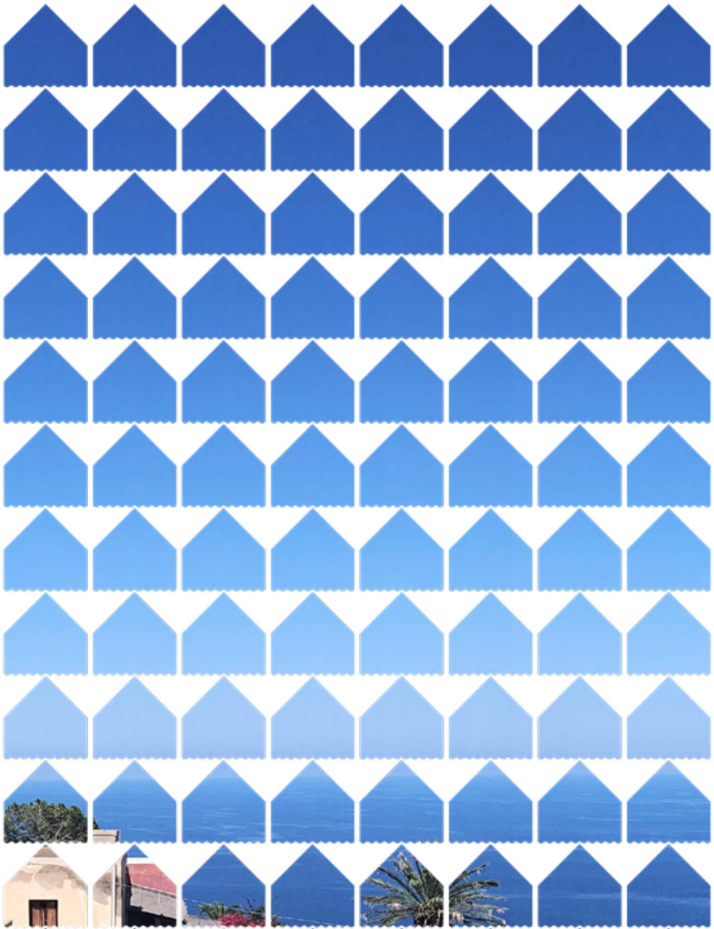
HIGHER EDUCATION AND INNOVATION



Design of an Innovative Teaching Module for an Intensive Programme on Aeolian Architecture

Edited by:
Vincenzo Sapienza
Luca Finocchiaro
Marius Voica

MDPI
VVITA

HIGHER EDUCATION AND INNOVATION

Design of an Innovative Teaching Module for an Intensive Programme on Aeolian Architecture

MDPI

ACKNOWLEDGEMENTS

The authors acknowledge the research framework and financial support provided by the European Community, that has financed the project "Modernizing Learning and Teaching for Architecture through Smart and Long-lasting Partnerships leading to sustainable and inclusive development strategies to Vitalize heritage Villages through Innovative Technologies" – VVITA, under the programme ERASMUS+; key action KA2 – Cooperation for Innovation and the Exchange of Good Practices; action KA203 – Strategic Partnerships for higher education. The European Commission's support for the production of this publication does not constitute an endorsement of the contents, which reflect the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

All images belong to the authors, except if differently specifieds in the caption.

Layout by Sebastiano Greco

HIGHER EDUCATION AND INNOVATION

Design of an Innovative Teaching Module for an Intensive Programme on Aeolian Architecture

Editors: Vincenzo Sapienza, Luca Finocchiaro, Marius Voica

Authors: Alessandra Bonazza, Simona Calvagna, Rosa Caponetto, Luca Finocchiaro, Antonio Gagliano, Mihaela Hărmănescu, Elena Cristina Mândrescu, Michele Mangiameli, Giuseppe Mussumeci, Gianluca Rodonò, Vincenzo Sapienza, Alessandro Sardella, Markus Schwai, Marius Voica

VVITA Participants: Chiara Bertolin, Ivo Caliò, Simona Calvagna, Luca Finocchiaro, Antonio Gagliano, Marina Mihăilă, Mihaela Hărmănescu, Elena Cristina Mândrescu, Giuseppe Margani, Adrian Moleavin, Gianluca Rodonò, Vincenzo Sapienza, Markus Schwai, Marius Voica

MDPI

EDITORIAL OFFICE
MDPI
St. Alban-Anlage 66
4052 Basel, Switzerland

ISBN 978-3-03943-712-2 (Hbk)

ISBN 978-3-03943-711-5 (PDF)

doi.org/10.3390/books978-3-03943-711-5

CONTENTS

Rosa Caponetto

CONSTRUCTIVE CHARACTERISTICS OF TYPICAL AEOLIAN ARCHITECTURE AND METHODS FOR EVALUATION OF SUSTAINABILITY

1. INTRODUCTION

This session aims to identify the main characteristics of the typical Aeolian architecture and to indicate the most appropriate systems to assess its sustainability. In this peculiar context, the sustainability assessment is particularly complex because the Aeolian architecture denotes a homogenous and specific housing style, which is intrinsically linked to local culture. It is characterized by a construction code, which is a direct expression of necessities, that is linked to environmental conditions and to locally available resources. The archipelago is protected by a Territorial Landscape Plan and is included in the list of the Intangible Cultural Heritage of Humanity (in 2000, UNESCO placed the Aeolian Archipelago among the 691 sites in the world protected by virtue of their "environment and/or cultural characteristics").

2. TYPICAL AEOLIAN ARCHITECTURE

To carry out the analysis on a building's sustainability, it is important to know the functional and construction characteristics that distinguish it. Therefore, the first part of the session concerns just the characteristics of typical Aeolian architecture. In particular, we will start with the typical architectural elements and then, we will describe the specific technical solutions.
Aeolian architecture is the result of objective and contextual necessities due to environmental conditions and the historical genesis. The geomorphological characteristics of places of volcanic nature, the climatic factors (characterized by a high level of sunshine, minimum temperature range, and low amounts of rain), and the limited quantity of available resources (economical, material) have strongly influenced the construction of traditional types of buildings [1].

2.1. TYPOLOGICAL CHARACTERISTICS

Aeolian architecture was strongly influenced by the architecture of the sixteenth century Campania region, which, after migration, was grafted onto a previously Greek–Roman and Islamic architecture. In reality, the first settlements occurred as far back as the Neolithic age between 5500 and 4000 BC. During the following centuries, the archipelago was populated by Etruscans, Carthaginians, Greeks, and Romans, then, Arabs and Normans, followed by the Spaniards; but, most of the current villages were built in the nineteenth century. The original element of the typical architecture is a single cubic or parallelepiped shaped cell, with only one entrance door and two possible round windows. The building mainly responded to the needs of defence from external dangers, in particular possible invasions or raids by enemies coming from the sea. Inside the houses, there was the kitchenette (*cufularu*) on one side and the beds on the other. Nowadays, on the Aeolian archipelago, it is possible to identify two different types of buildings: the vertical one (in steep areas), and, most frequently, the horizontal one (in flat areas). Both types are generated using a "cellular" construction, through the superimposition or combination of cubic elements (rooms), and have similar building characteristics, which are reflected in the most recurrent pathologies and on the life cycle of the various components and of the entire building. The other traditional buildings are a combination of these two types. Figure 4 shows the combination of cubic elements for the "horizontal type"; originally, only a single cubic "cell" and a terrace composed the house (fig.1). Subsequently, another "cell" was put beside the first, in place of the patio. This one rotated and adapted to everyday life with functional elements. The typical elements of the traditional building are the following.

• The *bagghiu* (baglio), a large terrace a the front of the house.

• The *bisòlu*, small stone walls that delimit the terrace and are sometimes decorated with majolica tiles.

• The *loggia*, a trellis of wooden beams covered with cane, the roof of the terrace.

• The *pulèra*, columns that support the loggia.

• The *princu*, a stone washbowl that restson the *pila*, an outdoor tub used to do the laundry.

• The *furnu*, the oven, which is dome-shaped, positioned to the side of the terrace above a base used to store firewood.

• The *astricu*, the horizontal roof. It has an-important function: to isolate the house from the cold in winter and from the heat in summer; but in the past, it was normally used for collecting rainwater (the raised edge of the terrace, called "petto di colomba" – "dove's breast" – enabled the collection of rainwater in order to convey it to an underground cistern).


