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Article

A Methodological Comparison between Energy and Environmental Performance Evaluation

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Abstract: The European Union is working on strategies in order to increase the energy efficiency of buildings. A useful solution is to identify the energy performance of buildings through the Energy Performance Certificate (EPC), as it provides information for the comparison of buildings with different architectural typology, shape, design technology and geographic location. However, this tool does not assess the real energy consumption of the building and does not always take into account its impact on the environment. In this work, two different types of analysis were carried out: one based only on the energy efficiency and the other one based on the environmental impact. Those analyses were applied on a standard building, set in three different Italian locations, with the purpose of obtaining cross-related information. After the evaluation of the results, interventions on some parameters (walls insulation, windows frame, filler gas in the insulated glazing) have been identified in order to improve the energy behavior of the building with an acceptable environmental impact. The aim of this paper is to propose a methodology that integrates the EPC with green building rating systems, leading to a more conscious choice of retrofit interventions as a compromise between energy performances and environmental impact.

Keywords: Energy Performance Certificate; ITACA protocol; environmental impact; energy consumptions; buildings analysis

1. Introduction

Energy consumptions are increasing on a world scale, and the highest energy demand is in the residential sector and in services related to buildings [1].

In order to reduce energy consumptions, one of the goals set by the European Union is to improve existing buildings and to design buildings with high energy performances [2]. On the European level, reaching a "near-zero energy building" has been set as a goal for the public sector from 2018 and for new buildings from 2020. In order to reach this aim, several strategies have been examined and realized in different application fields: many works analyzed the design of technologic solutions at an urban scale as the cogeneration and the district heating and cooling systems [3–8] or at the single-building scale as the use of devices with higher energy performance or innovative materials [9–13]. However, the energy analysis is not always combined with an in-depth examination of the indoor environment [14,15]. Other research focused on the analysis of the outdoor context in terms of meteorological data [16–18], on the optimization of passive devices and techniques [19–23]. However, these strategies are not always easy to apply, especially to existing buildings. Indeed, European building heritage needs to be preserved because of its historical, artistic and architectural values, and often, retrofit interventions cannot be realized. This situation is particularly identifiable in Italy, which is the country with most UNESCO World Heritage Sites [24].

The Energy Performance of Buildings Directive (EPDB) disposes also that every member country should arrange a national plan about energy efficiency and made mandatory the Energy Performance Certificate (EPC) for existing and new buildings. However, at least in Italy, the EPC tool does not take into account the impact that it has on the environment. Energy demand connected to the production process, the use of certain kinds of raw materials and the disposal of the final product are not evaluated in the Italian EPC. The Italian energy regulation does not consider the so-called life cycle assessment (LCA) approach [25], which sets the goal to quantify the environmental impact of a product along its entire lifecycle. The application of the environmental evaluation on existing and new buildings is not mandatory, and it is rarely applied during the design stage, since it often needs long times, a wide amount of accurate data about the building and its location and a long elaboration stage.

In addition in the Italian energy regulation, only the evaluation of winter heating and domestic hot water (DHW) production consumptions is mandatory with the result of a weak and misleading energy evaluation. Applications of the Italian EPC can be found in [26–30]. Fantozzi *et al.* [26] evaluated the energy demand of two new residential building in Tuscany (Italy) testing different labelling criteria suggested by European standards and Italian local administrations. Still Fantozzi *et al.* [27] studied the thermal performance of the architectural envelope of a building prototype in winter and summer conditions with particular attention to the wall stratigraphy. Evangelisti *et al.* [28] evaluated the energy performance of a test-cell, characterized by three different wall types, through a dynamic calculation code and a steady-state code based on Italian standards, concluding that these simplified procedures do not allow one to correctly evaluate the building's inertial behavior. Asdrubali *et al.* [29] examined nine buildings, covering several different construction techniques, in terms of energy performance, evaluated with *in situ* measurements and numerical simulations. De Lieto Vollaro *et al.* [30] conducted a comparative analysis on the energy performance of an old building using a semi-stationary software and a dynamic one considering transparent elements characterized by progressively improved properties of thermal transmittance and solar gain factor.

There are more mandatory requirements for buildings performance in the Mediterranean European context compared to the ones asked by Italian standards [31]. The Spanish Ministry of Industry, Tourism and Commerce developed a software for buildings energy certification, which takes into account cooling consumptions, as well. In Cyprus, the EPC implementation became mandatory with the Ministerial Order for the Minimum Energy Performance Requirements of 2009 for all residential and non-residential buildings and includes cooling needs expressed in terms of primary energy. In France, the Réglementation thermique 2012 is in effect for all new construction; it covers cooling consumptions of the building and reports the environmental impact related to building energy consumption.

The present paper wants to show how the incompleteness of the Italian energy performance analysis can lead to misleading results. A generic case study has been examined with two different approaches: one based only on the energy efficiency improvement and one based on the environmental impact decrease. In order to apply the latter method, a preliminary study of the tools available in Italy for the environmental impact evaluation of buildings was carried out, with particular attention to the ITACA protocol [32]. A simplified methodology was proposed in order to integrate the energy performance evaluation with environmental considerations. The obtained results show how the energy performance approach actually gives a more impacting role to the winter period, orienting choices on high performance materials without considering the embodied energy and emissions in production, transportation and disposal processes. On the opposite side, the integrated approach shows also how the overall energy demand of the building can decrease both in the summer and winter period using natural materials, even if they have lower thermal performance.

