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Design standards for residential N-ZEBs in mild Mediterranean climate

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Abstract. In this paper the authors intend to investigate into the possibility of obtaining the Net Zero Energy Building (N-ZEB) standard for a residential building type widespread in Mediterranean climate. To this aim, the study considers a terraced-house apartment building with an external envelope made of clay blocks and concrete structure, which is a very common solution in Italy. At first, the building is thought to be designed according to the current national regulations concerning the insulation level of the envelope; for such configuration, the current energy needs for heating, air-conditioning, lighting and hot water production are calculated through dynamic simulations tools. Then, the study discusses the interventions, both on the envelope and on the energy systems, needed to transform this conventional building into an N-ZEB, avoiding excessive modifications to its design. Due to the diffusion of this typology, the case considered in the paper is very representative, and the conclusions might be extended to a significant portion of the building real estate. The final aim is to define a construction standard that might become a reference for the design of future residential N-ZEBs in Mediterranean countries.

Key words

Net Zero Energy Buildings, Mediterranean climate, hollow clay bricks, terraced houses.

1. Introduction

The European Directive 31 [1] requires in Article 9 that Member States shall ensure that all new buildings are nearly ZEBs by 31 December 2020; furthermore, by 31 December 2018 the new buildings occupied or owned by public authorities should also be nearly ZEBs. The Member States are also required to create national energy plans with the aim, among others, of increasing the number of near ZEBs and defining this concept in practice. Furthermore, Article 2 of the previously mentioned Directive provides the definition of a “nearly zero-energy building”: this is a building that has a very high energy performance, and where the very low amount of energy required should be covered to a very significant extent by renewable sources produced on-site or nearby. According to the Directive, only the energy needs for ambient heating and cooling, hot water production, ventilation and lighting must be taken into account when determining the building energy consumption.

A recent study, published in 2010, reports that in the last 20 years around 280 projects with the claim of a net zero energy balance have been realized all over the world [2]. To date, most finished Net ZEBs have been built in northern European countries (Germany and Austria, mainly), USA and Canada. However, a relevant activity in this field is also registered in France, where 18 projects have been already either presented or realized, as described in Ref. [3]. Here, the authors emphasize that the actual energy needs of a very low-consumption building can be far higher than the values predicted in the design stage, because of the unpredictable and usually inappropriate behavior of the occupants. Some interesting indications can also be drawn from the project carried out in Portugal [4], where the impact of passive cooling through natural ventilation is discussed, as well as the role of an “intelligent” façade. In Germany, an estate containing 59 terraced houses was realized in Freiburg [5]. The houses were designed in compliance with the Passivhaus standard, and the low energy consumption was balanced by the photovoltaic yield from the roofs. Not all the apartments satisfied the N-ZEB conditions, but the whole settlement actually did. Other studies focused on the Italian context are reported in Ref. [6] and [7].

However, most examples of N-ZEBs discussed in the literature are tertiary buildings, while only few residential buildings are considered. Furthermore, not many studies refer to mild Mediterranean countries, where usually the energy needs for ambient cooling overcome those for ambient heating; this determines a profoundly different approach to the design of an N-ZEB, not oriented only on the increase of the insulation level. For these reasons, the study presented in this paper applies to residential buildings. The site here considered is placed in Southern Italy, with mild and short heating seasons and relatively hot and long cooling seasons; the main weather data for the site are shown in Fig. 1.

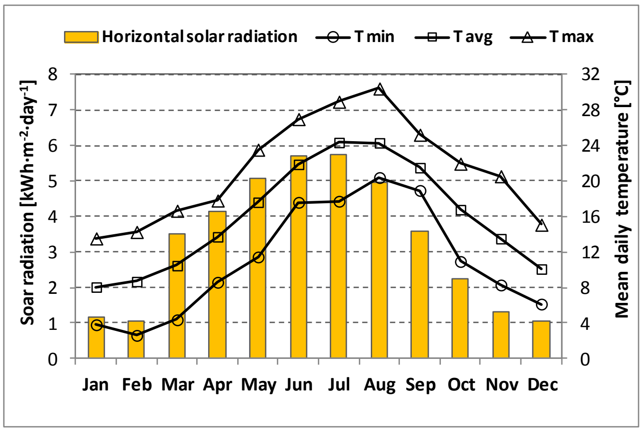

Fig. 1. Weather data for the site considered in the study.

