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HVAC solutions for energy retrofitted hotel in Mediterranean area

Cristina Becchio[a,*], Stefano Paolo Corgnati[b], Michele Vio[c], Giulia Crespi[b], Leonardo Prendin[d], Mattia Magagnini[d]

[a] TEBE Research Group, Department of Regional and Urban Studies and Planning (DIST), Politecnico di Torino, Viale Mattioli 39, 10125 Torino, Italy

[b]TEBE Research Group, Energy Department (DENERG), Politecnico di Torino, Corso Duca degli Abruzzi 24, 10129 Torino, Italy

[c]RHOSS Consultant, Via delle Industrie 211, Arquà Polesine (RO) 45031, Italy

[d]RHOSS, Gruppo IRSAP, Via delle Industrie 211, Arquà Polesine (RO) 45031, Italy

Abstract

To meet the European targets for achieving high-performing buildings, the refurbishment of the existing building stock and, in particular, of historical buildings represents a great challenge.

The research aims at identifying the most energy-effective HVAC configuration for retrofitting historical hotels in Mediterranean area, where the objective is to minimize the consumptions for both space heating and cooling. A Reference Building for an historical hotel was simulated in five Mediterranean cities and different HVAC solutions were assessed, using EnergyPlus software coupled with tools specifically set to emulate the energy behaviour of certain HVAC technologies, aiming to highlight the most efficient alternative.

Peer-review under responsibility of the scientific committee of the Climamed 2017 – Mediterranean Conference of HVAC; Historical buildings retrofit in the Mediterranean area

Keywords: energy retrofit; energy efficiency measures; HVAC systems design; hotels; Mediterranean climate.

1. Introduction

Energy security and climate changing make it necessary to improve the global energy performance, especially in the

* Corresponding author. Tel.: +39-011-090-4524.
E-mail address: cristina.becchio@polito.it

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construction sector, where the high levels of energy consumption and greenhouse gas (GHG) emissions are a strong challenge. In this context, European Commission's Roadmap established that GHG emissions in buildings must be reduced by around 90% by 2050 compared to 1990 levels [1]. The most immediate and effective way of achieving this target is through a combination of cutting energy demand through increased energy efficiency of the buildings and systems and a wider deployment of renewable technologies.

Consequently, European legislation set out a cross-sectional framework of ambitious targets for achieving high-energy performances in buildings. The recast of the Directive on the Energy Performance of Buildings (EPBD) defined that all new buildings will be nearly zero-energy buildings by the end of 2020; this represents a real step-change to the current way of designing the building, from both architectural perspective and technical systems side, including HVAC. Furthermore, the EPBD Recast strengthened the focus on existing buildings, considering the low annual growth rate of new constructions, mainly due to the consequences that the financial crisis had on the construction sector. Moreover, a large share of European buildings stock was built before 1960s, when there were few or no energy efficiency requirements and only a small part of these was subject to energy retrofits [2]. Since surely the oldest part of the buildings contributes greatly to the high-energy consumption in the sector, it is evident that the largest energy saving potential is associated with existing buildings.

Nevertheless, the wide variety of existing buildings, which may differ in age, dimensions and location, does not allow having a unique approach to the problem. Another particular case is the one of historical buildings, which must be dealt case-by-case [3]. Historical buildings can be defined as buildings having important artistic value and historic significance. Therefore, retrofit interventions must be carefully defined and designed for the existence of historical or architectural constraints, with attention to maintain their historic physical integrity. In this sense, planning authorities and other organizations may restrict the type of renovation that can be undertaken. However, historical buildings cannot be excluded from energy renovations: according to the Building Performance Institute of Europe, "there will always be some energy efficiency measures that can be applied, even if it is not a total renovation" [2]. The problem of refurbishment of historical buildings is also due to the lack of defined European plans. Indeed, generally, special national or local laws protect historical buildings and any retrofit action must get permission from the local planning authority, which typically consults the national Cultural Heritage agency. Accordingly, any energy retrofit must be authorized by these competent authorities, which aim to preserve the existing identity of the building [3], often requiring the use of existing materials in the retrofit and the preservation of the external building envelope.

The increasing interest toward historical buildings and their energy issues led many researchers to develop and propose retrofit actions able to combine architectural heritage and energy efficiency. Ciulla et al. [4] express the need to find the most applicable retrofit actions and understand whether these retrofit plans are effectively able of reducing the energy needs of historical buildings. Currently, this theme is absolutely challenging for architects, engineers and owners. The present paper fits in perfectly with this challenge, analyzing which are the possible efficiency measures that can be implemented in existing historical hotels in Mediterranean area. This area presents a rich cultural and historical heritage, in line with the objectives of the research field. Furthermore, the Mediterranean region is one of the most visited tourist destination areas in the world and this justifies the choice of the hotels as case study for the research. The analysis of energy consumption of accommodation structures is a topical issue, since the United Nations General Assembly approved the adoption of 2017 as the International Year of Sustainable Tourism for Development [5]. In the non-residential sector, hotels are ones of the most energy-intensive buildings, since these structures must provide services to guests and guarantee their internal comfort. Coming to numbers, in 2005 the contribute of tourism sector was estimated to 5% of global CO_2 emissions and the breakdown among sub-sectors highlights that the accommodation sector causes more than 20% of the total emissions, ranking third behind plane and cars transports [6]. Nevertheless, in the accommodation sector the high GHG emissions permit high potential for improvement, representing an interesting research topic.

