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Research paper

PROTOCOLS FOR THE ASSESSMENT OF BUILDING SUSTAINABILITY LEVEL. A NEW PROPOSAL FOR THE ITALIAN CONTEXT

Roberta Moschetti, Livio Mazzarella

Politecnico di Milano, Energy Department, via Lambruschini 4, 20156 Milan, Italy

ABSTRACT

The paper aims at illustrating an innovative methodology for the development of a system to assess and rate the sustainability level of buildings, with particular reference to the Italian context.
First, a review of the state of the art is presented, focusing on the existing sustainability tools, which characterize the building sector. Afterwards, the main criticalities of the current systems are pointed out, laying the basis for the setting-up of the new protocol.
Consequently, the paper illustrates the process leading to the development of the new sustainability evaluation system, showing all the main steps towards its final inner structure.
Finally, the research work introduces the concept of 'benchmark', underlining its importance within the new protocol framework. In particular, the absence of reference or limit values for some performance indicators is emphasized and a computation methodology is proposed for those performance indicators lacking of benchmark values, with respect to the Italian background.
As a result, the paper provides an effective methodological and operative tool for decision makers, such as designers, constructors, developers and users of sustainability systems.
The outcomes offer a contribution to the national and international development of methods and guidelines, supporting the overall sustainability evaluations in the building field.

Keywords: Sustainability; Building assessment and rating systems; Life cycle; Benchmarks; Residential buildings.

1. Introduction

The article illustrates a methodology for the development of a new system to assess the building sustainability level, with particular reference to the Italian context.
Initially, the state of the art is presented with a focus on the existing sustainability tools for buildings. Afterwards, the main drawbacks of the current evaluation systems are shown, providing the basis for the definition of the proposed protocol.

1.1 State of the art

Over the past decades, the concept of sustainable development emerged as primary in several areas. In particular, the construction sector is one of the most significant fields of intervention for achieving the sustainability objectives, in its three basic pillars, namely: environmental, social and economic spheres. Buildings are responsible for high consumptions of energy, greenhouse gas emissions, use of natural resources and generation of waste; they represent the main place where people spend most of their time, significantly influencing their health and wellbeing. In addition, the built environment is a major part of the economic resources of individuals and populations, contributing substantially to the advancement of the national economy.

In this context, many countries began to promote the use of innovative products and processes to foster the growth of sustainable buildings and to establish procedures for the development of protocols to define the level of sustainability of buildings.

In recent years, there was the diffusion of numerous systems for the evaluation and certification of sustainability performance of buildings (Haapio and Viitaniemi, 2008), which provide a useful support to the assessment of environmental impacts, as well as social and economic effects of constructions.

Currently, in most countries, the sustainability certification is voluntary and complementary to the well-known energy certification, which is the definition of building energy consumption, as required and regulated by specific laws. Instead, the certification of sustainability level represents a broader process, which includes different aspects, such as the consumption of energy and materials, the production of pollutants, the life quality of the occupants.

In the construction sector, two major categories of sustainability evaluation protocols spread. The first, widely used in the research field, contains tools that draw up a strict budget of the various environmental impacts during the entire life cycle of the building (from cradle to grave); they are based on the methodology called 'Life Cycle Assessment' (LCA) and some examples are: Eco-Quantum (Netherlands) [1], EcoEffect (Sweden) [2], Envest2 (UK) [3], BEES (US) [4], ATHENA (Canada) [5], SimaPro (Netherlands) [6]. The second, more common in the construction practice, refers to tools based on environmental /economic/social requirements (criteria) to each of which a numerical rating scale is assigned, leading to the definition of a total score about the building sustainability level; they include, e.g.: BREEAM (UK) [7], LEED (US) [8]; CASBEE (Japan) [9], HQE (France) [10], SB Tool (International) [11].

In recent years, a growing number of sustainability protocols [12, 13] defined an integrated approach, in order to include analyses related to the entire building life cycle, in addition to the specific mentioned criteria. This new approach is based on the use of objective and recognized methods, such as the LCA and the 'Life Cycle Costing' (LCC).

Finally, from a regulatory standpoint, both ISO and CEN worked actively to outline standard requirements for sustainability assessments of buildings.

