Exploring occupant behaviour potentialities for historic buildings¿ energy retrofit

Abstract

In recent years, the topic of historic buildings' energy retrofit has been investigated increasingly by the energy research sector, especially in the European area. This phenomenon is related to a number of reasons, among which the increasing awareness of the role that this category of buildings have to reach the European carbon emissions' reduction targets by 2050. In fact, more than 14% of the European building stock dates from before 1920, but this percentage rises to 50% in several urban centres. Despite the increasing interest on the topic, several studies on historic buildings' energy retrofit seems not aware of cultural heritage protection and conservation legislations and practices. For this reason, nowadays, the objectives of these two sectors seems to be unbalanced. Since the tradition of heritage conservation and protection are rooted in the society's cultural background, there is the necessity of proposing a change of perspective about the role of the energy sector in the restoration field. Primarily, energy retrofit should be addressed at increasing the liveability and economic sustainability of historic buildings, having their social profitability as a central scope. In terms of solutions, the architectural heritage is characterized by a great variability, so its energy retrofit requires a high level of multidisciplinary knowledge. Moreover, due to the uniqueness of historic buildings, the necessity of individuating replicable solutions for their energy retrofit can be satisfied at a maximum degree by proposing a common procedural approach, which could be realized thorough the elaboration of a methodology. Based on the previous aspects, for the present work a strand of the energy research has been individuated as a potential ground to balance heritage conservation and energy efficiency aims. This strand is occupant behaviour or, more generally, building operation.

This PhD dissertation tackled the previous aspects by proposing the elaboration and test of a methodology called "BIOSFERA" (Building Intelligent Operational Strategies For Energy Retrofit Aims"). Testing the methodology on a pilot study, which consisted on the experimentation on four case studies, a first answer to the following research question was provided: *What are the potentialities of energy saving and indoor environmental conditions' enhancement by acting only on the way non-residential historic buildings are operated by occupants and operators?*

The results obtained in the pilot study were promising, especially in perspective of a broader application of this methodology on a larger scale. In fact, in all buildings for which an energy consumption assessment was possible, the obtained energy savings ranged from 11% to 16% considering the whole experimentation, with seasonal peaks of more than 30%. In terms of indoor environmental conditions, the energy saving trend resulted, in the large majority of cases, on occupants' perceived thermal comfort amelioration or stability.

In the following, a synthetic summary of the PhD dissertation is provided.

The **first part** of this work is dedicated to the investigation of the two corpus of knowledge that constituted the basis for the elaboration of the BIOSFERA methodology. After an introductory chapter, the tradition of conservation and protection of cultural heritage was summarized in a chapter

dedicated to “Preservation”, in which two main questions were answered: *Which buildings are protected and why? How to deal with protected buildings?* The third chapter, dedicated to “Adaptation”, contains the energy-related literature that guided the elaboration of the methodology. In particular, the chapter incorporates:

i) A summary on how the topic of energy retrofit has been faced in researches and energy-related legislations and guidelines;
ii) An overview about literature on the management of indoor environmental conditions for artworks conservation;
iii) An outline of a strand of the energy research that has been chosen as a basis to develop the BIOSFERA methodology: building energy–related operation and occupant behaviour.

A fourth chapter is dedicated to summarize the aspects emerged from the previous two ones and introduces how they have been integrated in the theoretical framework of the BIOSFERA methodology.

The **second part** of the dissertation describes the BIOSFERA methodology design and theoretical phases. Chapters 5 is dedicated to an introduction to the methodology design. Chapters 6-8 describe the three theoretical phases (Diagnosis, Intervention and Control) in terms of objectives, materials to be acquired, analyses and results’ elaboration. In this part, the objective is to provide a comprehensive overview of a series of instruments and analyses that should be successively chosen based on the application context’s specificities and necessities. Based on the previous theoretical framework, chapter 9 proposes conclusions about the methodology potentialities and barriers.

The **third part** describes the application of the BIOSFERA methodology in a pilot study executed in four Italian case studies. In particular, chapter 10 is dedicated to the description of how case studies were selected for the experimentation. Chapter 11 is aimed at describing how the theoretical phases enunciated in part II can be translated on a real application. This detailed description is provided by reporting the experience on one case study. Chapter 12 is addressed to show how the created methodology can be flexible based on the specificities of the buildings to which it is applied. To this aim, the experimentation on the other three case studies is outlined by coupling a synthetic description of the experiment with specific focus topics that were chosen to stress the methodology’s flexibility and potentialities. Finally, chapter 13 provides a general “picture” of the impact that the methodology had on the four case studies, providing a first answer to the study’s research question.

The **fourth and final part** is articulated in two chapters. Chapter 14 is dedicated to a critical review of the methodology design and theoretical phases in perspective of a possible implementation on a broader scale. The critical review is based on the experience gathered during the pilot study. Chapter 15 contains the conclusive summary, characterized by an outline of the results obtained in the dissertation, as well as the recognized potentialities and barriers in perspective of further researches towards a broader application of the BIOSFERA methodology.