The case study has been analyzed in different locations in order to underline the applicability of the proposed approach in areas of the Italian territory characterized by different climate and heating/cooling needs.

2. Tools for the Buildings Evaluation

In the Italian context, the EPBD directive has been implemented into the Legislative Decree 192/2005 [33] and then into the Legislative Decree 115/2008 [34], which prescribes referring to the UNI/TS 11300 (Technical Specification) [35] for buildings' energy demand calculation. In addition, the Presidential Decree 59/2009 [36] recommends the procedures for building performance analysis and refers to the UNI/TS 11300.

The UNI/TS 11300 shows two possible methodologies:

- The asset rating, which evaluates building and plants through design data;
- The operational rating, which provides an analysis of the building through real data.

The choice of the most suitable methodology for the energy performance evaluation depends on two main factors: the building type (existing or in the design stage), the level of accuracy and the comparability of the results with other certifications. Obviously, for new buildings, the lack of energy consumption data forces the choice on the asset rating. The calculation methodology is simplified: this means meteorological data refer to a standard year; plants and systems are always turned on; and the interior temperature is constant.

The building classification is based on the EP_{gl} (Energy Performance Global Index), which is the sum of different energy consumptions calculated by other partial indexes:

$$EP_{gl} = EP_i + EP_{acs} + EP_e + EP_{ill} \tag{1}$$

where:

- EP_i: primary energy for the heating during the winter season;
- EP_{acs}: primary energy for DHW;
- EP_e: primary energy for the cooling during the summer season;
- EP_{ill}: primary energy for the artificial lighting.

After the calculation of the EP_{gl}, it is possible to classify the building consumptions on a scale from A (best) to G (worst). This classification system allows one to compare buildings with different shapes, sizes and located in different parts of the Italian territory.

As previously said, today's Italian regulation requires the energy performance calculation to take into account only the energy consumptions for space heating in winter and DHW production. According to UNI/TS 11300 Part 1, the summer condition is considered through the $Ep_{e,invol}$ index, which indicates the performance of the building envelope during the summer season or through the analysis of the delay time and the thermal lag. Depending on the consumptions resulting from the $Ep_{e,invol}$, the building is classified on a scale from I (excellent) to V (bad). This is the required approach by the national legislation, although it is evidently weak to analyze the real consumptions for cooling a building during the summer season.

3. Green Building Evaluation: The ITACA Protocol

Green building certification tools are based on two methodologies [37]: the multi-criteria approach and the LCA approach. The multi-criteria tools are structured in different hierarchical groups, which have different weights on the final evaluation, based on a scoring system. Among them, the most known are the British BREEAM (Building Research Establishmemt Environmental Assessment Method) [38] and the American LEED (Leadership in Energy and Environmental Design) [39]. In the Italian view, a national protocol was developed by ITACA (Institute for Innovation and Transparency of Contracts and Environmental Compatibility) and it refers to the Sustainable Building (SB) method [40], a multi-criteria methodology internationally managed by iiSBE (International Initiative for Sustainable Built Environment) for the research project Green Building Challenge.

Several works investigated the green building rating systems. Ding [41] analyzed different environmental building assessment methods used in different countries in order to develop a sustainability index. Ali and Al Nsairat [37] developed a green building rating system for developing countries by integrating criteria from different assessment methodological frameworks. As results, they obtained a green residential building assessment tool for Jordan. Lee [42] compared five green building schemes, BREEAM, LEED, CASBEE (Comprehensive Assessment System for Building Environmental Efficiency), BEAM (Building Environmental Assessment Method) Plus and Chinese ESGB (Evaluation Standard for Green Building), showing that they are based on relative performance. Especially, LEED is less flexible in its assessment criteria, but is the only one that adopts an energy cost budget approach. Asdrubali *et al.* [43] compared LEED and ITACA rating systems, applying them on two residential Italian buildings in order to suggest a more balanced score distribution. They concluded that ITACA could focus more on the site, while LEED gives great importance to the site sustainability.

As the other multi-criteria tools, the ITACA protocol is structured into different criteria, which are the elemental units, grouped into different categories; the categories are also grouped into evaluation areas (Figure 1, Table 1).

Figure 1. ITACA protocol structure.

Table 1. Evaluation areas of the residential version of the ITACA protocol.

Evaluation Area	1. Site Quality	2. Resources Consumption	3. Environmental Loads	4. Interior Environmental Quality	5. Services Quality
Weight	5.17%	43.97%	18.10%	13.79%	19.0%

The main difference among these systems is the weight of every criterion, since the evaluation areas are roughly the same (Figure 2).

