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Proposals to energy efficiency cooling processes and hot water preparation in buildings located near surface water sources

Propuneri de eficientizare energetică a proceselor de răcire și prepararea apei calde în clădiri situate în apropierea surselor de apă de suprafață

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Abstract. *The article aims to present in general terms a concept that can be applied to streamline the cooling and hot water preparation processes in buildings located near surface water sources. The proposed solutions use logical principles, available equipment and are economically accessible from the point of view of cost-benefit analysis.*

Key words: energy efficiency, free cooling, hot water, water-water heat pump

1. Introduction

In recent years, reducing energy consumption in buildings has become a priority, especially in developed countries around the world, and has led to significant efforts in terms of improving energy efficiency and implementing it in all building categories [1]. In practice, the concept of energy efficiency in buildings is related to the energy supply necessary to ensure environmental comfort conditions while minimizing energy consumption [2], [3]. In most building categories (residential, public, industrial, etc.) most of this energy is used in heating, cooling and mechanical ventilation systems and it is expected that by 2050, energy consumption for cooling buildings will triple [4], especially in urban areas. A distribution of energy consumption for residential and commercial buildings is shown in Fig. 1.

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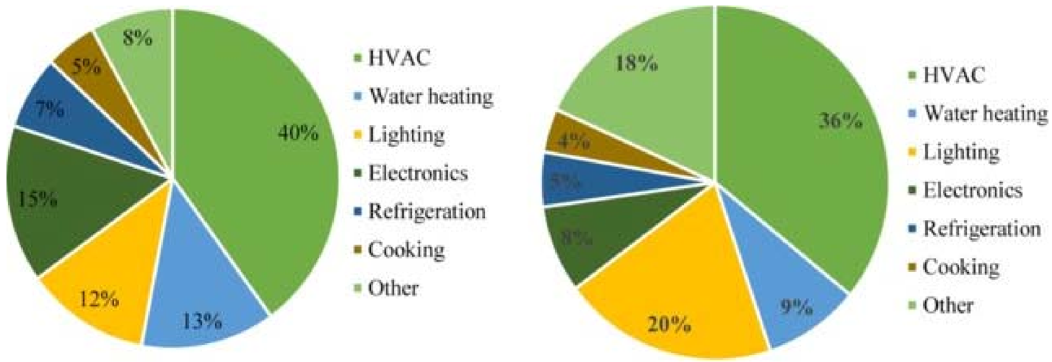

Fig. 1. Energy consumption distribution [4-7]
a) commercial buildings, b) residential buildings

F. J. Zarco-Soto et all. say that it is expected that by 2030, in the world, the population living in cities will reach 60% and by 2050 it will exceed two thirds. Moreover, currently, in Europe these percentages exceed 75%, and it is estimated that in 2050 they will reach 85% [8]. Therefore, the highest energy consumption is and will be recorded in urban areas. In 2023, in a report by the United Nations Environment Programme, it is stated that the built environment sector is responsible for 37% of CO2 emissions and over 34% of global energy demand [9].

On the other hand, F. J. Zarco-Soto et all. and Shahrokni et al. also say that, usually, natural gas is used for heating buildings, and electricity for cooling [8], [10]. Practically, for a correct approach to energy efficiency solutions, it is necessary that design criteria that can reduce energy demand are addressed in the design phase. Regarding the heating and cooling of buildings, the criteria are based on the adoption of appropriate parameters, the parameters that are synthesized by Ekici and Aksoy, as follows [11]:

- *physical parameters of the environment:*
  - daily outdoor temperature, in °C;
  - solar radiation, in W/m^2;
  - wind direction and speed, in m/s.
- *design parameters:*
  - building form factor and orientation;
  - thermophysical properties of building materials;
  - building spacing;
  - type of roof;
  - glazed surfaces;
  - shading systems;
  - passive heating and cooling mechanisms.

Thus, to design an energy-efficient building, the design variables and parameters of the building must be optimized [12], and the integration of sustainable strategies should be done in the conceptual design phase. W. Wang et al. demonstrated that if these mechanisms are put into action right at the beginning of the construction phase, the implementation costs will be reduced compared to the situation in which they are implemented in the later stages of construction [13]. Obviously, these concepts based on energy-saving criteria will reduce costs and CO_2 emissions throughout the life of the building, due to lower energy consumption, and this is worth more than a large initial investment.