Furthermore, the issue of building energy performance in Southern Europe and in Mediterranean climates is taking on increasing prominence in recent times. Indeed, it is well known that in the European framework the issue of low consumption buildings was initially addressed in the Northern countries, where the control of thermal loads in heating periods is fundamental and where the external climate conditions make the free cooling with external air possible. On the contrary, in Mediterranean area, the great design challenge is to minimize the energy consumption for both heating and cooling; depending on climate areas and conditions, these loads can be comparable or the cooling needs in summer may prevail. Consequently, the scenarios to face are extremely different, based on climate conditions; in the countries of South Europe, the climate conditions may significantly differ in terms of winter and summer design temperatures and in terms of relative humidity in winter and in summer. In fact, many countries included within the Mediterranean climate area are characterized by a variety of climates, unknown in North Europe, as for example, the alternation of cold and dry winters and hot and wet summers.

In detail, a Reference Building for an historical hotel was modeled and simulated in five cities of the Mediterranean area: Rome, Bari, Barcelona, Athens and Tunis. As previously remarked, applying energy efficiency measures on the building envelope is often impossible due to architectural restrictions and the only chance to reduce energy consumptions is that of operating on the systems, increasing their efficiency. For this reason, the aim of the research is to identify for each city the most energy-effective HVAC solutions. Alternative HVAC system configurations were defined and assessed by means of dynamic simulations with EnergyPlus code coupled with energy-evaluation tools specifically set to emulate the energy behaviour of the HVAC technologies.

Finally, a comparison of the results achieved in the analyses in the different climatic conditions was carried out and the most efficient solutions highlighted.

2. Reference Building

Reference Buildings' (RB) aim is to characterize the energy performance of typical building categories under typical operations in the interests of generalizing the energy and economic results obtained to the whole building category [7].

In this study, the Reference Building is built starting from the model of Large Hotel post-1980 construction from the American Department of Energy (DOE) database [8] and adjusting it in order to achieve the features of an historical hotel. The selected RB presents six storeys above ground, with a total conditioned net area of 9366.3 m². The building has a rectangular plant, with the major façades North- and South-oriented; the 27% of the envelope is glazed. A lobby, a storage, a technical room and a café for guests' exclusive use constitutes the ground floor ($area_{net}$ = 1978.8 m²; $height_{net}$ = 3.96 m). The intermediate floor ($area_{net}$ = 1477.5 m²; $height_{net}$ = 3.05 m) is completely occupied by guestrooms and distribution areas. The last floor ($area_{net}$ = 1477.5 m²; $height_{net}$ = 3.05 m) is occupied by a kitchen, two breakfast rooms and a corridor, as well as by guestrooms. Totally, the hotel presents 179 rooms, of which 161 have an area of 25 m² and 18 an area of 39 m²; the 20% of the rooms is empty.

All the construction typologies for the different five Mediterranean cities are selected from TABULA Webtool [9] considering the apartment block category (the most similar to the hotel building) for the period of construction 1901-1920. Tunis is not part of the European TABULA project and its typical construction type in the selected period derives from [10]. Table 1 summarizes the thermal features of the main envelope components and their relative U-values.

Table 1. Thermal features of the building envelope.

City	External Wall	External Roof	Window
Rome	Brickwork 38cm plastered on both sides (U=1.48 W/m2K)	Flat roofs with reinforced brick-concrete slab (U=1.46 W/m2K)	Single glazing, wood frame (U=4.9 W/m2K)
Bari	Brickwork 50cm plastered on both sides (U=1.14 W/m^{2}K)	Flat roofs with reinforced brick-concrete slab (U=1.46 W/m^{2}K)	Single glazing, wood frame (U=4.9 W/m^{2}K)
Barcelona	Brickwork 20cm plastered on external side (U=2.54 W/m^{2}K)	Flat roofs with reinforced concrete slab (U=3.07 W/m^{2}K)	Single glazing, wood frame (U=5.3 W/m^{2}K)
Athens	Brickwork 20cm plastered on both sides (U=2.2 W/m^{2}K)	Flat roofs with reinforced concrete slab (U=3.04 W/m^{2}K)	Single glazing, wood frame (U=4.9 W/m^{2}K)
Tunis	Stonewall 45cm plastered on both sides (U=2.4 W/m^{2}K)	Flat roofs with reinforced concrete slab (U=3.07 W/m^{2}K)	Single glazing, wood frame (U=5.7 W/m^{2}K)

In the guestrooms and in the breakfast rooms, windows are equipped with internal white blinds. During the whole year, in the guestrooms blinds are close from 00:00 to 18:00 in order to prevent overheating. In the breakfast rooms, blinds are close when the zones are unoccupied (from 11:00 to 07:00). In the empty guestrooms, the shading devices are always close during the whole year.

Occupancy levels of the different zones are fixed as follows: 10 m²/pers for guestrooms [11]; 0.2 m²/pers for lobby and café, 0.6 m²/pers for breakfast rooms, 0 m²/pers for the corridors and service spaces [12]; in absence of specific

European values, the kitchen value of 5.56 people is maintained equal to the original DOE value. The schedule for occupancy in guestrooms (Fig. 1) is defined accordingly to EN 15232:2012 [11], while the schedules for the other spaces are taken from DOE model.