2. Methodology

At the moment, EU countries have not agreed on a common and official definition for zero energy buildings; even the calculation method has not yet been defined. Several choices must then be made before assessing a potential zero energy building, such as (see Ref [6] and [8]):

- Energy uses included in the calculation
- Floor area to be considered
- Balance period and balance metric
- Types of renewable energies to be included

In this paper, the energy uses that will be considered in assessing the energy performance of the building are those related to heating (H), cooling (C), production of hot water (W), ventilation (V) and lighting (L). Electricity for household appliances is not included in the current scope of the EPDB.

The energy consumption will be normalized with reference to the net floor area of the building; a year is the period of time to be used to make all the energy balances. As concerns renewable energy sources (RE), only on-site contributions will be considered. Finally, primary energy is the indicator used for making the balance between energy uses and renewable energy production. As a consequence, the following expression holds:

$$\mathrm{PE} = \sum_{\mathrm{year}} \left(\mathrm{PE_H} + \mathrm{PE_W} + \mathrm{PE_C} + \mathrm{PE_L} + \mathrm{PE_V} - \mathrm{PE_{RE}} \right) \quad \left[\frac{\mathrm{kWh}}{\mathrm{m^2 \cdot y}} \right] \tag{1}$$

The result of Equation (1) shall not be positive in order for the building to be a Net-ZEB.

3. Case study

In order to investigate into the requirements of residential Net Zero Energy Buildings in mild Mediterranean countries, a terraced house located in Southern Italy has been chosen. In fact, this building typology forms a considerable part of the Italian real estate and is suitable to this study because, if compared to other common types such as apartment towers, it shows a higher surface to volume ratio (S/V), which enhances the role of the building envelope.

A sketch of the sample considered for the simulations, realized with SketchUp version 8.0, is shown in Fig. 2. The building contains 7 apartments: four out of them, identified by letter A, are single-storey apartments, all with the same surface and the same number of rooms, but each having a different exposure. The other three are duplex apartments; apartment C has a flat roof, whereas apartments B have an empty attic under the pitched roof. The overall net horizontal surface is 435 m^2, while the gross volume is 1670 m^3. The shape factor S/V is 0.67.

As regards the envelope, the building has a reinforced concrete structure, most widespread in Italy and usually characterized by significant thermal bridges along the concrete framework. The external walls are based on a double-leaf construction: one lightweight clay blocks layer on the outer side (25 cm) plus one common clay blocks layer on the inner side (8 cm). The blocks are divided by a 9-cm gap, where an insulating material might be installed according to the desired U-value. The overall thickness, including inner and outer plaster, is 46 cm.

Here, it is to be reminded that, in its initial configuration, the envelope of the building is designed to comply with Italian regulations for new constructions. More in detail, the Decree 59/09 imposes a maximum U-value for all the outer surfaces, that is determined according to the number of winter degree-days (1185 in the case of the site chosen for present study, located in Southern Italy). To this aim, 2 cm of expanded polyurethane were added in the gap between the clay blocks leaves. Furthermore, concrete pillars and beams are 30-cm thick and, in order to form coplanar surfaces with the outer walls, 6 cm of polystyrene and a 4-cm leaf of hollow flat clay blocks are added on the outer side and on the inner side, respectively. This also allowed to correct the thermal bridge.

As regards the flat roof, as well as the floors under the attic, it consists of a slab of 20 cm made of concrete and hollow bricks, overlaid by a 0.3-mm polythene vapour barrier and 8-cm extruded polystyrene insulation, covered by a concrete screed (5 cm) to receive the flooring system. It represents a very common roofing system in Italy. Table I reports the U-value of all the elements considered in this study, together with the maximum value allowed in Italy starting from 2010. All the external surfaces are light-coloured, which implies a solar absorptance as high as 0.4. The windows have an aluminium frame with thermal break and a double 4-mm glazing filled with argon; the inner glazing is treated with a low-emissive coating (ε = 0.4). Each glazed surface is protected by light internal curtains, whose solar transmittance is 0.5.

Table I. Heat loss coefficient for the envelope components in the initial configuration.

