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Obtaining a NZEB in Mediterranean climate by using only on-site renewable energy: is it a realistic goal?

Diana D'Agostino[a], Concetta Marino[a], Francesco Minichiello[a*], Francesco Russo[b]

[a]University of Naples Federico II, Department of Industrial Engineering, Piazzale Tecchio, 80, 80125 Napoli, NA, Italy
[b]University of Sannio, Department of Engineering, Piazza Roma, 21, 82100 Benevento, BN, Italy

Abstract

A new concept of building is represented by Zero Energy Buildings (ZEBs).
This paper evaluates the possibility to obtain a NZEB (for office building) by using only "on-site" renewable energy, solely on the roof. A dynamic energy simulation code, EnergyPlus, is used.
Two different Italian climatic zones (Palermo and Naples) and two typologies of building are considered: square or rectangular basis.
For the building with square basis, the energy self-sufficiency is kept up to a higher number of the building levels (8 for Naples, 10 for Palermo) compared to the case of rectangular basis (7 levels for Naples, 9 for Palermo).

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Keywords: Net Zero Energy Buildings; Dynamic energy simulation; Mediterranean climates; On-site renewable energy

1. Introduction

In Europe, the energy requirement of the building sector represents the 40% of the global energy demand. Therefore, energy saving measures for this sector are introduced by European Directives 2002/91/EC [1] and 2010/31/EU [2] on the integrated design of the building and related systems.

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* Corresponding author. Tel.:+39-081-2538665; fax:+39-081-2390364.
E-mail address: minichie@unina.it

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These Directives promote the improvement of the energy performance of the building sector by means of several factors, i.e.:

- passive innovative strategies, such as solar shading devices and others [3];
- innovative and high energy efficiency technologies for HVAC systems [4];
- use of renewable energy sources [5];
- recovery of heat that would otherwise be lost [6];
- artificial lighting with high energy efficiency [7];
- transport systems with high energy efficiency.

Again, other aspects to consider for an optimal building performance are thermal and acoustic comfort, indoor air quality, adequate levels of natural light and rainwater recovery [8,9,10].

In cold climates, construction of high energy performance buildings is more common and simpler compared to hot climates. Thermal insulation and low specific weight have a key role [11].

Contrariwise, in hot climates, dissipation of heat accumulated is more difficult. In fact, high thermal insulation of the building envelope can produce negative effect in Mediterranean climates [12]. In order to obtain significant thermal improvements, the opaque building envelope is optimised in [13], and vacuum insulation panels are proposed in [14].

The impact of innovative passive strategies, such as cool paints for residential sector, is evaluated in [15]. The results show that the thermal energy needs for summer cooling can be reduced up to 60% by using "cool paints" on the external surface (walls and roof). In [16], various reference buildings are considered to evaluate the incidence of surface finishes, and relevant energy savings (up to 21% on annual basis) are obtained by applying the outside and inside innovative surface finishes. Besides, a new factor, the outside coating factor, is introduced in [17] and [18], to optimise the choice of surface finishes as a function of the climate. This factor depends on the cooling/heating degrees-day and solar radiation.

New cooling techniques for the reduction of the cooling demand, i.e. phase change materials, are evaluated in [19] and [20].

Recently, environmental and energy questions have led to a new concept of building, i.e. Zero Energy Building (ZEB). The 2010/31/EU Directive [2] introduces the nearly Zero Energy Buildings (nZEBs), i.e. buildings characterized by very high energy performance where the nearly zero or very low energy requirements should be extensively covered by renewable energy sources produced on-site or nearby.

The Net Zero Energy Buildings (NZEBs) are buildings which totally balance the energy requirements by means of renewable energy sources (non-renewable primary energy request is equal to 0 kWh/m2 on annual basis). The Plus Zero Energy Buildings (PZEBs) are buildings characterized by energy production higher than energy needs (non-renewable primary energy request is <0 kWh/m^2 on annual basis); they are also named as "plus energy buildings" or "net energy plus buildings" [21], or "positive-energy buildings" [22].

It is important to define the type of balance about the building, and various units can be used:

- delivered energy;
- primary energy;
- CO_2 equivalent emissions;
- exergy.

Other parameters, such as metric of the balance and balancing period, are defined by national policy [23].