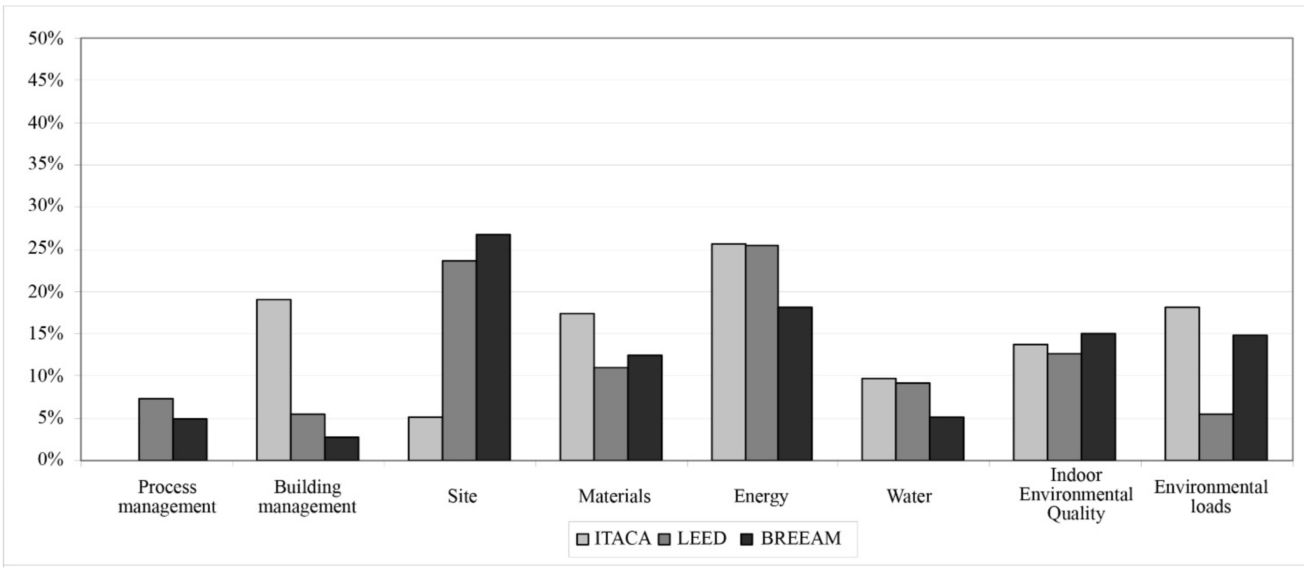

Figure 2. Evaluation areas weighing among ITACA, LEED and BREEAM from [44].

In this work, the residential version of the ITACA protocol [45] was considered, which is described by 49 criteria. For each criterion, there is a score ranking from −1 to +5 assigned to the building, where zero is the minimum performance required by actual laws. Each criterion has a different weight on the final score, and they are divided into two categories:

- Relative: the importance of the criterion is related to its category;
- Absolute: the importance of the criterion is related to the entire evaluation system.

The weight of criteria is assigned by the Italian regions in order to adapt the evaluation to a specific territory or area.

As the final result of the analysis, a global environmental score is achieved, which represents the energy-environmental sustainability performance of the investigated building on the basis of the evaluation scale adopted by ITACA. The environmental score is the threshold established by region regulations to obtain subsidies. On this basis, the percentage of goals achieved is calculated.

4. The Combined Approach

Results obtained from the energy analysis are completely based on the winter period, although thermal problems deriving from the summer season are prevalent in the Italian climate.

In order to design a more complete evaluation methodology, which could be able to combine the energy performance certificate with environmental impact considerations, all of the criteria of the ITACA protocol were examined. The criteria forming a part of the categories in Table 2 were considered useful to reach the aim of this work.

Table 2. Chosen criteria of the ITACA protocol.

Evaluation Area	Category		Criteria	
2. Resources Consumption	2.1	Non-renewable primary energy needed during building's lifecycle Weight: 53.3%	2.1.1	Building materials' embodied energy
			2.1.2	Thermal transmittance of building envelope
			2.1.3	Net energy for heating
			2.1.4	Primary energy for heating
			2.1.5	Solar radiation control
			2.1.6	Building thermal inertia
			2.1.7	Net energy for cooling
			2.1.8	Primary energy for cooling
	2.3	Eco-friendly materials Weight: 24.4%	2.3.1	Material from renewable resources
			2.3.2	Recycled/recover materials
			2.3.3	Local materials
			2.3.4	Local materials for finishing construction
			2.3.5	Recyclable materials
3. Environmental Loads	3.1	Equivalent CO_2 emissions Weight: 52.6%	3.1.1	Embodied emissions in building materials
			3.1.2	Expected emissions in the operational phase

These criteria were integrated in the Italian standard energy performance evaluation in order to create a simplified analysis containing also environmental considerations. The proposed combined approach allows a better control of building energy consumptions in the wider time of its life cycle.

A case study of a standard building has been chosen and analyzed. Its architectural elements have been studied, and some of them have been changed in order to obtain two different results: one oriented on a better energy performance and the other one oriented on a better environmental sustainability. Energy and environmental performances of the building have been studied in three different Italian locations characterized by different heating/cooling needs with the standard Energy Performance Certificate and the partial ITACA protocol evaluation.

5. The Case Study

Nowadays, the design phase of a building and the assessment of its future energy consumptions are conceived together. Otherwise, designing a building and evaluating its energy performance only in a second stage would not respect current legislation. Indeed, new buildings are required to meet minimum standards in terms of thermal transmittance of the envelope and of global energy performance. Furthermore, new buildings have to be consciously designed in order to satisfy the evolution of future European directives, which expect the buildings to become "near-zero energy buildings" by 2020.

In order to analyze the proposed integrated approach, which could be applied in different locations, a new residential building was chosen. The designed building is one linear element composed of five typologies of flats, differing from each other in shape, exposure and net area and arranged in four floors for a total amount of 40 flats (Figure 3).