Figure 1. Single cell house


Figure 2. Two-cell house (vertical type)


Figure 3. Two-cell house (horizontal type)

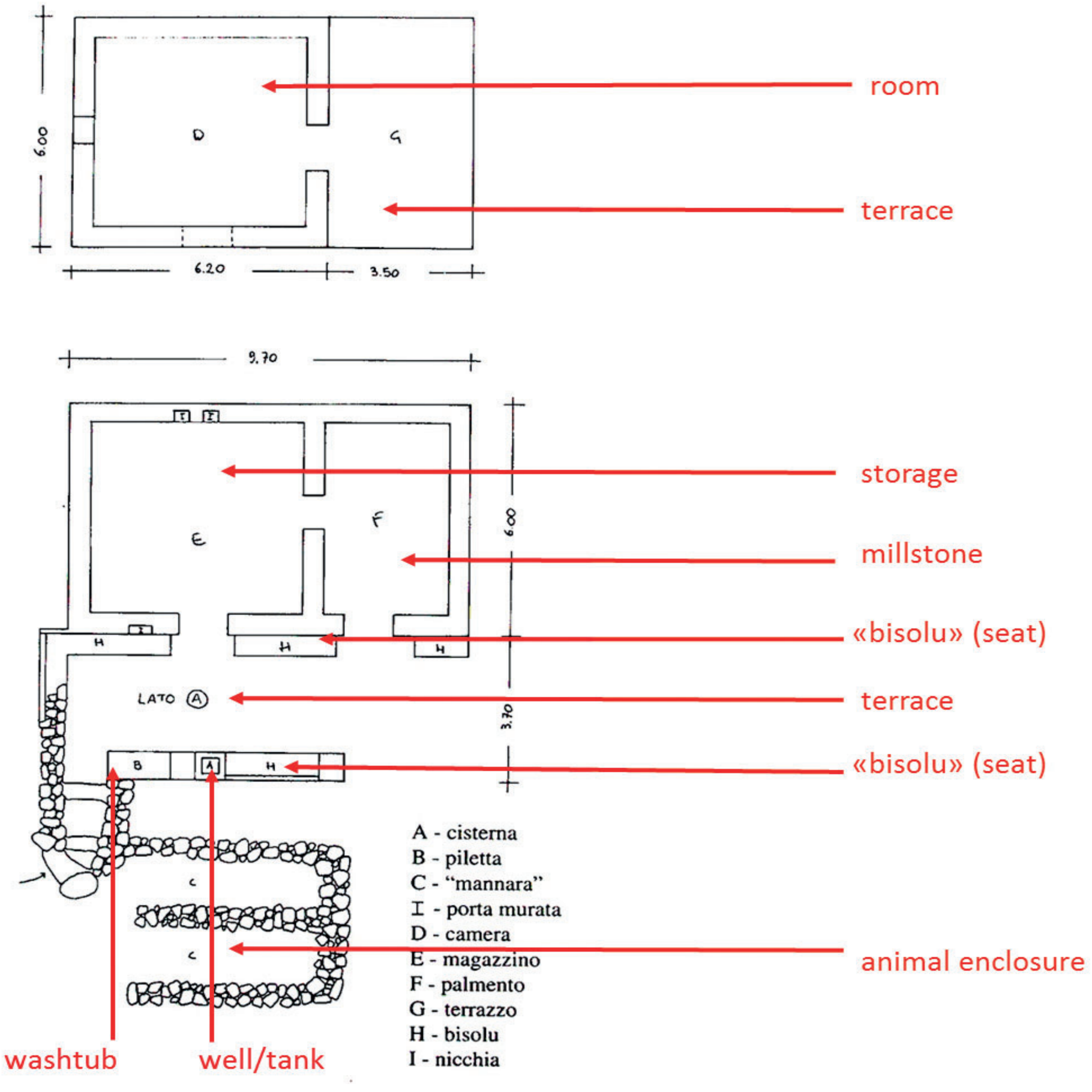


Figure 4. Combination of two "cells" in a "horizontal type" house

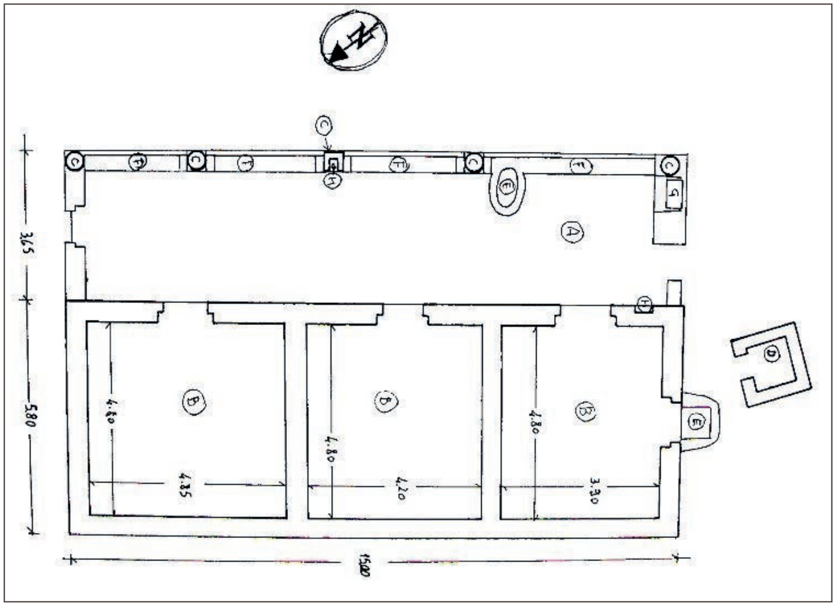


Figure 5. Layout of a typical house

Figure 6. “Bagghiu”

Figure 7. “Pila” and “princu”

Figure 8. “Furnu”

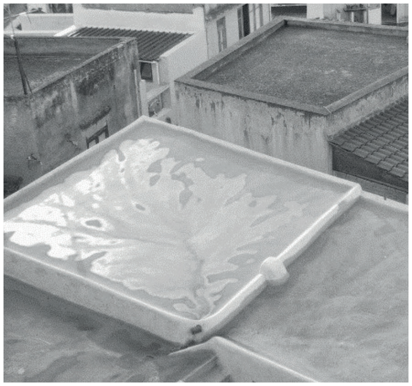


Figure 9. “Astricu”

2.2 ANALYSIS OF THE "TRADITIONAL" BUILDING SOLUTIONS AND SOME REFERENCES ON NEW TECHNOLOGIES

As mentioned above, the typical architecture of the Aeolian Islands is strictly linked to the environmental conditions and to the locally available resources. The geo-morphological characteristics of the locations and the climatic factors have strongly limited the local "modus aedificandi"; however, simultaneously, the architectonic and technological choices have delivered unique places and cultural facts of the Mediterranean area.
Throughout time, several factors have influenced the building procedure (availability of raw materials, costs of materials and skilled workers, the ease and speed of the work carried out, the elements' durability, etc.). This has led to a progressive technological transformation extraneous to the local culture.
Starting from the nineteenth century, Aeolian construction practices were characterized as follows:

FOUNDATIONS AND WALLS

- foundations made of lava stone, with limeand pumice mortar;
- very shallow (h=less than 40 cm) fora-one-storey house;
- no taller than 70 cm tall, for multi-storey-buildings;
- walls usually made of shapeless stone (quarried in the islands) and mortar (rich in lime and coarse pumice called "rupiddu", lava lapillus). Subsequent to the Messina earthquake (1908), rough-hewn stone masonry was used, with horizontal mortar courses (distance=70 cm);

Figure 10. Shapeless stones wall

Masonry made of shapeless local stones and lime mortar (with coarse pumice called "rupiddu"). The lava stones are heaped together almost without mortar and the masonry corners do not have capstones.

Figure 11. Rough-hewn stones and horizontal "courses" of lime mortar

Masonry made of rough-hewn stones and lime mortar with coarse pumice. Mortar courses are present (at a distance of 70 cm) giving stability to the wall in opposition to horizontal forces (see construction standards in seismic area).

• for the internal partitions, either tuff or lava stone were often used.

HORIZONTAL FLOORS

The solid ground floor was made of lime and pumice stone (sometimes there was a crawl space). The traditional intermediate floor was made of wood and conglomerate: there was a double system of beams (main and secondary unhewn logs) on which a reed mat was laid; a special conglomerate (made of volcanic lapilli, lime mortar, and fine pumice) was casted. The flat roof (called “astricu”, thickness 12–15 cm) had a screed made of lime mortar, volcanic lapilli, and fine pumice, laid on a layer of broken stones, whose flat side rests on a layer of canes, the entirety supported by beams made of local chestnut wood. The *astricu* collects the meteoric waters, which are channelled/transported into the cistern

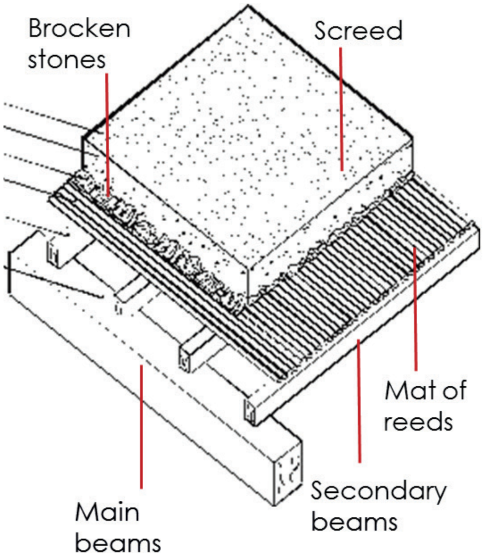


Figure 12. Some images of the “astricu”

(generally located under the house), through the drainpipe, made of terracotta elements. A careful processing by beating the surface layer, still fresh (in order to completely saturate the voids and therefore, the porosity), ensured the water tightness of the terrace.

VERTICAL CONNECTIONS

The external staircases and the internal stairs connecting the ground floor with the first generally consisted of solid basalt steps laid on a rampant masonry arch; inside, wooden stairs were used for all other floors.

FINISHES

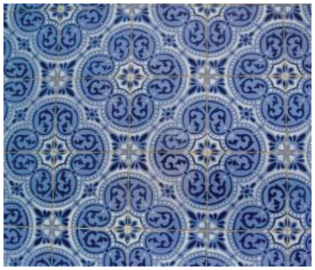
The traditional plaster (in two layers) was made of lime mortar with very fine lapilli. Often there was lime-based painting, which was used until the 1970s. As for the flooring, for both interiors and exteriors, coloured ceramic tiles (coming from S. Stefano di Camastra) or pressed cement tiles (sometimes with marble flakes) were used. The external floors (for storage rooms and terraces) are made of lime, and pumice (after cement, lime, and pumice). Traditional doors and windows are made of chestnut wood with oil paint.