Building element	**U-value** [W m^{-2} K^{-1}]	**Max U-value** [W m^{-2} K^{-1}]
External walls	0.37	0.40
Concrete beams/pillars	0.36	0.40
Flat roof	0.36	0.38
Inner floors / walls	0.71	0.80
Floor on the ground	0.42	0.42
Windows	2.50	2.60
Overall U-value = 0.55 [W m^{-2} K^{-1}]		

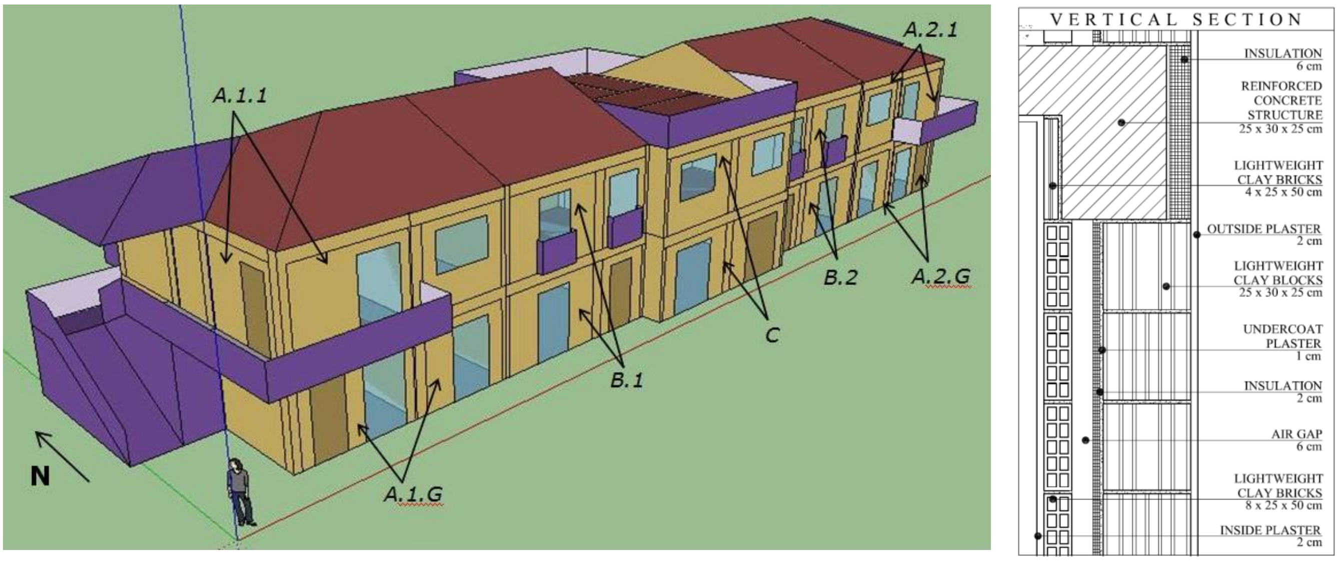

Fig. 2. Left: view of the terraced-house apartment building modeled on SketchUp. Right: detail of the external envelope.

With reference to the internal gains (associated with people, artificial lighting and electric appliances), conventional values are used, suggested by the National Regulation for the calculation of building thermal energy needs (UNI TS 11300/1). Such values change according to the type of room and to the time interval, ranging from 1 W/m^2 (bedroom, from 07:00 to 23:00) to 20 W/m^2 (kitchen and dining room, from 17:00 to 23:00).

As concerns ventilation, no mechanical system is normally installed in residential buildings in Italy. Thus, the fresh air supply is entrusted to the occupants through the occasional windows opening. Conventionally, a ventilation rate as high as 0.5 and 0.3 air changes per hour (ACH) can be taken into account in the cooling and the heating season, respectively; this also accounts for air infiltration through leaks.

4. Results and discussion

In this section, the results of the dynamic simulation of the building in its initial configuration will be first presented, leading to the evaluation of the energy needs for heating, cooling, hot water production and artificial lighting; the simulations will be performed with EnergyPlus. Then, starting from these results, appropriate measures will be considered in order for the building to approach the goal of nearly–zero energy consumption.

First of all, Table II reports the building annual thermal energy demand for heating and cooling, respectively. Such values are obtained through the simulations by imposing a thermostat control which prevents the temperature in every room of the building from being lower than 20°C in winter (from November 15th to March 31st, according to Italian regulations for climatic zone C) and higher than 26°C in summer (here, from May 1st to September 30th). The energy demand for cooling also accounts for the latent load due to people and air infiltration; the set point for the indoor relative humidity is RH = 55%.

