Defining the Reference Hotel – toward nearly Zero Energy Hotels design

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SUMMARY

The ever mentioned “cost optimality” and “nearly Zero Energy Buildings” concepts, introduced by the EPBD recast, are still a blurry target at EU Member States’ level for non-residential buildings. Among the uncertainties hampering a quantitative description of cost optimal and nearly Zero Energy (nZE) level of energy performance in these building categories, the definition of the “typical energy use of a building” [1], is a key issue. Indeed, in non-residential buildings the energy use for maintaining occupants’ comfort (identified as the “typical”) is complementary to the energy use for maintaining the offered services’ quality. Given the general issue, the paper focuses on hotels. As an initial step toward nZE hotels, this study presents the definition of an existing Reference Hotel. First, typical and extra functions of a small-medium hotel were defined. Then, the general procedure for defining a Reference Hotel (RH) was drafted and an Italian RH was modelled: internal layout, envelope, systems features and operation profiles were identified. A dynamic energy simulation of the model was run to evaluate its energy performances. Results were then compared to benchmarks from literature. Next steps will exploit the Reference Hotel to investigate potential relations with the energy uses for extra services and to propose cost-optimal and energy efficient retrofit measures.

INTRODUCTION

In the European Commission view, Nearly Zero Energy Buildings (nZEB) and cost-optimal level of energy performance are notions that will overlap in a very near future. As widely known, both nZEB and cost-optimality were introduced in EU regulation by the recast of the Energy Performance of Building Directive [1]. nZEBs have very high energy performance and their energy need is covered to a very significant extent by energy from renewable sources. Cost-optimal level is defined the energy performance level which leads to the lowest cost during the estimated economic lifecycle. It is obtained by testing the effectiveness of several energy saving measures in improving the energy performance of buildings while taking into account their global cost. Whereas cost optimality is prescribed as the current framework regarding ambition level of typical energy performance for renovation and new buildings, nearly Zero Energy is the ambition level that Member States (MS) have to reach for all new buildings and major renovation by 1 January 2021 [2]. Because of their common nature and goal, the two energy performance levels also share the basic steps of their definition methodology, shown in Figure 1.

Figure 1. Steps of the methodology for defining cost-optimal and nZE performance levels.

In this paper the attention is focused on hotel buildings, identified as a specific building category to be considered in nZEB and cost-optimal calculations [1], but, at present, not taken into account in most of Member States. Indeed, MSs are allowed to derive all reference buildings and cost-optimal level of energy performance of the non-residential sector from basic reference buildings for offices (one RB for new buildings and minimum two RBs for existing buildings), if other specific non-residential buildings minimum requirements do not exist in their national regulations [3]. Due to the calculation efforts required, this strategy is the most widely used. Nonetheless, such an approximation may be misleading in deriving cost-optimal level of energy performance for other categories of non-residential buildings. For instance, the typical features of a hospital or a restaurant may widely differ from those of an office building. Therefore, despite not compulsory, realistic cost-optimal levels of energy performances, and consequent minimum energy performance requirements, ask for a higher number of reference buildings, when the building stock is diverse.

As a first step toward cost-optimal and nZE level of energy performance levels, the Reference Building needs to be drafted. It "represents the typical building geometry and systems, typical energy performance for both building envelope and systems, typical functionality and typical cost structure in the Member State and is representative of climatic conditions and geographic location" [3], in order to obtain representative and achievable energy performance levels as final outcomes of the methodology. Despite RBs key role, the lack of representative/reliable/detailed data about the existing building stock dampens their descriptive accuracy. Moreover, even if several past and present project collected information on the existing RBs or tried to develop national sets of RBs [4, 5, 6, 7], a procedure guiding the RBs definition is not yet clearly outlined [8].

What's "typical"?

Levels of energy performance to reach both cost-optimality and nZEB are referred to the "**typical energy use"** of a building [1], and they are based on calculation performed on Reference Buildings, which represent the **typical building-plant-operation** of the building stock [3]. However, the concept of **"typical"** is not convincingly addressed for all the building categories listed in EPBD recast [3]. EPBD [9] suggests that the energy performance of a building depends on the climatic indoor environmental quality targets set for it; therefore energy performance of a building for its standard use (heating, cooling, ventilation, hot water, lighting, possibly equipment) should refer to the standard indoor environmental conditions [10]. This approach allows considering the whole building stock as a set of "empty boxes" to which a rather uniform set of energy efficiency measures can be widely applied. In residential buildings, where maintaining the indoor environmental quality is the main goal of the systems installed, the so-defined "typical energy use" is the most suitable parameter to take into account in energy and economical evaluations. In non-residential buildings, instead, the energy use for maintaining occupants' comfort is complementary to those for maintaining the offered service's quality. Indeed, for each non-residential building use, offered services are the characterizing element and their energy consumption is very dependent on the service quality, which in turn in related to the activity's business success. In these buildings the typical energy use should be coupled with additional energy uses related to extra functions.