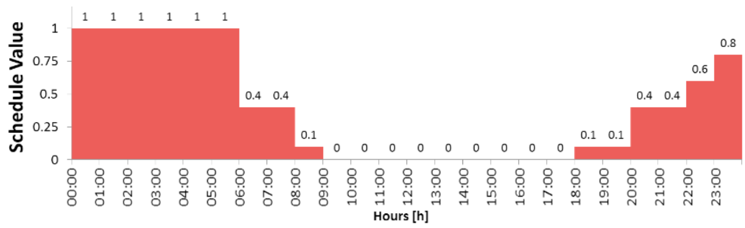

Fig. 1. Occupancy schedule for guestrooms for everyday [11].

A typical sedentary activity of 1.2 met is assumed in all the occupied rooms, with the exception of lobby and kitchen, where a higher value is implemented, equal to 1.6 met. In terms of clothing, typical resistance values are assumed: 1 clo for winter season and 0.5 clo for summer season [13].

Lighting power density is fixed to 3 W/m² in the whole building, assuming the presence of LED systems. Equipment power densities are set equal to 4 W/m² [11] in the guestrooms while all other data are maintained from the initial DOE model. All the unitary values reported so far are associated to the relative activities schedules in the EnergyPlus model; the guestrooms' ones are fixed accordingly to ISO 18523-1 [14], while the other ones are maintained from DOE model (Fig. 2, 3). In the empty guestrooms, the lights are always off and the appliances are scheduled equal to 0.2 for the whole day.

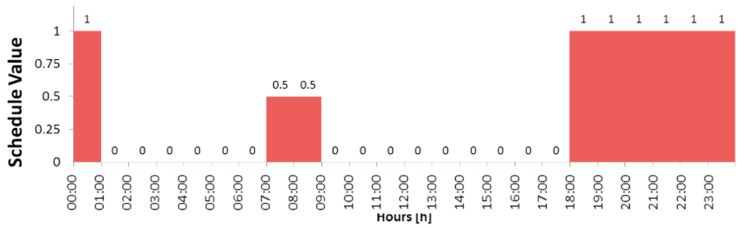

Fig. 2. Lighting schedule for guestrooms for everyday [14].

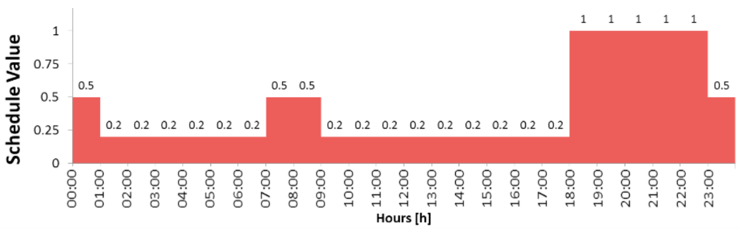

Fig. 3. Equipment schedule for guestrooms for everyday [14].

Operative temperature set-points are fixed according to the comfort class I of EN 15251:2007 [13], in order to compare the results of the different HVAC system configurations under the same conditions of thermal comfort (Table 2). Heating system operates during the sole heating season, while cooling is active throughout the year; for each city heating and cooling seasons are fixed in compliance with regulations. Typical climatic conditions are taken from DOE Weather for energy Calculation Database of Climatic Data.

Table 2. Operative temperature set-points and set-backs and HVAC operational schedules.

	Heating set-points and schedule	Cooling set-points and schedule	Winter Cooling set-points and schedule
Guestrooms	21 / 15°C 18:00 – 09:00	25.5 / 28°C 18:00 – 09:00	25.5°C 18:00 – 09:00
Empty Guestrooms	15°C 00:00 – 24:00	28°C 00:00 – 24:00	Not active 00:00 – 24:00
Café	21°C 00:00 – 24:00	25.5°C 00:00 – 24:00	25.5°C 00:00 – 24:00
Breakfast Rooms	21 / 15°C 06:00 - 11:00	25.5°C 06:00 - 11:00	25.5°C 06:00 - 11:00
Corridors, lobby, storage, kitchen	18°C 00:00 – 24:00	25.5°C 00:00 – 24:00	25.5°C 00:00 – 24:00

2.1. Buildings energy demand

Figure 4 shows the buildings annual energy demands. They take into account the heat transfers through the envelope components, the solar gains and the internal loads, while they do not consider the fresh air treatment.

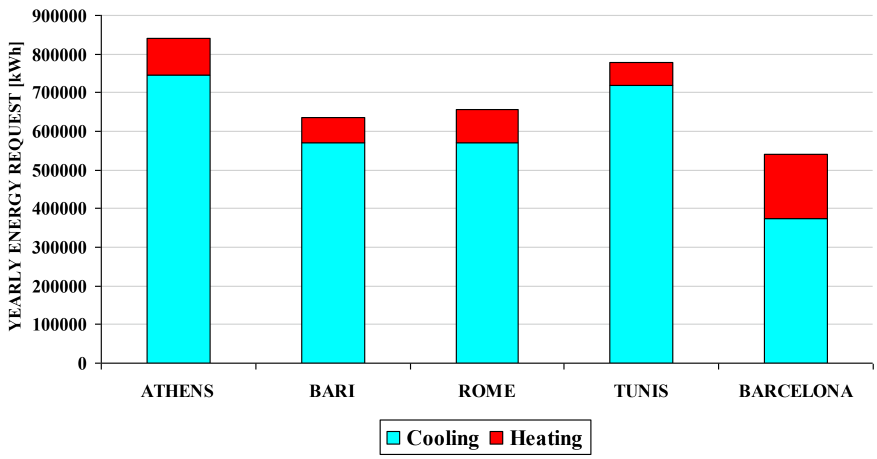

Fig. 4. Heating and cooling needs.