Table II suggests that the energy demand for cooling is fairly higher than for heating. Actually, this is a common feature for well-insulated buildings in mild Mediterranean climate: here, heat losses in winter can be easily reduced just through an average insulation level of the envelope, whereas the thermal load due to internal gains and to solar radiation in summer is prominent and much more difficult to tackle. As a general rule, the highest energy needs are measured in the apartments at the first floor (A.1.1 and A.2.1): their energy consumption in winter is between 30% and 40% higher than the corresponding apartments at the ground floor, that can benefit from the low heat exchange with the ground. Apartment C is also penalized, especially in winter, as its roof is directly in contact with the outdoors.

Now, in order to assess the overall primary energy needs, it is necessary to account for the energy systems and the energy usage other than ambient heating and cooling.

As concerns Domestic Hot Water (DHW), the National Standard UNI TS 11300/2 introduces a conventional value for the daily demand of hot water at 40°C (V_W), calculated as a function of the net surface of the apartment (S_{net}), see Eqn. (2). Starting from this value, the annual thermal energy demand for DHW can be easily assessed, by imposing a water inlet temperature of 15°C, as in Eqn. (3). Here, c = 1.162 Wh.kg^{-1}.K^{-1} is the specific heat of water, whereas $\eta_d = 0.95$ and $\eta_e = 0.96$ are the *distribution efficiency* and the *supply efficiency*, respectively.

$$V_w = 4.514 \cdot \left(S_{net}\right)^{-0.2356} \quad [\text{liter.day}^{-1}.\text{m}^{-2}] \qquad (2)$$

$$Q_W = 365 \cdot \rho_w c \cdot V_w \cdot S_{net} \cdot (40-15) / (\eta_d \eta_e) \quad [\text{kWh.y}^{-1}] \quad (3)$$

Table II. Energy demand for heating and cooling

Apt.	*Surface* [m^2]	*Heating* [kWh.m^{-2}.y^{-1}]	*Cooling* [kWh.m^{-2}.y^{-1}]
A.1.G	47.4	15.4	25.0
A.1.1	47.4	22.6	29.5
A.2.G	47.4	16.8	24.3
A.2.1	47.4	21.0	29.9
B.1	75.1	16.8	23.8
B.2	75.1	15.4	24.1
C	95.5	20.3	24.1
Average	-	**18.3**	**25.4**

Each apartment has its own heat generator for the combined management of ambient heating and DHW preparation. The nominal thermal power Q_{hg} for each generator is 22.5 kW, whereas the overall system efficiency η_{hg} (for production, distribution and delivery of the thermal energy) can be estimated as being equal to the minimum value imposed by Italian Regulations:

$$\eta_{hg} = 75 + 3 \cdot \log\left(Q_{hg}\right) = 79.1\ \% \qquad (4)$$

Furthermore, in order to evaluate the electricity consumption for artificial lighting, one should know in the detail the type of lamps and their utilisation pattern. However, in this paper we decided to rely on well-established statistical data, according to which such electricity consumption amounts to around 100, 90 and 80 $kWh.y^{-1}$ per person, for residential units occupied by 3 (apt. A), 4 (apt. B) or 5 (apt. C) people, respectively.

Finally, the building energy demand for cooling is covered through individual air-conditioning units (split system), which is a very common practice in residential buildings of Southern Italy. The energy efficiency (EER) of such units is a function of the outdoor air temperature T_{out}, and can be derived from manufacturer data, like in Eqn. (5):

$$EER = 6.841 - 0.1 \cdot T_{out} + 0.001 \cdot T_{out}^{2} \qquad (5)$$

The conversion factor from electric energy to primary energy is equal to 2.174 kWh_{PE} per kWh_{el}, as suggested by the National Standard UNI TS 11300/4. This corresponds to an average conversion efficiency of 46%.

Table III reports the detailed results of the primary energy consumption for each apartment and for the whole building, according to Eqn. (1). Here, $PE_V = PE_{RE} = 0$, as there is neither a mechanical ventilation system nor a system exploiting renewable energy sources.