The Italian Law 90/2013 [24], implementing the EPBD recast, confirms that the energy demand of nZEBs is extensively covered by only renewable energy produced on-site. The energy balance regards the net primary energy, i.e. the difference between energy demand of the building and energy production with renewable energy systems. In NZEB, the net primary energy need is called "net weighted energy". This indicator represents the difference between weighted imported energy and weighted exported energy (equal to 0 kWh/m^2) (Fig. 1). Energy balance considers the primary energy [25], by using energy conversion factors. The NZEB balance can be determined considering the balance between load and generation or using the balance between delivered and exported energy. This balance is calculated as in Eq. (1):

$$\text{Net ZEB balance: (weighted supply)} - \text{(weighted demand|)} = 0 \qquad (1)$$

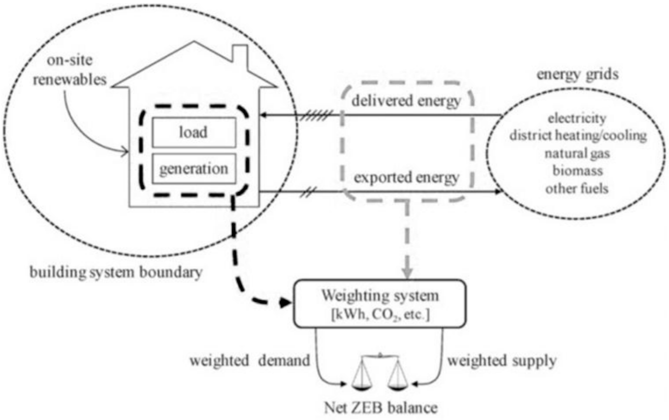


Fig. 1. Scheme of the building and connected energy grids. From [25].

An Italian Ministerial Decree [26] fixes the primary energy factors:

- non-renewable primary energy factor ($f_{P,nren}$);
- renewable primary energy factor ($f_{P,ren}$);
- total primary energy factor ($f_{P,tot}$).

For example, in order to pass from electric energy to primary total energy, a coefficient equal to 2.42 kWh_{pr}/kWh_{el} should be used, while the coefficient is 1.05 kWh_{pr}/kWh_{gas} to pass from natural gas to primary total energy.

The standard EN 15603 defines the non-renewable primary energy. This is calculated as difference between the imported and exported energy, both multiplied for primary energy factors [27].

In USA and Northern Europe, some NZEBs have been designed, while in Mediterranean climate the situation is not satisfactory [28].

The feasibility of a net ZEB for residential sector in Datong (China) is investigated in [29], aiming at a technology improvement in both the design phase and final construction.

In cold climates, the windows properties, thermal insulation, window-to-wall ratio and shading devices are analysed in [30]. The energy simulations show that the nZEBs have a primary energy demand lower than 100 kWh/m^2y.

In [31], nZEBs in European and Mediterranean climates are evaluated and optimal position of phase change materials, building integrated PV and/or building integrated PV/ST systems are analyzed. With the best configuration, very low heating and cooling demands are achieved (0.9 and 1.5 kWh/m^3 y, respectively).

Again, in [32] the possibility to obtain a NZEB in Mediterranean climate using only on-site renewable energy on the building roof is analysed (with and without an earth-to-air heat exchanger).

Passive techniques and renewable energy sources are strategic elements to obtain a zero-energy balance in a NZEB [22].

The passive techniques and use of renewable energy in design phase are investigated in [33]. This work shows the possibility of converting a public building characterized by high energy demand in a nZEB.

In [34], a multi-family NZEB with reasonable costs is studied. In particular, the paper shows how a Life Cycle Cost (LCC) approach is useful to implement renewable energy solutions to obtain a NZEB.

Also in [35], passive techniques, energy efficient mechanical systems and renewable energy technologies are analysed to obtain a NZEB.

The optimal cost and energy performance levels in residential nZEBs are investigated for Estonian climates in [36], achieving a global primary energy requirement of 110 kWh/m^2y.

The optimal costs of an office nZEB are evaluated in [37], considering various fenestration design solutions. The nZEB ($\leq$ 100 kWh/m^2y) does not achieve the optimal cost, while low-energy buildings ($\leq$130 kWh/m^2y) reach it.

The ZEBRA project [38] individuates the nZEB distribution in Europe (Fig. 1). In Italy, characterized by climatic zones with

- Heating Degrees-Day (HDD) between 886 and 1962 and Cooling Degrees-Day (CDD) ≥525
- HDD between 886 and 1962 and CDD <525
- HDD <886 and CDD ≥525,

100 buildings constructed in accordance with nZEB concept are present (15 residential buildings and 85 non-residential buildings).

A report on the progress of the European Member States [39] shows that the additional costs of NZEBs compared to traditional buildings are variable: for example, in Bulgaria they are about 130 €/m^2, while in Italy about 380 €/m^2.

Fig. 2. nZEB distribution in Europe and Italy. “From (ZEBRA Project)”. Note: the climatic zone subdivision follows the indications of [40].

In this paper, a construction design criteria for office NZEBs in Italian climates is discussed. In particular, the possibility to obtain a NZEB for offices by using only “on-site” renewable energy, in particular solely on the slab roof, is evaluated. This subject has been poorly analysed in the scientific-technical literature.

The study is conducted by means of a dynamic energy simulation code, EnergyPlus. Two different Italian climatic zones and two typologies of building are considered: square and rectangular basis. The solar energy is used by means of two systems (both on the building roof): photovoltaic system (PV) and solar thermal collectors (ST).