Specifically, the ISO, within the Technical Committee TC 59 'Building construction', established the subcommittee SC 17 'Sustainability in construction', with the aim of publishing a series of technical specifications, focusing on the development indicators for buildings and evaluation methods of environmental efficiency. Instead, CEN established the Technical Committee TC 350 'Sustainability of construction works', which deals with the development of standard methods of assessment related to sustainability aspects for new and existing buildings and sets standards for the environmental product declarations (EPDs).

1.2 Criticalities of existing protocols

Sustainability protocols were developed trying to meet the growing demand for assessing the overall quality by operators and users in the construction industry. These tools were therefore designed to compensate for the lack of agreed and standardized guidelines for the global estimation of the sustainability level of buildings. Nonetheless, some problems concerning protocols emerged in the course of their spread.

Overall, the systems based on LCA include in their configuration only environment-related issues, which can be estimated in a quantitative way. Furthermore, they require several input data, which may not be fully available for the analyzed building, such as information related to materials locally produced. Finally, due to the large number of already existing LCA tools, a harmonization work is unquestionably necessary.

The protocols based on criteria provide for the evaluation of the sustainability performance in relation to numerous requirements to be met in terms of specific reachable levels. Unfortunately, the achievement of some levels is defined only in qualitative terms, which is not in conformity with the principles of the qualification of a construction work: measurability, to ensure reliability, objectivity and comparability, to allow the examination and comparison of different design alternatives. Furthermore, some protocols require that, in order to reach a default certification level, only some specific prerequisites are obligatorily met, leaving a free choice of the other criteria. In this way, some important evaluation requirements may be omitted by the users, who could be more careful to choose criteria easily achievable rather than to verify the actual building sustainability performance.

Another important open question concerns the need for an appropriate balance between the different dimensions of sustainability in the estimation of the overall quality of the buildings. So far, the tools based on LCA and those based on criteria were characterized by separate pathways of definition and development: the former were mostly focused on the calculation of the environmental impacts, while the latter often lacked an approach based on the entire cycle of life. Currently, one of the main objectives in the field of building assessment tools is to define a protocol that takes into account all the sustainability issues, considering the whole life cycle. Indeed, existing tools often neglect sustainability criteria referred to some stages of building life, as for instance the energy use in the pre-use phase of the building, implying the absence of specific limit or reference values (benchmarks) for basic criteria in the definition of the overall quality.

From these considerations, it emerges the need for a holistic system for building performance assessment, which involves the whole life cycle and which is, at the same time, functional, transparent and flexible enough.

The critical issues and potential developments of existing sustainability tools constituted the basis on which the new methodological proposal for the Italian context is founded, as below illustrated.

2. Methodology

Below, the protocol proposed for remedying the problems set out in section 1.2 is described.

2.1 Definition of the structure of the new protocol

The definition of the structure of the new protocol was based on five main stages.

In the first stage, after the analysis of the state of the art, some sustainability tools were selected, among the already existing ones, to be examined in more detail. In particular, since the aim was to define a new national methodology, it was decided to analyze two protocols specifically developed for the Italian context and other tools defined abroad, but which are also available in a European or international version. The ISO 21929-1 and the proposal of an Ecolabel[1] for buildings were also examined.

The analyzed instruments are summarized in Table 1.

Tab. 1 – The examined sustainability assessment tools.

Sustainability assessment tools	Source
1. ITACA protocol	SB tool
2. LEED Italy	LEED (US)
3. BREEAM Europe Commercial	BREEAM
4. DGNB International Certification	DGNB
5. HQE International	HQE
6. EU Ecolabel. Criteria for Office	EU
7. ISO 21929-1:2011. Sustainability in building construction-	ISO

The proposed tool was set by reference to the typical structure of protocols based on criteria, which are characterized by global areas, assessment criteria, performance indicators and calculation methods.

Firstly, starting from the analysis of the areas included in the examined sustainability tools, the global areas to be included in the new protocol were identified, i.e. those

[1] The EU Ecolabel (EC Regulation n. 66/2010) is the EU label that rewards the best products and services from the environmental point of view.

categories that describe the performance of a building with respect to a sustainability key aspect. Afterward, to examine the interdependencies between the different areas, a multi-criteria method was applied, namely the Decision Making Trial and Evaluation Laboratory, DEMATEL (Hiete et al., 2011). The Analytic Hierarchy Process, AHP (Äukyaz and Sucu, 2003), was also implemented, in order to define a scale of priorities among the analyzed categories. Finally, to obtain the final set of global areas to be considered, the calculation of an index of preference was proposed, taking into account the results obtained with both methods. The application of these multi-criteria methodologies required the constitution and the consultation of a panel of experts, whose members belonged to several Italian universities.