2.2. Domestic hot water demand

The domestic hot water (DHW) demand is estimated as follows, in accordance with [15]:

- 80 litres per person per day for the bathrooms;
- 50 litres per person per day for the breakfast rooms;
- 25 litres per person per day for the cafe.

The water consumption of the breakfast rooms was divided in 6 hours rather than the 4 hours of actual service, in order to consider the dishwashing after the service is terminated.

The daily requirement amounts to 39960 litres. The required energy depends on the climate of the locality, because it varies with the tap water temperature. Table 3 shows the annual requirement for each city.

Table 3. Yearly energy required for domestic hot water [kWh].

Athens	Bari	Rome	Tunis	Barcelona
578093	594211	597215	560069	598315

3. Systems' features

Concerning the generation system, three different configurations were analyzed: boiler and chiller, Polyvalent Heat Pump (HP), Polyvalent Heat Pump and booster. In order to define the size of the generators, the energy requirements related to the fresh air treatment and to the other components of the HVAC system must be added to those shown in Figure 4.

Three different solutions were examined (Table 4), one with only fan-coils (FC) and two with fan-coils and primary air (PA).

Table 4. Examined solutions.

Solutions	Fresh air flow	Fan coils inlet water temperature
FC	40 m^3 per person: constant throughout the day*	7°C constant
PA1	40 m^3 per person: constant throughout the day	7°C constant
PA2	60 m^3 per person: variable with the real people presence	7°C, rising up to 14°C in function of sensible load

*Hypothetical condition, assumed only to compare the systems on equal terms

Regarding the two solutions with primary air, the following heat recovery solutions for the exhaust air were examined:

- Sensible heat recovery;
- Enthalpy heat recovery;
- Sensible heat recovery assisted by Indirect Adiabatic Cooling (IAC).

Each recovery system has 73% of efficiency (sensible or total). The pressure drops are assumed identical for all the heat recoveries analysed; only in the case of IAC, an increase in the pressure drop due to the presence of a humidifier was considered.

In addition, for each of these solutions, a Run Around Coil (RaC) for cooling (heat recovery for the post-heating) was added, obtained by piping in series the pre and post-heating coils.

Each of the nineteen examined solutions produced different loads. Figure 5 shows the power demand throughout the year for the hotel located in Rome, in the case of sensible heat recovery (red = heating, blue = cooling), comparing the two investigated solutions of primary air (PA1 and PA2, Table 4).

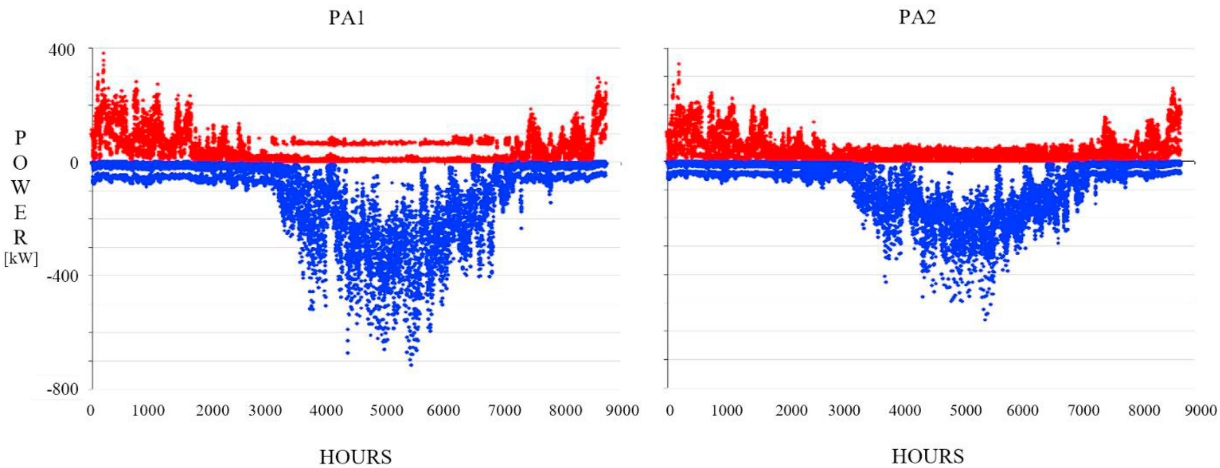

Fig. 5. Power requested by HVAC Primary Air systems with sensible heat recovery in Rome.

As reported in Table 4, the PA2 solution provides the injection of a greater flow of fresh air (60 m³/h per person against 40 m³/h of the PA1 solution), but it provides the variation of the fresh air flow in function of the real presence of people. The fresh air flow is blocked in empty rooms, while in common areas it is controlled by air quality sensors. This results in a net decrease in power demand, especially during the cooling period, since the rooms are empty during the hottest hours.