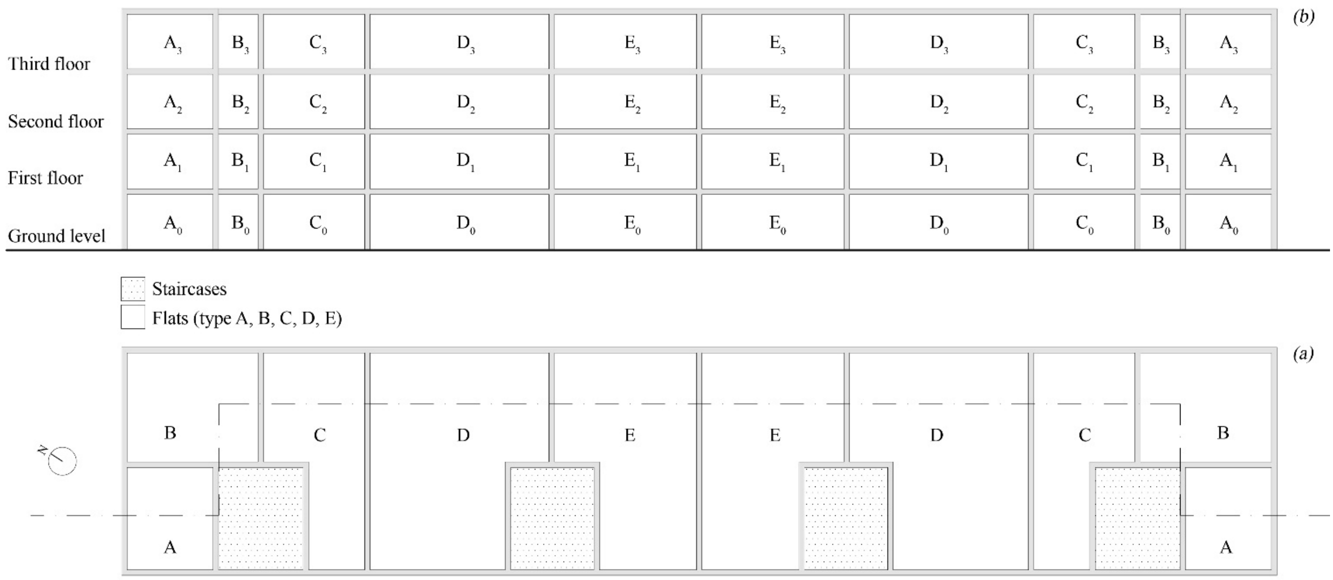

Figure 3. Schematic plan (**a**) and section (**b**) of the building.

The building structure is composed of pillars and beams made of reinforced concrete. The stratigraphy of infill walls and ceilings has been defined during the last phase of the design stage, according to the environmental parameters taken into account.

The building is equipped with a central heating system with a condensing boiler for the space heating and the DHW supply. In addition, the building is also equipped with a solar thermal energy system, which covers about 65% of DWH supply. The contribution of the renewable energy sources has been detracted by the overall energy demand of the main thermal system with a consequent improvement of the Energy Performance Indexes and a decrease of fuel demand and CO_2 emissions.

Passive devices were not used, except for large glazed elements and screening systems. The main characteristics of the building are summarized in Table 3.

Table 3. Building characteristic.

Intended Destination	Architectural Typology	Floors	Air-Conditioned Gross Volume	Net Area	External Area	Area/Volume Ratio
Residential	Reinforced concrete frame	4	9576 m^3	2503 m^2	3391 m^2	0.35

The architectural elements were divided into two categories: fixed and variable parameters (Table 4). Variable parameters differ from fixed, since they can be changed to improve the energy-environmental performances of the building (Figure 4). All of the parameters operate as input data for both energy and environmental evaluations.

Table 4. Fixed and variable parameters of the building.

Fixed Parameters	Variable Parameters
General architectural data (volume, area, *etc.*)	Insulation type (fixed thickness: 10 cm)
Architectural structure	Windows frames
Thermal and electrical systems	Filler gas in the insulated glazing (fixed thickness: 6-9-6 mm)
Interior wall and ceilings stratigraphy	