Next, for each global area specific assessment criteria were defined, which are sustainability requirements within the general categories. To this aim, a critical analysis of the criteria contained in the existing protocols and standards was made, identifying redundancies, similarities and gaps. In particular, some criteria were modified and new ones were introduced, such as those concerning LCA, connected to the quantification of environmental impacts and LCC, related to the cost estimation.

Global areas and assessment criteria were then associated to a weight in order to determine their relevance in the protocol structure. The weight of the global areas was derived from the combination of the results obtained by DEMATEL and AHP, by applying the method Analytic Network Process, ANP (Äukyaz and Sucu, 2003). Instead, the criteria were weighted through the application of the AHP method with a further consultation of the panel of experts.

The last step consisted in the connection of the various assessment criteria with one or more performance indicators, linked to an appropriate method of calculation, to enable the estimation of the effective sustainability performance. Specifically, the choice resulted from the analysis and the comparison of indicators and calculation methods contained within the existing sustainability tools, which were appropriately modified and implemented with new indicators and computation methods.

The methodological steps followed for the definition of the new protocol structure are shown in Figure 1 (Moschetti, 2015).

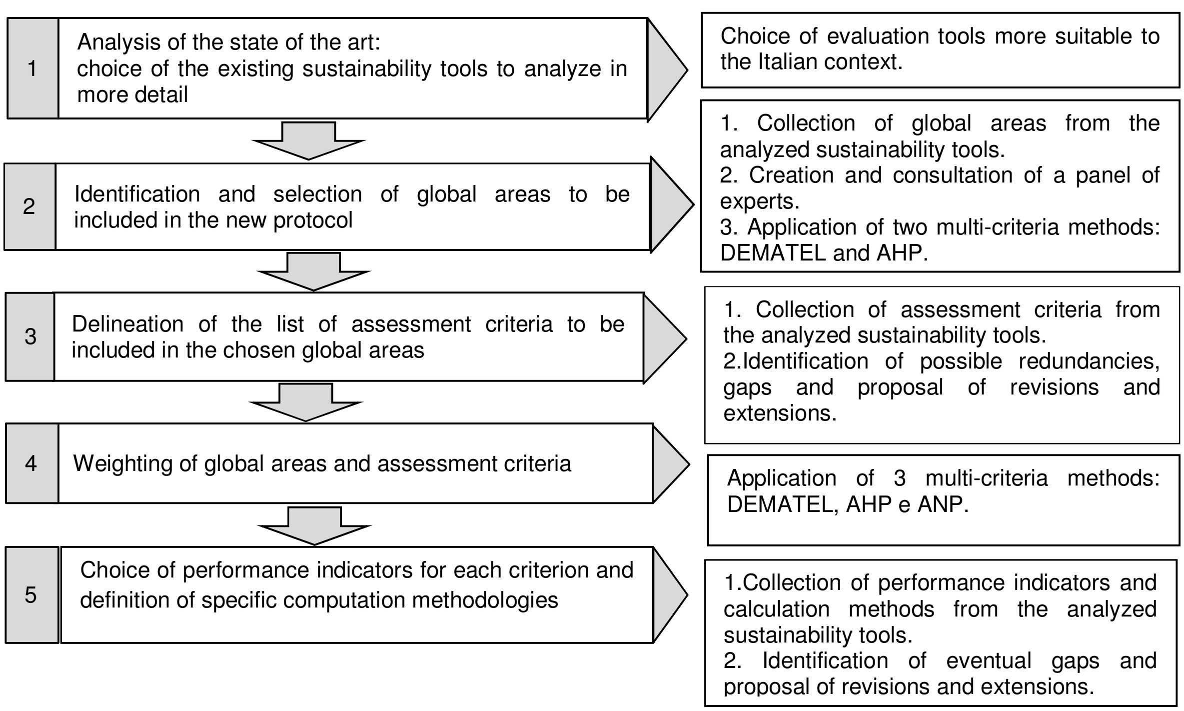


Fig. 1 - Methodological steps for the definition of the structure of the new protocol.