The capacities shown in Figure 5 are related to the request of the HVAC systems, without considering the demand for DHW production. Certainly, in order to obtain the total power required to the generators, it is necessary to add this demand. Focusing on the PA2 solution, Figure 6 compares the power required by the sole HVAC system (on the left) with that required by HVAC system together with DHW production (on the right). Clearly, it can be noticed how the power demand for the hot water generator increases. For this reason, the domestic hot water production system must be chosen properly.

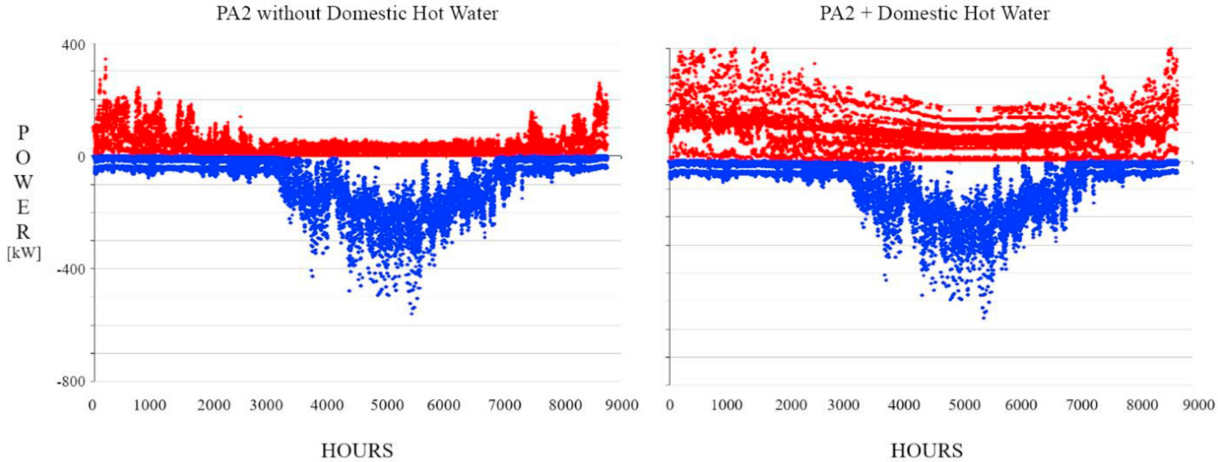

Fig. 6. Power requested to the generators in PA2 configuration with sensible heat recovery in Rome.

3.1. Domestic hot water production

Three different systems for the DHW production were considered:

- Natural gas boiler;
- Polyvalent HP;
- Polyvalent HP combined with a water-to-water HP equipped with R134a (as a booster).

Figure 7 describes the latter two solutions, both powered only by electricity, in order to avoid the difficulties related to the installation of a boiler. The scheme on the left shows the case where only Polyvalent HPs are used, in the best configuration with two units. Both Polyvalent HPs are connected in parallel to the cooling hydraulic circuits, while on the hot side, one unit works connected to the heating circuits and the other one is connected to the domestic hot water production loop.

It is recommended to use two units rather than one, because the water temperatures required are different: 55°C for the domestic hot water and 45°C or less for the space heating circuits. Using only one unit the production of the hot water should be at 55°C in order to satisfy both the heating and the DHW requirements, causing an energy loss due to the worsening of the Coefficient of Performance (COP) oh the heat pump. Anyway, the major limitation of this solution is the maximum water temperature achievable: 55°C at the heat pump side, which becomes at most 52°C-53°C at the DHW side. This value is too low to eliminate the risk of legionella bacteria, which requires chemical treatments or the use of an inertial tank with external exchanger for the instantaneous production of DHW. The thermal shocks with electric heaters are not advised because extremely expensive, from an energy point of view.