Figure 13. Typical staircase (exterior and internal)

Figure 14. The traditional plaster: lime mortar and fine lapilli

lime and pumice floor

colored ceramic tiles



pressed cement tiles

pressed cement tiles

Figure 15. Typical floors

Figure 16. Colourful wooden windows and doors

RECENT TECHNIQUES

Over time, different factors have strongly influenced local building procedures: the exhaustion of several natural resources, the closure of stone quarries, and the consequent use of artificial materials, sourced from other places (Sicily and south Italy); the consequent higher cost of materials, due to maritime transport; the scarce availability of workers with consolidated experience; the research and application of building procedures considered appropriate for the swift execution of the work, but lacking in assimilation and elaboration processes that aim at a long-lasting maintenance of the specific performances of each individual technological unit. All of these factors have determined a progressive transformation of the built environment. Building technologies and typological models foreign to the local culture have sometimes been passively imported, determining a relevant and diffused technological and environmental decay. For example, starting from the 1920s, the "pomicemento" blocks (for load-bearing walls and partitions) made of pumice and cement mixtures were produced in Lipari and exported. In the 1960s, the reinforced concrete conglomerate (cast in place) was introduced, for bearing frames and for ribbed hollow block floors. From 1970 onwards, the floors have been made of prefabricated joists and lightening bricks. For the exterior surfaces, in the 1970s, a plaster made of "marble powders" with a new finishing in lime paste and white cement was used. The last decade saw the introduction of "Terranova" plaster. Since the mid-1980s and up to the early 1990s, colored plastic paints (absolutely not recommended) were introduced onto the islands, but they are no longer utilized. The use of asphaltic and bituminous sheaths for the waterproofing of flat roofs began in recent decades.

3. BUILDING SUSTAINABILITY IN SPECIAL CONTEXTS

This section also concerns the sustainability of Aeolian architecture. The aim of these notes is to give basic information to evaluate, quickly, the effective sustainability of local buildings.

Aeolian architecture, like all types of vernacular architecture, represents the result of a stratification of empirical knowledge, linked to the socio economic, cultural, and environmental needs of a specific community. Local communities were normally in charge of maintaining their own traditional construction processes, or system of knowledge. These are very "fragile", since the processes of transmission of experience are especially sensitive to social, economic, and environmental change. However, they are considered key elements for a sustainable development of our built environments, because they are an expression of social diversity and sources of practical and technological culture strongly connected to the environmental, economic, and social needs of any location.

Among the negative effects of globalization and industrialization is the tendency toward cultural homogenization, which in architectural terms translates into the use of standard project solutions, which in many cases require a high consumption of environmental and energy resources and present scarce references to the cultural heritage of the places where they are used

“Pomicemento” blocks

Wall made of “Pomicemento” blocks

Reinforced concrete and hollow clay blocks mixed floor

Prefabricated joists and hollow clay blocks floor

“Marble powders“ plaster

“Terranova” plaster

Figure 17. Some recent technologies used in the islands

[2]. Contrary to what happens to monumental architecture, which usually survives more easily to substitutions and alterations over time, the ordinary traditional home requires periodic modifications to adapt it to new standards of living space and safety. There are several risks during an intervention on a minor building and they can be mainly due to the replacement of existing materials and the contrast between industrial and craft production; a fragility that occurs in areas related to several architectural elements such as the replacement of inappropriate consolidation of horizontal structures, or the insertion of systems performed with inappropriate methods. Generally, the aim of the project must be to achieve a balanced compromise between the preservation of the traditional building and its necessary adaptation to functional needs [3].
Additionally, in the case of the Aeolian Islands, the traditional architectonic signs and the expression of a naturally sustainable construction technique are today undermined by a saturation of the empty spaces and from a progressive typological transformation, foreign to the local culture, that, while taking advantage of new (not truly compatible) technologies, has caused a generalized degradation.
It is necessary to guarantee the possibility of carrying out the necessary adjustments, avoiding, as far as possible, the mutation of the character and materiality of these buildings.
This is why it is exceptionally important to evaluate the sustainability of such peculiar contexts. If, on the one hand, the energy consumption needs to be reduced with more thermally performing building solutions and components, and the seismic response of these buildings must be improved to prevent collapse due to an earthquake (a highly plausible risk in an area such as the Aeolian one), on the other hand, the characteristics of such unique places can not be ignored. In this sense, as we will see, many of the rating systems for the evaluation of sustainability have the limit of giving little weight to the component of local specificity. However, this will be further discussed in the next paragraph.

4. SUSTAINABILITY AND ASSESSMENT SYSTEMS

Before understanding how to assess the sustainability of buildings in a specific context, we need to take a step back and recall the concept of sustainability, which has gradually undergone a transformation in relation to the different needs that have arisen over time and which have caused a transformation in the way of conceiving sustainability. After the oil crisis of the 1970s, all nations promoted measures and regulations against energy consumption from real estate. The energy consumption assessment became the criterion to evaluate the sustainability of buildings. Subsequently, the concept of sustainability evolved and nowadays, energy consumption is assumed only as one of the parameters by which sustainability is assessed. This is why a multidisciplinary approach to sustainability is preferred today [6].
Continued economic growth has led to an overuse of environmental resources, but also an increase in greenhouse gas emissions. Today, all economic sectors have to ensure a long-term ecological balance, reducing the consumption of natural resources according to the restoring capacity of

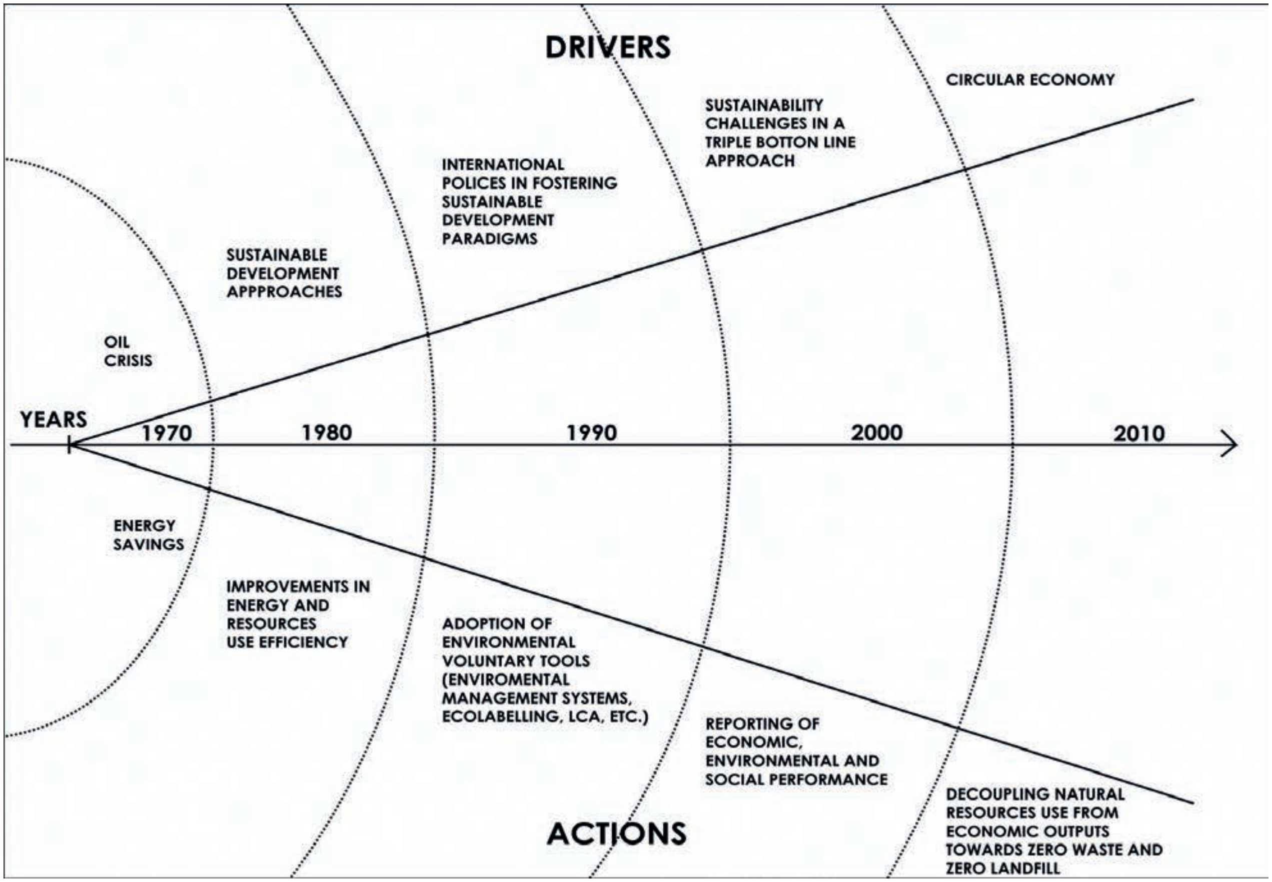


Figure 18. The approach to "sustainability" over time

the planet [5].

As is known, nowadays, sustainability (according to ISO 15392-2008) is commonly examined through three dimensions: the effect of a phenomenon or system on society (often referred to as social sustainability), its impact on the environment (often referred to as environmental sustainability), and its economic implications (often referred to as economic sustainability).