The building has a reference configuration characterized by two levels, but successively the number of levels is increased until the building energy self-sufficiency is no more obtained. Therefore, by extending the number of the building levels up to this limit, it is possible to obtain the trend of energy self-sufficiency (expressed in percentage terms) as a function of the level number (equal to the ratio between total useful floor surface and roof surface, S_{useful}/S_{roof}).

Nomenclature

CDD	Cooling Degrees-Day, °C
COP	Coefficient Of Performance, ND
CO_2	Carbon dioxide
EER	Energy Efficiency Ratio, ND
EPBD	Energy Performance of Buildings Directive
$f_{P,nren}$	Nonrenewable primary energy factor, ND
$f_{P,ren}$	Renewable primary energy factor, ND
$f_{P,tot}$	Total primary energy factor, ND
HDD	Heating Degrees-Day, °C
HVAC	Heating, Ventilation and Air Conditioning
IWEC	International Weather for Energy Calculation
nZEB	nearly Zero Energy Building
NZEB	Net Zero Energy Building
PV	Photovoltaic
S	Surface, m^2
S_{roof}	Roof surface, m^2
ST	Solar Thermal
S_{useful}	Total useful surface, m^2
U	Unitary thermal transmittance, $W/(m^2K)$
V	Volume, m^3
W_p	Peak power, W
ZEB	Zero Energy Building

2. Methodology and case study

The study is conducted by means of a dynamic energy simulation code, Energy Plus [41]. EnergyPlus was validated in many works, and several validation tests are available for building envelope [42] and HVAC systems [43]. International Weather for Energy Calculation (IWEC) climatic data have been used for their authoritativeness.

Two different climatic zones of Southern Italy are considered: Palermo, with very warm summers and very mild winters; Naples, with warm summers and mild winters.

Two typologies of buildings are considered (Fig. 3): square basis (side of 15 m) and rectangular basis (25 m x 9 m). For both the cases, each floor has an area of 225 m^2 and a height of 3.20 m. The unitary thermal transmittance (U) of the building envelope components is fixed considering the limit U-values reported in the Italian law [26], with a reduction of 30 % (Tab. 1).

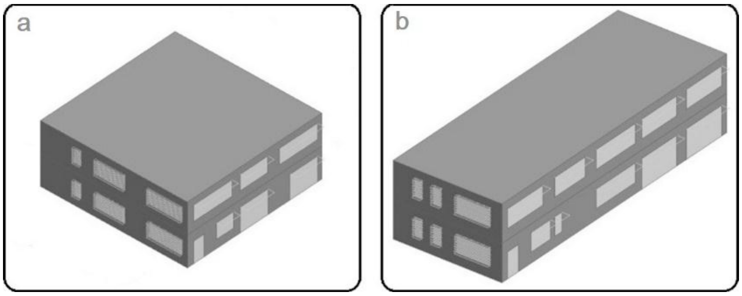


Fig. 3. Geometrical layout of the two examined typologies of the building case study: a) square basis and b) rectangular basis.

The systems for heating, cooling and domestic hot water production are the following: a trivalent air-to-water electrical heat pump, fan-coils units and mechanical ventilation system. The energy efficiency values of the heat pump are different depending on the locality climate (these values and other main boundary conditions are reported in Tab. 2).

The solar energy is utilized by means of two systems (both on the building roof):

- a photovoltaic system (PV) for the electricity energy production (two analysed tilt angles: 5° and 35°), with a peak power of 345 W_p for each monocrystalline module;
- thermal solar collectors (ST) for the domestic hot water production (evacuated tube solar collectors, tilt angle of 60°).

The building is connected to the national electric grid and therefore it does not require electricity storage for the considered PV system.

The building has a reference configuration characterized by two levels, but successively the number of levels is increased (Tab. 3). Following the bioclimatic architecture indications, the S/V coefficient (area of the perimeter vertical and horizontal walls / volume of the heated zones) is acceptable when <0.60 m^{-1}.

Table 1. Unitary thermal transmittance (U-values) of the building components (W/m^2K).

	U_{law} - DM 26/06/15 [26]	$U_{project}$
	Palermo	
Walls	0.45	0.32
Roof	0.38	0.27
Floor	0.46	0.32
Windows	3.20	2.24
	Naples	
Walls	0.38	0.27
Roof	0.36	0.25
Floor	0.40	0.28
Windows	2.40	1.68

Table 2. Main boundary conditions.

	Office
Occupation level	0.17 person/m^2
Metabolic rate	0.90 met (for light office work)
Clothes thermal resistance	Winter: 1.00 clo - Summer: 0.50 clo
Indoor air set-point temperature	Winter: 20 °C - Summer: 26 °C
Nominal COP of the heat pump	$COP_{PA} = 3.30$ - $COP_{NA} = 3.20$
Nominal EER of the heat pump	$EER_{PA} = 2.70$ - $EER_{NA} = 2.80$

Table 3. S/V coefficient (m^{-1}) for the examined building, as a function of the number of levels, in both the cases of square and rectangular basis.