2.2 Benchmarks

The second phase of the research involved the analysis of the so-called benchmarks, i.e. the reference or limit values with which to compare the quantitative information obtained from the computation of performance indicators.
In recent years, the issue of benchmarking in the field of sustainable building was addressed by scientific literature and regulations.
For instance, ISO 21931-1 (ISO, 2010) states that, for the quantification of performance indicators within the evaluation methods, reference levels and/or scales of values can be used; they have to be documented and justified. However, this standard does not provide any value or procedure for the benchmarking process.
To define benchmarks for the indicators of the developed protocol, it was initially investigated the presence of any limit value established by specific rules or reference value derived from other sources, such as statistical data and scientific literature; in case of absence of limit and reference values, a specific calculation procedure was proposed.
Figure 2 illustrates the approach for the definition of benchmarks for all performance indicators of the new protocol.

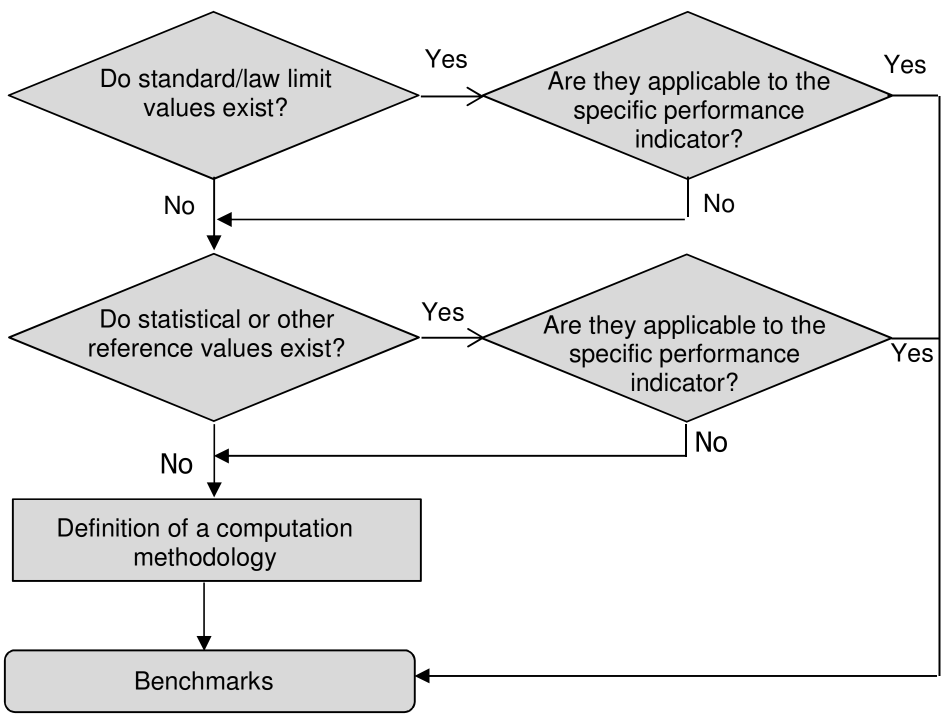
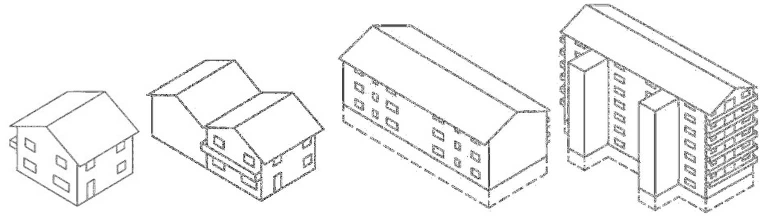


Fig. 2 - Schematic approach to the definition of benchmarks.

Some of the key performance indicators that have currently no benchmark values are: environmental impacts throughout the life cycle, embodied energy in materials, energy, non-renewable and renewable during the entire life cycle, global costs; ventilation rates/pollutant concentration in indoor air.
For these indicators, the direct calculation of the lacking benchmarks was made, through specific analyses on reference buildings. In particular, the class of residential buildings was examined, using as the main source the European project TABULA (Corrado et al., 2011), which defined a "national matrix of buildings" consisting of a set of residential buildings with typical energy characteristics. This project analyzed the most common classes of Italian buildings, from single family houses to apartment blocks, considering eight different construction periods and an average climatic zone.
For the analyses carried out in this research, the data extrapolated from TABULA were handled to define 36 building archetypes,

considering: the latest construction class, i.e. after 2005; massive envelope elements, resulting from the constructive period; three major Italian climatic zones; 4 categories of buildings; and three building system solutions, common in Italy. Table 2 shows the main geometrical characteristics of the analyzed building archetypes.

