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EVALUATION ON THE CONVENIENCE OF A CITIZEN SERVICE DISTRICT HEATING FOR RESIDENTIAL USE. A NEW SCENARIO INTRODUCED BY HIGH EFFICIENCY ENERGY SYSTEMS

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ABSTRACT

The target of the study is to assess, in the light of today’s energy production technologies with high efficiency, the actual energetic advantage, in terms of environmental and economic sustainability, of traditional district heating systems for residential use. It was examined a real case study consisting of a residential complex in Milan served by the district heating system of the city. The study was conducted by comparing costs for heating and hot water supplied by district heating with those of alternative potential systems for energy production present on the market today. Two proposals for the replacement of the district heating system with high efficiency heat generators or with heat pumps were evaluated .Therefore, was carried out an evaluation of technical and economic feasibility with particular reference to the payback period, considering interruption of district heating services currently ongoing.
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Keywords: Environmental sustainability, High efficiency systems, District heating.

1. INTRODUCTION

In the last three decades in the North European countries characterized by colder climates there is widespread district heating, motivated by the fact that historically these countries have always been more attentive to environmental problems.

In Italy in recent years there was a considerable development of the techniques of district heating, this has been produced by the incentive laws on the cogeneration (6/92) [1-6]

For district heating TLR, means a network built mainly on lands public, at service a district urban existing or in project, for the supply of thermal energy (in the double meaning of “hot” and “cold”)

The thermal energy produced in one or more control units, is distribuited to a plurality of buildings belonging to different subjects, for the air conditioning, industrial and production of hot water for hygienic-sanitary.

In a district heating network, the heat generated from the plant. Circulating in a network via a carrier fluid (warm or hot water at temperatures which depend on the technical specifications of the network, or steam).

The carrier fluid distributes the heat to users through pipes of “flow hot and cold”, and then returns to the production plant. In the evaluations of the district heating, it is confirmed its superiority compared to traditional systems of heating, both under the aspect of energy saving that from the environmental point of view [7-11].

In recent years there have been significant technological advances in terms of heat generators (premix burners and modulating, condensing boilers, etc.), and that in district heating, it is worth taking into account the comparison between these systems and possible plant solutions alternatives.

Considerable studies have been performed to assess from the point of view energetic environmental, various systems for civil heating, starting from the use of natural gas as fuel.

Some of these require local processing of chemical or electrical energy into heat energy.

The study was commissioned by a condominium of a building complex in the province of Milan.

Which has required a technical and economic assessment in order to identify alternative solutions by the district heating network citizen, for heating and hot water production, in order to allow costs reduction.

Established the technical feasibility of the proposed solutions, we have proceeded with energy assessment, of the environmental and economic investments, and the estimating the payback time, trying not to underestimate the presence of any radiating surfaces that may have significant weight in the estimation of the global energy needs of the building complex [12-16].

2. BUILDING AND EQUIPMENT PLANT TECHNOLOGY DESCRIPTION

The building complex under study, located in the province of Milan, is intended exclusively for residential use activities.

The condominium consists of two detached buildings with eight floors above ground level each.

It was built between 1960 and 1970 and it is characterized by a raditional masonry- building envelope and is not equipped with thermal insulation.

The window frames are made with thermal break equipped with double glasses.

The heat production plant in service for the building complex is constituted by two distinct heat exchange substations, fed by hot water from the district heating service.

A substation dedicated to the internal heating system, while the second in service for the hot water production system for sanitary use.

Each substation is constituted by a stainless steel plate heat exchanger fed on the primary circuit by superheated water, from the district heating network citizen, and on the secondary circuit by the thermo-vector fluid of the internal system.

In addition, each heat exchange substation is equipped with a temperature control system to adjust the flow on the primary circuit, in function of the demand for heat registered on the secondary circuit.

In Figure 1 is shown an example of the substation currently employed.

Figure 1. Heat exchange substation for district heating

Radiant floor panels constitute the internal thermal emission systems.

The heat transfer fluid used is water with inner flow temperature of 40 °C and outlet flow temperature of 30 °C.

The production of domestic hot water (DHW) takes place through a vertical axis heat exchanger accumulating with 4000 liters of volume.