The need to evaluate sustainability in order to classify/label buildings has arisen, and so has the need to guide the design, moving towards a more sustainable approach. Public disclosure of results encourages stakeholders (property owners, planners, and local administrations) to design and build cities and buildings with superior environmental, social, and economic performance.

However, the question is: how does one exactly evaluate sustainability?

More than 600 sustainability assessment rating systems are available worldwide. New systems are continually proposed and the most diffused ones receive a yearly update. This evolving situation has led to the release of the standards “Sustainability in Building Construction – Framework for Methods of Assessment of the Environmental Performance of Construction Works – Part 1: Buildings” (ISO 21931–1, 2010) and “Sustainability of Construction Works – Sustainability Assessment of Buildings – General Framework” (ISO 15643–1, 2010) [6].
Systems for sustainability assessment have various subjects – from energy performance evaluation to multidimensional quality assessment.

Berardi [6] groups them into:

• CED: cumulative energy demand systems (on energy consumption);

• LCA: life cycle analysis systems (on environmental aspects);

Figure 19. The three dimensions of sustainability

• TQA total quality assessment systems (ecological, economic, and social aspects).
However, many systems can not exclusively be included in one of the abovementioned categories. CED systems, generally monodimensional, evaluate the sustainability of a building through energy-related measurements. LCA systems measure the impact of a building on the environment by assessing the emission of substances related to the building’s construction and operation. LCA can have one or more evaluation parameters, while TQA systems are multidimensional because they evaluate different parameters.
The first two systems have a quantitative approach, while the TQA system is qualitative or quantitative in relation to different criteria [6].
While assessment systems have been giving value to the environmental characteristics, the surge in importance of economic and social evaluations has manifested in systems tailored to developing countries, where evaluating the environment alone is insufficient. In turn, this should shift the assessment systems toward a new perspective of sustainability. Owing to the evaluations’ thorough approach, systems demanding considerable detailed information have been developed. The criteria’s intricacy is reported as being the restricting factor for the promulgation of rating systems, and even sustainability, within building stakeholders who would be slow to endorse sustainability practices. Therefore, to promote sustainable building assessment systems, it is crucial tocompromise between ease of use and thoroughness of analysis. The fact that multi-criterion TQA systems are more widely used than their LCA counterparts can be attributed to their simplicity

The system boundaries of the building's LCA can be of three types: cradle-to-grave, cradle-to-gate, and gate-to-gate. The cradle-to-gate approach is an assessment of a partial life cycle of a product, from resource extraction to the factory gate, before the product is transported to the consumer. It is usually used as a basis for environmental product declaration. The gate-to-gate approach is a partial analysis that looks at only one process in the entire production chain. Information about each gate-to-gate module can be linked accordingly in a product chain, including information about the extraction of raw materials, transportation, disposal, and reuse, to provide a full cradle-to-gate evaluation. The cradle-to-grave approach is the most used because it starts from the pre-use phase, including raw material acquisition, goes through manufacturing and transportation to site, and terminates with the end-of-life phase, which includes demolition, recycling potential, landfill, and reuse [5].
LCA assessments consist of four phases (ISO 14040, 2006): the goal and definition phase, the life cycle inventory, the life cycle impact assessment and the improvement assessment phase. LCA diffusion in the building sector is limited by a lack of information. In fact, the specificities of the construction processes require data for every building material in any region. This lack of information on building materials is especially frequent for the existing buildings. Databases have been created for LCA evaluations and implemented in specifically designed software in several geographic areas: BEES in the US, BOUSTEAD and ENVEST in England, SIMAPRO and Eco-Quantum in the Netherlands, Ecoinvent in Switzerland, and GaBi in Germany. However, these databases are only valid for assessments in a specific region. Another obstacle for LCA diffusion is its specialist structure: outputs of LCA systems are represented by environmental impacts expressed through chemical substances, which are not easily understood by construction sector actors. LCA systems assess the environmental paradigm of sustainability without considering social and economic impacts. To fit this limit, some studies relate the disaggregation analysis necessary for an LCA to an evaluation of economic costs. For example, BEES and GaBi systems already permit the selection of cost-effective environmentally preferable products [6].

Figure 20. The LCA process: definition and limits

and checklist structure. Nevertheless, LCA system analyses can be more exhaustive compared to multi-criterion systems but still hard to understand, with their use limited to a number of specialists [5].
For these reasons (according to which multidimensional, quicker methods are preferable), the topic of TQA will be analyzed in the next paragraphs.

4.1 RATING SYSTEM FOR ASSESSING SUSTAINABILITY

To establish an objective and comprehensive method of assessment on the wide range of environmental performances of a building is the goal of the rating systems used to evaluate them. They aim to measure a building's performance with a system that is consistent and harmonized with respect to pre-established standards, guidelines, factors, or criteria.

In order to produce rating systems for the evaluation of a building's environmental sustainability, scoring methods established on the following four major components have been employed most often:

- Categories: a certain set of environmental performance-related items to be accounted for in the evaluation;

- Scoring system: a performance measurement system combining points, or credits, earned through the achievement of a performance level set for each point of assessment;

- Weighting system: the importance that each point pertaining the scoring system is given;

- Output: a result produced to demonstrate the environmental performance attained

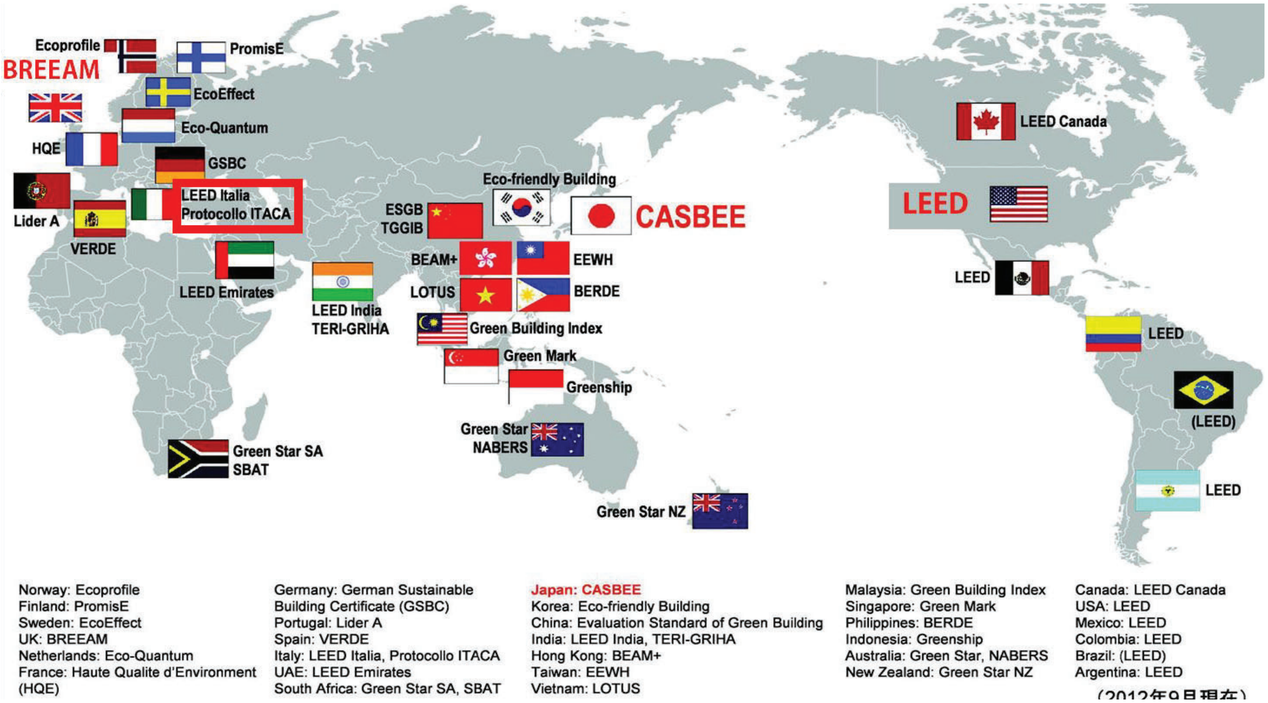


Figure 21. Diffusion of main sustainability rating systems in the world (modified from [8])

throughout the scoring phase through an extensive, direct approach.

This is the structure that each rating system employed in the assessment of a building's environmental impact is built upon; however, a number of significant parts prove different after a study of the details [5].

Different scopes are examined in all the systems, with different levels of detail.

In Table 1, the scopes' distribution among the schemes/systems is presented graphically.

Some of the most diffused systems (BREEAM, CASBEE, LEED, SBTool) were presented in detail during the lesson, though for the scope of the present document they were only mentioned and compared. A broader understanding may be obtained by consulting the respective websites and specific manuals.

Other important European systems are DGNB (Deutsche Gesellschaft für Nachhaltiges Bauen, Germany) and HQETM (Haute Qualité Environnementale, France), but they are not as common and are not covered in this lesson.

BREEAM (BUILDING RESEARCH ESTABLISHMENT ENVIRONMENTAL ASSESSMENT METHODOLOGY)

BREEAM, published by the Building Research Establishment (BRE) in 1990, is the world's oldest established method of assessing, rating, and certifying the sustainability of buildings.

