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Innovative use of Hydrogen in energy retrofitting of listed buildings

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Abstract

Existing buildings represent the major challenge in energy efficiency strategies applied to the building stock. Moreover, architectural and landscaping constraints related to listed buildings are further limitations to possible interventions. When listed buildings are used as museum, achieving the same effectiveness level of typical energy efficiency measures is very difficult and, if possible, very expensive. In order to couple preservation of cultural heritage and CO2 emission reduction, the approach would move to energy supply rather than modifications in building envelope or installation of new HVAC components. So, this study focuses on the opportunity to green NG supply of existing heating systems by means of Power to Gas option at district level. Thus, the recent advancements in Hydrogen enriched Natural Gas produced by RES electricity excess offer a zero-impact strategy to decarbonize the listed buildings using existing energy infrastructures. At the same time, the absence of changes in building features and the introduction of a renewable share in the supply address the sustainability issues of cultural heritage. In conclusion, a first original attempt was made towards the future crucial task of museum's deep energy refurbishment.

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Keywords: Power to Gas; historical buildings; energy efficiency; cultural heritage; existing building; energy transition.

1. Introduction

Recently, many research activities are coping with the hot topic "energy efficiency in existing buildings". Within this matter, an interesting sub-topic is related to the listed buildings, characterized by further issues of interventions due to constraints such as preservation of architectural and landscaping values as well as cultural identity.

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Nomenclature

CHP	Combined Heat and Power
CO_2	Carbon dioxide emission
H_2	Hydrogen
H_2NG	Hydrogen and Natural Gas
RES	Renewable Energy Sources

Among those barriers, when a museum is established in a listed building, it represents the hardest challenge. This latter is identified by Todorovic et al. [1] as the future crucial task starting from the tracing phase towards a fully green construction status after a new way of Museum's deep energy refurbishment project. While, an immediate feasible intervention regards the outdoor thermal comfort. It was studied to improve historic buildings accessibility and fruition [2] but, the achieved energy efficiency goal can be considered sometimes negligible if compared to thermal and electrical energy needs.

Other research activities investigated on how to use cool materials to replace damaged building components made by stone [3]. This strategy could be used when there are not landscaping constraints because even the colour of materials must be preserved. Furthermore, a sustainable integration of the increasing RES share in energy mix results demanding for current energy systems so as to require particular attention to solve the mismatch between production and consumption profile by means of storage option at different scales [4]. In order to achieve the CO_2 emission reduction and to account for the aforementioned barriers, recent research lines focused on greening the energy supply by partial substitution of the fossil fuel such as Hydrogen enriched Natural Gas [5] or, if locally available, by total replacement with bioenergy [6]. It is noteworthy to point out that bioenergy availability and feasibility is strictly dependent on territorial features and their typology, sometimes being producer of higher GHG emissions amount than conventional fuels [7]. The increasing energy efficiency requirements for public buildings was set by EU Parliament through the Energy Efficiency Directive [8], aiming at reducing of 3% the CO_2 equivalent emissions every year. Listed buildings are excluded from this duty but, the growing environmental awareness drives research to find viable energy efficiency solutions, especially, when they are part of large building complex [9].

So, the authors of this study explored the decarbonisation potential of heating systems fuelled with H_2NG blends to meet the thermal energy needs of a listed building. The renewable energy integrated in this system comes from the Power to Gas option, i.e. Hydrogen produced by means of electrolysers fed by PV and, then, direct injected into Natural Gas pipelines. Different H_2 volumetric fractions in the mixtures were considered along with their environmental benefits in term of CO_2 emission reduction [10]. Well-established energy infrastructures are already present in a wide range of listed buildings due to the restoration activities carried out during the first decades of 20th Century, before the approval of an international minimum standard for cultural heritage preservation [11].

2. Heating systems terminals and restoration

Since all the interventions made to listed buildings contributed to its history, great part of heating systems installed at the beginning of 1900 were currently considered to be preserved, even if they are the outcome of disruptive measures. Especially for heating system terminals, they became part of the interior design but, sometimes they were also hidden by furniture or ornaments when no socially accepted. The first installed radiators were made by cast iron and placed on the floor due to their heavy weight as shown in Figure 1. Their color was immediately adapted to classical wall paper, i.e. dark tonality or bronze. The importance of their integration in the interior design was underlined by the ornaments in wrought iron. A further evolution was the implementation of a hole in the heating terminal to heat food up. Their importance in everyday life and the adaptation to the furniture gave them an historical value, not negligible for any restoration. Following the importance of traceability of historic stratification in cultural heritage, a viable energy retrofitting strategy could be limited to the analysis of reliability, maintainability and availability as essential features of the thermal energy plant to fulfill the heating demand [12]. This strategy involves the heat transfer fluid, the fuel burnt by the heating supplier and the centralized thermal power plant.