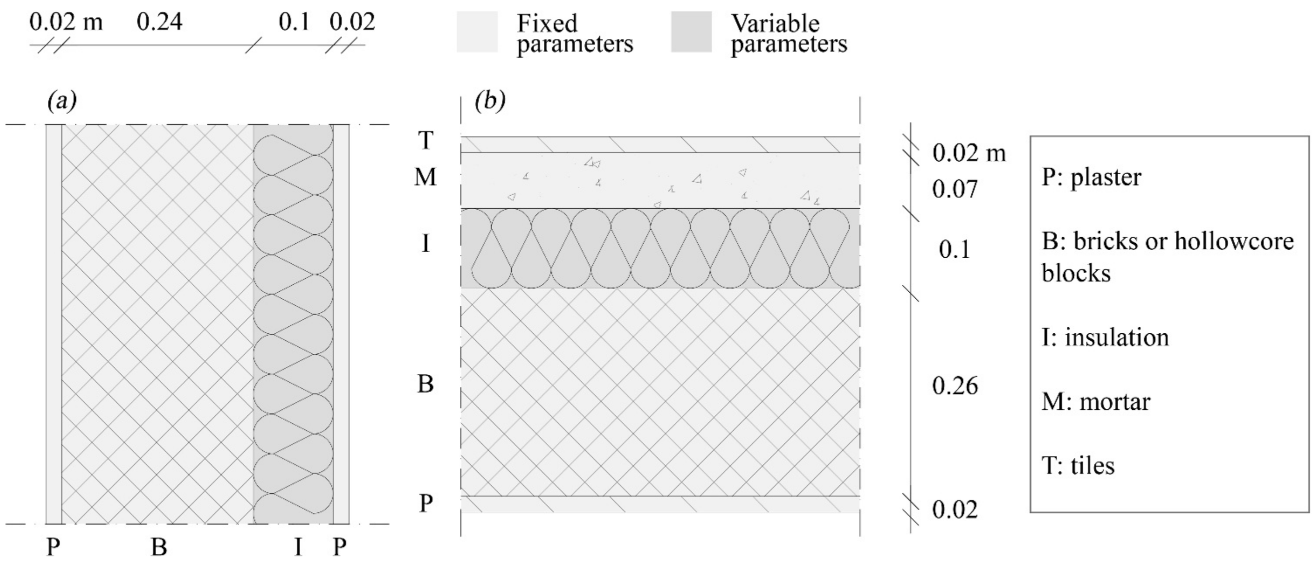

Figure 4. Schematic stratigraphy of infill walls (**a**) and ceilings (**b**) of the building.

5.1. Fixed Parameters

Even if good practice requires that the design phases of a building follow both energy and environmental considerations from the beginning to the end of the executive process, it is very difficult to fully comply with these requirements. For this reason, setting some parameters of the building as fixed has been considered as a more realistic approach. These elements are related to building morphology, architectural typology, architectural envelope and air-conditioning systems (Table 5). They were designed in order to pick standard efficient choices from the energy and environmental points of view.

Table 5. Fixed parameters of the building.

Frontiers to the Outdoor Space	Windows	Shading Devices	Wind Sensitivity
External insulation and finishing system	Double glazing with low emissivity film	External brise-soleil	Low

5.2. Variable Parameters

Directive 1989/106/CEE [46] establishes the essential requirements for materials used in the construction industry for public and private buildings. At the international level, the environmental declaration of building products is regulated by ISO 21930:2007 [47]. The characteristics of different kinds of external insulation, windows frames and filler gas in the insulated glazing have been studied (Tables 6–8). For the insulation, a fixed thickness of 0.1 m was chosen, while the insulating material was varied, as well for the window air gap, the thickness of which is of 0.09 m. These analyses were carried out in order to orient the variable parameters choice according to a high energy performance and a low environmental impact. This phase was necessary to understand how different building materials impact on human health and on the environment during their entire lifecycle.

Thermal characteristics (conductivity, specific heat capacity, density) make reference to UNI 10351:1994 [48] and UNI EN ISO 10456:2007 [49], while embodied energy (EE) and embodied carbon (EC) make reference to the ITACA protocol database and to the Inventory of Carbon and Energy (ICE) [50] of the University of Bath.

Table 6. Characteristics of different thermal insulations.

	Conductivity	Specific Heat Capacity	Density	Embodied Energy (EE)	Embodied Carbon (EC)
	W/mK	J/kgK	kg/m^3	MJ	kgCO_2
RENEWABLE MATERIALS					
Wood fiber	0.037	2000	265	1,182,562.5	52,821.1
Kenaf fiber	0.039	1700	50	89,250	2380
Cork panel	0.041	1670	105	829,355.6	8277.9
RECYCLABLE MATERIALS					
Expanded cellular glass	0.055	1000	140	1,143,292.5	63,932.8
Cellulose fiber	0.058	1900	67.5	99,101	3213
Glass wool	0.039	1030	20	149,940.0	7497
MINERAL MATERIALS					
Rock wool	0.037	1030	30	100,406.3	6827.6
Expanded perlite	0.037	1000	90	224,910	13,119.8
FOSSIL MATERIALS					
Expanded polystyrene (EPS)	0.034	1500	20	297,500	9996
Extruded polystyrene (XPS)	0.04	1450	38	565,250	18,992.4
Polyurethane	0.03	1260	30	592,620	58,012.5

The values in Table 6 show that the best thermal insulation is guaranteed by the polyurethane (conductivity 0.03 W/mK), but the kenaf fiber has the lowest environmental impact considering both EE (89,250 MJ) and EC (2380 kg CO_2 eq.) during the production process.

Table 7. Characteristics of different window frames.

Window Frame	Thermal Transmittance	Embodied Energy (EE)	Embodied Carbon (EC)
	W/m^2K	MJ	$kgCO_2$
Aluminum	5.88	5470	279
PVC	2.00	2310	118
Wood	2.7	360	19

Table 8. Characteristics of different filler gasses for the insulated glazing.

Filler Gas	Thermal Transmittance	Embodied Energy (EE)	Embodied Carbon (EC)
	W/m^2K	MJ	$kgCO_2$
Xenon	2.48	4500	229
Krypton	2.53	510	26
Argon	2.76	31	2
Air	2.97	0	0

The same considerations can be done in terms of window frames materials (Table 7), where the wood has the best performance on both EE and EC profiles, but the PVC has a low thermal transmittance, and in terms of filler gasses for the insulated glazing (Table 8), where the xenon has the best thermal transmittance (2.48 W/m^2K), but the air is better on the environmental profile.

Previous analyses show that good quality materials from the energy point of view generally assure a high thermal performance, but on the other side, they are mostly detrimental for the environment. This is the reason why two different paths have been carried out: the first is based on the high energy profile of chosen materials (Configuration A); the other one (Configuration B) is based on the low embodied energy and emissions of chosen materials (Table 9).