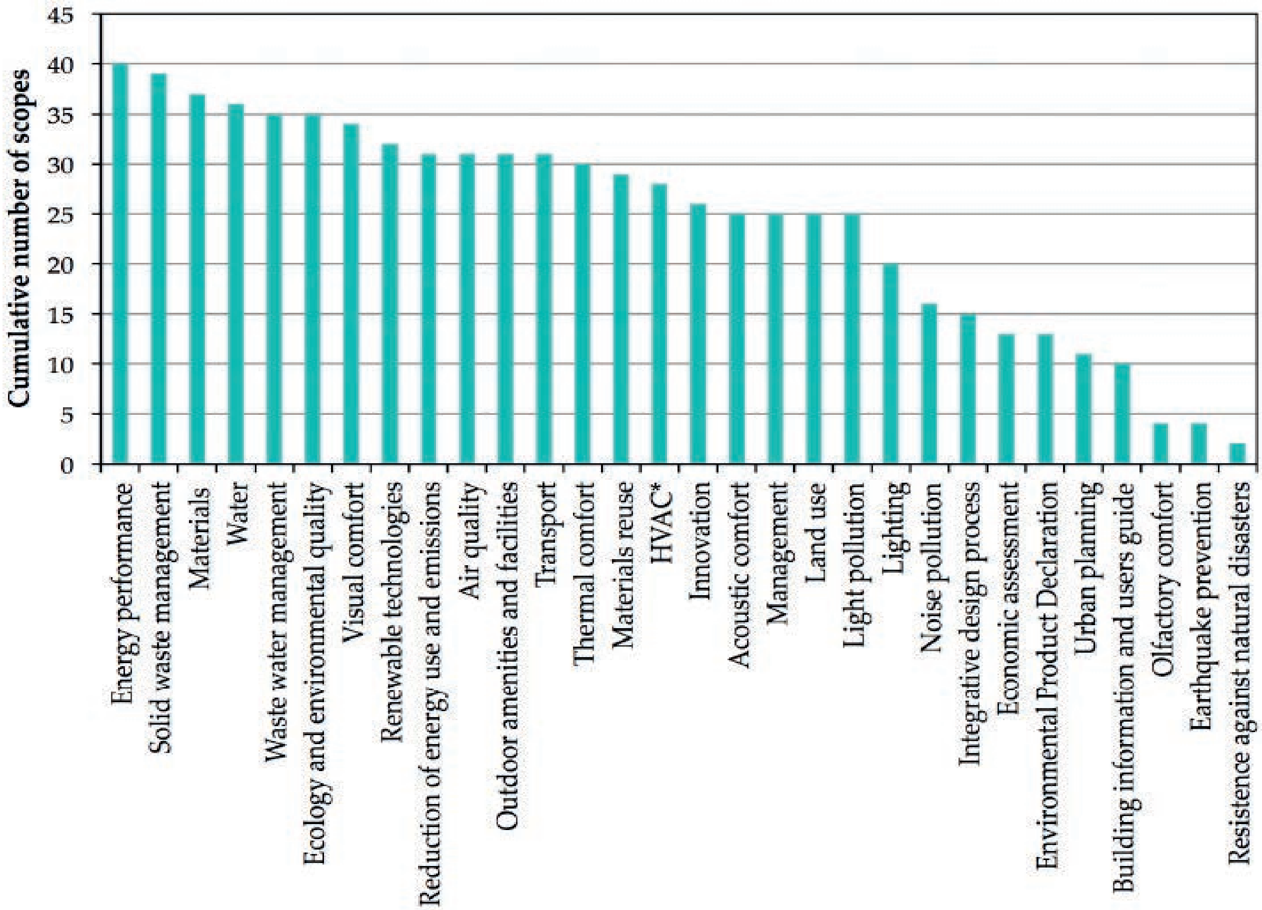


Table 1. Scopes' distribution among the analyzed rating schemes (* HVAC: heating, ventilation, and airconditioning) [5]

There are different types of schemes, applied to different types of building or situation, as shown in the next page, regarding Refurbishment and Fit-Out Technical Standards, In use, New Construction, and Infrastructure. They are all defined in 11.
The scheme's ten categories and 71 criteria allow for the description of the sustainability.

For each category, a percentage-weighting factor and a totalof 112 credits are assigned commensurably, although the latter feature the following conditions: the categories "Energy and CO2" and "Water and Waste" have a set minimum achievement listed in Table 2, along with the schemes' categories [5].

Refurbishment and Fit-Out Technical Standard. Through the assessment and certification process, the standard recognizes and reflects the performance of the building once improvements have been made to the external envelope, structure, core services, local services, or interior design of a building. The standard can be used to assess the refurbishment and fit-out of most types and uses of existing buildings, including homes (note: in the UK, there are separate standalone technical standards for non-domestic and domestic projects). The standard includes specific assessment criteria for heritage buildings that take into account the constraints on these types of projects.
In-Use. The standard can be used for all existing non-domestic buildings. It is a scheme to help building managers reduce the running costs and improve the environmental performance of existing buildings. It has three parts – Parts 1 (building asset) and 2 (building management) are relevant to all non-domestic, commercial, industrial, retail, and institutional buildings. Part 3 (occupier management) of the BREEAM In-Use certification scheme is currently restricted to offices. BREEAM In-Use is widely used by members of the International Sustainability Alliance (ISA), which provides a platform for certification against the scheme.
New Construction Homes and Commercial Buildings. The New Construction standards can be used to assess the design, construction, intended use, and future-proofing of new building developments, including the local, natural, or manmade environment surrounding the building. The standards can be used to assess most types of new buildings, including new homes and additions to existing buildings. Each one uses a common framework that is adaptable, depending upon the type and location of the building.
Infrastructure – Civil Engineering and Public Realm. In the short term, a new CEEQUAL will be launched as the successor to CEEQUAL Version 5.2 and BREEAM Infrastructure (Pilot). This will bring together the best of both schemes into a new best practice approach to challenge projects to deliver better outcomes in infrastructure sustainability. It will combine the legacy and track record of CEEQUAL with the new thinking from BREEAM. For now, new projects have two options: register with CEEQUAL Version 5 or pre-register for CEEQUAL (2018).
Communities. This standard focuses on the master-planning of whole communities. It is aimed at helping construction industry professionals design places that people want to live and work in, that are good for the environment, and that are economically successful.

CASBEE (COMPREHENSIVE ASSESSMENT SYSTEM FOR BUILT ENVIRONMENT EFFICIENCY)

The CASBEE is the Japanese sustainability rating system for buildings. It was developed by a research committee established in 2001 through the collaboration of academia, industry and national and local governments, which established the Japan Sustainable Building Consortium (JSBC) under the auspice of the Ministry of Land, Infrastructure, Transport, and Tourism (MLIT) [12]. The launch occurred in 2005 for the international market, then it became compulsory in 24 municipalities of Japan, where it was made mandatory that the results of an assessment performed through CASBEE be attached to the building permits' application. The dimensions of a building are the basis for the schemes allowed by CASBEE, which address the four main building life phases [5]:

Rating System	Categories																		
	Energy and CO_2 emissions	Water	Materials	Surface Water Run-Off	Waste	Pollution	Health and Wellbeing	Ecology	Management	Governance	Social and Economic Wellbeing	Resource and Energy	Land Use and Ecology	Transport and Movement	Innovation	Landscape and Heritage	Integrated Design	Stakeholders	Resilience
BREEAM Communities 2012										•	•	•	•	•					
BREEAM New construction 2016	•	•	•		•	•	•		•				•	•	•				
BREEAM In-use 2015	•	•	•		•	•	•		•				•	•					
BREEAM Infrastructure 2016	•	•	•		•	•	•						•	•	•	•	•	•	•
BREEAM Nondomestic refurbishment 2015	•	•	•		•	•	•		•				•	•	•				
EcoHomes	•	•	•		•	•	•		•				•	•	•				
Code for sustainable homes	•	•	•	•	•	•	•	•	•										

Table 2. BREEAM, categories for each scheme [5]

- CASBEE for Predesign, used in site selection and building planning;

- CASBEE for New Construction, used in the first three years following the building's completion;

- CASBEE for Existing Buildings, used no earlier than one year of operation;

- CASBEE for Renovation, whose purpose is to support a building refurbishment.

With the intention of attaining the specific purposes, a vast number of ancillary rating systems are available to CASBEE when the base system is insufficient, for instance for detached houses, temporary constructions, heat island effect, urban development, or cities and market promotions.

Under CASBEE [12], there are two spaces: internal and external, divided by the virtual enclosed space boundary, which is defined by the site boundary and other elements, with two factors related to the two spaces. Thus, we have put forward CASBEE, in which the "negative aspects of environmental impact which go beyond the virtual enclosed space to the outside (the public property)" and "improving living amenity for the building users" are considered side by side.

Under CASBEE, these two factors are defined below as Q and L, the main assessment categories, and are evaluated separately. Q

(Quality) – Built Environment Quality: Evaluates “improvement in living amenity for the building users, within the virtual enclosed space (the private property)”.
L (Load) – Built Environment Load: Evaluates “negative aspects of environmental impact which go beyond the virtual enclosed space to the outside (the public property)”.
The core concept of CASBEE is called BEE (Built Environment Efficiency). BEE is an indicator calculated by using Q as the numerator and L as the denominator.

$$\text{Built Environment Efficiency (BEE)} = \frac{\text{Q (Built environment quality)}}{\text{L (Built environment load)}}$$

With three subcategories from which to base the values’ calculations, as reported by the score sheet in Table 3, Q and LR can range between 0 and 100. With the Q and LR values on the y-axis and x-axis, respectively, BEE is expressed as the gradient of the line on the graph. The BEE value is used to assign a level of performance ranging from C through B–, B+ and A, up to S to the project in question. Applying the Q and LR values and the coefficients of every item, the assessment results sheet analyzes and sets weights, then produces a final BEE index score in its last step.

