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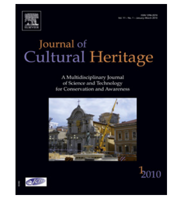

Original article

Innovative technologies for energy retrofit of historic buildings: An experimental validation

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A R T I C L E   I N F O

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A B S T R A C T

Refurbished buildings should also increase their energy efficiency, according with current regulation; however, in case of historical buildings, preservation orders are so strict to hamper usual energy efficient interventions on the building envelope side. As a consequence, in historical buildings, HVAC (Heating, Ventilation and Air-Conditioning) systems and control strategies should be further improved, since they are the only true means for energy efficiency. This paper presents the set of technologies implemented in the frame of the refurbishment of an historical building in the very center of Venice, in order to lower energy consumption and increase occupants' comfort. The refurbishment consisted mainly in the application of the following technologies: Surface Water Heat Pump (SWHP), Demand Controlled Ventilation (DCV) and trigeneration. Furthermore, the paper proves the achieved energy savings by comparing the actual energy consumption against detailed building energy simulations for baseline HVAC system configurations. For such a purpose, the authors take advantage of the installed extensive building management system (BMS), which is able to record detailed data about flow rates (of air and water), temperature and humidity for all of the key devices of the HVAC system. The building used as a case study is very significant because of its energy intensive intended use as well as for the very strict preservation orders acting on it. In particular, global primary energy savings equal to 36% have been calculated, if compared with a traditional baseline HVAC system.

1. Research aim

This research is aimed at presenting the energy savings achieved in a relevant historical building in the very center of Venice, after a delicate refurbishment implying interventions pertaining only to energy and heating/cooling systems, with no modification of the building envelope. The set of technologies used in this refurbishment may be efficiently replicated in many other cases and allow the building energy managers to achieve relevant primary energy savings, which, in the present case, reached 36%. The present case study is a relevant reference also because of the extensive building management system allowing the authors to have the full description of the actual behavior of each device involved in the chain of energy generation/distribution/use.

2. Introduction

Achieving a drastic reduction in building energy consumption, is nowadays a big challenge, facing actual global emergencies for natural resources conservation and environmental protection. Buildings are responsible of 48% of energy used on a global scale, and they contribute to 19% of CO_2 total emission, linked to energy (6,4% of direct emissions and 12% of indirect ones) [1,2]. In December 2009 the European Community, by the 20-20-20 legislation targets, dictated the reduction of 20% of fossil fuels energy consumption by 2020, through energy efficiency actions, the increase of the renewable energy sources share by 20%, and the decrease of greenhouse-effect gas emissions (specifically CO_2) by 20% [3].

To achieve these results, it is important to act on existing buildings. In particular the reuse of existing buildings may imply issues, if no objective and systematic approach is used, taking into account, for instance, the property of the building (private or public), the existence of historical, artistic, cultural, economical constraints, and the presence of various actors as public representatives, architects, architecture historians, designers and owners [4–7]. For this reason it is very difficult to consider buildings subject to preservation orders in the framework of sustainable growth. Interventions

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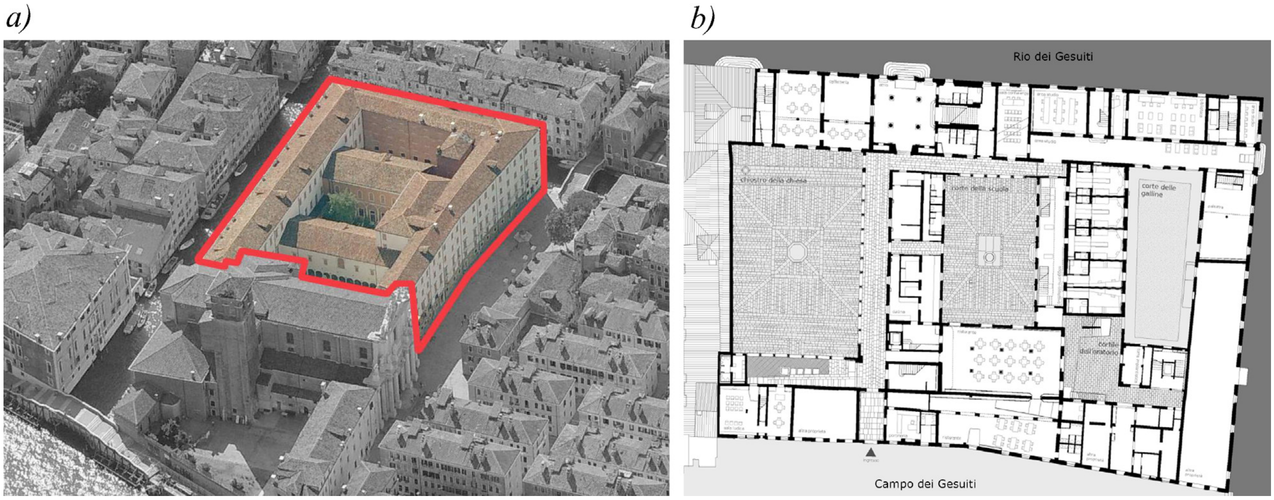