	S/V coefficient (m^{-1})	
Number of levels	Square basis	Rectangular basis
1	0.88	0.91
2	0.57	0.60
3	0.46	0.49
4	0.41	0.44
5	0.38	0.41
6	0.36	0.39
7	0.35	0.38
8	0.33	0.36
9	0.33	0.36
10	0.32	0.35

The feasibility of a NZEB in Italian climate, using only renewable energy on-site, is evaluated from an energy point of view. Considering different localities and types of building (square or rectangular basis), the energy performances of the buildings and related systems are analysed. The aim is the evaluation of the maximum number of the building levels (equal to the ratio between total useful floor surface and roof surface, S_{useful}/S_{roof}) for which the energy self-sufficiency is allowed by the on-site renewable energy systems. The term "self-sufficiency" implies that the NZEB is achieved and the global non-renewable primary energy is zero on annual basis.

The global primary energy required (for heating, cooling, mechanical ventilation, domestic hot water, lighting and electric devices) is evaluated for all the cases.

Obviously, above a given number of the building floors, the thermal energy and electricity produced by means of the PV and ST systems become insufficient for the building requirements, because the roof area available for PV and ST systems doesn't vary. The building has a reference configuration characterized by two levels, but successively the number of levels is increased until the building energy self-sufficiency is no more obtained. Therefore, by extending the number of the building levels up to this limit, it is possible to obtain the trend of energy self-sufficiency (expressed in percentage terms) as a function of the level number (equal to the ratio between total useful floor surface and roof surface, S_{useful}/S_{roof}).

3. Results

In Figs. 4 and 5, the primary energy demand and the other main results are reported for each alternative and for the two chosen localities. The tilt angle considered for the PV panels is 5°. It can be noted that:

- Palermo - the building characterized by rectangular basis presents a greater global primary energy demand (for 10 levels: about 94000 kWh), compared to the building with square basis (for 10 levels: about 86000 kWh), i.e. +9.3%;
- Naples: the building characterized by rectangular basis presents a greater global primary energy demand (for 10 levels: about 131600 kWh), compared to the building with square basis (for 10 levels: about 104000 kWh), i.e. +25.9%.

Figs. 6 and 7 confirm that the building with square basis is characterized by lower global primary energy demand compared to rectangular basis, and show that the energy demand for Palermo is lower compared to Naples: the specific global primary energy is equal to about 35-42 kWh/m^{2}y for Palermo (Fig. 6) and 45-58 kWh/m^{2}y for Naples (Fig. 7).

Again, the results show that a lower tilt angle of the PV system (5°) allows obtaining a higher number of the building levels for which the energy self-sufficiency is kept, compared to the tilt angle of 35°. For the building with square basis, the energy self-sufficiency is kept up to a higher number of the levels (8 for Naples, 10 for Palermo) compared to the case of rectangular basis (7 levels for Naples, 9 for Palermo). This is evidenced in Figs. 4 and 5 (by grey area) and in Fig. 8 by a vertical line, which identifies the maximum number of building levels for which the complete energy self-sufficiency (100 %) is allowed.

Considering a PV tilt angle equal to 35°, the results (Fig. 8) are worse compared to the case of 5°: the energy self-sufficiency is kept up to a lower number of the levels (5-6 for Naples, 7 for Palermo).