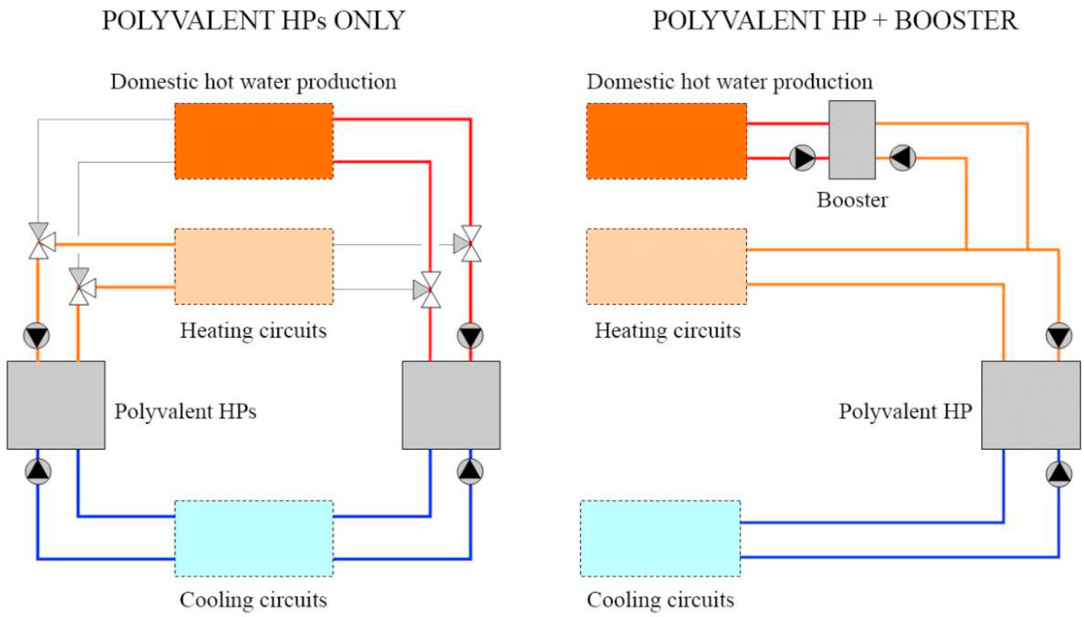

Fig. 7. Production of domestic hot water with electric powered generators.

The problem is overcome when considering the solution outlined in the right diagram of Figure 7. A water-to-water heat pump (booster) is connected to the Polyvalent HP hot water circuit on the return pipe, which works as a cold heat source. This heat pump produces all the required domestic hot water. The refrigerant R134a allows to reach water temperatures above 60°C, thus eliminating the danger of legionella bacteria.

From an energy standpoint, the system is less convenient than the solution with only Polyvalent HPs due to the additional consumption of the booster unit, but it greatly simplifies the installation. Moreover, the booster could be positioned within the building, since it is a water-to-water unit, solving the problem of finding an additional external place for its installation.

3.2. Optimization of hydraulic circuits

In order to minimize the plant energy consumption, when possible, it is important:

- To install buffer tanks on primary circuits. The ideal size would be 10 litres per kW of thermal power. In historical buildings, this is not always possible, for reasons of available space. However, generally, the greater the water content is, the greater the efficiency of the system will be.
- To select the right pumping groups on secondary and on primary circuits: in this second case, dual-pumps systems should be adopted [17].
- To vary the chilled and hot water temperatures produced, according to the HVAC system requests.

4. Focus on the systems' installation problems in historical buildings

The inclusion of an air conditioning system in an historical building, built before 1900, is a complex operation.

Generally, in historical downtowns, the background noise is very low (especially if there is no car traffic) and the buildings are very close to each other. The noise of all HVAC equipment must be addressed, especially in hotels buildings, where the generators usually work also during the night.

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.

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. In fact, 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.

Furthermore, 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. In these conditions, a Polyvalent Heat Pump should be used, in place of traditional chillers and boilers for cooling and heating respectively. In the temperate climate of the Mediterranean area, a Polyvalent HP may be the only one generator in the building; the result is a plant simplification and a space saving, since the size of a Polyvalent heat pump is the same of a traditional chiller [16].

5. Analysis of the results

The total number of results is considerable; for each building, 540 different combinations were considered. A summary is given in the paragraphs below.

5.1. The Photovoltaic Equivalent Surface: a new energy index

It is always difficult to understand the order of magnitude of the energy consumption. During the research, there was the need to find a comparison parameter, correlated to the location climate, understandable to everyone, including the owner or the tenant of the building, who may not have experience in the energy field.

This parameter was identified in the Photovoltaic Equivalent Surface (PVES), which can be defined as the surface of a photovoltaic array required in order to bring to zero the difference between the yearly self-produced electricity and the overall consumption of the plant, including the auxiliaries (pumps and fans).

The selected PV array consists of crystalline silicon panels with 14.4% electrical efficiency, oriented to the south and with a 40% slope, so as to apply the solar electric generating estimates of the European Commission Joint Research Centre (JRC). With this performance, to obtain 1 kW of electric peak power with an irradiance of 1000 W/m^2, 7 m^2 of panels are needed.

Considering that the best electricity generation technology actually available powered by natural gas can produce electricity with 55% efficiency, the Photovoltaic Equivalent Surface (PVES), expressed in m^2, is given by the following formula:

$$PVES = 7 \cdot P_{PVpeak} = 7 \cdot \frac{EC_{tot}+(9.6 \cdot MC_{tot} \cdot 0.55)}{SEG_{Estim}} \quad (1)$$

Where:

- is the required surface to reach 1 kW$_{peak}$ power for the reference photovoltaic panel considered (η_{el} = 14,4%), in m^2/kW$_{peak}$;
- P_{PVpeak} is the photovoltaic peak power needed to produce all the energy required to bring to zero the difference between the electricity self-production and the total consumption of the plant, in kW$_{peak}$;
- EC_{Tot} is the total annual electricity consumption of the plant, included the auxiliaries (pumps and fans), in kWh;
- 9.6 is the specific heat capacity of natural gas, in kWh/m^3;
- MC_{Tot} is the yearly consumption of natural gas of a boiler, in m^3;
- 0.55 is the best electrical efficiency of the currently available electricity generation system powered by natural gas;

- *SEG_{Estim}* is the annual solar electricity generation estimated by JRC for 1 kW_{peak} of PV systems, in $kWh//kW_{peak}$: this value is equal to 1420 kWh/kW_{peak} in Barcelona, 1180 kWh/kW_{peak} in Rome, 1260 kWh/kW_{peak} in Bari and 1480 kWh/kW_{peak} in Athens and Tunis.

