Energy and Buildings 144 (2017) 87–103

Contents lists available at ScienceDirect

Energy and Buildings

journal homepage: www.elsevier.com/locate/enbuild

Methodological framework for assessment of energy behavior of historic towns in Mediterranean climate

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ARTICLE INFO

Article history:
Received 11 November 2016
Received in revised form 14 February 2017
Accepted 11 March 2017
Available online 21 March 2017

Keywords:
Energy assessment
Energy retrofitting
Mediterranean historic buildings
Building-types

ABSTRACT

Within the ongoing international debate on methods and tools that might help include the built heritage as strategic target within the policies for NZE buildings, the paper develops a methodological framework for performance assessment and control of historic buildings and districts in coastal and sub-coastal towns of South Italy, as specific geocluster of Mediterranean traditional architectures.

In detail, based on the environmental, architectural and constructional investigation at different scales, the definition of some building-types is proposed, as descriptive models that might support the identification of energy deficits, building pathologies, inherent bioclimatic qualities and historical-architectural values, as well as the selection of effective and compatible intervention strategies within scenarios of integrated building refurbishment and urban regeneration of homogeneous areas.

The application to two representative case studies details the operation phases and the achievable results toward the validation of the general methodology. Particularly, the study highlights how the energy improvement of the built heritage should focus on innovative products and solutions (e.g. aerogel, PCMs, .) that might guarantee the challenging and desirable balance between improvement of performances of building systems and safeguard of formal and material original features, as a compromise between prescriptive accomplishment and acritical exception of the normative standards.

1. Introduction

The promotion in the construction sector of the efficient exploitation of energy resources on the road to decarbonisation has been for some years a key aspect in cultural debates, institutional policies and market trends at international level. According to the International Energy Agency (IEA), taking into account the dramatic incidence – about 30% – of building products and processes on global impacts and consumptions, a virtuous framework of codes, plans and investments has been developed worldwide, with double interventions in 2014 compared with 2009. Particularly, based on the main development tendencies, the interventions have concerned the construction of new buildings in countries like China and United States or the refurbishment of existing buildings in countries like Germany [1].

In fact, compared with the American and Asian contexts, the European Community, where the annual rate of new constructions for the residential sector is about 1% [2], has strongly promoted in the Member States several measures and actions toward the energy retrofitting of the existing building stock. Particularly, within the European buildings, which are responsible, according to the Buildings Performance Institute Europe (BPIE), of 40% of energy consumptions and 30% of greenhouse emissions in the sector, a great share, about 75%, comes from residential buildings. As a result, the Directive 2012/27/EU on Energy Efficiency points out the need to "*establish long-term strategies [. . .] for the renovation of the building stock*", which "*represents the single biggest potential sector for energy savings*". Similarly, the Directive 2010/31/EC on the Energy Performances of Buildings promotes the development of "*policies and measures such as the setting of targets in order to stimulate the transformation of buildings that are refurbished into Nearly Zero-Energy Buildings*" [3]. Such recommendations have been adopted in Italy too: according to the National Agency for new Technologies, Energy and Sustainable Economic Development (ENEA), national energy retrofitting actions have greatly concerned the residential sector, with about 2.5 millions of investments from 2007 to 2015 [4].

If the energy retrofitting of the existing buildings, particularly in Europe, has been undertaken though several programs, tools and applications, historic architectures and urban districts are still at the centre of attention by the scientific community. In fact, the EU prescriptions and relative national transpositions make an

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http://dx.doi.org/10.1016/j.enbuild.2017.03.029
0378-7788/

exception for them, due to the recognized challenge to conciliate transformation requirements and conservation principles [5]. For instance, the above-mentioned Directive 2010/31/EU, while focusing on "*existing buildings, building units and building elements that are subject to major renovation*" on the pathway toward NZEBs rule out "*the buildings officially protected as part of a designated environment or because of their special architectural or historical merit, in so far as compliance with certain minimum energy performance requirements would unacceptably alter their character or appearance*".

However, the exclusion of the historical-architectural heritage from the current efforts toward energy efficiency targets might trigger a dramatic loss of economic value for a great share of the real estate assets – in Europe 23% of buildings was built before 1945 [6]. Moreover, such a loss might affect the physical and functional obsolescence and environmental and social decay that are already quite severe – only in Italy 50% of buildings older than 70 years show poor state of conservation [7].

Within such a scenario, several studies [8] and projects [9] by universities, research centres and innovative SMEs, as well as some documents by government institutions and associations, at national [10,11] and international [12,13] levels, have been released. They all share the purpose to provide with guidelines and best practices for the selection of suitable energy retrofitting solutions for the historical-architectural heritage.