Fig. 1. Views of the Crucifers complex: a: an aerial photo of the southern part (marked in red); b: a plan view of the ground floor.

on this specific kind of buildings must fulfil new requirements without modifying the specific historical value of the construction [8–11].

Nowadays sustainable energy strategies about building refurbishment normally involve envelope insulation, air change control, lighting and HVAC system efficiencies. But who operates in historical neighborhoods or in cities with a significant amount of historic buildings, as Venice, knows that it is often impossible to modify existing envelope characteristics, for preservation orders [12]. As a consequence, the energy demand linked to leakage through the envelope, grows exponentially, and seasonal consumption increases dramatically to intolerable values if compared to modern attention for building energy saving [13,14]. In this case the law often permits to make exceptions on the actual application of energy regulations [15]. Guidelines in European standard EN16883 [16] have as a fundamental goal "to reduce energy demand and greenhouse gas emissions without unacceptable effects on the heritage significance of the existing built environment, by mean of a systematic approach", underlining that "it does not presuppose a need for energy improvements in all historic buildings". It seems that it will be very urgent to answer a question: is it important to give value to historical buildings changing their functions with modern ones (museums, schools, residences), or is it better to leave them as they are because of their unique monumental value? [17,18]. This second solution can seem the most simple, but lack of use of a building has negative consequences: a progressive risk of abandonment and a considerable decline, with huge maintenance costs [19,20]. Increasing building lifetime by changing their function can give, instead, a significant contribution to sustainability, by lowering pollution and energy consumption consequent to material production, transportation and use, compared with the construction of new buildings [21,22]. To reach a more sustainable reuse, however, it is important to properly design the building-plant system, finding those solutions capable of solving criticalities due to the risk of an energy demand greater than in new buildings [23,24]. A particular focus should be dedicated to HVAC system efficiency through solutions consistent with preservation orders [25–27].

This study analyses the introduction of innovative HVAC technologies characterized by high energy efficiency, but suited to be installed also in historic buildings. Their characteristics and performances are describing by referring to a real case study.

3. Method

3.1. Experimental validation in a typical historical context

New HVAC systems are often proposed for building retrofit. Normally the design is accompanied by performance forecasts based only on modeling and simulation with different levels of deepening and precision. But, precise evaluations about the system behavior based on field measurements during the following building management are rarely carried on. However, only such an experimental analysis is able to confirm the actual validity of the systems suggested. Therefore, in this paper the methodological approach consists in the presentation of the selected technologies by referring to their actual implementation in a precise context. Accompanying this presentation with the description of the design choices adopted for their installation and mainly with the result of long-term monitoring able to quantify the actual energy performance obtained.

The case study is the refurbishment of the southern part of the former Crucifer Convent by University Iuav of Venice to realize a university campus, which covers an area of about 10,000 m^2.

This complex is located in Cannaregio, Venice and, as shown in Fig. 1a, it faces west to the Campo dei Gesuiti, east to the channel Rio dei Gesuiti (Fig. 1b), north to the Church of Santa Maria and south to a minor channel.

From its foundation in 1150 to present days the convent was subject to different destination.

These changes start from the original use designated by the order of Crucifers: a mixed location for devotional confraternity and shelter for pilgrims and crusaders on their way to the Holy Land. Acquired by Jesuits in 1657 the convent was used as college/school until the religious order suppression in 1773. Since Napoleonic period, the southern part of the religious compound was used as barracks until 1990 and totally disconnected from the church.

These transformations never distort the original structure (Fig. 2). The previous religious dormitories became soldiers bedrooms and in the ground floor the common spaces of the convent were transformed in common and service spaces for the barracks. Therefore, as required by strict preservation orders, these spatial characteristics was kept in the refurbishment design: ancillary services in the ground floor, residences in the upper floors.

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