Typically, building cooling can be achieved using passive or active methods, such as:

- passive cooling: natural ventilation (indoor air refreshening by creating a volumetric flow to dissipate heat) [14], [15], thermal mass (the material’s property to absorb, store, and release heat - thermal lag is the time rate at which a thermal material releases the stored heat) [16], evaporative cooling (the process where water evaporates, absorbing latent heat and cooling the surroundings-used for dry climates) [17], [18], etc;
- active cooling: earth-to-air heat exchanger-ground coupling (an earth-to-air heat exchanger draws ventilation supply air through buried ducts or tubes in the ground) [1], [19], open or closed loop water-to-air heat exchanger (exploits the relatively stable temperature) [20], mechanical (or forced) ventilation (is driven by fans or other mechanical plant and can be of several types, for example: wall fan extract ventilation system, the roof fan extract ventilation system, the spot cooling system, etc) [21] , chilled water (Chilled water is typically provided by chiller units using absorption refrigeration or compression refrigeration) [22], [23], refrigerants (is based on the flow of refrigerant between an external condensing unit and multiple internal evaporators - typically fan coil units) [24], [25], etc.

Taking into account all the aspects presented above, the article proposes a conceptual approach to energy efficiency of cooling processes and hot water preparation in buildings located near surface water sources. For cooling buildings, it is proposed to reduce energy consumption by approaching the free cooling concept. The proposed free cooling system involves using the thermal potential of surface waters to cool buildings. That is, when surface water is cold enough, it can be used as a cooling medium or as a direct source of cold for buildings. Recent studies by the authors have shown that the external temperature of surface water (Bega Chanel) in the city of Timișoara in Romania is lower than the temperature inside buildings for the summer period, making free cooling of the analyzed space possible [26]. Studies by Hainan Zhang et al. show this is true for a long period of the year [27]. Recently, a new type of free cooling system has been developed and put into operation, namely the heat pipe cooling system, which can achieve considerable reductions in building energy consumption [28], but raises problems regarding the transmission of bacteria inside buildings.

2. Description of the concept

The concept is based on the use of the most favorable thermal potential for the preparation and supply of chilled water necessary for cooling indoor spaces. Such a cooling system is mainly composed of a water-water heat pump that uses, according to a logical prioritization system, a low-potential coolant from various sources, namely: water from the surface source, atmospheric air, cold water used for the preparation of hot water for consumption or for the consumption of sanitary objects.

Figure 2 presents the concept of a system that proposes energy efficiency the cooling processes and the preparation of hot water in buildings located near surface water sources using a heat pump and a local electricity production system using photovoltaic panels.