Table 9. Summary of the variable parameters' choice.

Variable Parameter	Configuration A	Configuration B
Insulation	Polyurethane foam	Kenaf fiber
Window frame	PVC	Wood
Filler gas	Xenon	Air

The design of the opaque building envelope in Configuration A contains a polyurethane foam layer as the thermal insulation. This material has the best thermal performance among the considered ones. However, the raw material required in the production process derives from the oil, and it is strongly impacting on the environment both for EE and EC. PVC frames and xenon were chosen for the windows. The PVC is a fire-resistant and acid-resistant material, with a good thermal conductivity and a very long lifetime. On the other hand, it is harmful to human health and the environment during both the production and the disposal phases, and one of the raw materials for PVC production is derived from oil. The xenon also has good thermal insulation properties, but its production strongly impacts the environment.

Following the environmental profile, instead, the kenaf fiber has been chosen as the wall insulation material, which is also characterized by a good thermal resistance. Wood frames and dehydrated air were chosen as options for windows systems. Wood is a recyclable and renewable raw material; it is light and resistant, ensures high thermal performances and good durability. Air allows good insulation without any previous treatment and is always available.

6. Results and Discussion

6.1. First Configurations of the Project

The two different proposed configurations (A and B) were applied on the hypothetical buildings, located in three different cities in order to find a methodology applicable in different locations (Table 10). The choice of the cities was made based on the Italian climatic zone classification established by the Presidential Decree 412/1993 [51].

The chosen places are the city of Palermo (Climatic Zone B), the city of Rome (Climatic Zone D) and the city of Cuneo (Climatic Zone F). Zone A was discarded since it involves only a few locations in Italy.

Table 10. Characteristics of the chosen cities.

City	Latitude	Longitude	Altitude	Climatic Zone	Degree Days	Operation Period of the Heating System	Daily Hours
Palermo	38°6′N	13°21′E	14 m	B	751	1 December–15 March	8
Rome	41°53′N	12°28′E	20 m	D	1415	1 November–15 April	12
Cuneo	44°23′N	7°33′E	534 m	F	3012	No limitation	No limitation

All of the analyses were carried out for the whole building in accordance with both the UNI/TS 11300 Parts 1 and 2 and the ITACA protocol for a total of 12 different sets of results (Table 11). The Energy Performance Certificates were obtained with the software MC11300 [52], while evaluations based on the materials' embodied energy and emissions were carried out with the ITACA protocol's frameworks.

Table 11. Summary of the parametric analyses.

City	Building Configuration	Analysis Name	
		UNI/TS 11300 Parts 1 and 2 (EPC)	ITACA Protocol (IT)
Palermo (PA)	A	PA_AEPC	PA_AIT
	B	PA_BEPC	PA_BIT
Rome (RM)	A	RM_AEPC	RM_AIT
	B	RM_BEPC	RM_BIT
Cuneo (CN)	A	CN_AEPC	CN_AIT
	B	CN_BEPC	CN_BIT

As the first choice, the building was located in Rome. Results obtained from RM_AEPC show that the building is evaluated in the B ranking with the annual global performance index Ep_{gl} equal to

33.11 kWh/m^2. The annual energy performance of the envelope during the summer cooling $Ep_{e,invol}$ is equal to 20.82 kWh/m^2, which is equivalent to the III class (medium quality) in accordance to the Italian regulations. In the RM_AIT, the building obtains an environmental score of 0.82 and a goal achievement from the environmental impact point of view of 43%.

In the RM_BEPC analysis, the building obtains a lower ranking in the energy classification. The annual Ep_{gl} is equal to 36.92 kWh/m^2, equivalent to the C class. Anyway, the $Ep_{e,invol}$ is equal to 19.82 kWh/m^2, and the quality of the envelope is the II class (good quality). The environmental score reached in the RM_BIT analysis is higher than the RM_AIT and is equal to 0.98 (51% of the goals achieved).

The comparison among the results obtained from the different configurations shows that the standard energy certification could be misleading if not well interpreted. If on the one side, the materials chosen for Configuration A seem more suitable for the decrease of energy consumptions during the lifecycle of the building, on the other side, the consumptions due to the production and the disposal phases are not considered at all. In addition, the results show that the eco-friendly materials have a better performance in the summer cooling, always considering that the energy demand during the summer season is only partially analyzed in the Italian standard energy certification.

The same parametric sets of analysis have been transposed in another two different climatic zones, and the previous considerations can be applied also to the new results (Table 12).

Table 12. Results for the three locations.

Indexes and Scores	**PALERMO (B)**		**ROME (D)**		**CUNEO (F)**	
	Building Configuration		**Building Configuration**		**Building Configuration**	
	A	**B**	**A**	**B**	**A**	**B**
Annual Ep_i (kWh/m^2)	11.49	13.27	29.95	33.75	57.73	64.03
Annual Ep_{acs} (kWh/m^2)	3.17	3.17	3.17	3.17	3.17	3.17
Annual Ep_{gl} (kWh/m^2)	14.68	16.47	33.12	36.92	60.90	67.20
Energy ranking	A	A	B	C	C	C
Annual $Ep_{e,invol}$ (kWh/m^2)	23.07	22.02	20.82	19.83	4.80	3.94
Quality class	III	III	III	II	I	I
Environmental score	1.02	1.25	0.82	0.98	0.90	1.32
Goals achievement	53%	65%	43%	51%	47%	58%

Configuration A presents a better performance from the energy point of view, with respect to Configuration B. In the same way, Configuration B presents a better performance from the environmental point of view, compared to Configuration A. This fact is even more obvious in the current Italian evaluation system. Despite that, the better performances in the summer period are not enough to shift the final choice on the environmental one. For these reasons, Configuration B was slightly changed in order to understand if there is convenience in the use of an eco-friendly design also from the energy point of view.