To summarise, the lower the PVES value is, the more efficient the building-plant system will be. The parameter has the advantage to be calculated considering the climate conditions of the place where the building is located, providing immediately an indication of the space and the investment necessary to bring to zero the energy uses for space heating and cooling, and DHW production.

5.2. Energy consumptions

Figure 8 shows the annual energy consumptions of the hotels in the different Mediterranean cities considered, expressed in PVES. The two primary air systems, PA1 and PA2, are both equipped with a sensible heat recovery for the exhaust air.

The graph immediately clarifies that the system with only fan-coils is the worst, mainly because a heat recovery system is absent. When the primary air treatment is not present, it is difficult to estimate the fresh air flow, because it is dependent on the opening of windows. For the solution with only fan-coils, it was assumed an air flow equal to the one considered for the PA1 case. Anyway, the fresh air flow could be lower and thus the consumption too, but the air quality inside the building is poor. However, it is important to explain that the solution with only fan-coils was still valued, since in some historical buildings often it is not possible to install the primary air ducts.

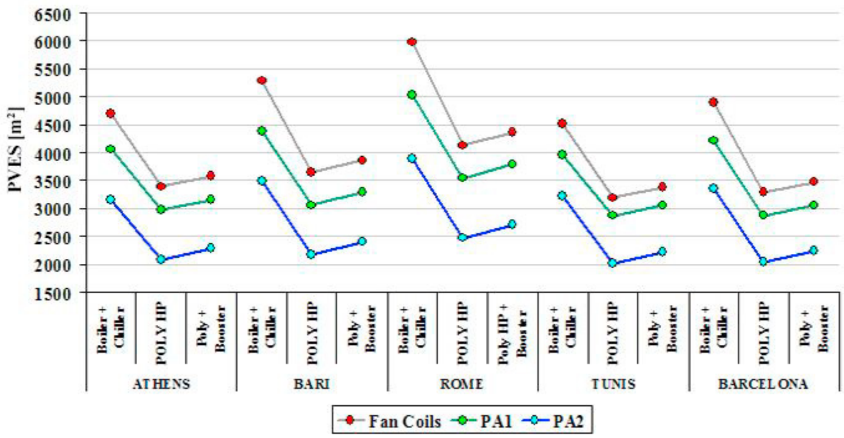

Fig. 8. Energy consumptions expressed in PVES for the different generation systems in the five analysed cities.

The PA2 system is always the best. The flow rate of fresh air is generally greater than that of PA1 system, resulting in a higher air quality, but it is blocked in empty rooms. The saving of PA2 depends not only on the lower energy requests to the generators, but also on the savings for the fans of the Air Handling Unit (AHU). Of course, the weight of the two energy saving voices depends on the location; for example, in Rome the global energy saving is due for the 55% to the reduction of the fans consumption and for the remaining 45% to the generators.

The two solutions in which Polyvalent HPs are used guarantee lower consumptions, but the solution with the booster gives slightly higher values.

5.3. Energy gains of the exhaust air heat recovery systems

The results shown in Figure 8 are valid when the sensible heat recovery from the exhaust air is used. Anyway, two other types of recovery systems were considered: enthalpy heat recovery and sensible heat recovery assisted by Indirect Adiabatic Cooling (IAC). The diagram on the left in Figure 9 shows the gains or losses of these solutions, compared to the sensible heat recovery one.

The graph is valid for PA2 systems, using Polyvalent HPs as generators, either with or without booster. The enthalpy heat recovery is the best solution only in Bari and Rome. In Tunis and Athens, cities characterized by dry climates, the enthalpy heat recovery gives worse results with respect to the sensible one. The recovery assisted by IAC performs better in Tunis, Athens and Barcelona. This represents a clear difference with respect to historical offices, addressed in [16], for which the enthalpy heat recovery is the worst solution even in Rome and in Bari.

As regards the graph on the right of Figure 9, it shows the gains (compared to the sensible heat recovery solution) derived from the use of a Run Around Coil (RaC). This solution in not obtained with two new coils, but by piping in series the two coils of pre-heating and post-heating, always present in the AHU and it could be added to any type of recovery system. Since the gains are high, the installation of RaC is always recommended.

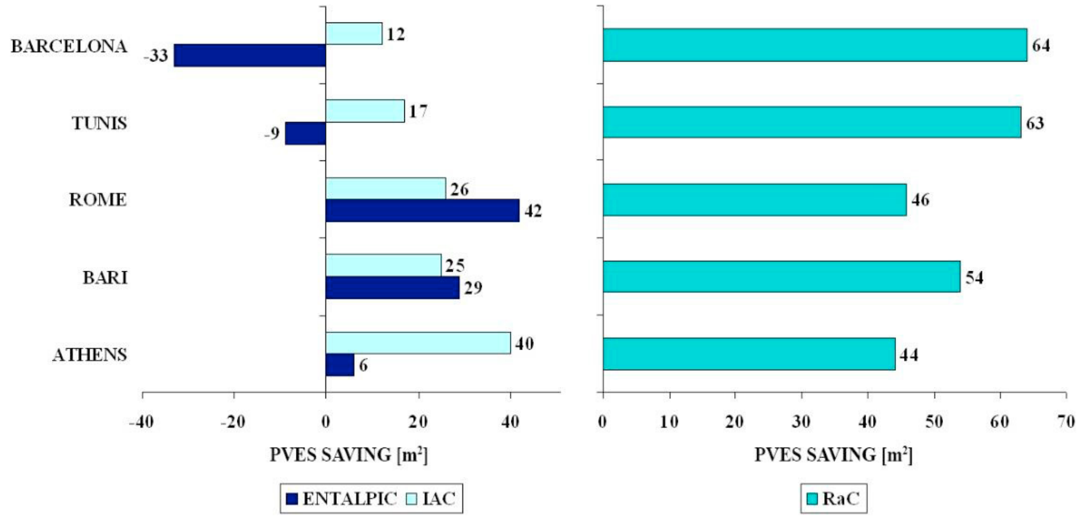

Fig. 9. Effects of different types of exhaust air heat recovery with respect to the sensible heat recovery.