Tab.2 - Main geometrical features of the building archetypes.

	Single-family house	Terraced house	Multi-family Building	Apartment block
				
Number of heated floors	2	2	3	7
Number of unheated floors	-	-	1	1
Elevation per floor [m]	2.70	2.70	2.70	2.70
Heated floor area [m^2]	151	127	753	2160
Gross heated volume [m^3]	622	536	2923	8125
External wall area [m^2]	234	156	646	1699
Window area [m^2]	21.7	15.9	104	270
Shape factor [-]	0.72	0.63	0.54	0.40

The building archetypes were subjected to:

1. energy evaluations for the use phase, performing dynamic simulations through the software EnergyPlus;
2. analysis of the environmental impacts during the life cycle by the LCA method, using the software SimaPro 8 with reference to the Ecoinvent database;
3. calculation of costs during the various life cycle stages, through economic evaluation based on the global cost, according to UNI EN 15459 (UNI, 2008).

In addition, a methodology was suggested for the definition of benchmarks related to the criterion 'ventilation rates/pollutant concentration in indoor air'. Specifically, a reference single-family, derived from the TABULA project, was subjected to indoor air quality analyses, through the multizone software CONTAM (Moschetti, 2015; Moschetti et al., 2015).

In Table 3, the overall structure of the proposed protocol is summarized and a percentage weight is shown for each global area and assessment criterion. Specifically, each criterion presents a weight within its global area and a weight within the protocol, the latter calculated by considering the weight of the area of belonging.

3. Results

In the following, some explanatory results obtained from the analysis conducted for the calculation of benchmarks are reported (Moschetti, 2015; Moschetti et al., 2015).

Figure 3 illustrates the outcomes achieved for one of the indicators of the criterion 'Environmental impacts of the life cycle', in the category 'Pollution', i.e. the indicator 'Climate Change'. The results are shown on a yearly basis, considering 50 years as a reference lifespan for buildings and they are distinguished for the different life cycle stages (pre-use, use and end of life) for the 36 archetypes examined. The use phase provides the largest contribution, confirming the trend that characterizes standard buildings, in which the impacts related to energy production for heating dominate the entire life cycle.

Figure 4 shows the global cost obtained for the 36 archetypes, divided into: investment costs, replacement costs, costs of energy/water and maintenance costs. The results are reported for a calculation period of 50 years and the costs are discounted by initial assumptions on inflation rate, interest rate and price rate development of gas/electricity/water.

Tab. 3 - Overall structure of the proposed protocol.

	Global areas– assessment criteria	Weight	
		In the global area	In the complete tool
1	Land use and impacts	7.30%	
1.1	Land use	10.52%	0.77%
1.2	Ecological impact	22.14%	1.62%
1.3	Impact on microclimate	67.32%	4.91%
2	Pollution	8.90%	
2.1	Life cycle environmental impacts	73.96%	6.58%
2.2	Outdoor light pollution	14.94%	1.33%
2.3	Outdoor acoustic pollution	11.09%	0.99%
3	Waste	8.60%	
3.1	Construction waste	73.68%	6.34%
3.2	Operational waste	26.31%	2.26%
4	Indoor air quality	7.15%	
4.1	Ventilation rates/pollutant concentration in indoor air	50.00%	3.58%
4.2	Indoor electromagnetic pollution	50.00%	3.58%
5	Occupant wellbeing	7.30%	
5.1	Hygro-thermal comfort	34.59%	2.53%
5.2	Acoustic comfort	29.86%	2.18%
5.3	Visual comfort	20.50%	1.50%
5.4	Controllability of comfort conditions	15.02%	1.10%
6	Energy	10.35%	
6.1	Non-renewable energy	48.70%	5.04%
6.2	Renewable energy	31.24%	3.23%
6.3	Overall building system efficiency	20.04%	2.08%
7	Water	6.30%	
7.1	Fresh water consumption	50.00%	3.15%
7.2	Handling of rain/gray water	50.00%	3.15%
8	Materials	9.50%	
8.1	Embodied energy	19.37%	1.84%
8.2	Local materials	21.31%	2.02%
8.3	Hazardous substances	19.12%	1.82%
8.4	Recycled content	40.18%	3.82%
9	Costs	6.30%	
9.1	Life cycle costs	100.00%	6.30%
10	Functional quality	7.90%	
10.1	Barrier free accessibility	23.93%	1.89%
10.2	Building flexibility	29.83%	2.36%
10.3	Space efficiency	28.00%	2.21%
10.4	Personal mode of transport	18.23%	1.44%
11	Technical quality	10.10%	
11.1	Fire safety	45.86%	4.63%
11.2	Envelope quality	25.67%	2.59%
11.3	Structural stability	15.18%	1.53%
11.4	Building maintainability	13.27%	1.34%
12	Management quality	10.30%	
12.1	Integrated project planning	40.17%	4.14%
12.2	Construction quality assurance	35.21%	3.63%
12.3	Commissioning	24.61%	2.54%