Table III. Primary energy consumption [$kWh.m^{-2}.y^{-1}$]

Apt.	PE_H	PE_W	PE_C	PE_L	*PE*
A.1.G	19.5	26.5	19.1	14.1	79.2
A.1.1	28.6	26.5	22.2	14.1	91.4
A.2.G	21.3	26.5	18.6	14.1	80.5
A.2.1	26.6	26.5	22.4	14.1	89.6
B.1	21.3	24.0	18.1	10.1	73.5
B.2	19.5	24.0	18.3	10.1	71.9
C	25.7	22.7	18.4	10.0	76.8
Average	**23.1**	**24.8**	**19.3**	**11.8**	**79.0**

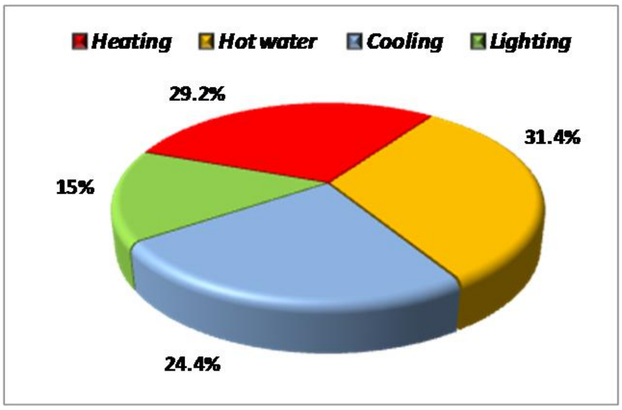

Fig. 3. Percentage contribution of each sub-system to the overall primary energy needs

From Fig. 3 one can learn that the most important contribution to the overall primary energy consumption is due to DHW preparation (31.4%). This is a quite common feature for new low-consumption residential buildings, that are designed according to the latest regulations for the improvement of the insulation level. Furthermore, the primary energy demand for cooling (24.4%) is not far from that for heating (29.2%), which is another peculiarity of newly-built energy performing buildings in mild Mediterranean climate. The primary energy consumption for artificial lighting is the lowest contribution (15%); however it is not negligible.

Photovoltaic

In order to improve the overall primary energy balance reported in Eqn. (1), it might be suitable to install a building-integrated solar PV system on the pitched roof. In this case, the surface available on the building shown in Fig. 2 for the placement of the PV modules is 102 m^2. The calculation of the electric energy produced by the PV system was carried out under the following assumptions:

- Monocrystalline solar cells, with a nominal efficiency (at peak conditions) corresponding to 14.6%, and a temperature coefficient $\alpha = - 0.485$ (%/°C);
- Rated power at STC = 15.2 kW;
- Nominal Operating Cell Temperature = 47.5°C;
- tilt angle = 17°, due south;
- inverter efficiency = 95%;
- mismatch losses = 3%.

The calculation was performed on an hourly basis over a whole representative year. As a result, the potential annual electricity production from the PV solar system is 38.6 $kWh.m^{-2}.y^{-1}$, which corresponds to 84 $kWh.m^{-2}.y^{-1}$ in terms of primary energy (average conversion efficiency = 46%).

Therefore, the application of Eqn. (1) now provides $PE = - 5\ kWh.m^{-2}.y^{-1}$. Since $PE < 0$, this result suggests that a terraced-house apartment building in Southern Italy, with a well-insulated envelope fulfilling the requirements of National Regulations, can become an N-ZEB simply through the installation of a suitable amount of PV modules on its roof (in this case, around 0.24 m^2 of PV panels per m^2 of useful floor area).

5. Criticisms and strategies for improvement

As discussed in Section 2, there does not exist at the moment an official definition for Zero Energy Buildings. However, the definition adopted in this paper is one of the most recognized in the scientific literature: it does not take into account the electricity consumption for household appliances, and it allows deducting all contributions coming from on-site renewable energy sources. On the basis of this definition, the building considered in this study is worth being classified as an N-ZEB.

However, in the authors' opinion, some issues should be raised. First of all, the EPBD Recast [1] specifies that a key feature of Zero Energy Buildings is their very high energy performance: this means that every effort should be made to improve the building performance before trying to compensate through the use of renewable energy sources. Furthermore, electricity consumption for household appliances is not negligible, thus the fact of not taking them into account in the energy balance make the N-ZEB classification just *conventional*, but not *real*.