With these premises and with the aim to give further push to the development of non-residential (and non-office) Reference Buildings in Italy, in the following paragraphs the definition of an

Italian existing Reference Hotel is outlined. Indeed, hotels exemplify the difference between typical and extra energy use of a building. Moreover, the nZEB target for hotels is object of the on-going European project “nearly Zero Energy Hotels – neZEH” [11], to which this paper may contribute. The obtained Reference Hotel is built in dynamic simulation software and evaluated in terms of typical and total energy consumption. As a final step, simulation results are compared to benchmarks value about energy use of the existing hotel building stock given by literature.

METHOD

Definition of an Italian Existing Reference Hotels

In order to define a representative Italian Reference Hotel, sub-categories of this building type were identified. Sub-categorization, despite not mandatory for MSs, is suggested by the Regulation [3] as a way to define different Reference Buildings, or the most representative one, for the main category. The different hotel typologies were defined by focusing on building parameters related to energy consumption. The selected criteria and the related classes are shown in Table 1. References and justifications for the choice and classification of each sub-category are here given:

- Climatic area; Building age. Suggested as sub-categories in [3], their division in classes, is taken from the Italian outcome of Tabula project [12]. Despite [12] only deals with residential buildings, the existing hotel stock is considered by authors very similar to the residential building stock in terms of geometry and construction typology, mirrored by each construction age.
- Hotel size. Building size is a mentioned subcategory in [3]. In the specific case of Italian hotels, size classes are provided, in terms of number of guestrooms, by Istat [13].
- Hotel category. The “stars” classification implies different minimum services to offer to guests, as required for Italy in [14], which affect the energy consumption of the building.
- Hotel opening period. This additional criteria and classification is suggested by [15], as it obviously influences the hotel plants system and energy use.

Table 1. Sub-categories and related classes for the definition a Reference Hotel.

<table>
<tr><th>SUB-CATEGORY</th><th colspan="120">CLASSES</th></tr>
<tr><td>CLIMATIC AREA</td><td colspan="40">ALPINE (HDD <3000)</td><td colspan="40">MIDDLE (HDD 2100-3000)</td><td colspan="40">MEDITERRANEAN (HDD >2100)</td></tr>
<tr><td>BUILDING AGE</td><td colspan="15">… - 1900</td><td colspan="15">1901 - 1920</td><td colspan="15">1921 - 1945</td><td colspan="15">1946 - 1960</td><td colspan="15">1961 - 1975</td><td colspan="15">1976 - 1990</td><td colspan="15">1991 - 2005</td><td colspan="15">2006 - …</td></tr>
<tr><td>HOTEL SIZE</td><td colspan="40">SMALL (≤24 guestrooms)</td><td colspan="40">MEDIUM (25-99 guestrooms)</td><td colspan="40">LARGE (≥100 guestrooms)</td></tr>
<tr><td>HOTEL CATEGORY</td><td colspan="24">1*</td><td colspan="24">2*</td><td colspan="24">3*</td><td colspan="24">4*</td><td colspan="24">5*</td></tr>
<tr><td>OPENING PERIOD</td><td colspan="40">ALL YEAR</td><td colspan="40">SUMMER</td><td colspan="40">WINTER & SUMMER</td></tr>
</table>

Further step of the existing RH developments was the identification of its detailed parameters, required to perform reliable energy calculations using a dynamic method (as suggested by [16]). The amount of information needed in this phase can be grouped in sections. Corgnati et al. [17], inspired by DOE RB models [18], defined 4 sub-sets to be detailed: form; envelope; system; operation. Brandão de Vasconcelos et al. [8] proposed to gather the detailed parameter in: configuration; constructive solutions and others. In this paper, the approach proposed by [17] was used. Irrespective of the data grouping method selected, the information can come from statistical analysis or from experts’ assumptions. According to the sources available, for each sub-set of parameters different approaches may be used to create a RB, described by Tabula [12]: (1) Example Building, based on experts’ assumptions and studies, when statistical data are not available; (2) Real

Building, existing building with the most typical building of a certain category, based on statistical analysis, (3) Theoretical Building, virtual building with a composite of the most common features within a category of buildings.