The temperature of the DHW storage has been set to values not below 75 °C, to prevent any phenomena of legionella and to ensure an adequate reserve of heat energy during periods of increased withdrawal.

In any case, the domestic hot water is sent to the end user at a temperature not exceeding 48 °C using a thermo-mixing valve.

The graph of Figure 3 shows, for the reference year, the values of total heat energy demand and the values of energy demand divided into thermal energy for heating and thermal energy.

3. THERMAL ENERGY DEMAND ANALYSIS

In order to carry out the feasibility study, were analyzed data, provided by the service network of the administration building, of energy demands monthly in the period 2009-2014.

Figure 2 shows the monthly values of total thermal energy, for the heating system and for the DHW production, provided for the reference period.

For the purposes of the study, noted the repeatability of the monthly energy demand during the years analyzed, appreciable by the graph of Figure 2, it was considered a single year period ranging from June 2012 until May 2013.

The graph of Figure 3 shows, for the reference year, the values of total heat energy demand and the values of energy demand divided into thermal energy for heating and thermal energy for domestic hot water production.

In the year under review, the overall demand for thermal energy was found to be 2,081 MWh.

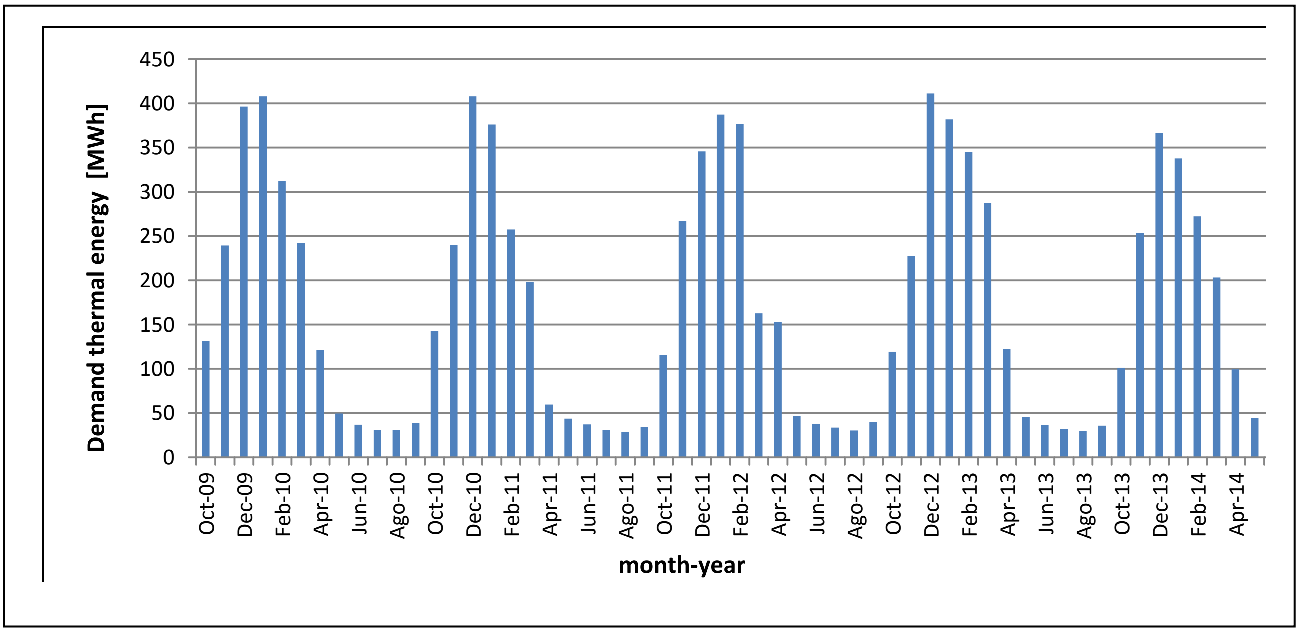

Figure 2. Total thermal energy demand (years 2009-2014)