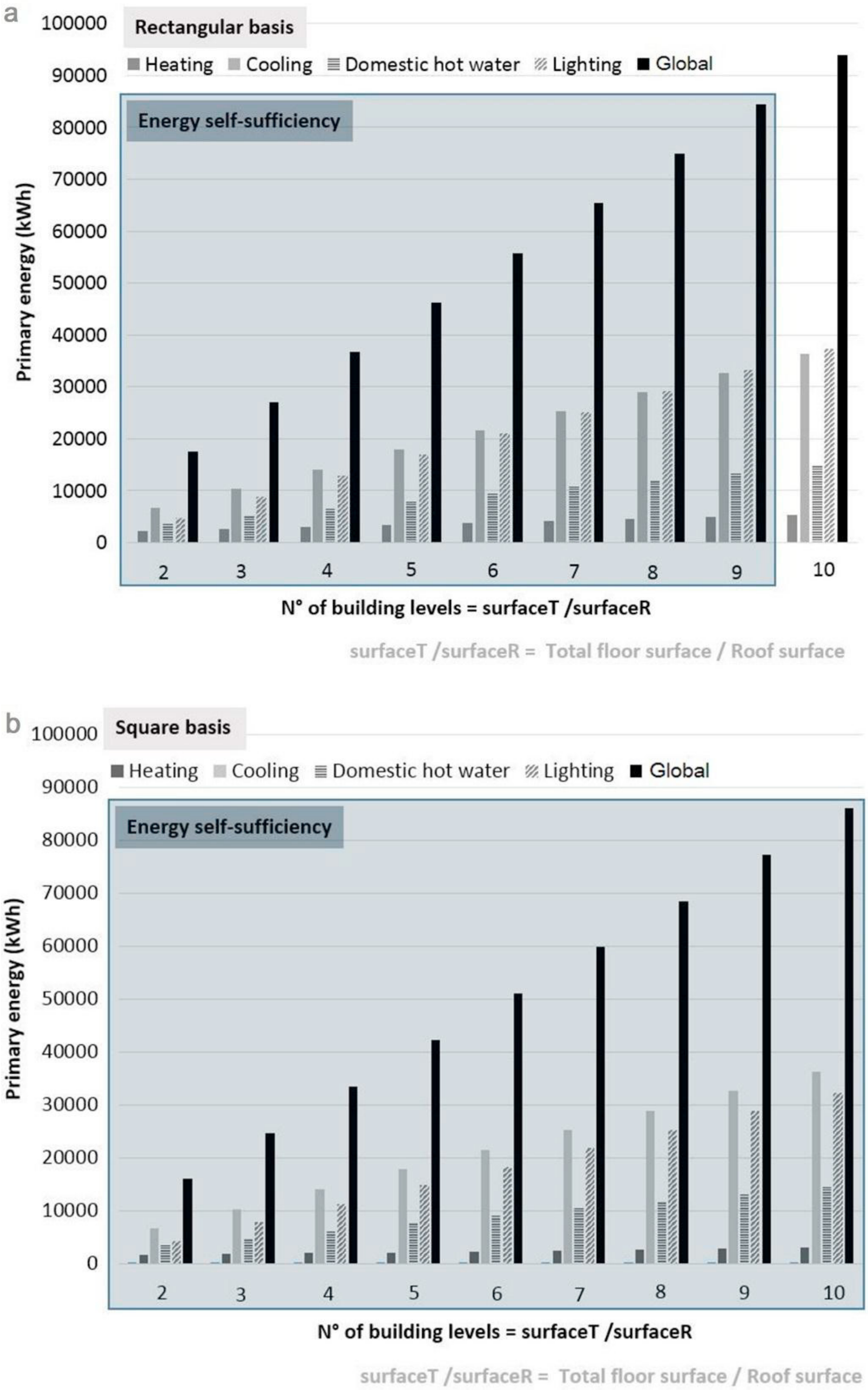
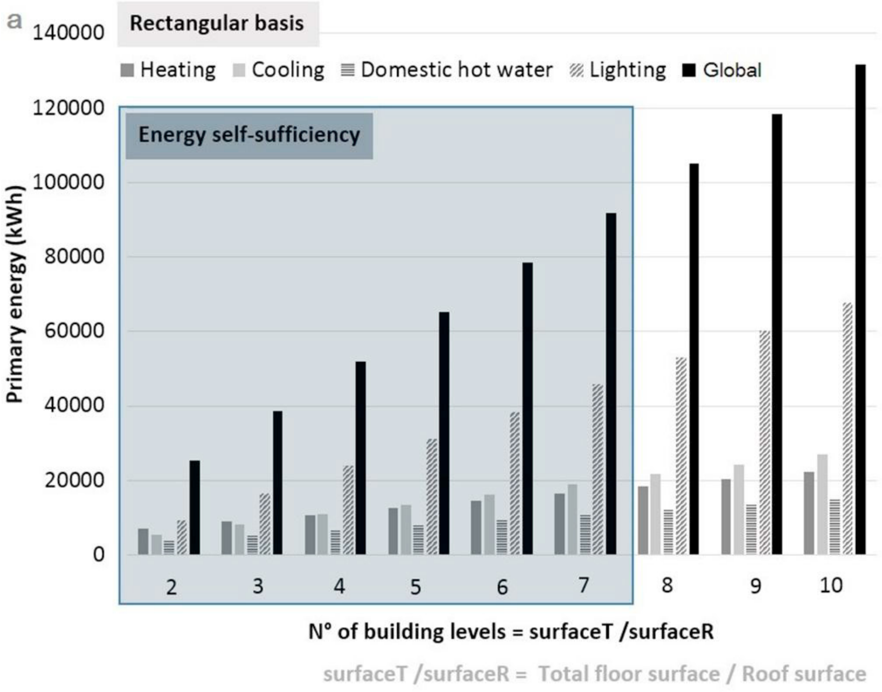


Fig. 4. Palermo: yearly global primary energy requirements (kWh) as a function of the building number of levels, for a) building with rectangular basis and b) building with square basis.



