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The Polyvalent heat pumps technology in retrofit of existing HVAC systems

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Abstract

In terms of existing buildings' retrofit, historical and non-residential buildings clearly represent two challenging categories. In historical buildings, due to architectural constraints, acting on the technical side is often the only way to reduce consumptions, while non-residential buildings usually require simultaneous production of hot and chilled water. In these cases, Polyvalent heat pumps represent an interesting solution, able to guarantee significant reductions of primary energy consumptions.
In detail, a Reference Building for an historical office was simulated in three Mediterranean cities, using EnergyPlus software and some evaluation tools specifically set to emulate the energy performances of the examined HVAC technologies.

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1. Introduction

When considering historical buildings, it is important to bear in mind that the inclusion of an air conditioning

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system is always a complex operation [1]. Ordinarily, the original design of historical buildings does not include a centralized HVAC system, while fireplaces secured the heating of the main rooms. In some cases, in the first decades of the 20th century, a system of radiators was realized.

Nevertheless, the main difficulty is to find the locations for the generators, especially for heat pumps and chillers, for which it is often necessary to find open spaces. Heat pumps and chillers are not pleasant to see, especially in the context of a building characterized by important architectural value and historic significance. Consequently, they must be hidden or masked. The best solution is to place them in the upper parts of the building on existing terraces or creating suitable space acting on the profile of the roof. Moreover, in some cases, there could be the problem of the equipment weight. Indeed, probably, the original design of the historical building did not include weights so great and, for this reason, the structure of the building must be carefully verified.

Generally, in historical downtowns, background noise is very low (especially if there is no car traffic) and the buildings are very close to each other. The noise of the HVAC equipment must be carefully considered.

Moreover, the lack of useful space and the need to protect the architecture of the building very often prevents the installation of thermal or photovoltaic solar systems.

Finally, in historical buildings, the use of boilers is never easy, because often there is not a gas flue chimney or, when it is present, it still remains the problem of the structure fire protection. [2].

In these conditions, it is interesting to evaluate the use of a Polyvalent Heat Pump (HP) in place of traditional chiller and boiler. In the Mediterranean area, characterized by a temperate climate, a Polyvalent HP could be the only generator in the building, allowing a plant simplification and a space saving at the same time.

The aim of this research is to present the results obtained by using the Polyvalent heat pumps technology in historical buildings. In particular, a Reference Building for an historical office was simulated in three Mediterranean cities: Rome, Bari and Barcelona. The energy-dynamic simulation software EnergyPlus was used to model the office Reference Building and to evaluate the energy needs, while some energy-evaluation tools specifically set to emulate the energy behavior of the HVAC systems were used to assess consumptions.

2. Polyvalent Heat Pumps technology

A Polyvalent heat pump is a packaged heat pump equipped with a flexible and versatile heat recovery system, which can produce cooling only, or heating only, or cooling and heating at the same time. Each unit is equipped with three heat exchangers:

- a refrigerant-to-water evaporator to produce chilled water;
- a refrigerant-to-water condenser to produce hot water;
- a condenser/evaporator where heat rejection in cooling mode or heat absorption in heating mode takes place.

The latter heat exchanger can be a finned coil in case of air-cooled units, or a refrigerant-to-water heat exchanger in case of a water-cooled unit. In each operating mode, only two heat exchangers are activated.

Figure 1 represents the working principle of a Polyvalent heat pump. In particular, when only chilled water is required, the unit works as a normal chiller (A1 mode in Fig. 1). When chilled and hote water are simultaneously required, the unit switches to the heat recovery mode: the heat removed at the main heat exchanger (E) producing chilled water is rejected to the condenser (R) producing hot water (A2 mode in Fig.1). If only hot water is required, the unit switches to the heat pump mode, using the third heat exchanger as an evaporator and rejecting the heat to the condenser (C) producing hot water (A3 mode in Fig.1). The unit can change its operating mode at any moment, according to system requirements.

The operation modes just described are valid for a 4-pipes Polyvalent HP model. Anyway, a 2-pipes model also exists and the difference lies in the operation of the exchanger E of Figure 1: in a 4-pipes model, it works only as an evaporator, while in the 2-pipes model it works as an evaporator in the cooling mode and as a condenser in the heating mode.

The 2-pipes model is suited for seaside hotels used mainly in summer season, where there is never a need for heating, or whenever it is not possible to install a 4-pipes system.

Some manufacturers have a single version of Polyvalent HP: the operating mode switches from 2-pipes to 4-pipes simply by selecting the function on the microprocessor control.

All the energy analyses described in the following sections were performed considering a 4-pipes model.