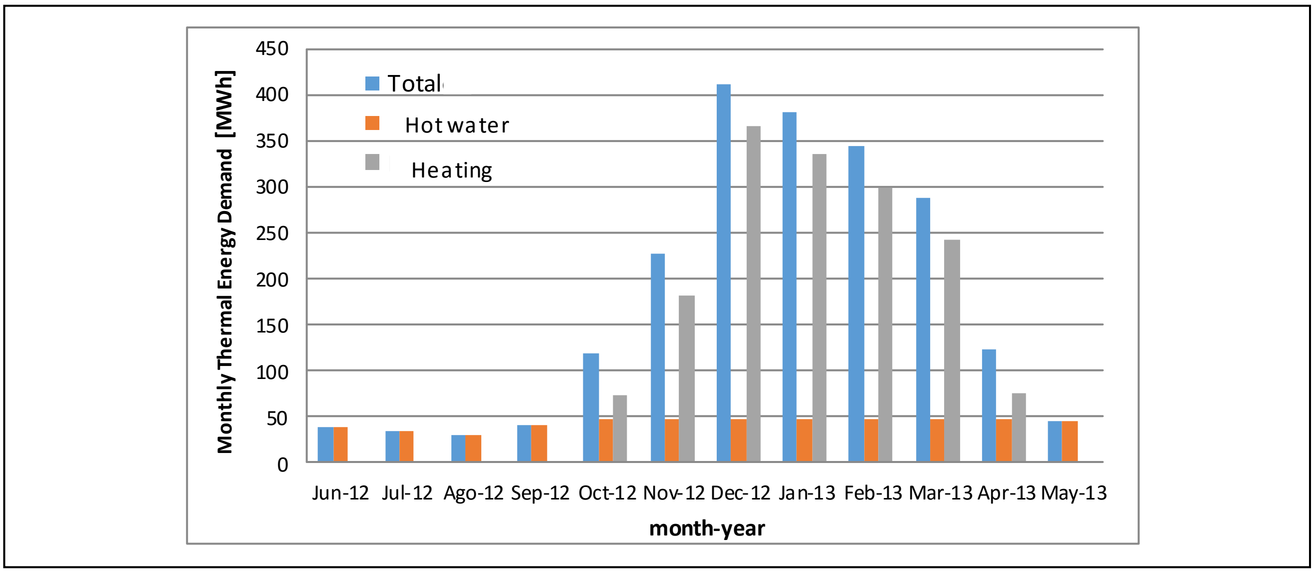

Figure 3. Monthly thermal energy demands (Total, for heating and for DHW production) in the period June 2012–May 2013

4. DESCRIPTION OF THE PROPOSED ACTION

Two alternative solutions have been proposed which provide the replacement of the existing heat production system.

Below are presented, with the name of "solution A" and "solution B", the descriptions of the potential measures examined to carry out the technical and economic evaluation.

"Solution A" - Total interruption of the district heating service and simultaneous installation of 2 high efficiency condensing heat generators fueled by natural gas in service respectively for the heating system and for the domestic hot water production system.

The generators chosen are of thermal power modulation type to keep high-energy efficiency levels, even at low load factor.

They are characterized by a rated power of 700 kW (generator in service for heating) and 250 kW (generator in service for DHW production).

In relation to the technical specifications and the operating conditions, the average seasonal efficiency of the condensing heat generator for heating use was estimated in1.05 and the one of the condensing heat generator for domestic hot water production was estimated in 0.96.

"Solution B" - In this case, it is expected to withdraw the service of the district heating and the installation of a heat generator in the heat pump ground water from 700 kW (2 machines from 350 kW/each) for the heating system and a generator condensing thermal-efficient 250 kW for DHW. For the heat pump it is assumed a mean value of COP of 3.8, assumed constant during the winter period by virtue of the almost invariance of the temperature of the ground water (value close to 14 °C - 15 °C for the entire annual period).

As can be seen in both solutions, it is expected to produce thermo-carriers fluids with low temperature suitable for operating with radiant floor.

As it is known, a lower operating temperature imply a greater percentage of annual operating in condensing state with a consequent reduction of operating costs. Condition that it is necessary for geothermal heat pump systems also to operate with high COPs.

5. ENVIRONMENTAL ANALYSIS

The analysis of pollutant emissions from various systems was conducted on the basis of the values obtained, reported in the literature.