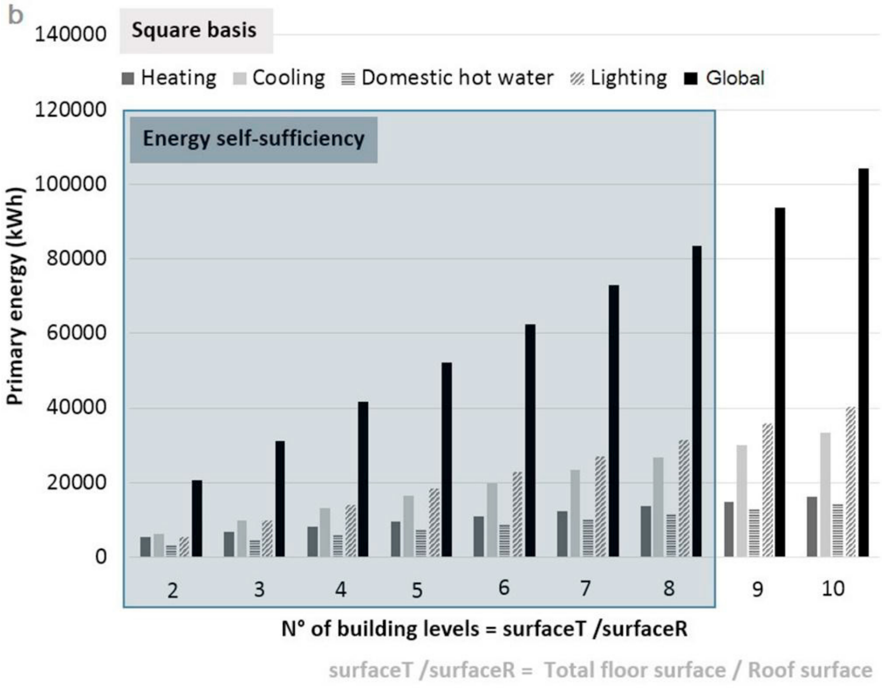


Fig. 5. Naples: yearly global primary energy requirements (kWh) as a function of the building number of levels, for a) building with rectangular basis and b) building with square basis.

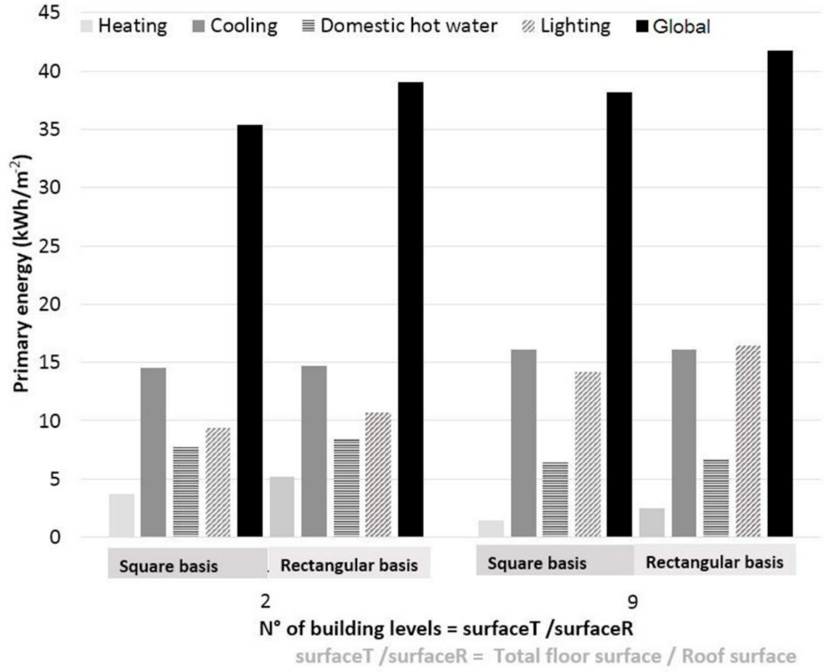


Fig. 6. Palermo: yearly specific primary energy requirements (kWh/m^2) for a building with 2 or 9 levels, in both the cases of square and rectangular basis.