6.2. Improvement of the Building Performance

For each location, according to the results obtained from the Energy Performance Certificate and the environmental evaluation, some small corrections and improvements to the initial Configuration B have been proposed and applied (Table 13).

Table 13. Summary of the improvement adopted for Configuration B in all of the locations.

Improvement	Palermo	Rome	Cuneo
Increase of the insulation thickness	-	√ External wall from 10 cm to 12 cm √ Covering from 10 cm to 15 cm	√ External wall from 10 cm to 12 cm √ Covering from 10 cm to 15 cm
Decrease of the insulation thickness	√ Wall and ceilings adjacent to non-heated space from 10 cm to 7 cm	√ Wall and ceilings adjacent to non-heated space from 10 cm to 7 cm	-
Increase of the insulation glazing thickness	-	√ From 0.9 cm to 0.12 cm	√ From 0.9 cm to 0.12 cm
Triple grazing for windows with particular exposures	-	-	√ Windows with NE exposure
Improve the shading system	√	-	-

With these changes, another six analyses have been carried out in order to quantify the differences with both the Italian standard energy regulation and the ITACA protocol. Results are summarized in Table 14.

Table 14. Results for the locations with the improved Configuration B.

Indexes and Scores	PALERMO (B)	ROME (D)	CUNEO (F)
Annual Ep_i (kWh/m^2)	14.33	31.68	55.29
Annual Ep_{acs} (kWh/m^2)	3.17	3.17	3.17
Annual Ep_{gl} (kWh/m^2)	17.50	34.84	58.45
Energy ranking	A	B	B
Annual $Ep_{e,invol}$ (kWh/m^2)	18.64	19.85	3.62
Quality class	II	II	I
Environmental score	1.22	1.05	1.32
Goals achievement	63%	54%	69%

Results show how these simple corrections bring good environmental results, improving also the energy performances. The environmental goal achievement is lower only for the building located in the city of Palermo, where there is a decrease of about 2%, but it is still higher than Configuration A (Figure 5). Regarding the energy profile, there is an overall improvement of the building envelope performance during the summer season (Figure 6). It only increases very little (0.02%) in the building located in the city of Rome. On the other hand, for the winter season (Figure 7), the energy consumptions for the space heating become lower than the one of Configuration A only for Climatic Zone F, increasing the energy ranking from Class C to Class B. Despite that, in Climatic Zone B, the energy ranking is the same between Configuration A and the improved Configuration B, while it is higher in the first Configuration B, and in Climatic Zone D, there is an improvement from Class C to Class B. Therefore, the improved Configuration B results in being the best option combining a good environmental score and only a slight decrease of the energy performance compared to Configuration A.

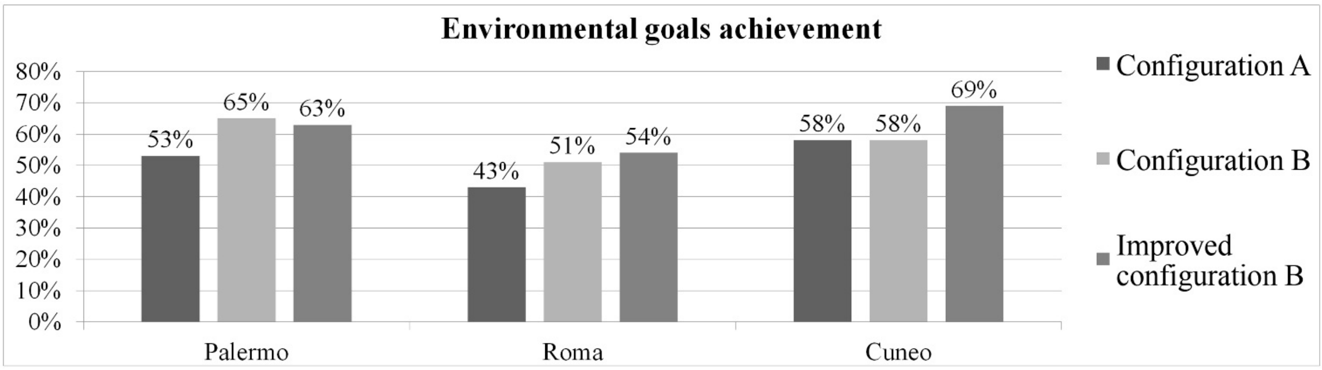

Figure 5. Comparison of the goals achievement in the ITACA protocol evaluation among the three configurations.