Hence, starting from the data presented in the previous section, some strategies are discussed in the following, aimed at improving the energy performance of the building, thus better approaching the requirements of a *real* Zero Energy Building. The main feature shared by these strategies is their technical and economical feasibility: indeed, this is a key issue for a green technology to establish itself on the market, as highlighted in [9].

Domestic hot water

The results presented in Table III show that DHW preparation is normally the most energy-consuming activity in a new well-insulated building in mild Mediterranean climate. In order to reduce the primary energy consumption for DHW, it is suitable to install a collective solar thermal system. The surface devoted to the positioning of the solar field is the flat roof on top of apartment C (see Fig. 2). For the calculation of the potential contribution of this solar system, the following assumptions are made:

- flat plate solar collectors (optical efficiency = 0.75, first order coefficient = 4.2);
- collecting surface = 20 m^2 (around 3 m^2/apartment);
- tilt angle = 40°, due south;
- thermal losses in the storage and the distribution network = 15% of the collected energy;
- storage volume = 1000 litres;

According to the calculation carried out in compliance with UNI TS 11300/4, based on the *f-chart* method, the annual solar fraction, i.e. the fraction of the overall thermal energy needs for DHW being covered through solar energy, is SF = 0.83. This means that only the 17% of the energy needs for DHW must be covered through a back-up system being driven by non-renewable energy sources (as an example, by an electric resistance), which corresponds to 3.3 $kWh.m^{-2}.y^{-1}$ of thermal energy. Actually, it is also necessary to take into account the additional electricity consumption for the circulation pumps and the control system of the solar plant: according to the calculations, this contribution amounts to 0.6 $kWh.m^{-2}.y^{-1}$.

Air infiltration and natural ventilation

As highlighted in Section 3, a ventilation rate as high as 0.3 ACH was considered in the heating season, which also accounts for air infiltration through leaks. This value is suggested by the Standard UNI 11300/1.

Now, the actual infiltration rate in a building depends on its air tightness, that is conventionally measured by the parameter n_{50}, i.e. the number of air changes per hour under a pressure difference $\Delta p = 50$ Pa between indoors and outdoors. In the case of the building of Fig. 2, since the average pressure difference resulting from the simulation is $\Delta p = 3.2$ Pa in winter, the value suggested by the Standard (0.3 ACH) corresponds to $n_{50} = 2.1$ ACH[1]. According to the standard Passivhaus, n_{50} should be lower than 0.6 in cold climates, whereas $n_{50} < 1$ is recommended in mild climates. Thus, a new simulation was performed, where the infiltration rate was reduced by a factor 3 (from $n_{50} = 2.1$ to $n_{50} = 0.7$); this is not a difficult task to accomplish in a low-rise double-leaf building, if all the details influencing the air tightness of the envelope (window frame, junctions) are well addressed during design and construction stage.

As a result, the average thermal energy demand for heating is reduced from 18.3 to 9.9 $kWh.m^{-2}.y^{-1}$.

Demand Controlled Ventilation (DCV)

As shown by the previous issue, the air tightness of the envelope should be improved to reduce the thermal energy demand for heating. However, in order to achieve acceptable levels of Indoor Air Quality, a suitable ventilation rate should be provided through a mechanical ventilation systems: this is not a constraint, but an opportunity for energy savings if an efficient dual-flow ventilation system with heat recovery is installed.

A new simulation was then performed under the following assumptions:

- inlet ventilation rate = 40 m^3/h per person;
- efficiency of the heat recovery = 75%;
- rated electric power of the fans = 70 W.

As a result, an additional thermal energy demand for heating arises (6.8 $kWh.m^{-2}.y^{-1}$), to be added to that calculated in the previous issue. Furthermore, the electricity consumption of the fans must be taken into account, that amounts to 1.2 $kWh.m^{-2}.y^{-1}$.

Free-cooling through natural ventilation

It is well-known that night ventilation in summer can assist the ambient cooling, since at night the outdoor temperature is - on average - lower than the desired temperature set point for indoor comfort. A new simulation was then performed by imposing a ventilation rate as high as 1 ACH at night in summer (from 22:00 to 06:00, between May and September). This might be simply achieved through a correct management of the windows by the occupants.

As a result, the average thermal energy demand for cooling is reduced from 25.4 to 22.6 $kWh.m^{-2}.y^{-1}$. This implies an electric energy consumption of 7.8 $kWh.m^{-2}.y^{-1}$ if adopting air-conditioning units with the efficiency described by Eqn. (5).