Typical and extra energy uses of a Reference Hotel

It is worth noting that sub-categorization and statistical information for the hotel building stock only takes into account features related to hosting functions, such as guestrooms number and equipment or reception and common areas services and opening times [13, 14]. Neither minimum requirements nor statistical data are given for extra services offered in hotels, e.g. fitness area, laundry or kitchen. Indeed different hotels offer a wide range of facilities, which entails a significant gap in total energy needs among buildings with the same general use classification, showing, in turn, similar energy consumption related to the their hosting function [10]. It may be derived that the "typical energy use" in hotels refers to the energy used to maintain indoor environmental comfort conditions related to hosting functions, that can be identified in guestrooms, reception hall, offices, bar and restaurant, meeting rooms. Following EU dispositions, these functions will be accounted for the definition of the Reference Hotel energy use. However, extra functions have complementary energy uses that cannot be disregarded, since their presence influences both the whole building energy performance and the hotel business success. Their relevance in the hotel energy balance is analyzed in this paper by applying the basic principle of the superposition of effects. Kitchen and fitness area, most common extra functions in the Italian hotel stock, are implemented as "additional entities" to the Reference Hotel hosting functions, in order to point out their role on the hotel total energy use.

Reference Hotel dynamic energy simulation and benchmarking

The defined Reference Hotel model was built in Energy Plus by implementing the detailed information previously gathered about form, envelope, system and operation. Once the building location was selected, an annual simulation was run. Outcomes were reported for typical (hosting functions) and extra energy uses (kitchen and fitness area) of the building. Results were expressed both in terms of delivered and of primary energy, for which Italian Primary energy conversion factors, given in [19], were applied (1,05 for Natural Gas, 1,95 for Grid Electricity).

As a final step, results were related to existing figures in literature. The RH simulated delivered energy was compared to 2 different energy efficiency ratings for existing hotels, reported in Table 2. The RH Primary Energy was compared to the preliminary assumption of neZEH project about primary energy use for hosting functions in Italian hotels, 222 kWh/m^{2}y [10].

Table 2. Energy efficiency rating for existing hotel (delivered energy) proposed by [20] and [21]

Energy performance rating	Rating [20]	Rating [21]
	Small hotels (4-50 rooms) without laundry, with heating and air conditioning in some areas	all hotel types
	Range [kWh/m^{2}y]	Range [kWh/m^{2}y]
Excellent	-	<195
Good	<240	195 – 280
Average	240-290	280 – 355
Poor	290-340	355 - 450
Very poor	>340	>450

RESULTS

An Italian Reference Hotel

Following Tabula procedure [12], the study focused on the **Italian Middle climatic zone**, where a **medium size**, **3 stars** hotel, **open all year** and built between **1921-1945** was selected as the subcategory of Reference Hotel to be developed, because:

- in the Italian middle climatic zone (e.g. Turin, Milan), urban hotels devoted to business and cultural tourism - therefore open all year - are representative of an important share of the accommodation market [15];
- 3 stars hotels represent the highest share of businesses (45%) and beds (43%) of the Italian stock [13, 22];
- medium size hotels, more common in the urban contexts, are the 42% of businesses and 56% of guests' beds of the Italian hotel offer [13, 22];
- hotel businesses increased constantly from 1930 onwards [22]. Hotels built between 1921 and1945 are taken as example of early stage buildings asking for deep retrofit actions.

The identified Reference Hotel sub-category was then developed in terms of detailed parameters, collected in 4 sections [17] and applying the approaches suggested by Tabula project [12]. The approaches implemented in the present study are presented in Figure 2 and references for each section are here detailed:

- "**Form**". Statistical information about the hotel building stock in terms of size, accommodation capacity, category and location were taken from the Italian statistic institute [13]. Based on these data, a real building representing the average stock for the chosen hotel subcategory was selected. Due to a lack of information about other dimensional/geometrical features of the hotel stock, the choice of a real hotel building, elected by statistics as representative of a specific category, was the only possibility to have enough detailed data to build a simulation model.
- "**Envelope**". Information were derived from the Italian Building Typology brochure [12], outcome of Tabula project, based on the review of the real building envelope features. Construction techniques adopted for hotel buildings were assumed by authors to be very similar to those for residential buildings, specific object of [12]. Indeed the selected real building envelope characteristics (not detailed enough to be used) are very similar to the features proposed by [12].
- "**System**". Specific information were derived from experts assumptions used in Tabula project [12] for heating and from field research findings presented in [15] for cooling.
- "**Operation**". Data were generally derived from DOE "Small Hotel" Reference Building [7], based on US typical operation schedules derived from methodologies (2) and (3). Set-points were derived from EN15251 [23], in order to comply with European requirements.