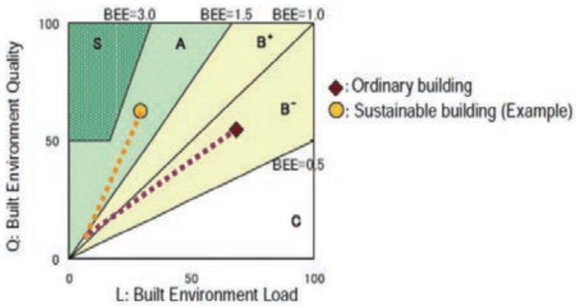


Figure 22. Environmental labeling based on Built Environment Efficiency (BEE) [9,12]

LEED (LEADERSHIP IN ENERGY AND ENVIRONMENTAL DESIGN)

The US Green Building Council (USGB), a nongovernmental organization with representatives from industry, academia, and government, first launched the Leadership in Energy and Environmental Design Pilot Project Program, referred to as LEED® Version 1.0, in the USA in 1998. This program has since been subject to revisions, integrations, and national customizations. In 2016, the last complete version (4.0) was released but in 2018, a beta version of the 4.1 version was introduced, starting with Existing Buildings.
The LEED® Green Building Rating System is one of the most widespread systems in the world (the most used according to the U.S. Green Building Council). It is a voluntary

Scoring for Q	Scoring for LR
Q1: Indoor environment	LR1: Energy
Q2: Quality service	LR2: Resources and materials
Q3: Outdoor environment on site	LR3: Off-site environment

Table 3. CASBEE’s score sheet [5]

BD+C Building Design and Construction	Applies to buildings that are being newly constructed or going through a major renovation; includes New Construction, Core and Shell, Schools, Retail, Hospitality, Data Centers, Warehouses and Distribution Centers, and Healthcare.
ID+C Interior Design and Construction	Applies to projects that are a complete interior fit-out; includes Commercial Interiors, Retail, and Hospitality.
O+M Building Operations and Maintenance	Applies to existing buildings that are undergoing improvement work or little to no construction; includes Existing Buildings, Schools, Retail, Hospitality, Data Centers, and Warehouses and Distribution Centers.
ND Neighborhood Development	Applies to new land development projects or redevelopment projects containing residential uses, nonresidential uses, or a mix. Projects can be at any stage of the development process, from conceptual planning to construction; includes Plan and Built Project.
Homes	Applies to single family homes, low-rise multifamily (one to three stories), or mid-rise multifamily (four to six stories); includes Homes and Multifamily Low-rise and Multifamily Mid-rise.
Cities and communities	Applies to entire cities and subsections of a city. Using the Arc performance platform, LEED for Cities projects can measure and manage their city's water consumption, energy use, waste, transportation, and human experience.

Table 4. Different schemes of LEED (modified from [10])

system. Numerous schemes are developed to rate new and existing commercial, institutional, and residential buildings (Table 4). Five categories are included in every scheme, containing the same list of performance requirements. Those which change substantially in accordance with the specific area of interest and building type are the number of credits, prerequisites, and points available.
Table 5 provides a description of the categories included in the LEED® environmental rating schemes.

The majority of the schemes contain mandatory prerequisites and non-compulsory credits, which can be selected observing the objectives that are to be achieved. The summation of points for each credit generates the evaluation outcome. A sole weight is allotted to each credit according to a strictly established scoring system that conceives a maximum score of 100 points, in addition of 10 bonus points awarded for the compliance with two special categories. A score of 40 points is the minimum requirement for passing the basic evaluation.

Category	Description
Sustainable sites	This section examines the environmental aspects linked to the building site. The goal is to limit the construction impact and verify meteoric water outflow.
Water efficiency	The section is linked to the water use, management and disposal in the buildings. The reduction of water consumption and meteoric water reuse are promoted.
Energy and atmosphere	In this section building energy performance improvement, the use of renewable sources and the energy building performance control are promoted.
Materials and resources	In this area the environmental subjects associated to the material selection, the reduction of virgin material use, the garbage disposal and the environmental impact due to transport are considered.
Indoor environmental quality	The themes considered in this section cover indoor environmental quality, taking into account for example healthiness, comfort, air renewal and air pollution control.
Innovation in design	The aim of this section is to identify the design aspects that improve on the sustainability operations in the building construction.
Regional priority	This area has the objective of encouraging the design groups to focus the attention on the local characteristics of the environment.

Table 5. LEED's categories and description [5]

CERTIFIED	SILVER	GOLD	PLATINUM
(40–49 points)	(50–59 points)	(60–79 points)	(80 points and over)

Table 6. Based on the number of points achieved, a project earns one of these four LEED rating levels (modified from: [10])

SBTool

The Sustainable Building Challenge, previously known as the Green Building Challenge, is an international initiative conceived in 1996 that set the goal of identifying standards for energy and environmental performance suitable for international and national conditions. More specifically, the aim of the Green Building Challenge was to develop and constantly update a methodology able to combine the advantage of using a common international standard with the possibility of its complete contextualization with respect to the single national application areas.
Thus, it was necessary to determine evaluation tools suitable for the objective assessment of a building's environmental, economic, and social impact throughout its life cycle by means of various methodological bases. The combined efforts of 20 countries' representatives led to the development of the SB method. In addition to a common international standard, another feature of this method is the ease of customization for each national context. The International Initiative for a Sustainable Built Environment (iiSBE) manages a technical committee tasked with updating the SB method, which is used in the evaluation of all design concepts or existing buildings, regardless of their prevalent use and geometrical extension, according to the four stages: predesign, design, construction, and operation.
The SB method is the base of origin of the Green Building Tool (GBTool), thereafter modified to be named the Sustainable Building Tool (SBTool). Four levels characterize the performance framework of the SBTool: performance issues, performance categories, performance criteria, and performance subcriteria. Table 7 demonstrates SBTool's issue areas, in which it is expressed per each phase of a building's life cycle [5,7].

4.2 COMPARISONS BETWEEN THE DIFFERENT SYSTEMS

It is normally difficult to compare the various systems, at times prohibitive. As the purposes targeted by every rating scheme are different, an accurate comparison between categories and subcategories is frequently unattainable.
However, below, we will briefly present some comparison tables in relation to different aspects [7].

Issue area	Predesign	Design	Construction	Operation
Site location, available services and site characteristics	•			
Site regeneration and development. Urban design and infrastructure		•		•
Energy and resource consumption		•	•	•
Environmental loadings		•	•	•
Indoor environmental quality		•		•
Service quality		•	•	•
Social, cultural and perceptual aspects		•	•	•
Cost and economic aspects		•	•	•

Table 7. Analysis of the SBTool's issue areas expressed per each phase of a building's life cycle [5]

Rating System	Launch Year	Launch Country	Certification Body	International Versions and National Adaptations	Weighting System	Rating Levels
BREEAM	1990	UK	BRE	*International versions:* • Nondomestic refurbishment • In-use • New construction: buildings *National adaptations:* • United Kingdom • USA • Germany • Netherlands • Norway • Spain • Sweden • Austria	Applied to each category	• Unclassified • Pass • Good • Very good • Excellent • Outstanding
CASBEE	2004	Japan	JSBC	N/A	Complex weighting system applied at every level	• S • A • B+ • B– • C
LEED v.4	1998	USA	USGBC	• LEED v3.0 for new construction and major renovations • LEED for homes • LEED for core and shell • LEED for existing buildings: operations and maintenance • LEED for commercial interiors • LEED for schools • LEED for retail • LEED for healthcare • LEED for neighborhood development (in pilot stage) *National adaptations:* • Argentina • Brazil • Canada • Italy	All credits are equally weighted, but the number of credits related to each issue is different	• Certified • Silver • Gold • Platinum
SBTool 2016	2002	International	iiSBE	*National adaptations:* • Czech Republic (SBToolCZ) • Portugal (SBToolPT) • Italy (Protocollo Itaca) • Spain (Verde)	Applied to each category	• –1 • 0 • 1 • 3 • 5

* Level available only for existing buildings.