5.4. Importance of hydraulic circuits with variable water flow

Figure 9 was obtained considering the best solutions described in paragraph 6.2. To express the importance of a variable water flow on the hydraulic circuits, Figure 10 was built, showing how using a constant flow on primary and secondary circuits, the energy consumptions increase. The figure is valid for sensible heat recovery and PA1 solution; anyway, energy losses are similar also with the PA2 solution.

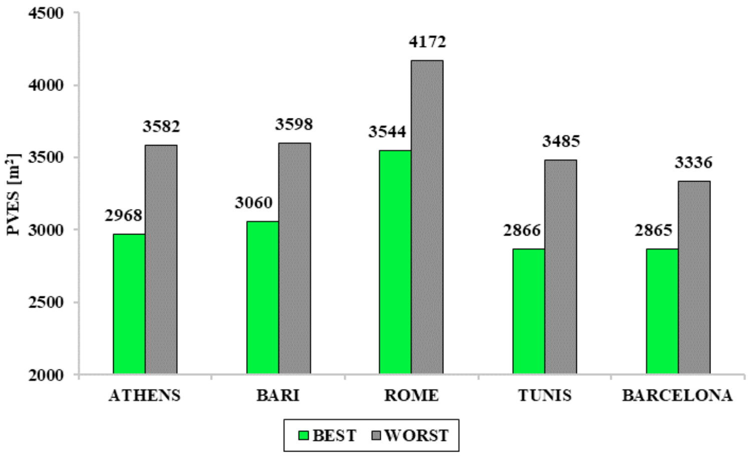

Fig. 10. Differences between best and worst solutions.

5.5. Comparison with new buildings

It is interesting to see how the consumptions of historical buildings may be different from those of new buildings. Figure 11 shows this comparison for hotel buildings located in Rome and Barcelona. The red curves identify the historical building, while the green ones represent the new building, with envelope features in accordance with the current national laws. The energy consumptions of historical buildings are greater with respect to the ones of the new better-insulated buildings, but these differences can greatly be reduced using the Polyvalent HP technology, with or without booster. Indeed, as it is possible to note in Figure 11, historical buildings with Polyvalent HPs have lower consumptions than new buildings with traditional generators (boiler + chiller).

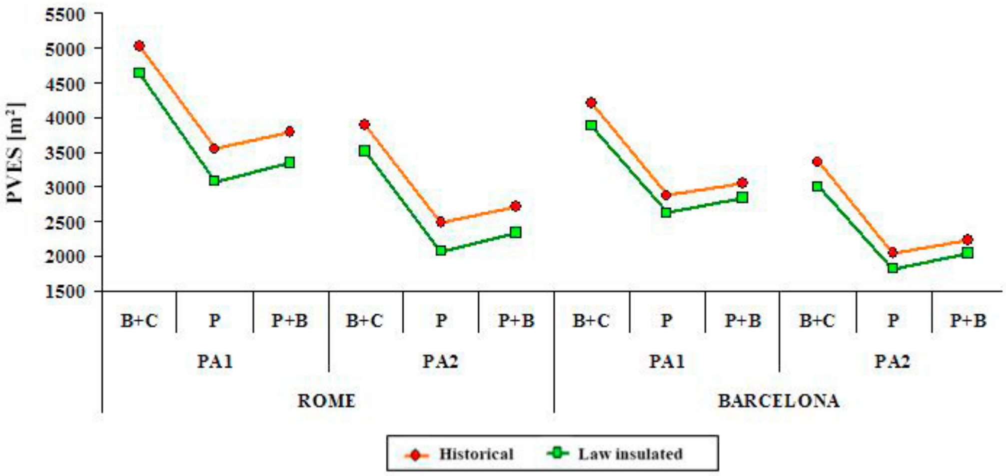

Fig. 11. Comparison between historical and new buildings.

6. Conclusions

Hotels consume a considerable amount of energy for air conditioning and domestic hot water production. Considering historical buildings, often it is not possible to act on the envelope components increasing thermal insulation or placing solar panels in order to reduce the energy demands.

In these cases, energy losses can be limited by paying attention to the design choices of the HVAC systems. The use of variable flow fans for fresh air, to be blocked by dampers when the rooms are empty, or the use of variable flow pumps on the hydraulic circuits can greatly reduce the consumption of electric power. Furthermore, the technology of Polyvalent HP maximizes the gains, thanks to the simultaneous production of chilled and hot water, which is commonly required in hotels, and especially in those located in the Mediterranean area, where it is possible to obtain high energy savings also during the winter time.

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