The pollutants considered are carbon monoxide (CO) and nitrogen oxides (NOx), expressed in mg/kWht or in mg/MJt as reported in Tab.1; types of major pollutants which are found in various plants.

No problem arises to for the interpretation of the values related at the various pollutants produced from boilers and heat pumps gas, while in the cogeneration systems is attributed to the thermal exchange, the global fraction of the pollutant emission that is equal to the share total useful thermal energy

As for the combined cycle in pure electrical production, the issue amount pollutant per unit of electricity produced is used to quantify the polluting emissions for electric heat pumps.

The comparison shows the current great superiority of the condensing boilers of latest generation with burner microflames with premix, both for emissions of CO that NOx.

The unfavorable characteristics of the motors at internal combustion, are very penalizing in terms of environmental pollution, both in the district heating with alternative engines or with gas turbine that in the heat pumps with heat engine

To optimize so that they can these systems approach the positive behavior of the new condensation boilers, it is necessary an adequate treatment of the exhaust gases after combustion, with the use of the catalyst for oxidizing CO and possibly reducer for NOx: in any case these systems do not allow to obtain the very low values provided by new technologies by combustion devices of small capacity.

Systems	CO mg/kWh_t (mg/MJ_t) Typical values of emission from	to	NO_x mg/kWh_t (mg/MJ_t) Typical values of emission from	to
District heating with steam turbines	68 (19)	136 (38)	161 (45)	560 (156)
Limits	168	(47)	367	(102)
District heating with combustion engines	872 (242)	1849 (514)	1171 (325)	2330 (647)
Limits	297	(83)	731	(203)
District heating with combined cycle	118 (33)	350 (97)	405 (112)	986 (274)
Limits	79	(22)	105	(29)
District heating with gas turbine	54 (15)	158 (44)	195 (54)	461 (128)
Limits	195	(54)	260	(72)
Condensing boiler	7 (2)	21 (6)	11 (3)	34 (10)
Limits	101	(28)	178	(50)
Electrical heat pump	28 (8)	68 (19)	170 (47)	308 (86)
Limits				
Heat pump gas	537 (149)	669 (186)	416 (116)	589 (164)
Limits	285	(79)	702	(195)

Table I. Emission comparison between different generation systems

6. ECONOMIC ANALYSIS AND PAYBACK PERIOD OF THE INVESTMENT

For the year under review, the overall demand for thermal energy is of 2,081 MWh.

Considering an average cost for thermal energy from the district heating services of about 0.11 €/kWh (including VAT 10%) results a total annual cost of € 220,210.

For natural gas was assumed a purchase price of 0.80 €/Sm^3 (taxes included).

In Figure 4 is shown a comparison between the monthly costs of the district heating system used today and the projections of the monthly costs for the alternative solutions suggested.

As can be seen, with regard to the solution ‘‘A ‘‘, the average reduction in the total annual cost is of about 26.1%, equal to an annual saving of € 57,503.

With regard to the solution “B”, there is a reduction of annual costs of € 94,612, equivalent to an annual saving percentage of 43.0% with a peak in January of 47.2%.

Moreover, it is noted that even in the months when the domestic heating service is not in use, the two solutions proposed showed a greater convenience compared with the district heating service.

The estimated investment costs for the solution ‘‘A’’, consisting in the installation of new condensing generators and the supplied plant, are estimated at € 225 000 (VAT 10% included).

Regardless of any government incentives to support the investment, the payback period is estimated in 3.8 years for such a solution.

While, for the solution "B", consisting in the installation of the heat pump, of the condensing boiler for DHW and the whole plant supplied, it is estimated an investment cost of € 300,000 (10% VAT included).

In this case, without considering any government incentives to support investment, the payback time is of 3.2 years.