The same procedure was applied to describe the features of kitchen and fitness area, for which specific schedules related to extra services of the hotel were adapted to the Italian hotel context.

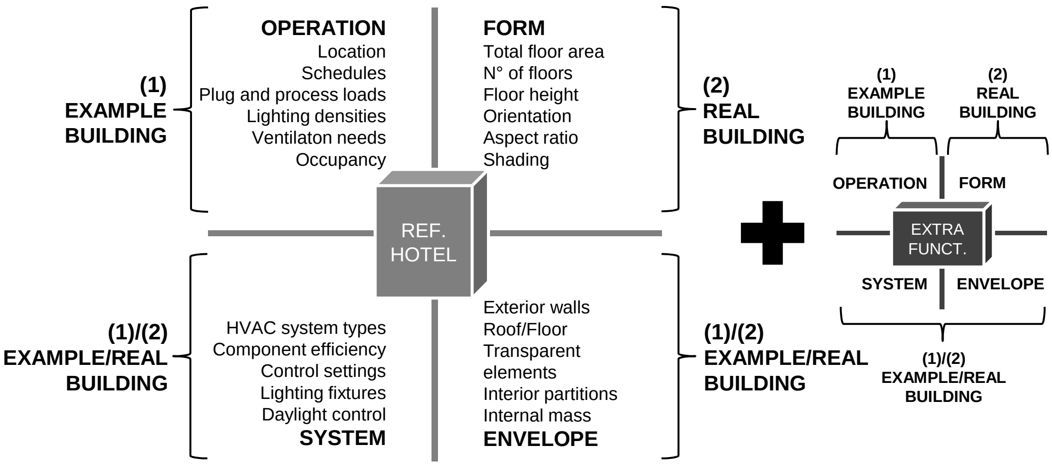

Figure 2. Approaches implemented for the definition of the detailed parameters describing the RH.

Table 3 summarizes the obtained RH main features and Figure 3 displays its internal layout.

Table 3. Italian existing RH main characteristics regarding form, envelope and system.

BUILDING CHARACTERISTICS		UNIT	DATA	DATA SOURCE
FORM	Gross area	m^2	2117	real building
	Gross conditioned area	m^2	1700	real building
	Average gross area/floor	m^2	423	real building
	Number of floors	-	5 (4 + basement)	real building
	Orientation	-	S-N	real building
	Aspect ratio (S/V)	-	0.28	real building
	Floor height (clear height + ceiling)	m	3.5	real building
	Number of façades	-	3	real building
	Façades total area	m^2	1275	real building
	Opaque façades area	m^2	1059	real building
	Window/Wall ratio	-	0.17	real building
	Number of guestrooms	-	49	real building
	Average guestrooms area	m^2	21	real building
	Number of beds	-	95	real building
ENVELOPE	External walls construction	-	Hollow wall brick masonry (U=1.1 W/m^{2}K)	[12], selection based on real building site visit
		-	Hollow brick masonry, low insulation (U=0.8 W/m^{2}K)	[12], selection based on real building site visit
	Internal walls construction	-	Hollow brick wall (U=2.3 W/m^{2}K)	real building
	Ground floor construction	-	Concrete floor on soil (U=2.0 W/m^{2}K)	[12], selection based on real building site visit
	Floors construction	-	Floor with reinforced brick-concrete slab (U=1.65 W/m^{2}K)	[12], selection based on real building site visit
	Roof construction	-	Floor with reinforced brick-concrete slab, medium insulation (U=0.7 W/m^{2}K)	[12], selection based on real building site visit
	Windows	-	Single glass wood frame (U_w=4.9 W/m^{2}K, g=0.85)	[12], selection based on real building site visit
		-	Single glass, metal frame without thermal break (U_w=5.7 W/m^{2}K, g=0.85)	[12], selection based on real building site visit
	Doors	-	Glass and metal doors thermally improved (U_w=3.8 W/m^{2}K, g=0.75)	[12], selection based on real building site visit

SYSTEM	Ventilation	-	Natural	[12], selection based on real building site visit
	Heating system	-	Centralized, with radiators	[12], selection based on real building site visit
	Heating energy source	-	Natural gas	[15], confirmed by the real building site visit
	Cooling system	-	Centralized, with split	[15], confirmed by the real building site visit