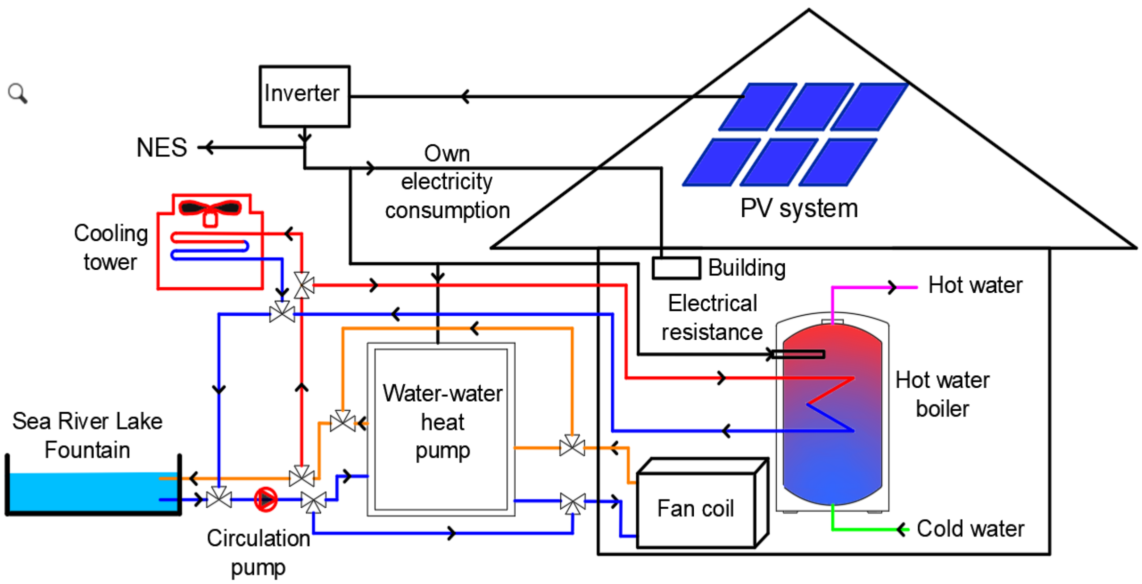

Fig. 2. Schematic diagram for energy efficiency of the cooling and hot water preparation system

The proposed concept can be applied, in the general situation proposed, for the energy efficiency of existing buildings. An improved version, with an electrical energy storage system and a diurnal storage system for chilled and hot water, is generally suitable as a solution for the design and construction of new buildings because they may require additional spaces to accommodate this equipment. In the case of the latter, the implementation of a cooling/heating system that allows the accumulation of thermal energy in the building's construction elements must also be considered.

The entire system is based on the logical correlation of input data that the automation system processes and interprets in order to make the best decision for prioritizing the energy sources that will be used so that the overall efficiency of the installation is optimal for the respective conditions.

Among the input data required by the system, we list: indoor temperature, outdoor air temperature, surface water source temperature, cold water temperature, hot water temperature, photovoltaic system electricity production, building operating schedule, cooling demand, heating demand, hot water demand, weather forecast, thermal inertia of the envelope system, annual history of surface water temperatures, etc.

All this data will be integrated into the building and HVAC control system so that the control system operates automatically and requires minimal operator intervention.

The physical implementation of the logical signals and decisions will be made simply by starting up equipment and operating three-way valves that will open/close various circuits as needed. The main elements of the system are temperature sensors, pressure gauges, and the PLC or ECL control system.

The conditioning method will be done by transmitting the given signals depending on the state of some logical operators of the type (and, or, etc.)

For even greater energy independence, the proposed concept also allows for other subsequent developments such as:

- using a system for storing electrical energy in accumulators to be used by HVAC systems when their efficiency is maximum;
- extracting the energy necessary to prepare hot water for consumption from surface water using a heat pump;
- the inclusion of solar panels for direct preparation of hot water and for providing a contribution to cover the thermal energy requirement during the cold season;
- use of tanks for accumulation in the daytime of cooled water and heated water in order to increase the energy efficiency of the system;
- analyzing the possibility of using the public district heating network to supply the adjacent buildings with surplus chilled water and hot water in case of availability (for example during the holidays);
- the system is designed to allow periods of the year when the surface water temperature allows, the use of the free/direct cooling mode of the interior spaces, reducing in this situation the consumption of electricity to a minimum.

3. Conclusions

Given the European Union's assumed objective of reducing the energy consumption of all public buildings by 2050, it is imperative to identify and exploit to the maximum and in a realistic manner all locally available renewable natural resources and all forms of residual energy resulting from technological, commercial or residential processes.

In this context, the article analyses a possibility of capitalizing on the energy potential of surface water courses. Thus, the thermal potential in the form of thermal energy contained in the surface water source was considered to be a resource that is found in abundance, and which is currently not sufficiently well capitalized, although in some cases these water sources are found even in the near of buildings. Therefore, the article proposes a concept that is based on the use of the most favorable thermal potential for the preparation and supply of chilled water necessary for cooling indoor spaces. Such a cooling system is mainly composed of a water-water heat pump that uses, following a logical prioritization system, a low-potential coolant from various sources, namely: water from the surface source, atmospheric air, cold water used for the preparation of hot water for consumption or for the consumption of sanitary objects.

The authors of the article intend to implement this concept on a pilot scale and compare the results obtained with the estimates obtained by using mathematical models that calculate the energy efficiency of the system for various configurations and loading and operating regimes.

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