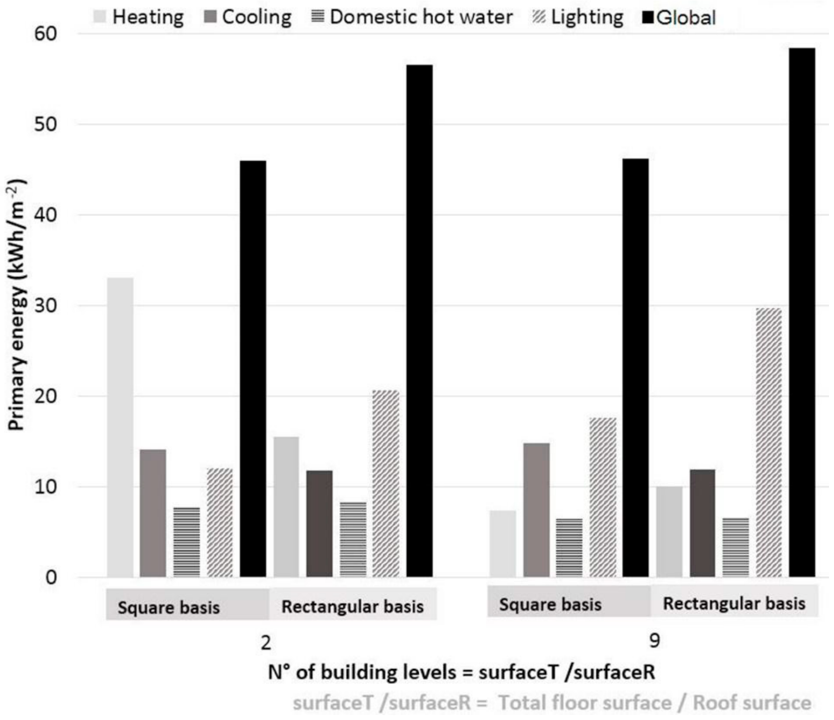


Fig. 7. Naples: yearly specific primary energy requirements (kWh/m^2) for a building with 2 or 9 levels, in both the cases of square and rectangular basis.

Fig. 8. Energy self-sufficiency (%) as a function of the number of the building levels for: a) building with square basis in Palermo, b) building with

[2] European Parliament. 2010. Directive 2010/31/EU of The European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast), Official Journal of the European Union.

[3] Ascione F, Cheche N, De Masi RF, Minichiello F, Vanoli GP. Design the refurbishment of historic buildings with the cost-optimal methodology: The case study of a XV century Italian building. Energ Buildings 2015;99:162-76.

[4] Ruivo CR, Angrisani G, Minichiello F. Influence of the rotation speed on the effectiveness parameters of a desiccant wheel: An assessment using experimental data and manufacturer software. Renew Energ 2015;76:484-93.

[5] Renno C, De Giacomo M. Dynamic Simulation of a CPV/T System Using the Finite Element Method. Energies 2014;7:7395-414.

[6] Angrisani G, Minichiello F, Sasso M. Improvements of an unconventional desiccant air conditioning system based on experimental investigations. Energy Convers Manage. 2016;112:423-34.

[7] Bellia L, Fragliasso F, Stefanizzi E. Why are daylight-linked controls (DLCs) not so spread? A literature review. Build Environ 2016;106:301-12.

[8] D'Ambrosio Alfano FR, Olesen BW, Palella BI, Riccio G. Thermal comfort: Design and assessment for energy saving. Energ Buildings 2014;81:326-36.

[9] Dragonetti R, Opdam R, Napolitano M, Romano R, Vorländer M. Effects of the wave front on the acoustic reflection coefficient. Acta Acust united Ac 2016;102(4):675-87.

[10] Bellia L, Fragliasso F, Stefanizzi E. Daylit offices: A comparison between measured parameters assessing light quality and users' opinions. Build Environ 2017;113:92-106.

[11] Al-Sanea SA, Zedan MF, Al-Hussain SN. Effect of thermal mass on performance of insulated building walls and the concept of energy savings potential. Appl Energ 2012;89(1):430-42.

[12] de' Rossi F, Marigliano M, Marino C, Minichiello F. A Technical and Economic Analysis on Optimal Thermal Insulation Thickness for Existing Office Building in Mediterranean Climates. Int J Heat Technol 2016;34, Special Issue 2:S561-S568.

[13] Oliveti G, Arcuri N, Mazzeo D, De Simone M. A new parameter for the dynamic analysis of building walls using the harmonic method. Int J Therm Sci 2016;88:96–109.

[14] Lorenzati A, Fantucci S, Capozzoli A, Perino M. The effect of different materials joint in Vacuum Insulation Panels. Energy Procedia 2014;62:374–81.

[15] Marino C, Minichiello F, Bahnfleth W. The influence of surface finishes on the energy demand of HVAC systems for existing buildings. Energ Buildings 2015;95:70-9.

[16] Marino C, Minichiello F. Existing Buildings and HVAC Systems: Incidence of Innovative Surface Finishes on the Energy Requirements. Energy Procedia 2015;82:499-505.

[17] Marino C. Ottimizzazione del sistema edificio-impianto: tecniche passive ed attive per la riduzione della richiesta energetica, dei costi di gestione e dell'impatto ambientale. Ph.D. Thesis (in Italian) 2016.

[18] Marino C. The optimal choice of the outside innovative surface finishes for buildings from a thermal and energetic point of view. Energy Procedia 2016;101:980-7.

[19] Khadrawi AF, Balabel A, Al-Osaimy Ali S. A new cooling technique using phase change material in a car ceiling and wall buildings. Int J Heat Technol 2014;Vol.32 n.1:185-190.

[20] Evola G, Marletta L, Sicurella F. Simulation of a ventilated cavity to enhance the effectiveness of PCM wallboards for summer thermal comfort in buildings. Energ Buildings 2014;70:480-9.

