

Parameters of the building envelope	Location			Parameters of the technical systems	Energy services			
	Milan	Rome	Palermo		Space heating	Space cooling	DHW	Ventilation
U_{wl} [W m^{-2}K^{-1}]	0.26	0.29	0.43	η_u [-]	0.81	0.81	0.70	-
$U_{f,attic}$ [W m^{-2}K^{-1}]	0.31	0.37	0.50	η_{gn} [-] (biomass)	0.72	-	0.65	-
U_g [W m^{-2}K^{-1}]	0.26	0.29	0.44	η_{gn} [-] (thermal solar)	-	-	0.30	-
U_w [W m^{-2}K^{-1}]	1.40	1.80	3.00	*COP* [-] (heat pump)	3.00	-	2.50	-
g_{gl+sh} [-] *	0.35	0.35	0.35	*EER* [-]	-	2.50	-	-
				E_V [Wh m^{-3}]	-	-	-	0.50
* does not apply at North, North-West, North-East				PV system efficiency	0.10			

3.3. Calculation methods and boundary conditions

According to the MD, the EP of the case study was calculated by means of the UNI/TS 11300 series [9], which specifies a quasi-steady state calculation method based on EN ISO 13790 [10] and EN 15316 series [11]. The energy need and the primary energy for space heating, space cooling, DHW and ventilation were determined on monthly basis. An *asset energy rating* was performed by applying standard building use and climate input data. The primary energy conversion factors of the energy carriers have been derived from the MD and are listed in Table 5.

The dynamic simulation was conducted by means of *EnergyPlus 8.3*. The geometrical model of the building was developed in *DesignBuilder 4.7*. The modelling procedures were made consistent, according to a previous work of the authors [12]. The noteworthy consistency options are the following: (a) the internal heat gains and ventilation flow rate of the quasi-steady state method are the mean values of the daily profiles of the dynamic method; (b) the same thermal system operation period was assumed in both models; (c) the same hourly operation of solar shadings and shutters is assumed both in *EnergyPlus* and in UNI/TS 11300-1.

Table 5. Total primary energy conversion factors of the energy carriers considered in the case study [1].

Energy carrier	$f_{P,nren}$	$f_{P,ren}$	$f_{P,tot}$
Solid biomass	0.20	0.80	1.00
Electricity from grid	1.95	0.47	2.42
Electricity from PV system	0.00	1.00	1.00
Thermal energy from solar collectors	0.00	1.00	1.00
Thermal energy from outdoor – heat pump	0.00	1.00	1.00

4. Results and discussion

4.1. Verification of the performance parameters and analysis of the reference building approach

The performance parameters verified for the case study variants are listed in Table 6. The comparison between the design building and the *reference building* is presented in Table 7 and in Figs. 1-2. All the variants comply with the MD 26/06/2015 requirements for a nZEB, as presented in Section 2.

Table 6. Comparison of the case study performance parameters with the requirements of MD 26/06/2015.

	Milan				Rome				Palermo			
	BIO+NV	BIO+MV	HP+NV	HP+MV	BIO+NV	BIO+MV	HP+NV	HP+MV	BIO+NV	BIO+MV	HP+NV	HP+MV
H'_T [W m^{-2}K^{-1}]	0.32				0.38				0.54			
$A_{sol,sum} / A_f$ [-]	0.028				0.029				0.026			
% $E_{P,W}$ covered by RES	88	87	88	89	89	89	92	92	90	90	92	92
% $E_{P,H+C+W}$ covered by RES	79	79	70	71	80	80	79	80	78	77	76	76

Table 7. Comparison of the mean global seasonal efficiencies of thermal systems between the design building (*D*) and the *reference building* (*R*).