Table 8. Summary of the main features of some rating systems (modified from [5])

Rating System	New Buildings	Existing Buildings	Buildings under	Urban Planning Projects
BREEAM	•	•	•	•
CASBEE	•	•	•	•
LEED	•	•	•	•
SBTool	•	•		

Table 9. Type of intervention covered by the selected schemes (modified from [5])

Rating	Residential	Office	Commercial	Industrial	Educational	Other type of	Urban
BREEAM	•	•	•	•	•	•	•
CASBEE	•	•	•	•	•	•	•
LEED	•	•	•	N/A	•	•	•
SBTool	•	•	•	N/A	•	N/A	N/A

Table 10. Building type assessed by the selected schemes (modified from [5])

Rating System	Predesign and Design	Construction	Post-Construction	Use/Maintenance
BREEAM	•	•	•	•
CASBEE	•	•	•	•
LEED	N/A	•	•	•
SBTool	•	•	•	N/A

Table 11. Life cycle phase of the building assessed by the selected schemes

Scopes	Energy					Indoor Environmental Quality					Innovation	Management				Materials and Resoures					Pollution and Waste				Resistance Against Natural Disasters		Site Quality			
Rating System	Energy Performance	Renewable Technologies	HVAC	Lighting	Reduction of Energy Use and Emissions	Olfactory Comfort	Visual Comfort	Thermal Comfort	Acoustic Comfort	Air quality	Innovation	Management	Building information and Users Guide	Economic assessment	Integrative Design Process	Materials Reuse	Environmental Product Declaration	Materials	Water	Land Use	Noise Pollution	Light Pollution	Waste Water Management	Solid Waste Management	Earthquake Prevention	Resistance against Natural Disasters	Outdoor Amenities and Facilities	Transport	Urban Planning	Ecology and Environmental Quality
BREEAM																														
BREEAM Europe Commercial 2009	•	•	•	•			•	•			•	•	•	•		•		•	•	•	•		•	•			•	•		
BREEAM In-use international 2016	•	•	•	•	•		•	•	•	•			•		•			•	•				•	•			•	•		•
BREEAM New construction: infrastructure 2016 (pilot)	•										•	•		•	•	•	•	•	•		•	•	•	•				•		•
BREEAM International new construction 2016	•			•	•		•	•	•	•	•	•		•	•		•	•	•	•	•	•	•	•			•	•		•
BREEAM UK Domestic refurbishment 2014	•	•	•	•			•		•		•	•	•					•	•				•	•						•
BREEAM Nondomestic refurbishment 2015	•			•	•		•	•	•	•	•	•						•	•	•	•	•	•	•			•	•		•
BREEAM UK Datacenters 2010	•	•	•	•	•		•	•	•	•	•	•	•	•		•		•	•	•		•	•	•			•	•		•
BREEAM Communities 2012	•										•	•		•				•	•	•	•	•	•				•	•		•
Code for sustainable homes 2010	•	•		•	•		•		•			•	•						•	•	•			•						•
CASBEE																														
CASBEE for home (detached houses) 2007	•	•	•	•			•	•	•		•					•		•	•		•		•	•		•				•
CASBEE for building (new construction) 2014	•	•		•			•	•	•	•						•		•	•	•	•	•	•		•		•			
CASBEE for market promotion (offices and retail) 2014	•	•			•		•	•								•			•	•				•	•			•		•
CASBEE for urban development 2014	•				•							•		•		•		•	•	•			•	•	•		•	•	•	•
CASBEE for cities 2012														•					•	•				•			•		•	•
LEED®																														
LEED v4 for Homes Design and Construction																														
Multifamily mid-rise 2010	•		•		•					•		•			•			•	•	•			•	•			•			•
Homes and multifamily low-rise 2010	•	•	•	•	•					•		•			•			•	•	•			•	•			•			•
LEED v4 for Interior Design and Construction																														
Commercial interiors and hospitality	•	•	•	•	•		•		•	•	•	•			•	•	•	•	•			•		•			•		•	
Retail	•	•	•	•	•		•			•	•	•			•	•	•	•	•			•		•			•		•	
LEED v4 for Operation and Maintenance																														
Existing buildings and schools	•	•	•		•		•	•		•	•	•				•		•				•	•	•			•	•		•
Retail, data centers, hospitality, warehouses and distribution centers, multifamily	•	•	•		•		•	•		•	•	•				•		•				•	•	•				•		•
LEED v4 for Building Design and Construction																														
Schools	•	•	•		•		•	•	•	•	•				•	•	•	•	•	•	•	•	•	•			•	•		•
Healthcare	•	•	•		•		•	•	•	•	•				•	•	•	•	•	•		•	•	•			•	•	•	•
Core and shell	•	•	•		•		•	•	•	•	•		•		•	•	•	•	•	•		•	•	•			•	•		•
New construction, retail, data centers, warehouses and distribution centers, hospitality	•	•	•		•		•	•	•	•	•				•	•	•	•	•	•		•	•	•			•	•		•
Neighborhood development	•	•									•					•			•	•		•	•	•			•	•	•	•
SBTool																														
SBTool 2012	•			•	•		•	•	•	•				•				•	•		•		•	•			•	•	•	•

Table 12. Comparison of the scopes and criteria of some rating schemes (modified from [5])

Energy performance and solid waste management are the main categories to be evaluated; however, the great majority of schemes also assess the following important categories: materials, water, waste, water management, and ecology and environmental quality. The least assessed scopes concern resistance to natural disasters, as they are taken into consideration exclusively by CASBEE (though, in reality, also by two other systems, that are not considered in this discussion – German Sustainable Building Council (DGNB) and Haute Qualité Environnement (HQETM). Instead, this factor should be introduced in all countries with high seismic/hydrogeological risk etc. (such as Italy).

4.3 OTHER TWO SYSTEMS FOR SPECIAL CONTEXT

Moreover, although they are not especially widespread, two other systems have been examined: the ITACA Protocol (owing to it being an Italian Assessment System) and GBC Historic Building (because it is particularly suitable for historical buildings). These two systems are more suitable for the peculiarities of a context such as the Aeolian one.

ITACA

The ITACA Protocol [13] is based on the SB method of IISBE, chosen in 2002 as a reference by the Italian regions (the first version of the Italian SBTool is from 2002 and was presented at the World Sustainable Building conference in Oslo. The Residential SBTool 2002 can be considered the matrix of the ITACA Protocol). The ITACA Protocol system is configured as a federation of regional evaluation protocols characterized by a common methodology and technical scientific requirements. The idea is to share a common standard while allowing it to be declined locally.
The ITACA Protocol, as a result of the characteristics of the SB Method, allows for contextualization to the territorial peculiarities of the regions, while maintaining the same structure, scoring, and weighting system. This quality is particularly important for Italy as it is characterized by different climatic profiles and construction practices.
To date, many Italian Regions have adopted the ITACA Protocol as a tool to support their local policies. There are regional versions of the protocol in Piedmont, Liguria, Marche, Tuscany, Lazio, and Puglia.
The ITACA Protocol (version 2011) is composed of 34 evaluation criteria, through which the level of sustainability of a building can be objectively analyzed.
The criteria are organized into five thematic areas:
- site quality;
- consumption of resources;
- environmental loads;
- indoor environmental quality;
- service quality;

For each criterion, depending on the level of performance achieved, the building receives a score ranging from –1 to +5 (where zero is the standard construction practice, 3 the best current practice and 5 excellence).
Each criterion has a weight, based on the SBTool methodology, which determines its importance compared to the others.
The weighted sum of the scores from each of the 34 criteria determines the overall sustainability score of the building.

The Green Building Council Italia has developed a new rating system for the certification of buildings subject to restoration or refurbishment. It is called GBC Historic Building®, based on the LEED® system matrix and, in particular, on the LEED® Italia 2009 New Construction and Restructuring version. It is quite recent: the first building project was certified in 2018.
The GBC Historic Building® protocol can be used for buildings constructed before 1945 (pre-industrialization). However, for buildings built after 1945 with a preindustrial building process, in the presence of historical testimonial or cultural values, linked to the formal, typological and/or constructive characteristics, it is possible to apply the GBC Historic Building® protocol.
Compared to LEED®/GBC, this protocol adds a thematic area related to sustainable intervention in the conservation field, named "Historic Valence" (VS). It has the ultimate goal of preserving all that is "testimony with the value of civilization".
As in existing LEED®/GBC systems, in GBC Historic Building®, the distribution of points is based on the effects of actions related to the design, construction, use, and maintenance of the building (for example, greenhouse gases, the use of fossil fuels, toxic and carcinogenic agents, air and water pollution, and internal conditions) on the environment and on human health.
All requirements are grouped within the following thematic areas:
- Historic Valence (VS);
- Site Sustainability (SS);
- Water Management (GA)
- Energy and Atmosphere (EA);
- Materials and Resources (MR);
- Internal Environmental Quality (IQ);
- Innovation in Design (IP);
- Regional Priority (PR).

The points system associated with credits is based on the following rules:
- the prerequisites are mandatory and do not give a score;
- all credits are worth at least 1 point;
- all credits have a positive integer value (there are no fractional or negative numbers).

The maximum score achievable is 110, divided into 100 points distributed between the VS, SS, GA, EA, MR, and QI areas and in 10 points for the IP and PR areas.

4.4. CRITICAL ISSUES

The public receives an easily comprehensible report of how "green" a building may be due to assessment methods producing quantifiable results. This is not to say that scoring systems are impervious to negative issues.
Firstly, the building is awarded a level of certification that does not directly or extensively report its performance within specific categories of sustainable design and they are also not reliably congruous to the total reduction in realized environmental impact. Points awarded to more positively impacting categories of a rating system are identical to others and, at times, building teams work toward accumulating points where they are most affordable, not by employing methods more beneficial to the environment. This is an issue present in all major sustainability rating systems that there are inconsistencies between the impact on the environment of a specific inclusion and its designer's reward.

The discrepancy of the difficulty to fulfil various metrics compounds the problem, as certain requirements are easily attainable in one context whereas they might be unfeasible in others. Promoting the use of bicycles and public transport award points in the LEED, BREEAM, Green Globes, and Green Star systems, for instance, though implementing this metric ranges from easy to near impossible whether the context is more or less urban.
Furthermore, the costs relative to the fulfilment of certain credits are higher than others; for example, the same credit is attributed to the use of highly refletive colors for a building's roof and the installation of a green roof system. Additionally, owners are not guaranteed direct lifecycle payback costs by employing some of the more environmentally positive credits, although they are a concrete incentive.
The result is that owners and developers tend to decide on the inclusion of credits not by their impact on the environment, but their potential economic benefit [9].
In summary, the evaluation a building's performance on the basis of a score inevitably involves simplifications that are occasionally excessive. In general, scoring methods have these other limitations:

- Each indicator is associated with a different score, weighted, and decided arbitrarily by an external commission, regardless of the context and the specific case.