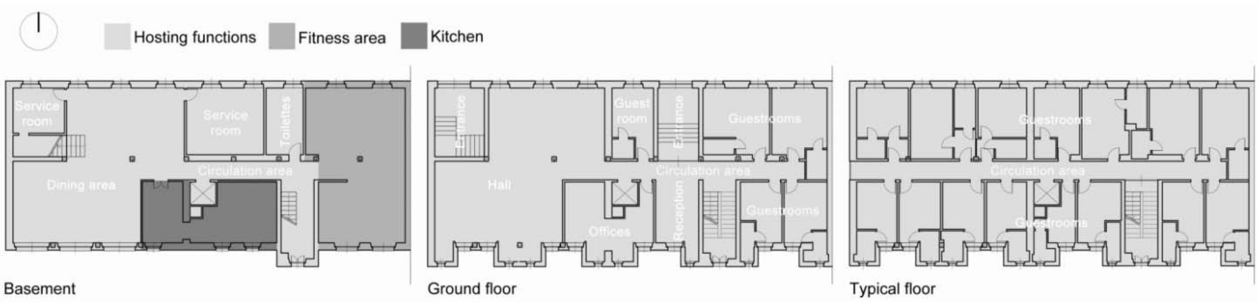

Figure 3. Italian existing RH internal layout for basement, ground floor and typical floor.

RH simulation results

For the purpose of the simulation, the RH was located in Turin (HDD=2617), representative of the Italian Middle Climatic Zone. Its annual delivered and primary energy use are reported in Table 4 with regard to its end-uses and in Table 5 with regard to the relevance of its hosting and extra-functions.

Table 4. Delivered and primary energy use of the Italian existing RH for its end uses.

End use	**Electricity**	**Natural Gas**	**Primary Energy (PE)**	**Share of PE for end-use**
	kWh/m^{2}y	kWh/m^{2}y	kWh/m^{2}y	-
Lighting	54.36	-	106.00	27.1%
Equipment	64.48	2.19	128.03	32.7%
Fans & Pumps	4.69	-	9.14	2.3%
Cooling	48.60	-	9.77	24.2%
Heating and DHW	0.03	50.98	53.58	13.7%
TOTAL	172.16	53.17	391.53	100%

Table 5. Primary energy use of the Italian existing RH for its functions.

Function		**Hosting functions**	**Fitness area**	**Kitchen**
Share of the whole Primary Energy use		90.56%	6.26%	3.18%
Specific primary Energy use [kWh/m^{2}y]	Lighting	104.62	167.87	53.65
	Equipment	127.96	85.95	211.63
	Fans & Pumps	9.14	9.14	9.14
	Cooling	98.23	46.83	22.99
	Heating and DHW	36.44	335.16	326.31
	TOTAL	376.39	644.94	623.72

DISCUSSION

Built on the EPBD recast dispositions, the paper aimed at drafting an Italian existing Reference Hotel, and, from a wider standpoint, to point out the need for a wider range of RBs, in order to achieve realistic cost-optimal minimum energy requirements. The RH, modeled following procedures suggested by literature and based both on literature and observed data, was simulated in

Energy Plus. Simulation results are intended to show the energy performance level of a hotel building, in relation to the existing benchmarks for hotel energy efficiency.

In terms of delivered energy of the whole building, according to the proposed classifications [20, 21] the defined RH is ranking "good" (225.33 kWh/m^{2}y). However, these rankings may be to generic since they do not consider distinction among the services offered by hotels (except from specification about laundry). Dealing with Primary Energy, remarks are two-sided:

- on the one hand, the hosting functions' primary energy use (391.53 kWh/m^{2}y) is 76% higher than the average value for the Italian hotel stock identified by neZEH project (222 kWh/m^{2}y) [10]. However, the neZEH benchmark is based on analysis of the residential building stock, to which standard extra energy uses for cooling and ventilation were added. The primary energy results here presented may lead to the conclusion that in Italy hotels energy use for hosting functions is not comparable with residential ones.
- on the other hand, the extra functions simulated for the RH, despite their small relevance in terms of floor area (6%) and the low profile offered services (fitness area with gym equipment and kitchen serving breakfast only), accounts for approximately 10% of the whole building primary energy use, with specific primary energy consumption 66% (kitchen) and 71% (fitness area) higher than the one for hosting functions. These results suggest that, when dealing with retrofit measures options for hotels, extra services need to be accounted.

Taking advantage of these findings and considerations, next steps of the research will take the presented RH as the baseline model to apply retrofit measures in view to achieve the cost-optimal and the nZE level of energy performance.

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