[21] Rodriguez-Ubinas E, Montero C, Porteros M, Vega S, Navarro I, Castillo-Cagigal M, Matallanas E, Gutiérrez A. Passive design strategies and performance of Net Energy Plus Houses. Energ Buildings 2014;83(11):10-22.

[22] Kolokotsa D, Rovas D, Kosmatopoulos E, Ka-laitzakis K. A road map towards intelligent net zero and positive energy buildings. Sol Energy 2011;85(12):3067-84.

[23] Marszal AJ, Heiselberg P, Bourrelle JS, Musall E, Voss K, Sartori I, Napolitano A. Zero Energy Building – A review of definitions and calculation methodologies. Energ Buildings 2011;43:971–9.

[24] Italian Parliament (Parlamento della Repubblica Italiana). 2013. Legge n.90. Conversione in legge, con modificazioni, del decreto-legge 4 giugno 2013, n. 63, recante disposizioni urgenti per il recepimento della Direttiva 2010/31/UE del Parlamento europeo e del Consiglio del 19 maggio 2010, GU n.181 del 3-8-2013.

[25] Sartori I, Napolitano A, Voss K. Net zero energy buildings: A consistent definition framework. Energ Buildings 2012;48(5):220-32.

[26] Ministero dello Sviluppo Economico Italiano. 2015. Decreto Ministero dello sviluppo economico 26 giugno 2015. Applicazione delle metodologie di calcolo delle prestazioni energetiche e definizione delle prescrizioni e dei requisiti minimi degli edifici

[27] Piterà LA. Determinazione della prestazione energetica per la classificazione dell'edificio. AiCARR Journal (in Italian) 2013;19:56-60.

[28] Voss K, Musall E. Net zero energy buildings – International projects of carbon neutrality in buildings. Detail green books. München: EnOB; 2013.

[29] Jin Y, Wang L, Xiong Y, Cai H, Li YH, Zhang WJ. Feasibility studies on net zero energy building for climate considering: A case of "All Green House" for Datong, Shanxi, China. Energ Buildings 2014;85(12):155-64.

[30] Thalfeldt M, Pikas E, Kurnitski J, Voll H. Facade design principles for nearly zero energy buildings in a cold climate. Energ Buildings 2013;67(12):309-21.

[31] Buonomano A, De Luca G, Montanaro U, Palombo A. Innovative technologies for NZEBs: An energy and economic analysis tool and a case study of a non-residential building for the Mediterranean climate. Energ Buildings 2016;121:318–43.

[32] Ascione F, D'Agostino D, Marino C, Minichiello F. Earth-to-air heat exchanger for NZEB in Mediterranean climate. Renew Energ 2016;99:553-63.

[33] AlAjmi A, Abou-Ziyan H, Ghoneim A. Achieving annual and monthly net-zero energy of existing building in hot climate. Appl Energ 2016;165:511–21.

[34] Marszal AJ, Heiselberg P. Life cycle cost analysis of a multi-storey residential Net Zero Energy Building. Energy 2011;36:5600-9.

[35] Wang L, Gwilliam J, Jones P. Case study of zero energy house design in UK. Energ Buildings 2009;41(11):1215-22.

[36] Kurnitski J, Saari A, Kalamees T, Vuolle M, Niemelä J, Tark T. Cost optimal and nearly zero (nZEB) energy performance calculations for residential buildings with REHVA definition for nZEB national implementation. Energ Buildings 2011;43(11):3279-88.

[37] Pikas E, Thalfeldt M, Kurnitski J. Cost optimal and nearly zero energy building solutions for office buildings. Energ Buildings 2014;74(05):30-42.
[38] ZEBRA project. http://www.zebra-monitoring.enerdata.eu/ Copyright © Enerdata 2015-2016
[39] D'Agostino D, Zangheri P, Cuniberti B, Paci D, Bertoldi P. Synthesis Report on the National Plans for Nearly Zero Energy Buildings (NZEBs). http://publications.jrc.ec.europa.eu/repository/bitstream/JRC97408/reqno_jrc97408_online%20nzeb%20report%281%29.pdf 2016.
[40] Tsikaloudaki K, Laskos K and Bikas D. On the Establishment of Climatic Zones in Europe with Regard to the Energy Performance of Buildings. Energies 2012;5:32-44.
[41] U.S. Department of energy. EnergyPlus 7.2.0.006
[42] U.S. Department of Energy. 2011a. EnergyPlus Testing with Building Thermal Envelope and Fabric Load Tests from ANSI/ASHRAE Standard 140-2011; 1-32. http://apps1.eere.energy.gov/buildings/energyplus/energyplus_testing.cfm
[43] U.S. Department of Energy. 2011b. EnergyPlus Testing with HVAC Equipment Performance Tests from AN-SI/ASHRAE Standard 140-2011; 1-80. http://apps1.eere.energy.gov/buildings/energyplus/energyplus_testing.cfm

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