	Milan								Rome								Palermo							
	BIO+NV		BIO+MV		HP+NV		HP+MV		BIO+NV		BIO+MV		HP+NV		HP+MV		BIO+NV		BIO+MV		HP+NV		HP+MV	
	D	*R*	*D*	*R*	*D*	*R*	*D*	*R*	*D*	*R*	*D*	*R*	*D*	*R*	*D*	*R*	*D*	*R*	*D*	*R*	*D*	*R*	*D*	*R*
η_H [-]	0.64	0.54	0.75	0.65	0.54	0.48	0.65	0.57	0.59	0.54	0.71	0.65	0.65	0.54	0.77	0.65	0.58	0.54	0.66	0.61	0.58	0.49	0.66	0.55
η_C [-]	1.96	1.10	1.96	1.10	1.65	0.99	1.65	0.99	1.97	1.11	1.97	1.11	1.64	1.02	1.64	1.02	1.82	1.05	1.82	1.05	1.47	0.91	1.47	0.91
η_W [-]	0.67	0.50	0.65	0.50	0.58	0.47	0.58	0.47	0.62	0.52	0.62	0.52	0.56	0.48	0.56	0.49	0.61	0.53	0.60	0.53	0.54	0.47	0.53	0.47

The chosen technology, characterized by high thermal insulation, effective shading devices and high efficiency thermal systems, is common nowadays in the design of low-energy buildings. As these construction techniques are being established, no relevant issues of technical feasibility are encountered during the design and the construction phases of the nZEB. Meanwhile, these design solutions allow to fully comply with the energy performance requirements by the decree, like for instance the H'_T-value and the ($A_{sol,sum}/A_f$)-value (Table 6). Typical values of solar collectors area and of PV peak power demonstrated to respect the energy demand coverage by RES, in line with the legislative decree no. 28/2011 (Table 6). Through the comparison with the *reference building*, also the η-values are entirely verified (Table 7), as well as the *EP* indicators (Figs. 1-2).

The following main issues arose by the application of the *reference building* approach: (a) evaluation of the thermal bridges effect; (b) calculation of the electricity demand of technical system auxiliaries; (c) identification of the technical systems characteristics; (d) definition of the mean global seasonal efficiency of the thermal systems.

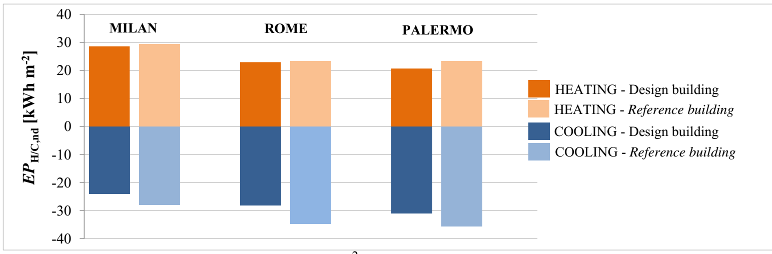


Fig. 1. Comparison of $EP_{\mathrm{H,nd}}$ and $EP_{\mathrm{C,nd}}$ [kWh m^{-2}] between the design building and the *reference building*.

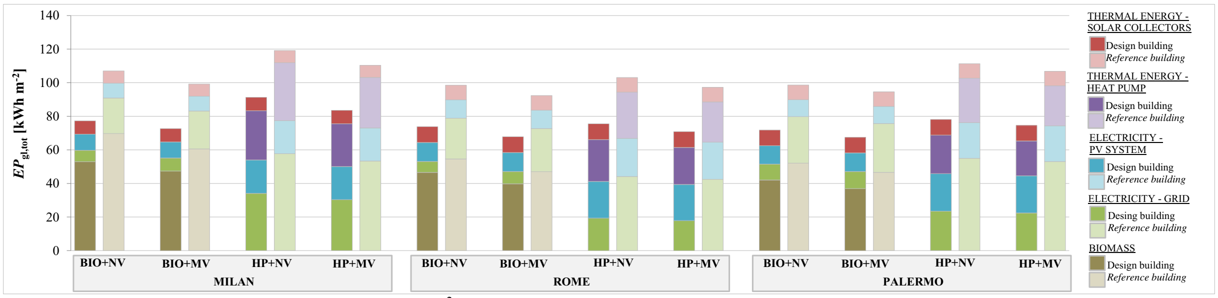


Fig. 2. Comparison of $EP_{\mathrm{gl,tot}}$ [kWh m^{-2}] between the design building and the *reference building*, by energy carrier.