In detail, the review of the state-of-the-art highlights some common topics in the cultural and scientific debate. Among them:

- Centrality of the context, which is not only the geographic-environmental background, but, according to the concept of "geo-cluster", a "transregional area with strong similarities in terms of climate, culture, behaviour, construction typologies, technological solutions and available products", in order to address the processes to the specific features of the local territory and community [14–16].
- Assessment of the actual behaviour of the fabric, based on direct investigation, in order to carefully define residual performances and, thus, effective and low invasive interventions [17–21].
- Identification of benchmarking categories for ex-ante assessment and ex-post control, given that the historic built heritage, despite its heterogeneity and variety, shows some recurring architectural, constructional and functional characteristics for specific building typologies and ages [22] [23].
- Enhancement of inherent bioclimatic qualities for air and heat passive control, which features the traditional architecture [24–26].
- Joint application of traditional and highly innovative retrofitting techniques in order to guarantee compatibility, reversibility and efficacy of intervention [27,28].

According to the above-mentioned topics, the authors have carried out in the last years several studies, as methodological and operational contribution to the debate on the energy assessment and retrofitting of the built heritage, with specific focus on historic districts in Mediterranean climate. Particularly, methods, tools and solutions have been targeted on the envelope components, taking into account that they mainly address the challenging balance between improvement of performances and safeguard of formal and material features of the fabric, compared with still relevant energy factors – e.g. plant facilities, users' behaviour, consumptions' monitoring and control [29–32].

1.1. Aim of the research

The main goal of the research concerns the definition of a methodological framework, in terms of investigation tools, assessment criteria and intervention paradigms for the energy improvement of the historic envelope, both in terms of "passive" behaviour and integration of "active" systems from renewable energy sources.

In detail, the general methodology, as described in Section 2, is herein validated on two representative case studies of the coastal and sub-coastal towns of South Italy, as thoroughly investigated in Section 3. Specifically, the validation has concerned the improvement of the thermal performances of the construction components, taking into account the Italian normative thresholds for "non-historical" existing buildings, as released after the Directive 2010/31/EC, in order to assess their feasibility for such a delicate domain, as reported in Section 4. Thus, the identification of suitable solutions is carried out, in terms of design interventions in Section 5, in terms of effective, compatible, low-invasive strategies for future installations that might include the built heritage within the NZEBs vision through balanced goals between prescriptive accomplishment and acritical exception of the normative standards.

2. Methodology

The proposed methodology for energy assessment and retrofitting of the built heritage has been elaborated within a national research project[1] and, then, developed and validated for the historic districts of the coastal and sub-coastal towns of South Italy, also by a regional funding program.[2]

In detail, based on the state-of-the-art review and on the well-established structure of the refurbishment process for the built heritage – including analysis, diagnosis and intervention –, the methodology (Fig. 1) introduces some specific aspects, phases and goals for the topics of interest.

Particularly, the analysis phase concerns the systematic investigation of the entire historic town (A), according to several aspects – environmental, architectural and constructional – and different scales – from the urban settlement to the building component. It aims at assessing the most recurring and representative characters of the built heritage, in terms of inherent features and relationships with the surroundings, in order to identify a limited number of "illustrative" building-types (B), as categories where the totality of the "real" buildings might be assigned. Thus, the following diagnosis should concern only the building-types (C), by performance-based models and parameters, supporting the assessment of both transformation/improvement necessities and conservation/enhancement opportunities toward the definition of suitable strategies (D). Such strategies, developed for each building component, are conceived as design guidelines and best practices to be translated in the selection of technological solutions (E), based on both traditional and innovative products and systems for energy efficiency. Finally, the technological solutions might be replicated for all the "real" buildings corresponding to a certain "illustrative" building-type. Moreover, they should be applied in connection with further measures for functional and structural retrofitting, according to an integrated building refurbishment vision (F), as well as within territorial development scenarios toward the overall regeneration of homogenous urban/building areas (G).

In all, the proposed methodology follows a scalar approach. The analysis and diagnosis proceed from the general to the specific, in

[1] Italian Ministry of Education, University and Research – Research Project of National Relevance: "Geo-cluster based innovative methodologies for energy retrofitting and performance improvement of the existing building stock (Partners: Politecnico di Milano, Politecnico di Bari, Università degli Studi della Basilicata, Università degli Studi di Catania, Università degli Studi dell'Aquila).

[2] Fondazione Cassa di Risparmio di Puglia – Research Project: "Methodological framework for assessment of energy behavior of historic towns in Mediterranean climate" (Scientific Coordinator: Prof. Fabio Fatiguso, Politecnico di Bari).