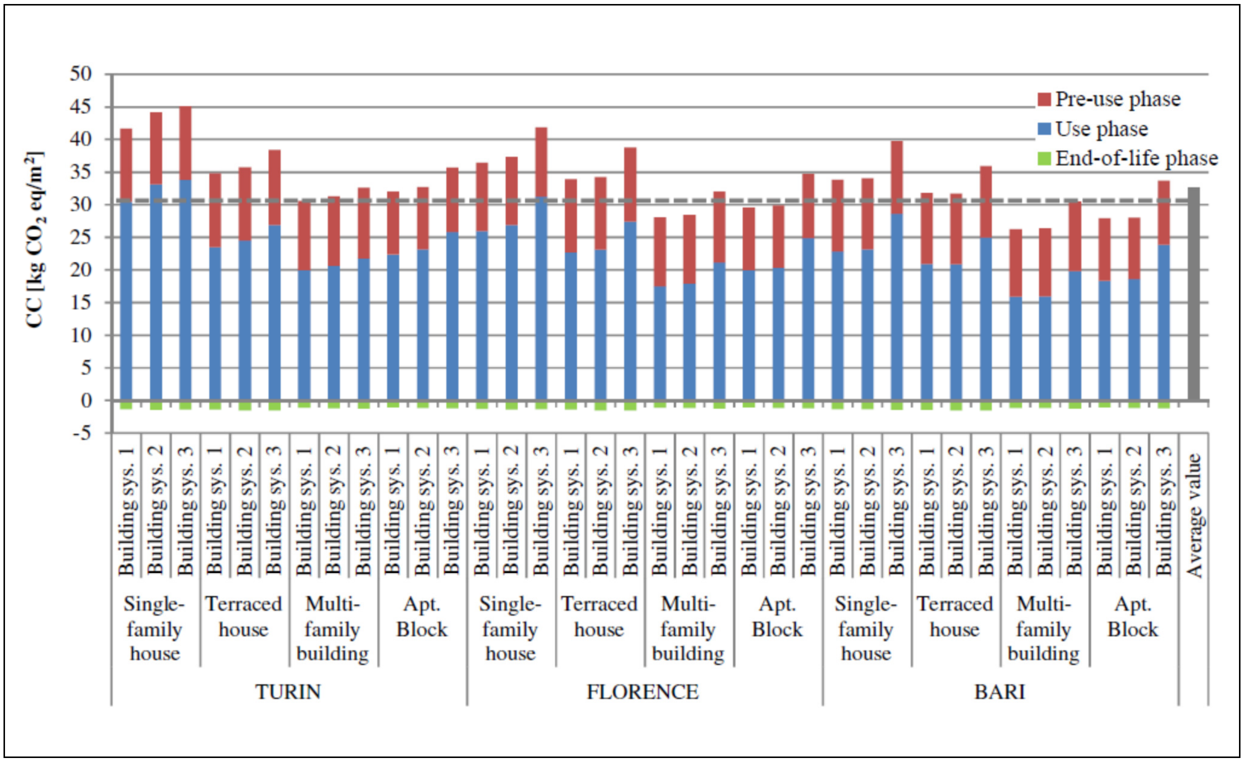


Fig. 3 - Annual values of the indicator Climate Change (CC) in different life cycle stages, for different categories of buildings, located in three Italian cities and equipped with three building system solutions (1 = only heating with underfloor panels, 2 = only heating with radiators, 3 = heating with underfloor panels & cooling with multi-split systems).