As in the *reference building* the thermal bridges effect is already included in the *U*-value of the envelope components, the design building envelope should have *U*-values lower than those of the *reference building* in order to verify the $EP_{\mathrm{H/C,nd}}$ limits. It consequently requires higher thickness of insulation material and higher investment costs. That could increase the risk that the designer does not take sufficient account of the thermal bridges and consequently makes a wrong energy design. The effect of thermal bridges cannot be neglected: in the case study, their weight on the heat transfer coefficient by transmission varies from 9% (Palermo) to 16% (Milan). Without considering thermal bridges, the energy need for space heating would decrease up to 18% (Milan).

A critical issue in the MD is how to calculate the electricity demand of technical system auxiliaries in the *reference building*. According to the decree, the subsystem efficiency of the *reference building* includes the "*effect*" of the auxiliary electricity consumption. However, it is not clear whether it is the thermal energy of auxiliaries recovered by the subsystem or the electricity consumption itself. The former interpretation is preferable, to avoid the inconsistency of mixing different energy wares when getting the auxiliary consumption from the overall subsystem efficiency. This issue could be solved by attributing the real technical system auxiliaries to the *reference* building, as done in the present work.

The MD specifies the efficiency of the heat generation subsystem in the *reference building*, but it does not provide more information about reference technologies and their characteristics (e.g. thermal power of the heat generator, solar collectors area, PV peak power, types of solar collectors and PV modules). A possible solution is to apply the same technology as that of the design building with its performance data.

The mean global seasonal efficiency of the thermal system (see Table 7) is usually calculated as the ratio of the energy need to the primary energy referred to a specific energy service. In absence of any specification, the "total" (renewable + non-renewable) primary energy was considered in the denominator. In the numerator, the energy need was calculated in *reference conditions*, thus considering a reference natural ventilation despite the presence of mechanical ventilation in the building (see also Fig. 1). The mean global seasonal efficiency is so representative of the actual technical system, including the effect of the heat recovery unit in case of mechanical ventilation.

4.2. Comparison between the calculation methods

The energy needs for space heating and space cooling of the two calculation models are compared in Fig. 3. The quasi-steady state method overestimates the energy need both for heating and for cooling, even if the yearly deviation for cooling is generally lower than for heating. The overestimation of space heating energy need significantly increases in Palermo, where higher outdoor air temperature and higher solar radiation occur. These results are in line with another work of the authors [13] and reveal the limits of the simplified method in predicting the energy needs of low-energy buildings.

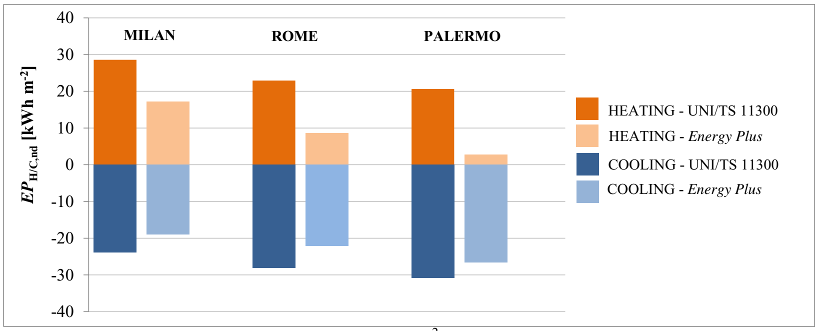


Fig. 3. Comparison of $EP_{H,nd}$ and $EP_{C,nd}$ [kWh m^{-2}] between UNI/TS 11300 and *EnergyPlus*.

5. Conclusions

In this paper the most feasible and wide spreading technical design solutions of nZEBs, concerning both the envelope and the technical systems, have been analysed. The results show the applicability of the MD for the design of the nZEBs.

The following suggestions to overcome the limitations of the *reference building* approach are provided: (a) the thermal bridge effect should be evaluated separately from the envelope component *U*-value; (b) the real technical system auxiliaries should be attributed to the *reference building*; (c) in addition to the average efficiency, other characteristics of the *reference building* thermal systems should be specified, possibly assumed as those of the design building.

The use of dynamic simulation as calculation methodology is advisable in the decree to accurately assess the energy performance of low-energy buildings. Indeed, despite the application of consistency options, huge deviations in the energy needs between the quasi-steady state and the dynamic model occur.

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