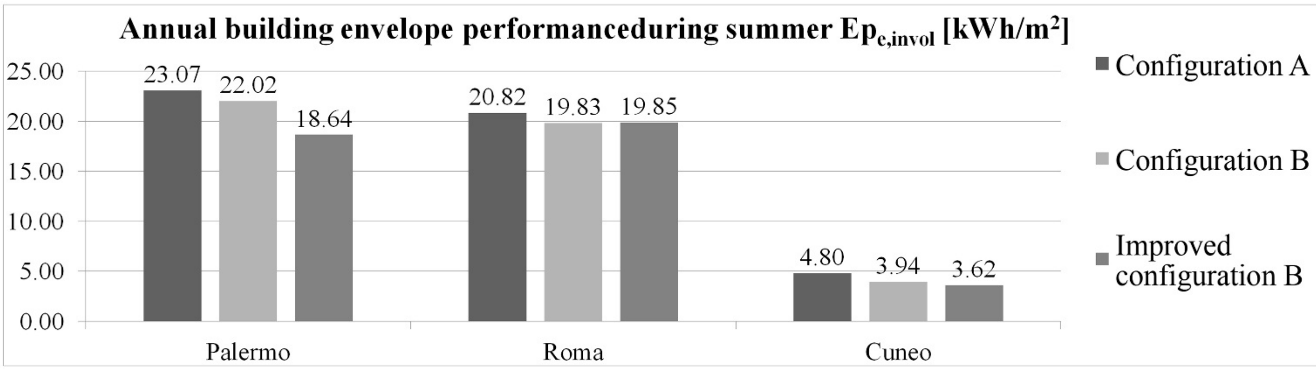

Figure 6. Comparison of the building envelope performance during the summer season among the three configurations.

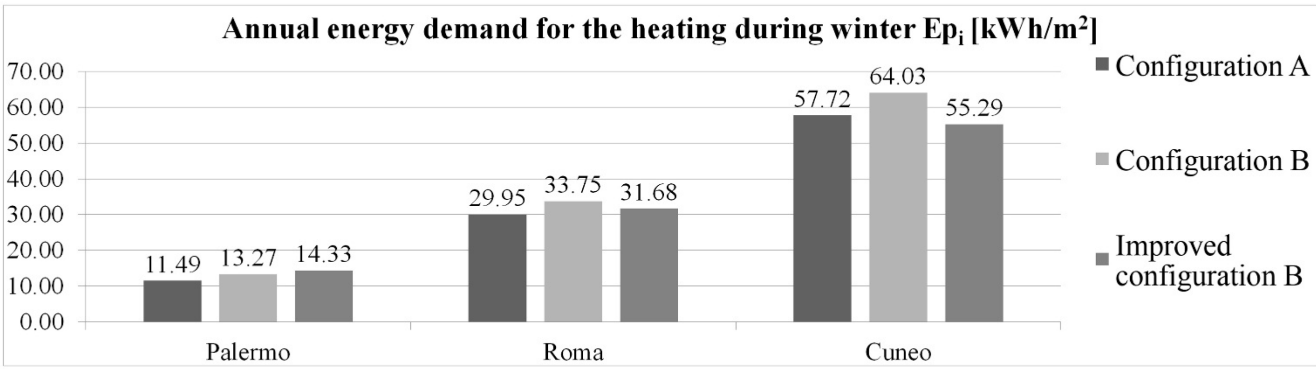

Figure 7. Comparison of the energy demand for the heating during the winter season among the three configurations.

7. Conclusions

In the present work, a study of the tools available in the Italian context for the Energy Performance Certificate of buildings has been carried out, highlighting that the Italian standards establish as mandatory only the evaluation of winter heating and DHW production consumptions. At first glance, the obtained values bring misleading results, which are far from the real energy demand of the analyzed building. In addition to that, they do not take into account the impact of the building on the environment during its lifecycle. For this reason, a simple case study of a new building has been studied, imposing some fixed and variable parameters and locating it in three different cities in the Italian territory. The variable parameters were changed in order to obtain two different configurations: one oriented to improve energy performances (Configuration A); the other one to lower the environmental impact (Configuration B). These configurations were analyzed in accordance with both the UNI/TS 11300 Parts 1 and 2 and the ITACA protocol's frameworks for the whole building. The results show that Configuration A fits into the energy analysis as well as Configuration B fits into the environmental analysis. On the whole, Configuration A obtains a better energy ranking than Configuration B. For this reason, few corrections to the variable parameters' selection have been applied. The improved Configuration B results in an increase of both the environmental score and the energy ranking.

This result underlines how the Energy Performance Certificate in Italy can be easily oriented also to considerations based on the environmental impact of buildings and materials. The proposed approach allows one to obtain that goal, combining the simplicity of the energy consumption evaluation with the completeness of the green building analysis. This methodology could take one to a higher awareness of the link between the energy performance of buildings and their environmental impact, orienting the design of new buildings and the choice of retrofit interventions respecting both evaluative areas.

Author Contributions

The study was designed by Francesca Pagliaro, Fabio Bisegna, Franco Gugliermetti and Andrea de Lieto Vollaro. The building case study was designed by Chiara Burattini and Lucia Cellucci. Ferdinando Salata and Iacopo Golasi retrieved the data from yearbooks and professional websites and reviewed the literature related to the research. The parametric analysis and simulations were carried out by Francesca Pagliaro and Fabio Bisegna. The results were then analyzed by Ferdinando Salata and Iacopo Golasi. English corrections were undertaken by Chiara Burattini and Lucia Cellucci. Franco Gugliermetti and Andrea de Lieto Vollaro, the full professors of the research group, supervised the work related to the paper and the execution of its various phases.

Conflicts of Interest

The authors declare no conflict of interest.

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