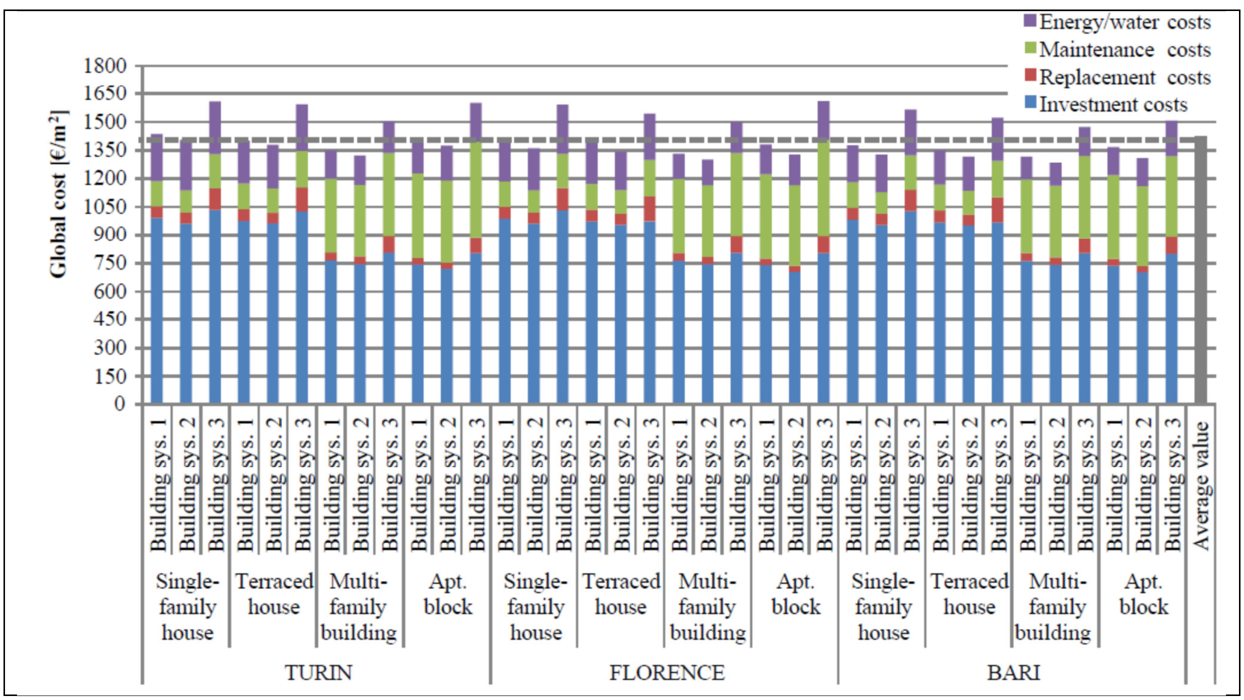


Fig.4 - Values of the global cost for different categories of buildings, located in three Italian cities and equipped with three building system solutions (1 = only heating with underfloor panels, 2 = only heating with radiators, 3 = heating with underfloor panels & cooling with multi-split systems).

The investment cost category contributes significantly to the global cost, followed by the cost of energy/water and maintenance, related to the phase of use. In addition, the single-family house presents the highest value of the global cost in all the analyzed cities, in relation to its significant initial investment cost and to the higher energy consumption during the use phase.

4. Conclusions

The analysis of the state of the art about sustainability assessment protocols has showed, in general, the lack of consistent and comprehensive evaluation tools, whose the parameters are essentially based on the principles of objectivity and measurability, in addition to the lack of an approach fully based on life-cycle, due to the absence of criteria relating to all life stages. At Italian national level, there is also an evident lack of many of the necessary benchmarks.

As a response to these gaps, the proposed protocol analyzes all the building life stages to reach a complete assessment of the overall quality of the buildings; it has as a key element of the objectivity, both for its content and for its definition process.

In this sense, the protocol gives a contribution to the national and international development of methods and guidelines for the sustainability assessments of buildings, concurring to their progressive standardization. In addition, the benchmarks developed could be implemented in the national rating systems, as soon as the latter will expand their structure including the missing performance indicators, here suggested.

The research work still has some limitations. First, the structure of the protocol only considers some existing systems, the most suitable to the Italian context. In addition, the panel of expert was made up of members from the Italian academic world, all sharing a similar background. Moreover, the process of benchmark development included only 36 residential building archetypes, within the identified categories. Finally, the examined reference buildings were chosen to represent the most common construction types.

A development of this research could then investigate other existing protocols, expand the panel with new stakeholders, include other archetypes to increase the reliability of benchmark values, enlarge the field of investigation by embracing, e.g., energy efficient buildings.

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