Artificial lighting

The average electricity consumption for artificial lighting in residential buildings, as highlighted from national statistics, lies around 350 kWh per year per apartment[2]; this amount is only the 12% of the overall electricity consumption in the residential sector, that is dominated by electric appliances and air-conditioning systems. According to the same statistics, the use of high-

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[1] The infiltration rate is proportional to Δp^n, where $n \cong 0.7$.

[2] Source: AEEG (Authority for Electric Energy and Gas)

efficiency fluorescent lamps may imply a reduction of around 60%. These figures will be retained in the following, which means reducing PE_L from 11.8 (see Table III) to 4.7 kWh.y^{-1}.m^{-2}, i.e. 2.2 kWh.y^{-1}.m^{-2} of electric energy.

Household electrical appliances

According to well established statistics, in Italy the average electricity consumption for household appliances in residential buildings (fridge, television, personal computer, washing machine) lies around 1900 kWh.y^{-1} per apartment, which means 22 kWh.y^{-1}.m^{-2} if considering an average surface of 85 m^2 per apartment. This electricity consumption can be reduced by around 40% through the use of energy-efficient appliances, leading to a final amount of 13 kWh.y^{-1}.m^{-2} of electric energy consumption.

Overall energy balance

Table IV reports the final energy balance obtained thanks to the design strategies previously discussed. The overall electricity consumption, here also including household appliances, is 24.8 kWh.y^{-1}.m^{-2}, that is to say still lower than the potential electricity production from the solar PV system (38.6 kWh.y^{-1}.m^{-2}).

Furthermore, the thermal energy demand for heating might be satisfied by installing a reversible heat pump, to be used also in summer for ambient cooling. If assuming an average thermal COP as high as 3.5, which is absolutely common in mild climates, the electric energy consumption of the heat pump would be around 4.8 kWh.y^{-1}.m^{-2}.

Finally, the back-up system for the solar DHW might simply consist of an electrical resistance, which would imply an electric energy consumption of 3.3 kWh.y^{-1}.m^{-2}.

Thus, the overall electricity needs would be as high as 32.9 kWh.y^{-1}.m^{-2}. The PV system would still be able to cover all of these contributions; actually, in order to get PE = 0, it is sufficient to install only 87 m^2 of PV panels.

Table IV. Energy needs of the building after the proposed strategies [kWh.m^{-2}.y^{-1}]

Apt.	*Electricity*	*Heat*
Lighting	2.2	-
Household	13.0	-
Solar DHW	0.6	3.3
Cooling	7.8	-
Heating and VMC	1.2	16.7
TOTAL	**24.8**	**20.0**

6. Conclusion

The study presented in this paper aimed at defining a standard for the construction of residential N-ZEBs in mild Mediterranean climate. The analysis was applied to a terraced house with a double-leaf opaque envelope made of hollow bricks, as this building typology is the most widespread in Southern Italy.

The results of the dynamic simulations show that a terraced house can be converted into an N-ZEB, if designed in compliance with Italian regulations about the envelope insulation level, and if thermal bridges – especially those due to structural concrete beams and pillars - are corrected. Indeed, it is sufficient to install on the pitched roof a suitable amount of monocrystalline PV panels, here quantified in 0.24 m^2 per m^2 of net floor area, i.e. on average 14.5 m^2 per apartment.

However, it is underlined that the evaluation of the energy performance is based on conventional scenarios concerning occupancy, air infiltration and artificial lighting. Furthermore, the electricity consumption for household appliances is not taken into account.

This led to evaluate some strategies to improve the actual energy performance of the building, thus making it a *real* N-ZEB (and not just a *conventional* one). These strategies mainly concern the correct design and management of mechanical ventilation systems, the exploitation of natural ventilation at night in summer, the use of solar thermal systems for DHW preparation, as well as the improvement of the air tightness. Obviously, the use of low-consumption lighting and household appliances is also recommended. Heating and cooling should be performed through high-efficiency reversible heat pumps. The final area of PV panels is 0.20 m^2 per m^2 of net floor area.

Of course, the proposed design strategy is only one of the possible solutions. Actually, any further intervention on the insulation of the envelope is welcome (very low-emissive glazing, additional insulation in the air gap of the walls), as it would help reduce the size of the PV system necessary to accomplish the N-ZEB requirements.

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