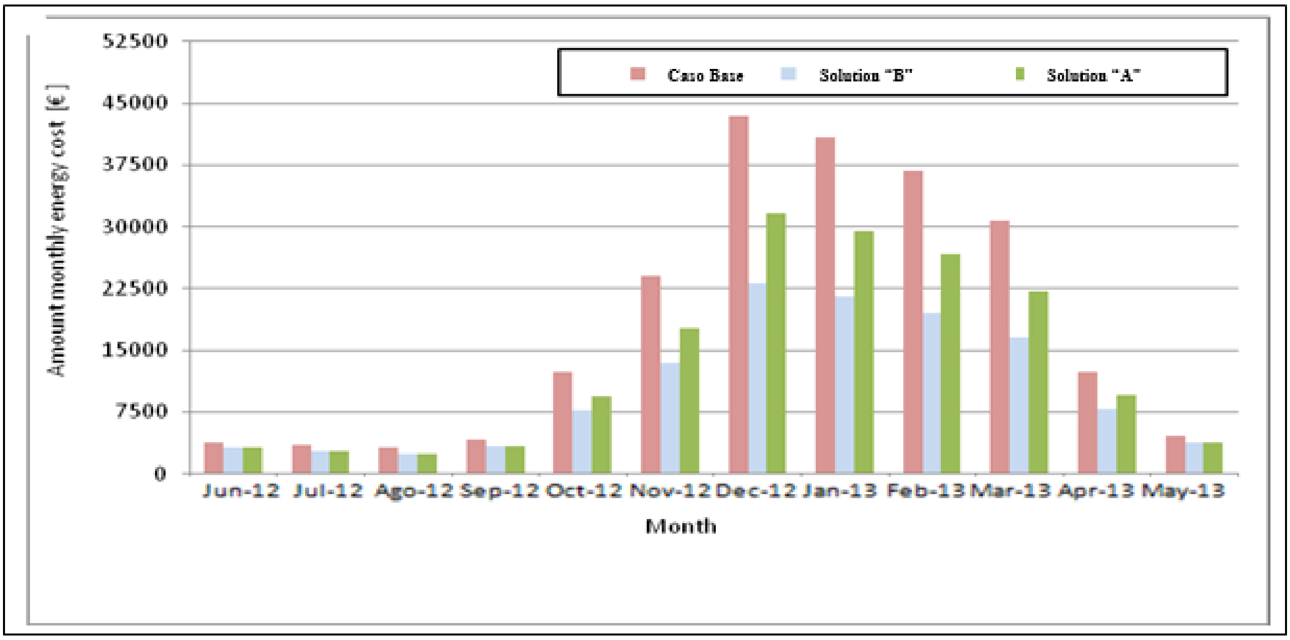

Figure 4. Comparison of monthly energy cost of the three solutions

7. CONCLUSION

This study has revealed that the district heating service, while allowing undoubted advantages from the energy point of view, it is often less efficient compared to the modern technologies.

Nowadays, condensing boilers and heat pumps provide energy efficiency higher than the "traditional" district heating (steam turbines and gas).

While heat pumps are exceeded in energy efficiency only by combined cycle systems.

The comparison on pollutant emissions is even more surprising, since, thanks to the many technological improvements that the boilers have had in recent years of development (low-NOx burners, modulating, premixed), their use generates a much lower environmental impact than the district heating plant (including combined cycles).

To overcome this important gap, cogeneration plants should be equipped with systems to reduce pollutants much more effective than the today used.

It should be added that also the district heating plants are now absorbed within the urban centers (due to the expansion of cities and for the need to have the thermal user near the production plant) thus contributing to the production of pollutants in atmosphere in towns.

The convenience of the proposed solutions, based on generation with condensing systems and heat pump systems, are particularly attractive in consideration of the reduced amortization times that characterize the investment.

From the economic point of view, in fact, the results in terms of energy savings shall be prosecuted by virtue both the annual savings achievable and the payback time less than five years for both proposed solutions. However, it is necessary to highlight that this analysis was conducted by taking as a reference a building complex served with low temperature terminals.

This condition considerably influences the yields of thermal generators hypothesized and the energy costs significantly.

It is evident that the conducted study cannot be taken into consideration in the case of plant employing high temperature terminals, such as in the case of traditional type radiators, operating with high thermal jumps.

In such a case, there are not excluded advantages of the proposed solutions also on district heating systems using conventional radiators, but is essential to make a careful technical and economic analysis of energy feasibility.

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