- There is a risk of standardizing design solutions. Many criteria tend to provide repetitive solutions that are not valid everywhere. In this sense, many systems are trying to overcome these shortcomings. Sustainability is global, but the same cannot be said about the methods to establish a building's level of environmental sustainability. Though in a number of rating systems, the point system varies, displaying a geographic and cultural singularity, any specific system lacks variation regarding climate or cultural differences.

- There is no database to obtain detailed information on the materials and products with which buildings are made. Many products have ecofriendly labels even in cases where the origin is not clear – often the methods overlook economic and social sustainability.

- The lack of a unified regulatory framework and unequivocal political choices have led to the definition of a high number of certification systems that are difficult to compare.

The importance of harmonization has also been implemented at the European level (Communication No. 445 – 01.07.2014 which highlights the need to create shared and comparable assessment tools to facilitate better use of resources in the construction sector). The Common European sustainable Built Environment Assessment (CESBA) initiative (2014, 13 European countries) provides a common framework. The mission of CESBA is promoting the promulgation and endorsement of principles of sustainable built environments by way of harmonized assessment systems throughout the built environment's life cycle. For this reason, it is CESBA's aim to be Europe's paramount organization, leading the harmonization of current and future built environment assessment systems [14].
The findings from the various systems' comparison [5] are reported below.

- The rating systems for the evaluation of a building's environmental impact are all appropriate for current and new buildings, also dealing with the refurbishment of buildings with the exception of the SBTool.

- BREEAM and CASBEE are able to assess all types of buildings, unlike LEED®, which does not concern industrial buildings. The most restricted is the SBTool, as urban planning projects are not covered by it, in addition to any building type different from residential, office, commercial, and educational buildings.

- BREEAM and CASBEE deal with a building's entire life cycle phases.

- The SBTool system has solely been designed for certifying a building's low performance level.

- Quantitively speaking, the categories most considered by the schemes are energy performance, solid waste management, material, and water.

- The least considered categories are "resistance against natural disasters", "earthquake prevention", and "olfactory comfort". The lack of attention to the issues such as "resistance against natural disasters" and "earthquake prevention" is a serious deficiency when we operate in a high-risk territory (hydrogeological or seismic) like the Italian one.

- Only the new GBC Historic Building® gives a specific answer for the certification of historic buildings subject to restoration or refurbishment.

In conclusion, regarding the further development of these schemes, beneficial features would be as follows:

- Completeness, indicating the appropriate analysis of all the elements denoting a building and its life cycle;

- A clear representation of the weighting system, with reliable evidence to support the scoring system;

- Greater harmonization at the international level would be desirable, while respecting the specificities of places.

Rosa Caponetto
Department of Civil Engineering and Architecture, University of Catania, Italy
Mail: rosa.caponetto@darc.unict.it

REFERENCES

[1] Caponetto R., Ferro V., Rodonò U., Architettura tipica eoliana: note per una metodologia di intervento sostenibile, in Atti Convegno "La riqualificazione delle coste del Mediterraneo fra tradizione, sviluppo e interventi sostenibili", editore, Napoli, 2003 (in Italian).

[2] Todesco S. (a cura di), Atlante dei Beni Etno-antropologici eoliani, EDAS, Messina 1995 (in Italian).

[3] Dipasquale L., Mecca I.,Vernacural architecture as codified model for the contemporary sustainable project. In: TECHNE n. 12, 2016.

[4] Mileto C., Vegas López-Manzanares, F., Diodato M., Tecniche costruttive tradizionali a Valencia. Metodo e risultati dallo studio materiale dell'architettura. In: Materiali e Strutture. Problemi di conservazione II (4): 95-111. Edizioni Quasar, ISSN 1121-2373 , http://hdl.handle.net/10251/60837 (2013) (in Italian).

[5] Bernardi E., Carlucci S., Cornaro C. and Bohne R. A., An Analysis of the Most Adopted Rating Systems for Assessing the Environmental Impact of Buildings, Sustainability 9 (7), 1226, 2017.

[6] Berardi U., Sustainability Assessment in the Construction Sector: Rating Systems and Rated Buildings. Sustainable Development, Volume 20, Issue 6, 2011.

[7] Nguyen B. K., Altana H. Comparative review of five sustainable rating systems, in: 2011 International Conference on Green Buildings and Sustainable Cities, Procedia Engineering Volume 21, Volume 1 of 2, Elsevier B.V., Bologna, Italy, 2011

[8] Shuzo Murakami Il contesto di sviluppo del sistema CASBEE (Comprehensive Assessment System for Building Environmental Efficiency) DOI: 10.14609/Ti_1_14_2i

[9] Say C., Wood A., Sustainable Rating Systems Around the World, CTBUH Journal, Issue II, 2008, http://ctbuh.org/paper

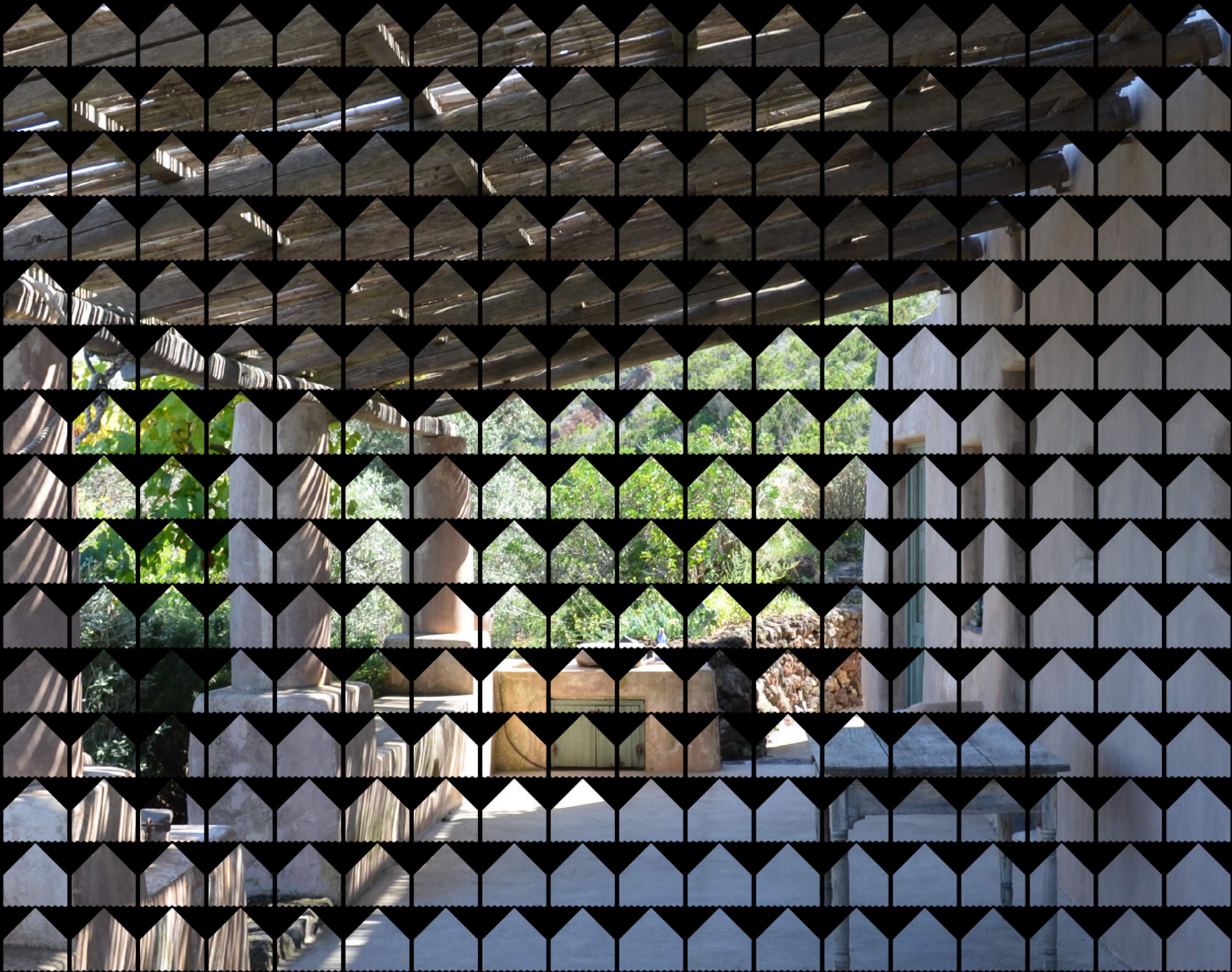
[10] "LEED rating system - U.S. Green Building Council" [Online]. Available: https://www.usgbc.org/leed (accessed on October, 2019).

[11] "Technical Standards - BREEAM" [Online]. Available: https://www.breeam.com/discover/technical-standards/ (accessed on October, 2019).

[12] "CASBEE - Comprehensive Assessment System for Built Environment Efficiency"[Online]. Available: http://www.ibec.or.jp/CASBEE/english/ (accessed on October, 2019).

[13] "iiSBE Italia" [Online]. Available: http://www.iisbeitalia.org/sbmethod/protocollo-itaca (accessed on October, 2019).

[14] "CESBA - Common European Sustainable Built Environment Assessment" [Online]. Available: https://www.cesba.eu/ (accessed on October, 2019).



978-3-03943-711-5 (PDF)